E-DESIGN IN ARCHITECTURE

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بسم الله الرحمن الرحيم

In the name of Allah, the Merciful, the Compassionate

وَاتَّقُواْ اللّـهَ وَيُعَلِّمُكُمُ اللّـهُ وَاللّـهُ بِكُلِّ شَيْءٍ عَلِيمٌ

So Fear Allah; for it is Allah that teaches you, and Allah is well acquainted with all things.

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Foreword

e-Design in Architecture

Computing has become one of the most important transformations of contemporary professions including architectural education and practice. Most recently the focus within the architectural profession is shifting from the relevance of drawing in pencil to the conceptual relationship between electronic and digital architecture and the architecture of the built environment. It is important to examine the computer's cognitive implications on architecture and whether there are emerging new modes of thinking about architecture, space and form of the built environment. Information technologies and the construction industry are coming together in ways once unimaginable, and their union is changing what people do inside buildings, as well as how buildings are designed and built.

The process of architectural design aims to define a physical form that will achieve certain functional and behavioral objectives in a particular context. The use of computers at various stages of the design process has implications for the way designing is carried out. Research in CAAD (Computer Aided Architectural Design) especially electronic design (e-design) has the potential to significantly enhance both the architectural design process and its outcome and the architectural education.

This Conference Proceedings can contribute in identifying various issues related to e-Design in Architecture and their potential impacts on architectural education and practice. The Conference Proceedings includes 23 refereed research papers from researchers and professionals coming from 13 countries worldwide. I commend and thank the authors for their response to the reviewers' feedback and thanks to Mr. Shakeel Ahmed at the KFUPM Press who helped me greatly while editing this Conference Proceedings.

Rabee M. Reffat, Ph.D.
Chair of Scientific Committee

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Section I

Computational Models in Design and Decision Support

A COMPUTER-AIDED SYSTEM FOR SITE SELECTION OF MAJOR CAPITAL INVESTMENTS

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Abstract: Site selection for capital investments is a crucial complex decision for owners and analysts. Difficulties are caused by the inclusion of the numerous possible sites that may qualify, multiple objectives that could also contradict each other, intangible objectives that are difficult to quantify, diversity of interest groups, uncertainties regarding external factors such as government legislations, uncertainties regarding the timing required for permitting the sites in question, and unknown construction challenges for the different sites. As such, these exercises are multi-facetted and necessitate the employment of analysts who possess in-depth knowledge in a number of fields. More importantly, a solution must satisfy a number of physical suitability criteria, as well as, meeting a number of social, economical, environmental and political requirements. Consequently, a number of specialized tools is frequently utilized to ensure reaching an optimal decision. This paper presents a new system that integrates Analytic Hierarchy Process (AHP) operations within a Geographic Information System (GIS) application to determine the optimum site for a specified facility. The system was validated through a facility for a selected metropolitan area.

1. Introduction

Capital improvement facilities are major, long-term investments for owners and investors. Selection of an appropriate site is a critical decision that could significantly affect the profit and loss of the project under investigation.

In a site selection exercise, the analyst strives to determine the optimum location that would satisfy the selection criteria. The selection process attempts to optimize a number of objectives. Such optimization often involves numerous decision factors, which are frequently contradicting. As a result, the process often involves a number of possible sites each has advantages and limitations.

A number of tools have been used to determine the proper site for a capital improvement facility including Expert Systems (ES), geographic information systems (GIS), and Multi-criteria decision-making (MCDM) techniques. Although these tools have played an important role in solving site selection problems, each tool has its own limitations and could not be used alone to reach an optimum solution.

This paper presents a new approach in which these three tools were integrated to facilitate the decision-maker’s job.

2. Selection Process and Characteristics

The process of industrial site-selection begins with the recognition of a need to meet new or growing markets. Once a need is recognized, the screening of geographic areas of specific interest starts. Suitable sites are selected on economical and technical criteria as well as social and environmental aspects (SIOR and NAIOP 1990, Stafford 1979, Barbaro 1975). Sites that satisfy the screening criteria are subjected to a more detailed evaluation and are compared as possible alternative sites for the proposed facility.

In today’s society, site selection problems are characterized by their multi-objectives and numerous stakeholders. Table 1 shows a listing of decision factors that generally characterize sitting problems and affect final selection (Williams and Massa 1983, Keeney 1980):

Table 1. Decision Factors that Characterize Site Selection Problems

Factors	Description	Impact
Numerous Possible Sites	There could be tens/hundreds of potential sites that could be chosen for the facility	Additional effort and time required to complete the analysis
Multiple Objectives	It is fairly common to find contradictions between the multiple objectives for a sitting problem. For instance, the objective of keeping minimum capital investment may contradict with the objective of keeping a long-term safe environment.	Difficulty of weighing each objective against the others and the delicate balance of keeping all stakeholders satisfied
Intangible Objectives	Many objectives lack means of quantitative measurements. Examples of those are the aesthetic deterioration of the view of a mountain scene as a result of the installation of transmission towers/lines, the social disruption felt by a community as a result of the expected rapid influx of workers during construction, and similar issues.	Difficulty of determining qualitative measures that describe the significance of each objective
Numerous Interest Groups	Within an owner's organization the management, shareholders, and employees may hold different positions regarding the selected site. In addition to their own organizations, several public groups frequently impact owners/investors decisions. Examples of public groups include consumers, local citizens, environmentalists, heritage committees and similar groups.	Difficulty of sorting out in-house and external views and reaching an acceptable balance to reach an approval by all participants
Impact Assessment	Placing a value on the impact of each objective could be problematic. It is not enough to state that there would/wouldn't be some impact. A value (number or quantity) is needed to support the comparison process.	Difficulty of determining qualitative measures that describe the impact of each objective

Timing Impact	The impacts identified by a sitting study may not all occur at the same time and may/may not continue over the lifetime of the project.	Difficulty of determining qualitative measures that describe the net impact of each objective with respect to the impact time
Uncertainties Impact	It is practically impossible to accurately forecast all possible impacts of all factors affecting the site selection for a facility. There will always be uncertainties regarding environmental outcome, actual costs, accidents, and similar issues.	Difficulty of determining qualitative measures that describe the risk of uncertainties
Uncontrollable Delays	Licensing and construction issues are examples of common unpredictable delays that may significantly impact the economic viability of the project	Difficulty of determining qualitative measures that describe the impact and risk in uncontrollable issues
Operation Reliability	Impact of natural phenomena such as storms, floods, quacks and similar phenomena can impact site suitability and add to the process uncertainty	Difficulty of determining qualitative measures that describe the impact of possible natural phenomena for each candidate site
Equity	Determining equity and fairness among all interest groups involves complex value judgments	Difficulty of determining qualitative measures that guarantees equity among stakeholders
Stakeholders' Risk Attitudes	Determination and compilation of the stakeholders' risk attitudes is important to the proper site selection	Difficulty, time and effort in determining qualitative measures that describe the utility functions of all stakeholders
Uncertainties in Government Decisions	Laws and regulations enforced by federal and state governments can greatly influence the relative desirability over time of various sites for a proposed facility	Difficulty of determining qualitative measures that describe the impact of external factors such as legislations, etc.

3. Proposed Approach

Geographic information systems (GIS), Multi-criteria decision making (MCDM), and Expert Systems (ES) techniques have been used in solving site selection problems for the last three decades. Integration of these tools is needed so that each tool is used to address certain aspects of the problem (Vlachopoulu et al 2001, Thomas 2001, Kao et al 1996, Siddiqui et al 1996, Jankowski and Richard 1994, Carver 1991, Janssen and Rietveld 1990).

The proposed system was developed employing a number of COM-compliant software packages. The ArcGIS ® 8.2 was used to manage the spatial data and to conduct the required spatial analysis operations (http://www.esri.com). The Visual Rule Studio® was used to develop the expert systems component (http://www.RuleMachines.com). Microsoft® Excel 2002 was used to implement the AHP method. The Microsoft® Visual Basic 6.0 was used to develop the system's user interface and to provide the shell for COM integration. Detailed description of the use of COM can be found else where (Eldrandaly 2003, Goodchild et al 1999, Goodchild et al 1992).

The approach presented here integrates the capabilities of ES, GIS and MCDM by using Microsoft® Component Object Model (COM). COM is a standard protocol that enhances software interoperability by allowing different software components, possibly written in different programming languages, to communicate directly (Microsoft® 2000). In the proposed system, the expert system component was developed using Visual Rule Studio® (http://www.RuleMachines.com), the management of spatial data and spatial analysis operations were conducted by ArcGIS ® 8.2 (http://www.esri.com), Microsoft® Excel 2002 was used to implement the AHP application, and the users' interface was written in Microsoft® Visual Basic 6.0.

Figure 1 presents the components of the proposed system. Provided below is a brief description of the procedural steps for the two phases of the new approach as depicted in Figure 1:

Step 1: In this step, the expert system is used to provide the recommended values for the site physical suitability criteria and the GIS is used to determine the alternative sites using the values obtained from the ES. This is accomplished through the following two steps:

(a) Establishment of suitability criteria -- According to the type of industry, the ES would define the suitability criteria (e.g., physical, environmental, geographical, etc) for the sites of interest. The experts of the field and/or the decision makers have the opportunity to review and change the recommended values.

(b) Site Screening – Once a decision is made to build a particular facility, the decision makers select the regions of interest. This is an important consideration as it eliminates all sites outside the selected region from the list of possible sites. The site screening process involves GIS analysis operations to identify candidate sites that meet the desired attributes obtained by the ES. The output of this step is a list of candidate sites for further assessment.

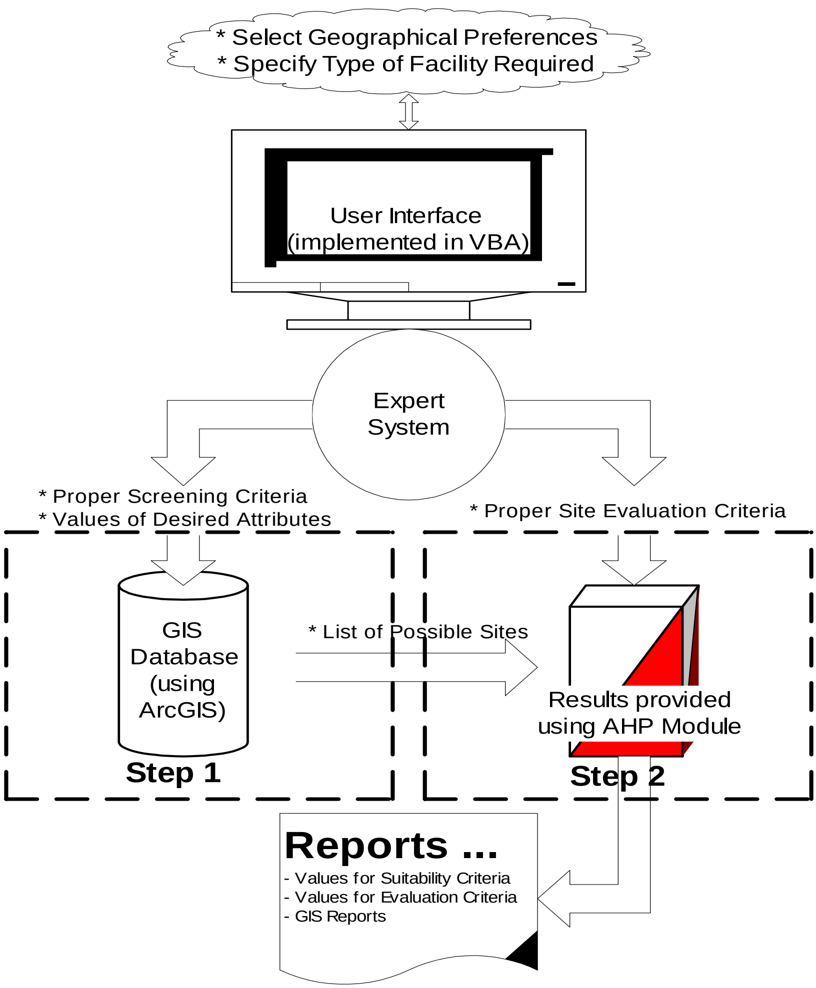

Figure 1. Architecture of the Intelligent GIS Approach

Step 2: In this step, the expert system is used to provide the recommended values for the site non-spatial selection criteria and the AHP is used to determine the rank of the alternative sites using the values obtained from the ES. This is accomplished through the following two steps:

(a) Establishment of the AHP evaluation criteria – According to the type of industry, the ES would define the AHP evaluation criteria (e.g., labor climate, economic costs, living conditions, etc) for the regions of interest. The experts of the field and/or the decision makers have the opportunity to review and change the recommended values.

(b) Site Evaluation -- The Analytic Hierarchy Process (AHP) is used to evaluate the candidate sites. The output of this module would be a list of sites ranked in the ordered of their level of suitability.

4. Case Study

An illustrative example is provided here through the exercise of identifying the optimum site for a water treatment facility that could serve a potential metropolitan area. Table 2 and Figure 2 summarize the physical suitability criteria recommended by the ES that had to be satisfied in the site-screening phase.

ArcGIS® 8.2 was used to perform the spatial analysis required in the screening phase of candidate sites. Twelve layers were created in ArcGIS® to address the physical suitability requirements. Upon the completion of the analysis, two candidate sites were identified.

The following evaluation criteria were used in the site evaluation phase: public opposition to new neighboring industrial facilities, neighborhood previous involvement in major public hearing, and cost of camouflaging the facility. These were the factors used by the AHP module to rank the sites that satisfied the physical suitability requirements.

Table 2. Physical Suitability Criteria for a Water Treatment Case Study

Criteria	Items	Values	Constraints
Terrain	Size Elevation Floods Slopes Soils*	> 150,000 sq. meter 365 meter > 0.5 Kilometer < 5% GW, GP, GM, GC, SW, SP	Minimum lot size To minimize pumping costs Buffer Zone to Avoid Catastrophes Erosion, Drainage, Constructability Stability, Strength, Drainage
Infrastructure	Roads Waste Water Residential Properties Public Parks Existing Utilities	< 50 meter 500-1000 meter > 150 meter > 150 meter < 2 Kilometer	Distance to existing road Distance to waste water facility Distance to residential properties Distance to recreational parks Communications, Power, Water Connections
Natural Resources	Land Use Occupancy Water Bodies	- - < 1000 meter	Avoid land of Environ/Cultural Sensitivity Vacant lots to minimize acquisition costs To minimize pipeline construction

Note: Soils classification followed the Unified Soil Classification System (USCS). The system follows a letter description in which the first is the group symbol (G= Gravel, S = Sand, M= Silt, C= Clay, PT= Peat), and the second describes the gradation (W= well graded, P= poorly graded) in the case of granular soils or the liquid limit (L= liquid limit under 50, H= liquid limit over 50) in the case non-granular soils. For example, GW= gravel well graded and SP= sand poorly graded.

5. Conclusions

Site selection is a crucial, multifaceted process that could significantly impact the profit and loss of capital investments. The proposed process includes four steps: establishment of suitability criteria, site screening, establishment of the AHP evaluation criteria, and site Evaluation. An integrated system was developed to aid the analyst in finding the optimum site for the facility sought. The system integrates two major tools (GIS and AHP) in a manner that reduces the user involvement with each component/tool and reduces the level of the computer skills required to reach the correct solution. The integration was achieved using Component Object Mode (COM) and the system included an advisory system to assist the decision maker in determining appropriate values for the physical suitability criteria. The system was successfully tested in determining the optimum site for a water treatment facility. This system is the first step in the authors' plan for further automation of the site selection process. The authors are working on developing a fully automated system in which the user interact with all the tools through a simplified user-interface and saves the user from having to develop in-depth expertise in the utilization of any of the necessary tools.

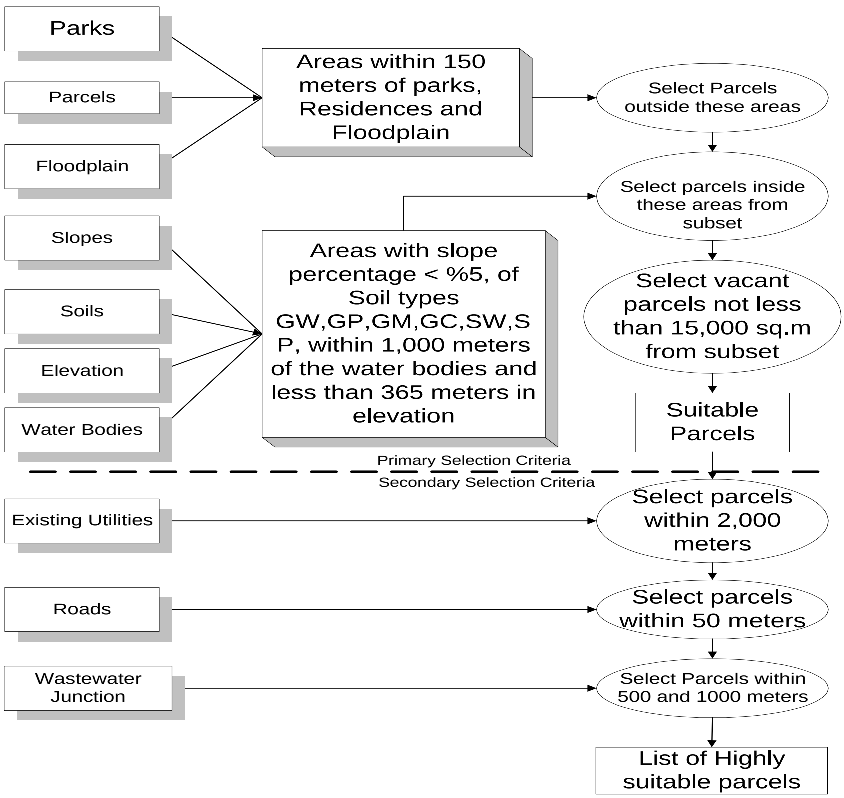

Figure 2. Physical Suitability Criteria Classification

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SPIROSPACES IN ARCHITECTURAL DESIGN

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Abstract: The proposal of this paper is to present "Spirospaces" and their utility in Architectural Design, exploring their relation with other geometrical disciplines such as knot theory, tiling and patterns generation. A spirospace is a geometrical entity generated from the spatial interpretation of a "Spirolateral", a well known bidimentional entity. A computer program to generate spirospaces configurations is presented and demonstrated with several examples. This is complemented with the exposition of the mathematical framework that supports closed spirospaces generation.

1. Introduction

The essential matter of this paper is the creative use of geometry in architectural design, in particular, the feasibility of using a set of complex geometrical entities, based on spirospaces, as creative triggers to empower inventiveness.

Although it is not always an explicit fact for the designer, there is an intrinsic order underlying architectural objects that maps to mathematical models. Furthermore, mathematical models can be abstracted into typological models or paradigms.

From this perspective, we can consider architectural objects as particular instances of typological models. Furthermore, we can use design procedures that uses some kind of deductive process to go from typological models to architectural ideas. This is an example of what, in academic communities, is called "to go from the form to the purpose". One way to accomplish this is by using a mechanism called creative triggers.

From a general perspective, a creative trigger is anything that is capable to inspire design ideas: an object, an image, a sensation, etc. In particular in this work, we postulate the potential of spirospaces as a powerful creative trigger for architectural design.

In order to provide even a higher degree of formal richness, we propose to combine spirospaces with other well known geometrical entities, such as knots, fractals, and patterns generation. This opens an astonishing explosion of geometrical combinations.

Due its complexity, the generation and manipulation of these graphical entities would not be practical without computers power. Therefore, for this specific purpose, we develop an application based on the general idea explained above. Demonstrative examples are exposed at the end of this paper.

2. The Design Process

The design process is a subset of an overall process intended to accomplish the materialization of a new building. It is carried out by an AEC enterprise.

It can be analyzed from the perspective of the product, the process, and the particular context where it takes place.

2.1. THE PRODUCT

The output of the design process is a technical and constructive definition of a building, in the form of a graphic representation. This representation, explicitly or implicitly, carries the definition of all architectural objects' attributes.

We consider the architectural object as a system composed by qualified spaces and masses. To our purpose, it can be analyzed from the dimensions of form, function and structure, each one defined as follows.

The form considers the architectural object from the human perceptual perspective. It comprises the architecture significant codes: aesthetics, symbolism, emotiveness, etc.

The function considers the architectural object from the perspective of purpose. It regards the elements of an architectural system from a utilitarian view referring them to the activities that they shelter.

The structure considers the architectural object from the organizational perspective. It is defined by the physical relationship between system's elements.

We will return to these dimensions later, when we explain the logical mechanisms involved in using creative triggers.

2.2. THE PROCESS

We are not intended to postulate a design method. Instead, we will point out some considerations about the design process inspired on the work of Dr. J. Samaja (2003).

We understand the design process as a rational, dialectic and epigenetic process. The designer operates on a system of ideas, called the object model, which is the subject of a re-configuration movement from the abstract to the concrete.

The object model intercedes between the architectural object and the designer, or from other perspective, between architectural theory and praxis. The logical mechanism used by the human rationality to traverse this way is the pair: induction/deduction. Deduction is used to go from theory to praxis (from the general to the particular), and induction is used to go from the praxis to the theory (from particular to general).

This explanation must be completed with the introduction of the couple: analogy/abduction, which comprises the fundamental logical mechanisms for creativeness. They are the tools that allow human to propose creative, and sometimes really complex, solutions extrapolated from existing regularities from other order or dimension.

Analogy and abduction are complementary logical operations. Abductions allow us to identify, from design requirements, typological organizations, which are capable, as a preliminary hypothesis, to be used as a solution for the design problem. Analogy, on the other hand, allows us to extrapolate some characteristic from the well known organization, usually identified by the abduction, to the design problem under consideration.

We must point out that only the pair induction/deduction is recognized by formal logic due its apodictic value. Even thou, not formally recognized, analogy and abduction are key operation for creativeness.

The construction of the object model begins with an initial comprehension of the whole situation that involves the design request. This is called "modeler pre-comprehension process" and implies to perform a simplification of the variables related to the design problem through the derivation of a first and fundamental creative analogy. On this paper we will focus our attention on this phase.

2.3. THE CONTEXT

By the context we understand all circumstances that round the design process. We will include ideas, values and other designer beliefs, that pre-exist before the design process.

In this point we include all tools and assets that the designers possess to accomplish her/his work.

3. Spirospaces

A Spirospace (Barrionuevo, 2003) is a tridimentional geometrical entity characterized by its formal configuration, which in the general case, resembles a spiral. It is inspired on a bidimentional geometrical entity called Spirolateral (Odds, 1973).

The main value of spirospaces for architectural design resides on its spatial potentiality. It is easy to verify from a simple observation of a spirospace, like the one shown on the Figure 1, its strong analogy with architectural forms.

Other valuable attribute is its capacity to generate complex forms without loosing its apparent simplicity. This allows us postulate its use as a support frame for other geometrical entities, as we will explain later.

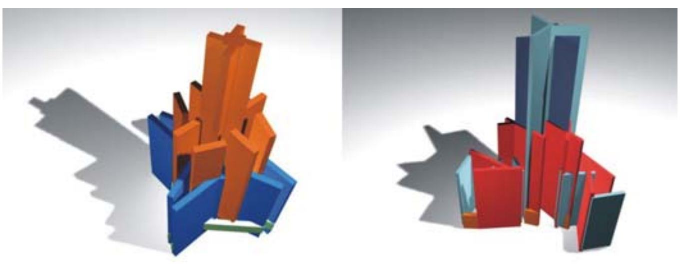

Figure 1. Typical spirospaces.

3.1. BACKGROUNDS

A first formal definition of spirolaterals was given by F. Odds (1973). The name spirolaterls derives from the words, "lateral" for sides, and spiro for hairsprings, since the first spirolateral was made up from "square hairsprings" (see Figure 2).

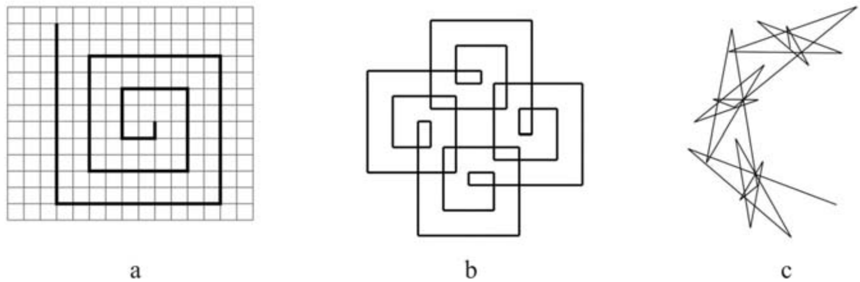

Figure 2. a) square spirolateral, b) closed spirolateral, c) open spirolateral.

Krawczyk (2001a, b) enriched the formal domain of spirolaterals, proposing the use of curves for its generation, and he developed the first computer program to automate their generation (see Figure 3).

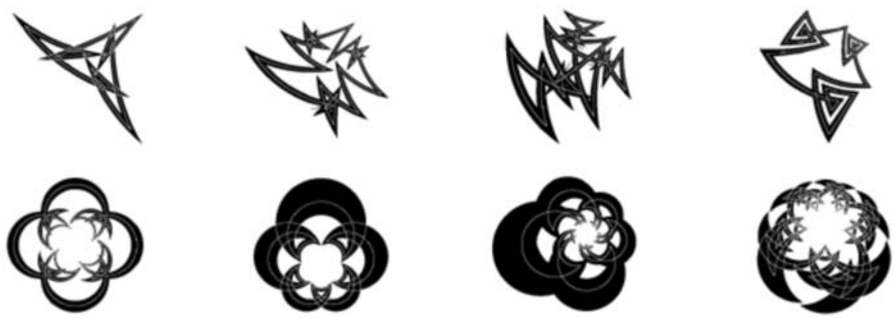

Figure 3. Curved spirolaterals. (Krawczyk, 2001a, b)

Barrionuevo and Borsetti (2001) extended the spirolateral definition to the three-dimensional space, introducing the concept of "Spirospaces". They developed a computer program to draw closed spiroraterals and they outlined the possibility to carry out rotations in three-dimensional space to generate more complex configurations.

Krawczyk (2002) proposed spirolaterals space interpretations by means of the "sculpture" concept. He developed three methods: by embossment, doing a simple extrusion from a bidimentional figure; by assembling, combining several positive extrusions all together; and by construction, introducing vertical supports at the rotation junctions of each segment, module, or segment (see Figure 4).

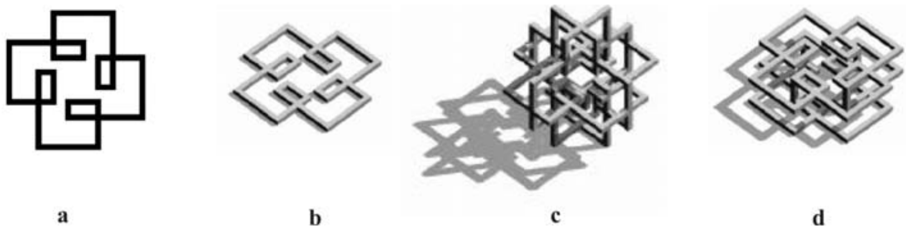

Figure 4. Krawczyk spirolateral interpretation of a by means of the sculpture concept.
a) spirolateral, b) embossment, c) assembling, d) construction. (Krawczyk, 2002)

3.2. SPIROSPACES COMPONENTS

To project a bidimentional object to the tridimentional space implies to add new levels of complexity. Therefore, some distinctions between spirolaterals and a spirospaces are required.

A spirolateral is conformed by a series of "segments" combined together according to a set of directional and dimensional rules. Segments conforms "modules" that rotate at a different angle than elements (see Figure 5).

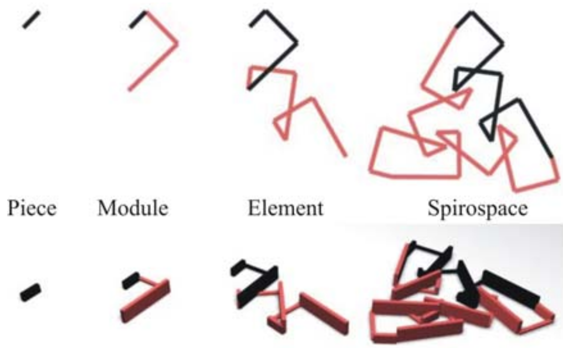

Figure 5. Spirospaces components.

On the other side, a spirospace is made up of tridimentional units, grouped by "packages" of variable complexity. A first package is compound by a set of "Pieces", somehow equivalent to spirolaterals segments. A second package is the "Module", conformed by consecutive pieces of variable length. A third package defines an "Element", which groups modules together. The integration of elements can continue indefinitely, generating even more complex elements.

3.3. SPIROSPACES PARAMETERS

In this work we will present only those parameters tightly related with spirospaces' appearance.

These parameters are directly related with the components that define a spirospace, which are: pieces, joints and spaces. Parameters that operate on the "pieces" are:

(a) Shape Parameter: defines the geometry of spirospaces' pieces (see Figure 6).

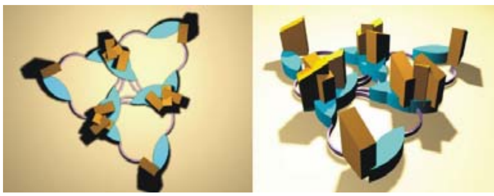

Figure 6. Spirospace shape parameter.

(b) Dimension Parameter: defines the size of spirospaces' pieces (see Figure 7).

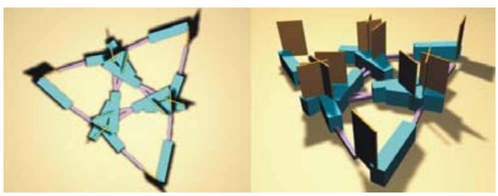

Figure 7. Spirospace dimension parameter.

(c) Orientation Parameter: controls the rotation angle for each piece that composes a spirospace. The angle variation is only possible along the longitudinal axis of each piece (see Figure 8).

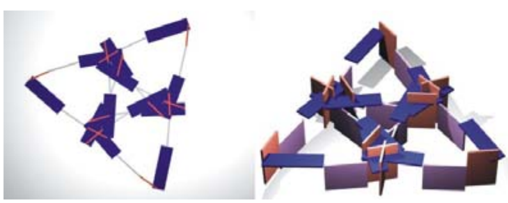

Figure 8. Spirospace orientation parameter.

(d) Materiality Parameter: refers to the appearance of spirospaces' pieces (see Figure 9).

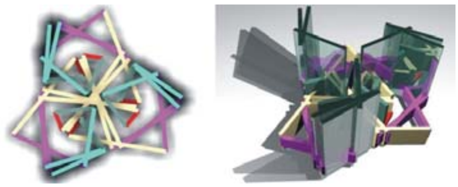

Figure 9. Spirospace materiality parameter.

(e) Joints Parameter: joints parameters are classified based on the relative positions of concurrent pieces. Considering plan and elevation relative positions, we propose the distinction between "Meetings" (plan), and "Encounters" (elevations).

"Meetings" parameter expresses all possible combinations of joints between two consecutive pieces. Figure 10 exemplifies this.

Figure 10. "Meetings" types.

Considering all pieces centered upon their longitudinal axis, the parameters of possible "encounters" between two pieces are as shown in Figure 11.

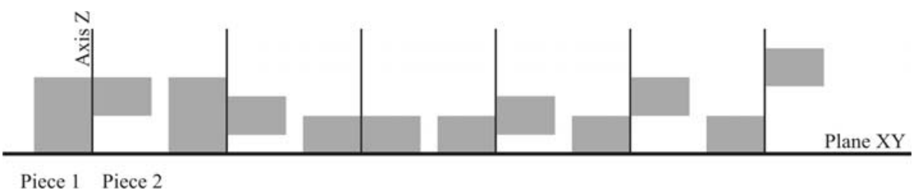

Figure 11. Possible "encounters".

Spirospace spatiality varies with the type of junction. Figure 12 shows the same spirospace with different junctions.

Figure 12. Spirospace junctions.

Spirospace spatial parameters are defined by its component pieces. In this point, we will apply a comprehensive concept for “space” and we will not make the traditional distinction between hollow or non hollow.

We define "Objectual space" as the space comprised by the pieces. On the other hand, we defined the "Interstitial space" as the space comprised among pieces. The composition of both spaces generates a "Mixed space".

The dimension of the objectual space is defined by the dimension of the piece, while the dimension of the interstitial space is variable in height, depending on the design intention (see Figure 13).

a **b** **c**

Figure 13. The same spirospace interpreted from different space definitions. a)- Objectual space b)- Interstitial space with established heights c)- Mixed space.

3.4. SPIROSPACES PROPERTIES

The properties of the Spirospaces can be considered according to three aspects: closing property, cycles property and compactness property.

3.4.1 Closing property

Spirospaces admit the closing property, which means that it is possible to generate open or closed spirospaces. If the initial point of their first component (segment or piece) does not match the final point of the last component, we say that the spirospace is open (see Figure 14). If it does match we say that it is closed (see Figure 15).

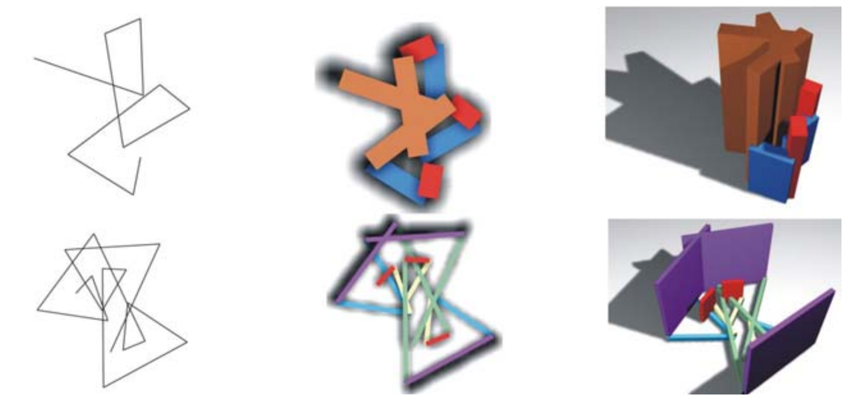

Figure 14. Open spirospaces.

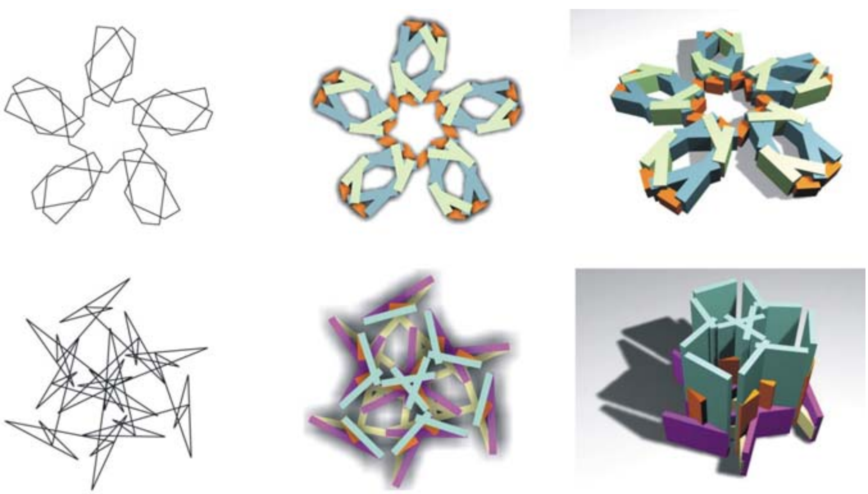

Figure 15. Closed spirospaces.

In both cases, components may accumulate turns, that is to say, it is possible to add cycles. This fact takes to the following property.

3.4.2. Cyclical Property

Closed spirospaces may have a variable number of cycles. A procedure to control this property, that establishes a relation between the number of elements "N" and cycles "C", is described below (see Figure 16).

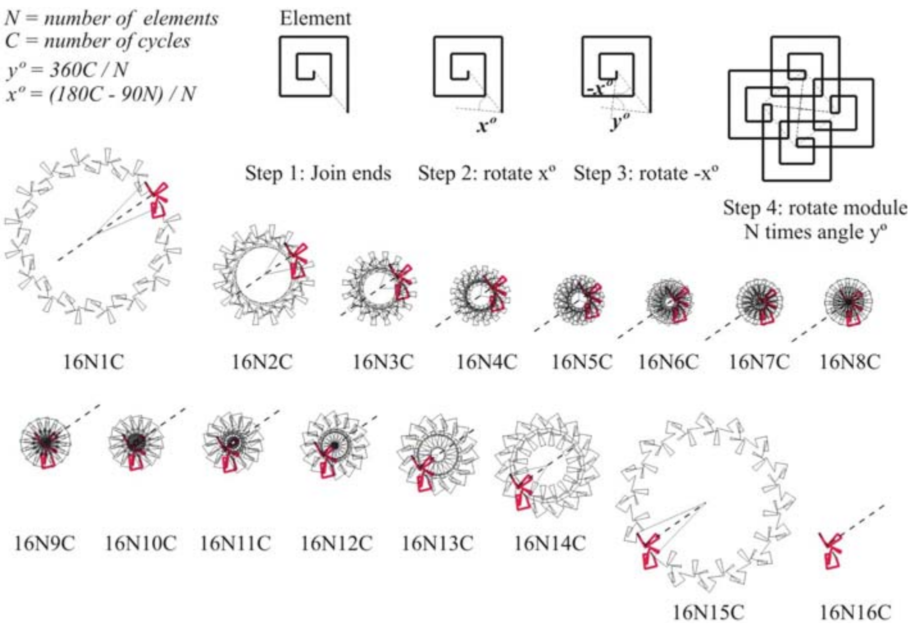

Figure 16. Procedure to generate closed spirospaces.

The procedure to generate closed spirospaces can be summarized as follows:

a) Draw an element of the spirospace.
b) Establish the quantity of elements N and the number of cycles C.
c) Calculate the angle of rotation of the element using the formula: $y^o = 360\ C / N$
d) Trace a segment among the extreme points of the element.
e) Calculate the angle of rotation of the traced segment with the formula:
   $x^o = (180\ C - 90\ N) / N$
f) Rotate twice the traced segment, with center in each one of the ends.
g) In the intersection between both rotated segments, establish the center of rotation of the element.
h) Rotate N times the element by an angle y^o.

3.4.3. Compactness Property

A spirospace contains both: objectual space and interstitial space. This property quantifies the relation between them. When the quantity of interstitial space is bigger than the quantity of objectual space it is said that the spirospace is "porous", Figure 17. In the opposite case it is say that the spirospace is "compact", Figure 18.

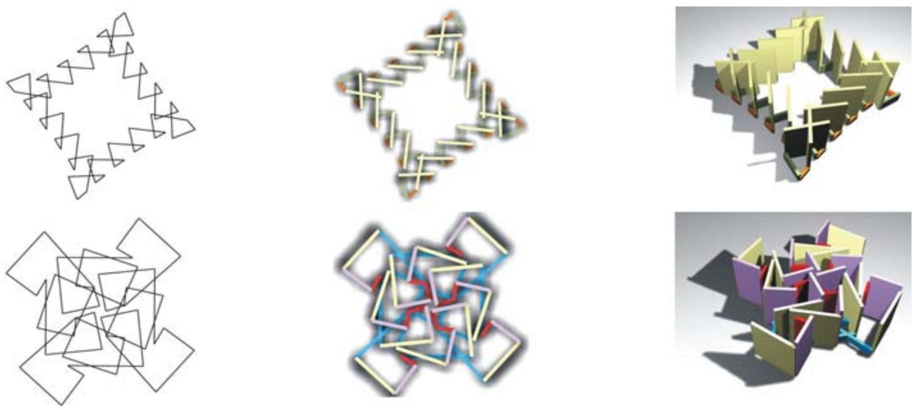

Figure 17. Porous Spirospaces.

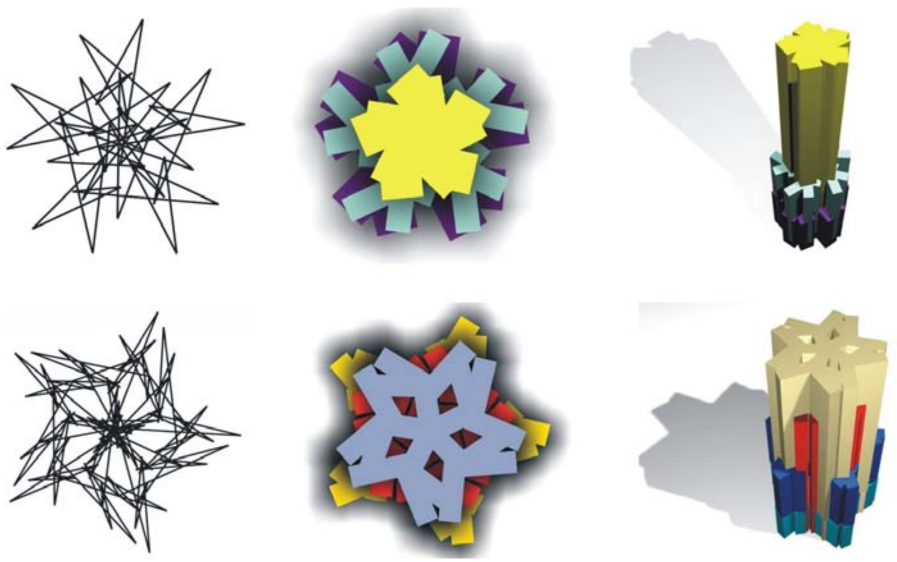

Figure 18. Compact Spirospaces.

4. Spirospaces and other Geometric Entities

The purpose of this work contemplates the possibility of empower architectural utility of the spirospaces exploring its relationship with other geometric disciplines such as knots theory, fractals theory, tessellations theory and generation of patterns theory.

Modern computer graphics has emphasized the fact that mathematics is a visual art, in which objects perception and visualization has primordial importance: certain mathematical forms constitute inspiring ideas for the generation of artistic or architectural forms. One could say that the key word that unifies art and mathematics is ***visualizing*** and, in fact, ***visualizing relationships***.

Creativity consists on visualizing from a new conceptual point of view. To look is a kind of action. To see is another. To look means to make an effort to see. It can take a lot of time and effort looking until one is able to see the set of relationships that intervene in form generation, satisfying different aspects like it happens in Architecture.

These "visualized forms" can have different significance and behavior according to the branch of geometry from which is used (Euclidean, topological, projective, fractal, hyperbolic, etc.). These different branches of geometry are usually identified by means of classes of entities, concepts or theories that characterize them. For example, topological geometry is identified easily with anything elastically deformable, which means that it can suffer transformations in its physical appearance without changing the relative position among its component points. A sphere and a cube are equivalent because, to obtain one starting from the other, it is only necessary a continuous deformation (it is demonstrated modeling with the hands some clay).

4.1. KNOTS THEORY

To define the theory of knots and nooses, we will say that it is a branch of mathematics that is in charge of studying the topological behavior of linear entities that configure forms in three-dimensional space.

A lineal entity is truly a knot when it has its extremes tied up in an immersive manner, that is to say, it should not have ends. It is a closed three-dimensional lineal curve and tied in itself, also well-known as topological knot, Figure 19 a. On the other hand, it is defined as a noose a piece of lineal curve tied up with open ends, Figure 19 c.

Those knots that are built starting from lineal pieces are denominated geometrical knots, Figure 19 b, conforming a polygonal path in three-dimensional space. These knots are also called tame knots or docile knots because it is possible to modify them twisting their axis to will. When two or more topological knots are tied up together we got a lariat, Figure 19 d.

Figure 19. a) Topological knot b) geometric knot c) noose d) lariat.

Establishing analogies between these concepts contributed by the Theory of knots and spirospaces, we will say that a rope with certain degree of mess can be topologically transformed into a ***closed spiro*** or into an ***open spiro***. If it is a ***knot*** (closed and tied curve) it is a ***closed spiro***. If it is a ***noose*** (with open ends) it is equivalent to an ***open spiro***. The Figure 20 shows a spirospace inspired by a knot.

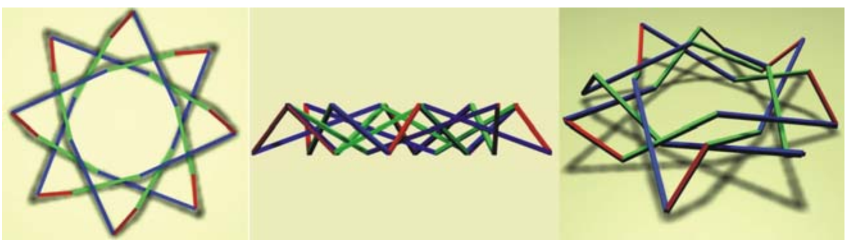

Figure 20. Closed spirospace inspired by a knot.

Knots are usually presented by means of diagrams or two-dimensional outlines that indicate where the knot crosses itself. The simplest knots that are really knotted are the trefoil knot and the double knot (figure eight knot). The Figure 21 shows two versions of the orthogonal projection of the trefoil knot and a double knot. The minimum number of crossings is of three in the case of the trefoil and of four in the case of the figure eight knot.

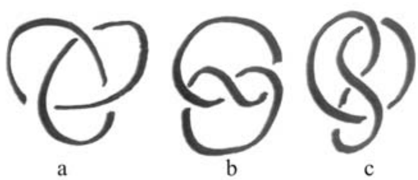

Figure 21. (a, b) Two versions of a trefoil knot, (c) Double knot.

Knots are useful mathematical forms for the generation of ideas with architectural ends, particularly when they are associated to "spirospaces". Being completely three-dimensional, not having front neither back, they favor creative freedom. Spirospaces associated with the theory of knots allows the development of designer imagination in spite of the restrictions imposed by the architecture (for instance, the necessity of a support plane).

A spirospace conceptualized as a knot, contains a great quantity of interpretations, depending on the multiplicity of points of view from where it is observed as an architectural object.

4.2. FRACTALS THEORY

Fractals theory, was introduced by Benoit Mandelbrot (1975) at the 70s. Their most relevant characteristics, from the perspective of this work, are:

(a) Irregularity (ruggedness, roughness).

(b) Self-similarity (shape similarity in different scales: the parts resemble the whole).

(c) Infinitely complex (seemingly chaotic, but it is described with simple algorithms).

(d) Recursivity (starting from a shape that operates as initiator, it is developed by means of the iteration of rules that act as generator).

(e) Initial conditions (their development depends on the initial conditions, that is to say, of the initiator and generator).

(f) Organic (it is common in nature).

When working with spirospaces it is possible to incorporate several of these characteristics, particularly if they are generated by means of iterated function systems (IFS) or by means of Lindenmayer systems (L-systems). The shape of the initiator is established, then the same element is reproduced recursively, changing its scale and modifying its shape by transformation rules. Figure 22 shows an example of a fractalized spirolateral (the first three steps) whose extrapolation to the space admits varied designs.

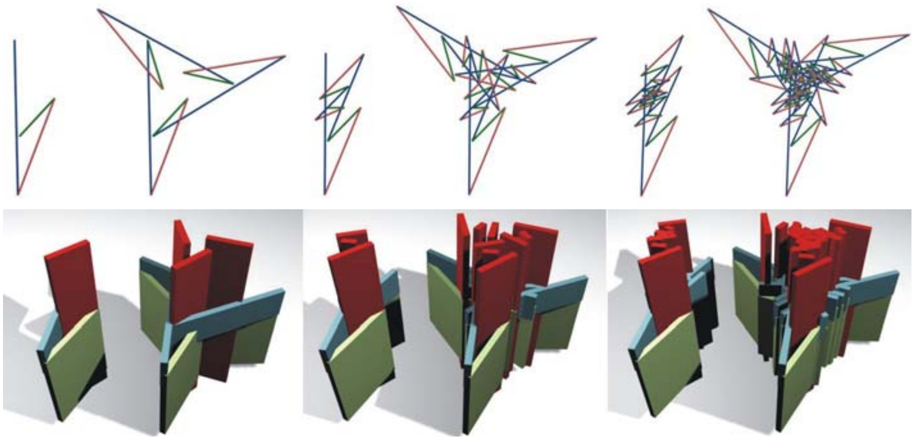

Figure 22. Three first steps of a fractalized spirospace.

4.3. PATTERNS THEORY

In the art or in the Nature a pattern is sustained by three characteristics: (1) a cell or unitary element (2) the repetition of that cell (3) a system of organization of the repeating parts. Spirolaterals in the plane as well as spirospaces in 3D fulfill these three characteristics, what allows us to conclude that all spirospace constitutes a repetition pattern.

5. The Computer Program

The authors of this paper have developed a computer program that produces spirospaces from a set of parameters and operators related to architectural principles of shape handling.

5.1. DESIGN OF SPIROSPACE OPERATORS

In order to generate and manipulate spirospaces with our computer program, a set of operators has been defined.

(a) Generation operators create entities considering the following parameters: Shape, Position, Dimension, and Orientation.

(b) Transformation operators work either on a specific spirospace component, or on a set of those components, depending on the nexus that exists among them. Some of these operators are: Translation, Size, and Rotation. They modify one or more shape parameters, for example the element position. These operators allow to gradually tuning the result.

(c) Edition operators administer the appearance of spirospaces. One of them is "visibility", which allows to show or to hide entities that compose a spirospace. Edition operators are: Color, Transparency, and Visibility.

It is possible to implement operators to manipulate other more valuable architectural parameters. For example: proportion, scale operators, compactness operators, etc.

5.2. BRIEF DESCRIPTION OF THE APPLICATION PROGRAM

The program for spirospaces generation has been implemented under the AutoCAD 2002 system, making use of the integrated development environment (IDE) Visual C++ 6 and the applications programming interface (API) ObjectARX 2000. The Figure 23 shows a dialog box for aleatory spirospaces generation.

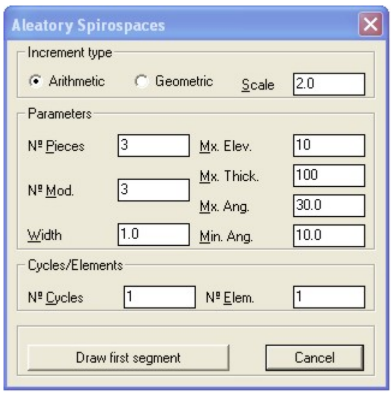

Figure 23. Dialog box for aleatory spirospaces generation.

Two modes of Spirospaces generation were considered: with results completely predetermined by the user, and another with the incorporation of a stochastic component. For the first case, the factor to consider was the predictability. The result obtained depends directly on the values entered by the user. In the second case one kept in mind the surprise factor, the unexpected thing. The use of the system is adapted to the mode of bank of tests, to define the architecture of the group in the early stage of the design.

6. Creative Analogy

Essentially, we propose to use the processing power of modern computers to manipulate complex geometrical organizations. These organizations become a useful source of inspiration for the modeling process, specially the conceptual pre-comprehension step which, as we saw, is the entry point to the design process.

This creative phase of the process, challenges the designer capability to settle analogies against entities of other orders, and is heavily conditioned by his/her vital and professional experience.

The analogy process implies to relate two organizations, two totalities, and to translate some characteristics from one to the other. As we stated, we propose spirospaces as the analogy source, and the design idea as the target. Now the question is, what do we get from spirospaces that can be translated into architectural ideas? To answer this question we will analyze the way we perceive spirospaces.

6.1. THE ANALOGY SOURCE

Even thou a spirospace can be a very intricate entity, it is always perceived with a strong sense of unity, provided by its generation rules. For this reason, we postulate that the characteristics related to the wholeness sense of spirospaces are valuable on three basic features: geometry, space, and syntax organization.

(a) Geometry: it refers to the morphological characteristics of a spirospace. The spirospaces arrangements usually have a remarkable formal personality, obtained from their generation rules, which means that this aspect has a powerful analogy potentiality.

(b) Space: it refers to the space generated by spirospaces. It implies the observer interpretation to consider either objectual or interstitial spaces configurations, mentioned before.

(c) Syntax: it refers to the conceptual organization of a spirospace. It implies a high degree of abstraction from direct observation. It is the form structure of the spirospace.

6.2. THE ANALOGY TARGET

Starting from a conceptual definition it is possible to associate some features of the object used as a creative trigger, establishing a relation by analogy. Creative analogy is accomplished by translating some characteristic from the paradigmatic entity used as a creative trigger to some characteristic of the architectural ideas. As we stated, we consider as relevant architectural features, the form, function and structure, and indeed, these are the target for the creative analogy. This means that we can use the geometry of a spirospace to inspire architectural morphological configurations.

We can use spirospaces to interpret some functional architectural schemes; those related to a central system with peripherical rotational subsystems, or to use the syntax organization of a spirospace to inspire the layout of the same kind of architectural ideas.

The function of the digital tool is to provide a manipulation interface by means of a geometrical operator set for complex geometric entities (spirospaces) in a way to favor these analogies.

The following table expresses all possible analogies between a spirospace and an architectural object. See Table 1.

Table 1: possible analogies between a spirospace and an architectural object

Spirospaces	**Analogy**	**Architectural object**
Geometry	Resembles morphological configurations	Form
Space	Resembles required spaces	Function
Syntax	Resembles organization structures	Structure

6.3. EXAMPLES

(a) Spirospace's geometry to architectural idea's form analogy. Spirospace element configuration inspires interior architectural solutions(see Figure 24).

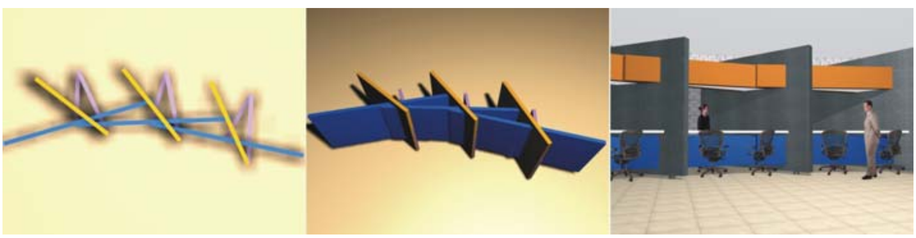

Figure 24. Architectural interpretation of an interior space (R. Borsetti)

(b) Spirospace's syntax to architectural layout analogy (see Figure 25).

Figure 25. Architectural layout from a spirospace interpretation (R. Borsetti).

(c) Spirospace's space to architectural function analogy (see Figure 26).

Figure 26. Architectural interpretation of a skyscraper.

7. Conclusions

The greatest challenge when using spirospaces as creative triggers for architectural design is to find out a procedure to obtain valuable architectural inspiration.

It is not enough just to generate geometry. It is required to define an interaction interface that provides the designer with an inference mechanism to translate spirospace potentiality into architectural ideas.

We hope the procedure stated on this paper will contribute to the development of a new generation of design tools, and, even thou it is possible to state some practical objections to it, we believe that this is the way to follow.

To conclude, this work embrace the idea that it is possible to enrich architecture creativeness by exploring the use of logical-mathematical operations, such as symmetry, combinatory analysis, recursion and parameterization, and that computer can be used not only as a representation media but also as a programmable tool for creative design

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MODELING WITH GESTURES: SKETCHING 3D VIRTUAL SURFACES AND OBJECTS USING HANDS FORMATION AND MOVEMENTS

The 3D SketchMaker Project

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Abstract: The 3D SketchMaker project has developed two prototypes for a gestural 3D sketching system to be used in the earliest phases of the design process. The goal of this ongoing research is to provide architects, and other designers involved in object conception, with a 3D gestural instrument that takes advantage of new virtual reality resources and is more natural than using the mouse, less difficult than learning complex software and less abstract than manipulating 2D entities on orthogonal projections. The system was conceived to assist or replace the first 2D drawing steps in the design process, generating rough 3D sketches that can be refined later using any 3D package. It is, in essence, a 3D modelling system directed to do sketching with hand movements and gestures in a virtual reality environment.

1. Introduction

Sketching is the means that architects, designers, artists and sculptors use to represent, visualise and study their concepts of three-dimensional objects. Traditionally sketching has been done with pencils and paper, resulting in a set of two-dimensional drawings representing three-dimensional objects. The current process of design is, usually, a sequence of 2D hand sketching, 2D computer drafting, 3D modelling, and finally, rendering. Usually this process involves two or more different professionals: one to sketch the concepts and others to translate these sketches into cad drawings and later to generate and to render a 3D model.

As a result, there is a gap between the first design sketches and the remaining design process (Brown, 1995). Architects and other designers are missing the potential of developing their ideas directly using the same tools that will be used later for the rest of the project's development and representation. Also they are missing the opportunity, resources and benefits of using virtual reality and 3D computer models from the very inception of the design process (Jacobs, 1991).

For many architects and designers, one of the main reasons for not using 3D modelling or even computers from the very beginning of the design process is that both current hardware and software are hardly appropriate to do the spontaneous and quick drawings that are used to assist in conceptualising their objects.

Three-dimensional modelling packages, for example, use two-and-three dimension elements, in a three-dimensional environment, but usually employ the paper-and-pencil metaphor or its pointing tools, through the pointer of the mouse. These kinds of interface and 2D input devices, such as mice or pen-and-tablets are not appropriate to work in 3D environments. Pointing devices and menus in 2D and 3D software do not allow the freedom, quickness and spontaneity needed to establish a "continuous cycling of information from paper to eye to brain to hand and back to paper" (Laseau, 1988) as hand sketching does.

The focus of this project is on the input interface. The goal is the development of an easy and intuitive 3D sketching gestural interface and system that is more natural than using the mouse, less difficult than learning complex software and less abstract than manipulating 2D entities on orthogonal projections.

One of the assumptions basic to achieving this goal is that the mouse 2D movements should be translated into 3D spatial movements, i.e., hand movements and gestures, considering that “the obvious fact that people have found two hands useful, even essential, in daily life has been ignored by the user-interface community, including those working with reality goggles.” (Krueger, 1991)

It is known that "spontaneous (that is, unplanned, unselfconscious) gesture accompanies speech in most communicative situations, and in most cultures..." (Cassel, 1998). Hand gestures are used in a variety of ways in association with spoken language to emphasise the speech, to give clues, to enhance the communication, etc. Thus, according to Cassel (1998), "...if our goal is to get away from learned, pre-defined interaction techniques and create natural interfaces for normal human users, we should concentrate on the type of gestures that come naturally to normal humans."

Among the common spontaneous gestures described by Mcneill (1992), the iconic are gestures depicting a concrete object or event and bearing a close formal relationship to the semantic content of the speech. Iconic gestures are representational and descriptive. Considering that most people use iconic gesture as an aid to language when trying to describe the shape or form of objects (Figure.1), it could be said that gestures are a natural way of "sketching" in the human three-dimensional environment.

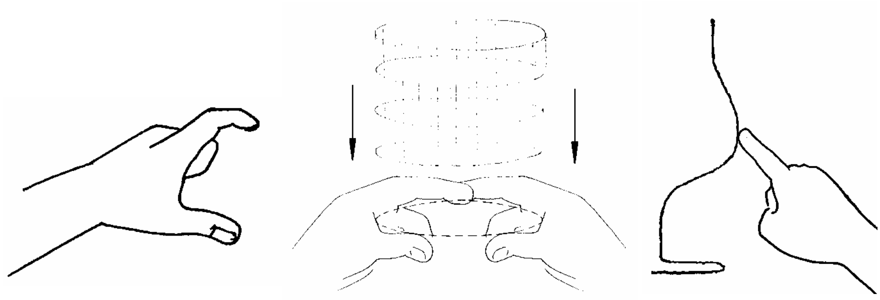

Figure 1. Iconic gestures are frequently used to help language in the description of the form and shape of objects

The 3D SketchMaker was conceived to take advantage of this natural tendency and to assist or replace the first 2D drawing steps in the design process, generating rough 3D sketches that can be refined later using any 3D package. It is, in essence, a 3D modelling system directed to do sketching with hand movements and gestures in a virtual reality environment.

2. The 3D SketchMaker Prototype

We intend the final 3D SketchMaker product to be a virtual-reality, 3D-modeling system for computer generation and manipulation, with hand movements and gestures, of quick and rough computer 3D solids or surfaces.

As we wanted, at the end, to be able to simulate clay modelling, the choice was the use of true three-dimensional input instead of a 2D input technique like Krueger's Videotouch (Krueger, 1991).

The first product from this project is a prototype of a desktop vr surface modeller that allows surface description with two simple hands movements. The basis of this prototype is a sensor that returns its xyz position, as well as its three orientation angles, azimuth, elevation and roll, to the application and a piece of software that collects and processes the data. For this prototype we have used a 3D mouse and the hardware of a flock of birds with a Silicon Graphics workstation.

Two crossing spatial lines describe the surface: one, a path, and the other, a profile that is extruded along the path (Figure2). While the user moves the hand with the 3D mouse (or any spatial sensor), the system acquires the data in three degrees of freedom, constructs and renders the surface.

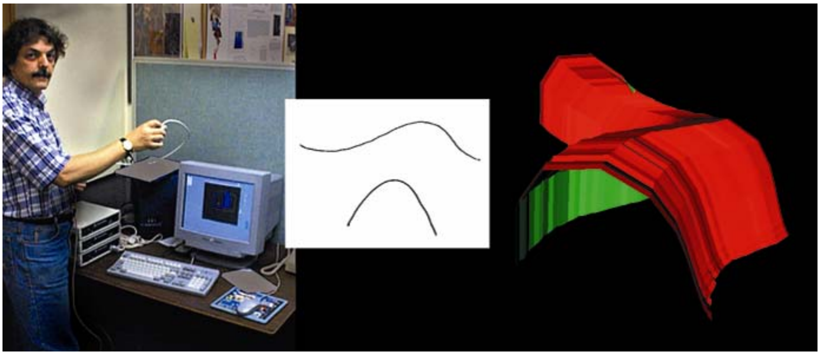

Figure 2. Tthe shape of a surface can be defined with a hand movement in the space, instead of tracing a line in the xy, xz or yz windows of a normal CAD or 3D package. Here, a line is not necessarily on a plane; it can be an actual spatial line.

As with any sketches, these 3D computer-generated models are rough representations of the objects, which will need later treatment and refinement.

3. Gesture Recognition

A second prototype has been developed to be used in association with the surface modeller in cases where the model has a basic regular shape, and to enable manipulation of all models. In this prototype, the input device is an instrumented glove that allows the system to recognise the user's hand formation.

A primitive solid is associated with the hand, as if the user were holding the object. After the solid's creation, designers will be able, using their hands, to grab, position, scale or modify the object with Boolean operations (Figures 3 and 4). Some 3D gesture-modelled surfaces are shown in Figure 5.

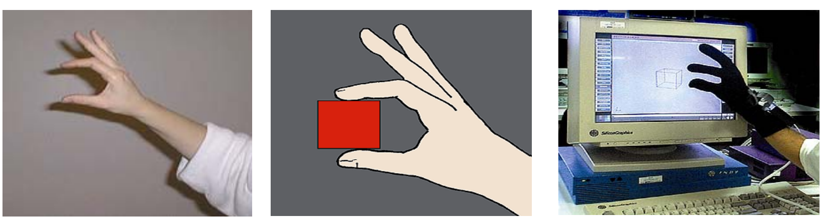

Figure 3. The recognition of hand formations allows the designer to generate the more common basic primitives: cube, sphere, cylinder and cone, as well as to grab, manipulate and do Boolean operations.

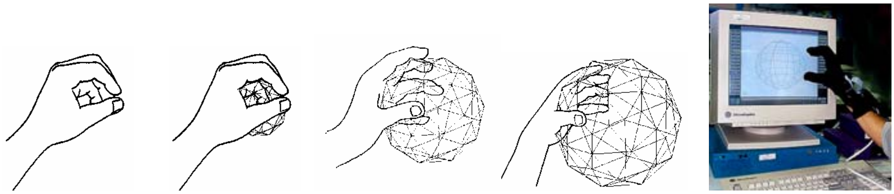

Figure 4. The hand formation is recognised by the system and a solid is associated to it, as if the user were holding the object. Once virtually grabbed, this object can be positioned with one hand movement, or scaled just with the aperture of the fingers, i.e., if the fingers are brought closer to each other, the model is scaled down, if the hand is opened, the model is enlarged.

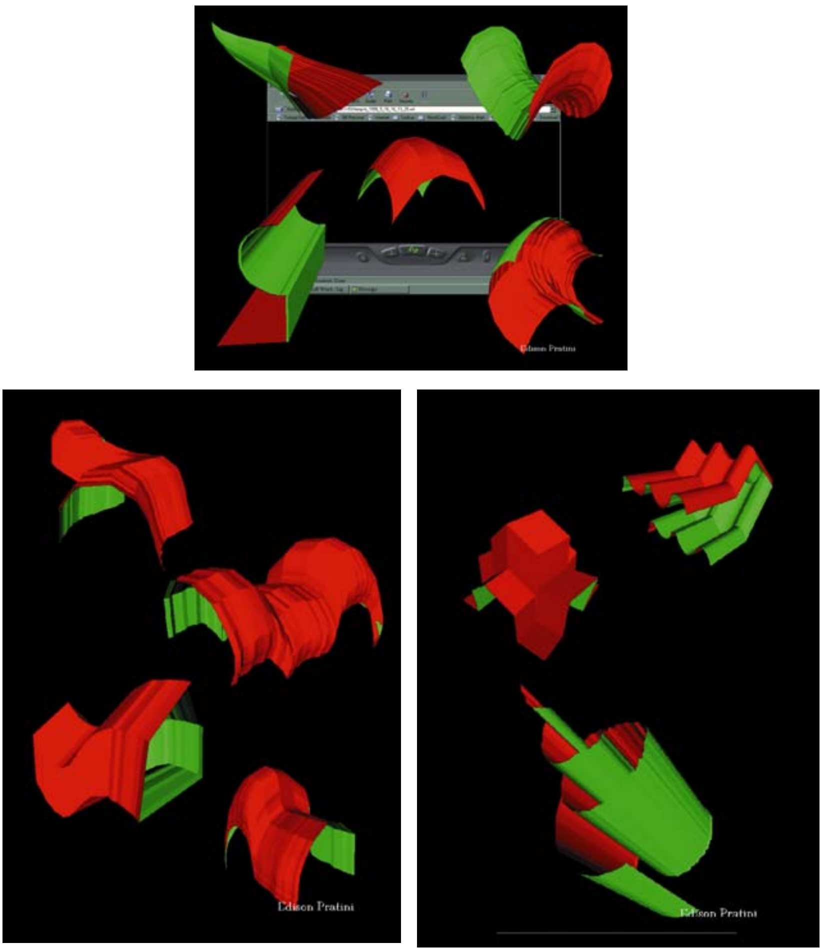

Figure 5. Some 3D gesture-modelled surfaces

4. Conclusion

Instead of trying to extract meaning from 2D drawings, the 3D SketchMaker is intended to allow direct 3D sketching in a real life 3D environment. Gestures are not used as a language in this system, but as a way of describing to the computer the form or the boundary surfaces of an object, employing the hand movements and gestures most people use when trying to describe the form or the shape of an object.

The system is still being developed and tested. Further development will include more methods of 3D sketching, clay modelling, sculpting, 3D-visualization devices and other vr features. We are moving toward an easy, intuitive and transparent modelling vr system.

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DESIGN GENERATION OF THE CENTRAL ASIAN CARAVANSERAI

Use of a parametric shape grammar for the analysis of historic Islamic architecture

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Abstract. Challenges for the study of Islamic architecture include its abundance and diversity in expression and its classification based on distinct functional or stylistic types. We address these issues by presenting shape grammars as a methodology for the analysis and design generation of Islamic architecture, with a specific example in the form of a parametric shape grammar for central Asian caravanserais. The grammar is developed by identifying distinct design types. Shape rules are created based on a study of the spatial elements and their organisation in the designs. We illustrate the utility of the grammar by deriving an extant design and as well as, previously unknown designs. We conclude by discussing possible extensions to the current grammar and future work involving the development of a grammar based framework for the comparative analysis of medieval Islamic courtyard buildings.

1. Introduction

The contribution of the Islamic civilisation in the field of architecture is both vast and diverse. Spread across three continents from Southeast Asia to North Africa and Southern Europe from 750 AD till the present time, Islamic architecture adapted itself to local climate and materials, and thus portrayed a unique face in each region.

The abundance and diversity in expression of Islamic architecture presents historians with several problems in classifying and analyzing Islamic architecture based on distinct functional, geographical or stylistic types, as very often these types overlap or have hazy borders (Hillenbrand, 1994), thus pointing towards a need for the development of an alternative method for the analysis of Islamic architecture (Menon, 1999). Another issue facing Islamic architecture is the generation of a contemporary idiom — one that projects the community's identity and specificity by relating itself to historic architecture, whilst being modern and true to its time (Lewcock, 1988).

This paper addresses the aforementioned issues by presenting shape grammars (Stiny and Gips, 1972) as a methodology for the analysis and design generation of Islamic architecture. One of the most important characteristics of Islamic architecture, which makes it a subject amenable to the methods of rule based analyses, was its basis on advanced concepts of geometry and mathematics and the use of modular design systems (Hillenbrand 1994; Holod 1988). Being a rule based methodology shape grammar are well suited to the design generation techniques of Islamic architecture.

The study relies on a brief examination of Islamic principles of design, which aid in the creation of a meaningful conjecture of the design process of historic Islamic buildings. This deduction of principles from the precedent of historic buildings is deemed as a vital factor, beneficial for the computation of meaningful designs of future buildings.

In this paper we describe a parametric shape grammar for the generation of the ground plans of Central Asian caravanserais and demonstrate its use for representing extant designs as well as generating new ones in the style of the caravanserai.

2. The Concept of the Central Asian Caravanserai

Caravanserais were rest houses for caravans, built on trade routes between central Asian cities in the middle ages. Several types of caravanserais developed in Asia from the 10th century onwards, varying according to time and place.

The central Asian caravanserai was designed as a fortified development with a central courtyard, and a cellular growth of rooms all around it. It was square, round or octagonal in plan, concentric in nature, with bastions marking the fortification wall and towers at the angles. The access was often through a single portal placed at a location on the orthogonal axis. Often, the courtyard of the caravanserai was surrounded by arcades, with emphasis at the central bays, following the traditional four *iwan* plan (Pope, 1971). Figure 1 illustrates a variety of caravanserais and related buildings.

The courtyard was used as a place to tether the animals, whereas cells provided living space for the travelers. Toilets were placed in the towers at the corners of the building. In later caravanserais, an extra zone between the living quarters and the peripheral wall was developed to house stables for the animals. Since caravanserais were often isolated outposts in the countryside, they also fulfilled the role of defense bases.

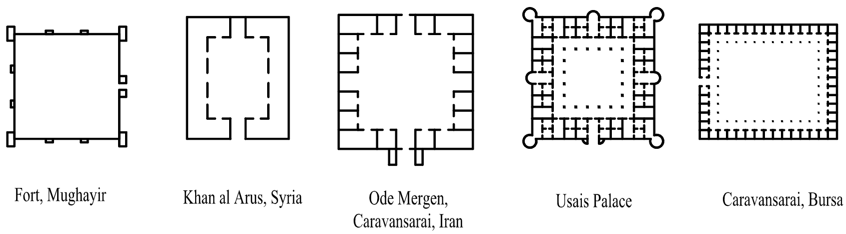

Figure 1. Examples of caravanserais, desert palaces and forts.

The complexity in design of the caravanserai grew with the increase in its functions and scale over the centuries.

Often a ‘four *iwan*’ plan was adopted for the caravanserai. In this type of a building, there was added emphasis on the central bays on the orthogonal axes, which were developed into large, arched rooms, open to the court. This was deemed as a ‘generic’ plan, at once applicable to various kinds of Islamic buildings such as palaces, private dwellings, caravanserais, mosques and madrasas (Michell, 1978).

The design of the caravanserai has been said to be influenced by Roman forts as well as domestic courtyard architecture. Some writers also point to Buddhist monasteries and Chinese military posts as possible sources of the caravanserais; although it is conceded that at an early stage, caravanserais most closely resemble forts, or *ribats*. The primary components of such forts were heavy construction walls, massive towers, bastions/buttressing and huge portals set at strategic points in the fortification. The local building tradition was followed in construction of fortifications, with round, square or elongated towers at the angles of the fortification (Michell, 1978).

3. Islamic Principles of Design Associated with the Central Asian Caravanserai

A universal characteristic of buildings all over the Islamic empires was their fundamental reliance on mathematics and geometry for planning and construction (Michell, 1978). The use of geometry has been ascribed an esoteric dimension, as it is seen as a vehicle to manifest the Islamic doctrine of unity (Critchlow, 1970; Ardalan and Bakhtiar, 1973). Geometric organisational principles such as symmetry, hierarchy and axiality were used (Hillenbrand, 1994) to create ‘perfect forms’ (Michell, 1978).

Symmetry is often seen as the basic principle of design in Islamic architecture. It involved the balancing of similar, not necessarily identical, parts of a design on the opposite sides of a fulcrum or axis (Golombek, 1988). Hierarchy was used as a primary means to subdivide a building and to highlight some spatial elements over the other. Hierarchical principles were used in conjunction with those of scale to create emphasis in design (Hillenbrand, 1994).

A proportional framework was used not only for the development of details, but also for layout and form development, with the intention of bringing all parts of building into a harmonious relationship with each other (Volwahsen, 1970). Building designs were developed on grids based on modules, which corresponded to the prevailing brick size. The dimensions of various parts of the building were based on simple ratios of these modules (Michell, 1978; Holod, 1988).

Thus, Islamic buildings can be seen as a configuration of spatial elements bearing formal relationships with one another. In the shape grammar formalism, such spatial elements can easily be translated into ‘shapes’ that constitute spatial relations. The ordering principles can be translated into ‘shape rules’ that are responsible for the organisation of spatial relations.

4. Shape Grammars as a Tool for Design Analysis and Generation

Shape grammars (Stiny and Gips, 1972) have been in use for over three decades. Their utility in design generation and analysis has been well documented (Knight, 2000). Grammars are both prescriptive and descriptive: the rules of a grammar generate designs but can also be considered descriptions of the forms of the designs. Stiny (1980) has made a number of observations on the benefits of using rules to produce languages of designs, among them:

- They are less complicated than the designs they generate;
- They create new directions for design within a given vocabulary;
- Rules shift the emphasis from individual designs to sets (languages) of designs;

- Use of a language of designs allows a designer to examine a design and its variation without loss of understanding, simply by applying the rules to construct them;
- Rules can be modified systematically to define new languages of design.

A shape grammar consists of a set of rewriting rules that can be used to generate a set of designs (the language). A computation starts with an initial shape. A rule can be applied when an instance (geometric transformation) of its left hand side shape can be found in the current state (shape) of the computation. This transformation is then replaced with the equivalent transformation of the right hand side of the rule. Figure 2 shows a simple grammar with one rule that can generate church plans based on the spatial relations of a Greek cross. The language of designs generated by a grammar can be considered analogous to a design style.

More complex grammars can be created by employing additional computational devices. Parametric grammars use variables to allow a wider variety of designs from a single grammar, e.g. to vary dimensions. The use of labels in the form or markers or points can constrain rules to be applied in specific contexts, e.g. as a means of establishing a specific sequence of operations that could represent stages of design.

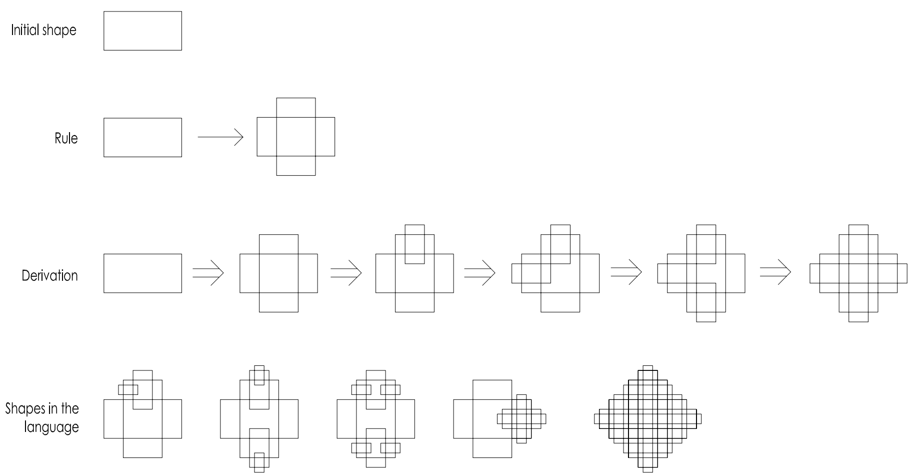

Figure 2. Simple shape grammar for Greek cross church plans (from Knight, 1994)

5. The Caravanserai Grammar

The caravanserai grammar generates the ground plan of a fortified courtyard with a configuration of corner towers, entrances and bastions marking the external wall. A maximum of two built-up zones (cells & colonnade) are generated by this grammar. The following sections elucidate the development of the grammar.

5.1 GENERAL CONSIDERATIONS

A special feature of Islamic architecture that has been acknowledged is that of its multi-functionality of building design. Islamic architecture developed 'perfect building forms' that could be adapted for various purposes (Michell, 1978). The same building plan could be utilised for fortresses or for caravanserais (Michell, 1978), and often one building would be indistinguishable from another judging by the ground plan alone (Hillenbrand, 1994). Hence the grammar created in this project generates ground plans not only of the caravanserai building type, but also of forts and desert palaces with similar designs.

The vast abundance and diversity in the historic buildings of Islamic architecture presents a problem in any generalisation of design. To make the task easier, only the buildings that shared a commonality in structure have been considered. Variations in design due to site constraints or other reasons have been ignored. The shape grammar so developed does not generate all varieties of designs that have existed in history, but would be able to generate a wide range of buildings.

Errors and slight inconsistencies in axes, proportions, and angles have been ignored in order to facilitate a more wholesome discussion of the generation of design. Wall widths have been ignored for the purpose of this project.

Parameterisation of space dimensions has not been detailed in this project. It is believed that if attempted, this would not pose any difficulty since building designs in Islamic architecture were based on modular systems. However, the size of the module as well as spaces based on it would vary according to time and place (Michell, 1978).

5.2 APPROACH

The following processes were followed for the development of the caravanserai shape grammar:

5.2.1. Identification of Design Types

Three related design types were identified. The generic design is that of a fortification which is constituted by an open space enclosed by a wall. The second level of design is that of a courtyard enclosed by a single built up zone, consisting of unitary or multiple cells. Finally, the third level design creates a courtyard surrounded by two built up zones i.e. a colonnaded space and a cell zone.

5.2.2. Identification of Spatial Elements & Their Organisation

Spatial elements such as the courtyard, the fortification wall, corner tower, primary and secondary bastions, primary and secondary entrances etc. were identified and delineated. The center of the courtyard, represented by an intersecting orthogonal axis, was identified as the generator of the design. Spaces and spatial elements have bilateral symmetry about these axes, with often a strong emphasis at the central bays.

5.2.3. Creation of Shape Rules and their Sequencing

The spatial elements were converted into parametric shapes bearing relationships with one another in shape rules. The primary parameter was established to be the size of a cell module, *m*. The sequential ordering of the rules was mostly intuitive and highly dependant on the shape recognition techniques of the shape grammars formalism.

5.2.4. Setting up Constraint and Control Mechanisms

Constraints were set up in the rules to control the applicability of a rule. This was considered necessary, in order to limit the generation of irrational designs, whilst allowing the possibility of a wide range of new and varied designs.

5.3. RULE CONTROL MECHANISMS

5.3.1. State Labels

State labels have played a significant role in the application of rules. One of their most important uses has been to make certain rules ‘obligatory’, where the requirement of a state change makes the application of a rule necessary for the progress of the design generation (Knight, 1994). For instance, rules 11a and 16a are obligatory for a design to reach a final state. Other rules may be termed as ‘optional’ for the development of a design. These contribute to the generation of a wide array of designs in the grammar.

State labels have also been used to control the number of times a rule could be applied to a design. For example, a constraint placed on the state label in rule 1a allows it to be applied only twice (note that states are indicated in the rules by Roman numerals).

5.3.2. Spatial Labels

The primary spatial labels used in this design are the orthogonal axes running through the center point, and the 'cross' signifying the courtyard. These spatial labels control the choice of the Euclidean transformations under which a rule may be applied. Other spatial labels that have been used are line markers, such as those used in rules 3b and 6a, which control *where*, or to what parts of a design a rule can be applied.

5.3.3. Other Labels

Dimension lines have been used to delineate the size of elements. Text labels have been used for the denotation of shapes.

5.4 SHAPE RULES

The shape grammar is developed in five stages. Stage A contains rules for the development of a generic design for the built zone of the building. Stage B allows the definition of this built zone. In Stage C, a generic design for the fortification wall is created, while stage D contains rules for the stylisation of the fortification wall. Stage E hosts termination rules.

The organisation of rules in such a manner gives a grammar the potential to be transformed easily by ascribing new forms to stylisation/definition rules. This would result in designs which are essentially based on an Islamic construct, but have a new expression.

5.4.1. Initial Shape

The initial shape (Fig. 3) is a labelled polygon *P(0)*, with its vertices marked. Orthogonal axes marks the centre point, whereas a dotted cross indicates the open space of the courtyard. The dimensions of the shape are based on multiples, n' and n'' of a modular length, m.

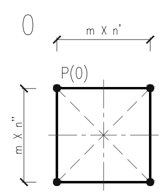

Figure 3. Initial shape in the caravanserai grammar

5.4.2. Stage A: Building Zone Development

Figure 4 illustrates the initial rules for defining building zones, the major organizing elements of the plan.

Rule 1a is an optional rule that creates a polygon inside the given polygon, thereby reducing the size of the courtyard by a multiple of the modular length m. The rule can be applied recursively to generate a single built zone (cell zone only) or two (cell & colonnade) built zone designs. A design with no built zone, i.e. a fortification, can be generated by skipping the rules in stages A, B and C.

Rule sets 2 to 4 govern the development of designs with one or two building zones.

Rule 2a is an obligatory rule for single zone designs. It creates entrances to the courtyard in the wall *P(1)* at all locations on the orthogonal axes. The dimension of the opening is parameterised to be dependant on the length of the module and number of bays in the entire length of the wall.

Similarly, rules 3a, 3b and 3c are obligatory rules for designs with two built zones. Rule 3a creates entrances on all orthogonal axes in shapes *P(1)* and *P(2)*. The size of the entrance is a multiple of a modular length, *m*. Rule 3b changes the labeled shape *P(2)* into a colonnade, by setting up a counter to create *n* bays of module *m*. The rule applies recursively till line markers overlap, making possible the application of rule 3c.

Rule 4 is an optional rule that can be applied recursively to create 1,2,3 or 4 ‘iwans’ or halls at central locations in both 1 or 2 zone designs.

5.4.3. Stage B: Cell Rules

Rule sets 5 to 8 (Fig. 5) govern the generation and design development of cells in single and double built zone designs. Rule set 5 concerns unitary cell configurations, whereas rules 6, 7, 8 apply to multiple cell configurations.

Rule 5a creates a break in the center of the wall *P(1)*, thereby creating an entrance to a large, unitary cell. Rule 5b is an optional rule for unitary cell configurations. It creates stables of modular length on the inner periphery of the wall *P(0)*. With the application of rules 5a and 5b, the design moves directly into stage D.

Rule set 6 deals with the creation of multiple cells of modular length *m*. Rule 6a is applied recursively till the desired number of cells are created. The application of the rules in rule set 6 makes obligatory the application of a rule from the corner cell rule set, which governs the correction of a closed corner cell.

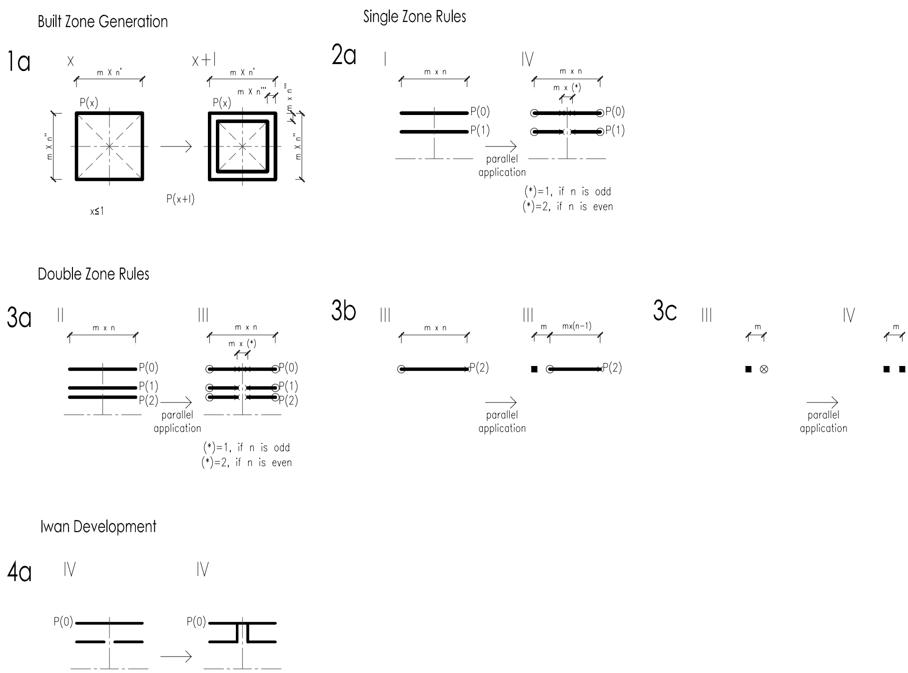

Figure 4. Stage A rules for building zone development.

Rule 7a deletes a wall, and merges the corner cell with one of the adjacent cells. Rule 7b creates a break in one of the walls of the corner cell so that it can be accessed from an adjoining cell. Rule 7c merges adjacent cells with the corner cell and bevels the corner. Other such rules may be defined.

Rule 8a is an optional rule that may be applied to designs that underwent multiple cell generation. It divides all the cells in the design into half. This rule is associated with a state change, so can be applied only once. Rule 9a is a state change rule that allows designs from earlier stages to jump over to the next stage.

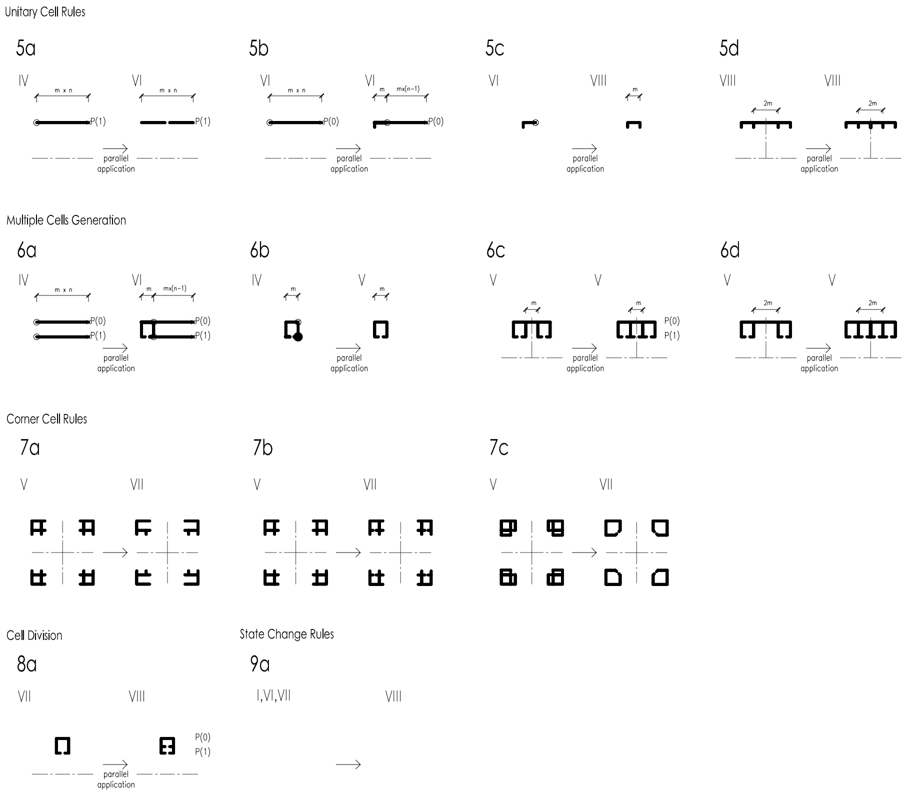

Figure 5. Stage B rules for cell development.

5.4.4. Stage C: Fortification Wall and Entrance Development

This stage (Fig. 6) marks the development of the fortification wall *P(0)*. Rules 10a and 10b are optional rules that place configurations of secondary bastion markers, *B(s)* on the fortification wall.

Rule 11a is an obligatory rule for all designs. It creates a primary entrance in the fortification by breaking the wall *P(0)* at a central location. Two secondary bastion markers *B(s)* are placed adjacent to the entrance. A circular marker signifying a stylised entrance is placed at the interior of the entrance.

Rules 11b is an optional rule that can create 2, 3 or 4 secondary entrances. Rule 11c places primary bastions at central positions on the wall.

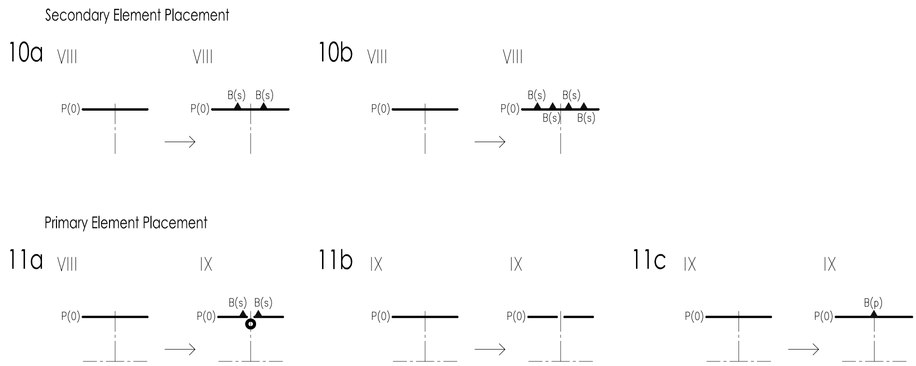

Figure 6. Stage C rules for entrance and wall fortification.

5.4.5. Stage D: Definition of Spatial Elements

Figure 7 illustrates the rules for defining spatial elements.

Rule set 12 lists the design definitions for a stylised entrance. Rule 12a merges the primary entrance bay with adjacent cells. Rule 12b creates openings in the walls adjoining the primary entrance bay.

Rule sets 13 & 14 define the various styles that corner tower and bastions may adopt in a design. Constraints have been placed such that although all corner towers will have the same designs, the bastions may adopt differing styles, thus in keeping with the Islamic design principle of conceptual symmetry. (Golombek, 1988).

Rule set 15 defines bastions at primary entrances.

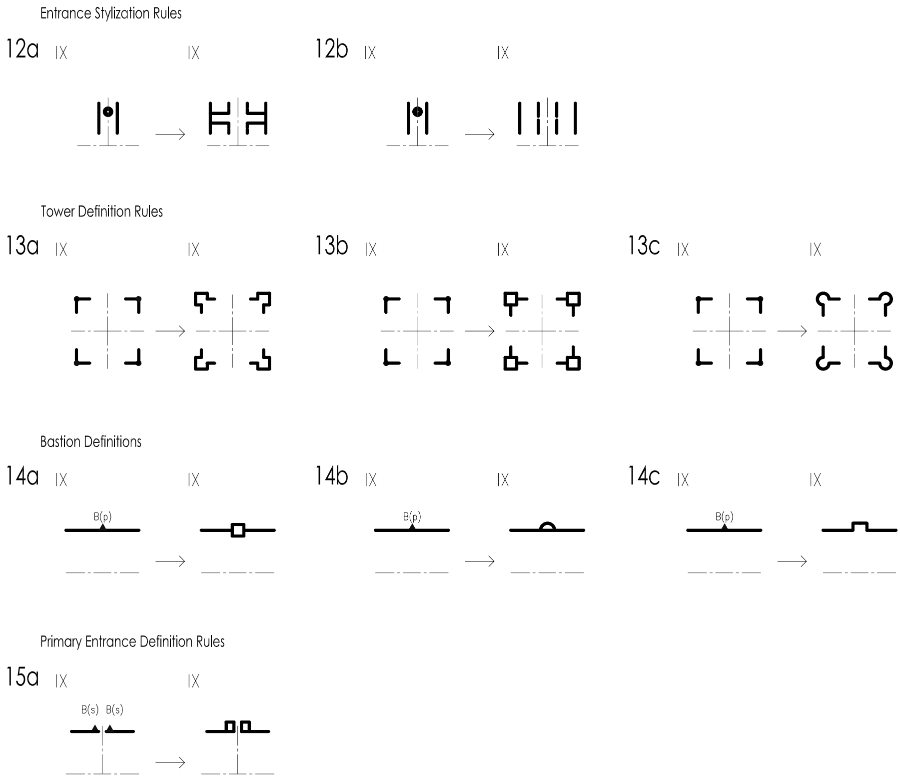

Figure 7. Stage D rules for the definition of spatial elements.

5.4.6. Stage E: Termination

Figure 8 illustrates rule set 16, which terminates rule application by erasing all the labels and markers remaining in the design and steps the design to the final state.

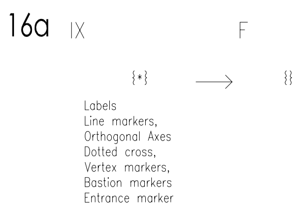

Figure 8. Stage E termination rules (in abbreviated form).

5.5. DERIVATIONS

In Figure 9 we present an example derivation of a caravanserai as depicted by Hillenbrand (1994, p. 557 #6.85). As buildings of this type tend to have minor idiosyncrasies, the grammar generates a design approximating that of the example without being an exact representation. The application of a rule used several times in sequence (typically to generate all instances of a duplicate feature such as a bastion) is shown only once. Figure 10 shows additional designs in the language generated by the grammar.

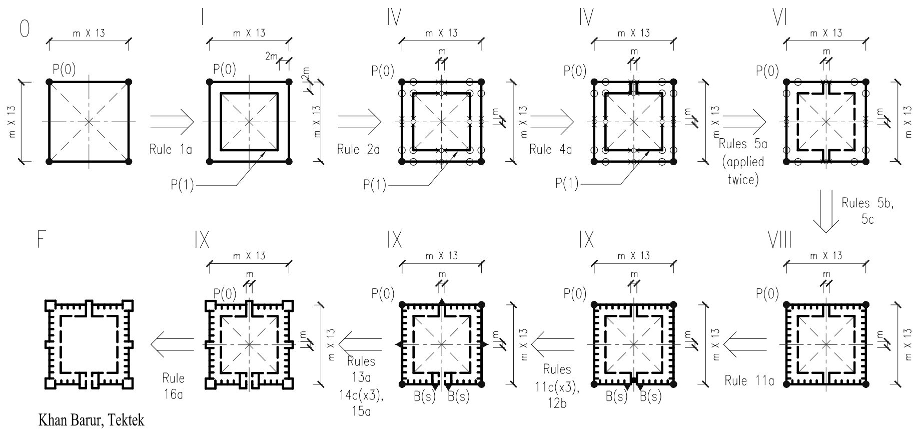

Figure 9. Derivation of a caravanserai.

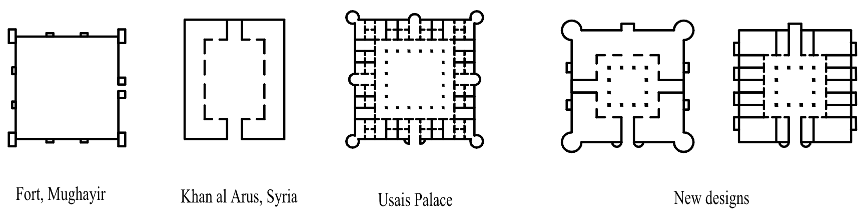

Figure 10. Additional designs in the language generated by the grammar. The three on the left are based on actual buildings, while the two on the right are new designs.

6. Discussion and Further Work

6.1. DISCUSSION OF THE CARAVANSERAI GRAMMAR

The shape grammars created in this project are limited to the generation of square or rectangular ground plans. This limitation can be overcome by parameterising the initial shape to generate polygons of six or eight sides. This would explain a number of designs with hexagonal and octagonal plans of medieval Iran, which closely resemble four sided plans in terms of their spatial organisation.

One of the biggest challenges in the creation of the grammar was to allow the possibility of generating a variety of designs, while limiting the rules. Moreover, strong constraints and control mechanisms had to be used to limit the generation of irrational designs.

As building types of Islamic architecture are fairly variegated (Hillenbrand, 1994), it is not claimed that the grammar written in this project would create all kinds of caravanserais existing in history. Rather it is felt that the caravanserai grammar embodies an approach to design based on Islamic principles. Its real scope lies in evolving the grammar to give contemporary meaning to elements generated in generic configurations, so that valid present day designs are generated.

6.2. COMPUTATIONAL FRAMEWORK FOR THE STUDY AND COMPARISON OF ISLAMIC BUILDINGS

Our ongoing work involves the investigation of the transformation of the caravanserai grammar to grammars that generate related building types of Islamic architecture. Among those we are investigating are more complex caravanserais, madrasas and mosques. We are adapting the techniques developed by Knight (1994) to investigate the relationships between similar design types.

This study points to the development of a set of related grammars that could be merged to create ‘composite’ grammars. This method of design development is consistent with the design methods of Islamic designers of the past, as a unique characteristic of Islamic architecture was that it developed by borrowing from various sources and was ‘notable primarily for the originality of the manner of combining diverse elements’ (Musgrove 1987; Hillenbrand, 1994). The shape grammar methodology also tackles the issue of the analysis of the great multiplicity in design in Islamic architecture of the past, and could lead to the creation of a great number of contemporary Islamic designs.

6.3. SUMMARY

By developing a parametric shape grammar for caravanserais, it was demonstrated how such a rule based methodology can be adapted to the geometric design generation techniques of Islamic architecture.

The use of the shape grammar methodology described here offers a new and alternative approach for the study and analysis of historic Islamic architecture, with a focus not on chronology, building style or type, but on design complexity. Such a study offers an analytical understanding to the structural changes that may have appeared in the designs of historic buildings. With reference to Islamic architecture in particular, the methodology can be used to understand the transformation of design in architecture, which drew inspiration from several sources.

The utilisation of shape grammars developed from the analysis of traditional historical styles has the potential to offer a unique computational method for the design of contemporary Islamic architecture.

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A JAVA PROGRAM MODEL FOR DESIGN-IDEA EXPLORATION IN THREE DIMENSIONS

Employed Visual Perception in Mass Exploration Process

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Abstract. *Visual Perception* of depictions is the basis of the act of imagining employed in visual design thinking of design process, and consequently in design-idea exploration. Digital-media use plays a significantly important role in these exploration processes. The underlying assumption of the research is that *Visual Perception* affects *Design-Idea Exploration* processes. The research investigates and sheds more light on the processes of *Visual Perception*, which architects use in mass exploration of design ideas. The research is a part of a series that presents a Java program based on creating 3d shapes, in order for architects to explore initial shapes related to design ideas. The initial version of the program, which is a part of another research, creates 3d shapes through controlling their dimensions and insertion point. Functions of painting, controlling the light position, and shading are added to the program that is presented in this research. The research discusses *Design-Idea Exploration* and *Visual Perception* and their correlation. The added features of the program that is used as a design medium are also presented and linked to the investigated areas.

1. Introduction

Architecture is classified as the high level of fine arts because of its functions, which are introduced to man besides aesthetics. Therefore, a design idea and its exploration process should be a goal-directed one resulted from main objectives of architectural design as creatively seen by the architect. Moreover, the methods of media use which architects employ have an important impact on the output of design process. This use, consequently, should be an assistance and addition to the role of architect, not a substitute especially in the immaterial issues. This point of view represents the unfolding of the research and the presented program.

Exploration processes of design-ideas occur in our brains through visual design thinking. These exploration processes are inextricably linked to visual design thinking and the act of imagining, performed in architectural design process. The research investigates how visual perception process is developed in our minds, and then, introduces new functions of a Java program, which are used in mass exploration of architectural design-ideas, in order to apply the investigated areas.

2. Human Mind and Seeing

Human mind could be seen as a dual system of perception through the senses of sight and sound. Art is generally perceived through sound perception (literary art, music) or visual perception (architecture, sculpture, painting). The creation processes of images as forms of art in the human mind are beyond its natural level of perception and creativity. It could be stated that an artist or designer thinks more and sees more. The human mind encompasses different visual images as raw material. The difference between a common man, and a visual artist or a designer actually lies in the mental skill of the last case to employ this raw material for art creation or design.

To see is only to mirror the physical properties of an object as reflected in the mind. This simple notion is different from visual perception, as the last is more constructive. Psychologists, while studying visual perception, give evidence that the image is not given to the mind, but it is structured by our mind, through past images and several other subjective aspects, which differ from one to another (www.artinarch.com/vp12.html). The human eye, at any situation, does not act as a mere camera. An art critic and psychologist, Prof. Margaret Hagen states that “there is a traditional and philosophical distinction between sight (seeing) and knowledge. Seeing is experience of sensation, and knowledge is construction of meaningful perceptions” (Hagen, 1986). The final image in mind of visual artist or designer transforms into shape after constant confrontation with past experiences in process of imagination.

Furthermore, there are two basic things in perception; data and knowledge. The philosopher James J. Gibson advocated a theory that visual data passes from the retina to the mind where it is formed into perception of a meaningful whole (Gibson, 1994). Some other philosophers, like Richard L. Gregory, go beyond that and adopt a constructivist stand that the knowledge decides what we see, and what is understood as seen (Gregory, 1998).

From the previous discussion, it could be stated that both perceived past experiences, and conceived data and knowledge, have impact on the final image created in mind of visual artist or designer.

3. Gestalt Laws and Visual Perception

Famous philosopher and psychologist, Larry Day while commenting on paintings as paradigms states that one cannot view any image as if it is the first image (www.artinarch.com/vp12.html). The images approach us with a history that we made up of resemblances, borrowings, biases, personal inclusions and exclusions. These images are more cultural in nature than physiological. An art critic and psychologist, Professor Margaret Hagen states that the product of perception is constructed out of sensory raw material through process of trial and error, and testing of hypothesis, rather than a mere product of simulation (Hagen, 1986). The foregoing findings give evidence, which links between visual perception and Gestalt laws.

3.1. GESTALT LAWS

Grouping is the idea of Gestalt theory. According to Gestalt laws, we perceive forms as well-organized patterns or as a whole, rather than separate component parts. The main factors that determine grouping in visual perception are: proximity, similarity, closure, and simplicity. Elements tend to be grouped together depending on their closeness and according to symmetry, regularity, and smoothness (Ellis, 1939).

There are many concepts in terms of illustrating the Gestalt laws. Two of them, however, are basically related to the investigated area of the research; namely:

1) The concept of shape and background: while forming any (abstract or symbolic) visual image, a dominant shape of image is separated from the image background (Ellis, 1939).

2) Perception of objects is far more constant or stable than retinal images: For example, if we relied only on the retinal images for visual perception we would always be conscious of people growing physically bigger when they come closer. With the same token, colors change with every shift of lighting condition [Figure 1], and objects change their shapes whenever we moved. But, this does not usually happen. In summary, key consistencies in relation to visual perception are site, shape, lightness, and color.

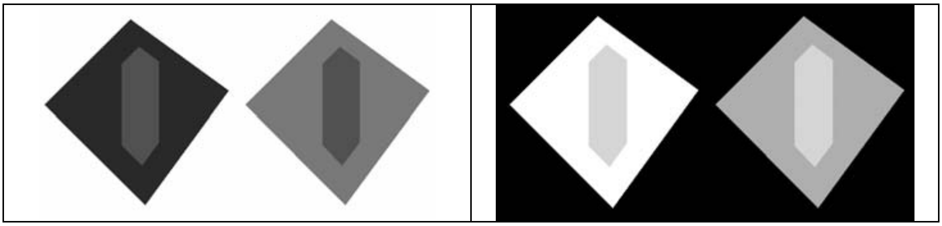


Figure 1. An example of the perceived brightness, which is influenced by the context and does not simply correspond to the physical intensity, prepared by the author.

3.2. VISUAL PERCEPTION AND DESIGN-IDEA EXPLORATION

It is hard (one may maintain impossible) to give and develop a design idea without the use of drawing or modelling. Designers shape, evaluate, and reshape their design ideas through drawing or modelling. In the early design process, designers use different kinds of depictions, through different methods of media use to explore, develop, and record ideas. While solving design problems, a diagram through visual design thinking is used to transform the data and documents of design program into a graphic context. “Diagrams are in the sketch books of famous designers such as Louis I. Kahn (Brownlee and Long 1991), Le Corbusier (Guiton 1987; Sekler and Curtis 1978), and Peter Eisenman (Eisenman 1987)” (Do and Gross, 2001).

The act of imagining is intimately bound with visual design thinking. Designers employ visual design thinking to visualize and understand the forms they work with.Visual perception of different representations has a crucial role in design thinking, imaging, and evaluating, which are used along with design process.

From the work of Schön that classifies the kinds of seeing and their functions, the structure of design is a cyclic combination of seeing-shaping-seeing (Schön and Wiggins, 1992). It, therefore, could be concluded that visual perception of design-idea exploration lies into three phases, namely: 1) factual visual apprehension of forms, 2) appreciative judgments of characteristic, and 3) comprehension of spatial gestalts.

The foregoing phases of visual perception occur during the interaction between mind of the designer or architect, and depictions (drawings and models). Consequently, visual perception processes are essential in the exploration of design ideas and proposed forms.

From the previous discussion, it could be concluded that the Gestalt laws related to visual perception are used through the act of imagining and thinking. The main factors of these Gestalt laws are color, light position (shade, brightness), and position of seeing (shape or site).

4. Applying Visual-Perception Factors in the Java Program for Mass Exploration of Architectural Design Ideas

This part of the research applies the factors that govern the processes of visual perception employed during mass exploration of architectural-design ideas. The program, used as a design medium, helps architects create, manipulate, and explore three dimensional shapes related to architectural design-ideas. Architects, by using this program, would be able to easily control the camera position to explore their initial forms.

The famous 3d modeling software (AutoCAD, 3ds max, FormZ, Sketch-Up, etc.) apply the approach of transforming the created drawing, when the user changes the camera position. The unique difference of the program from these programs is the approach of transforming the camera position without the drawing, which allows the manipulation (of both the objects and the camera position) in the new created views. Transforming the created drawings in X, Y, Z, or all the three directions are available functions of the program.

4.1. PREVIOUS FEATURES OF THE PROGRAM

The main features of the previous program version are the functions of transforming the created form or forms, by mouse clicking inside the boundary of one form to rotate or move the chosen form, or by mouse clicking any point outside the forms to rotate or move the whole combination. The grid, also, can be solely transformed. The snap, grid limit, and grid view can be reset from the edit menu of the program.

The previous version of the program is based on creating 3d shapes, through controlling their dimensions and insertion point in two different ways; pull down menu, and mouse click and drag.

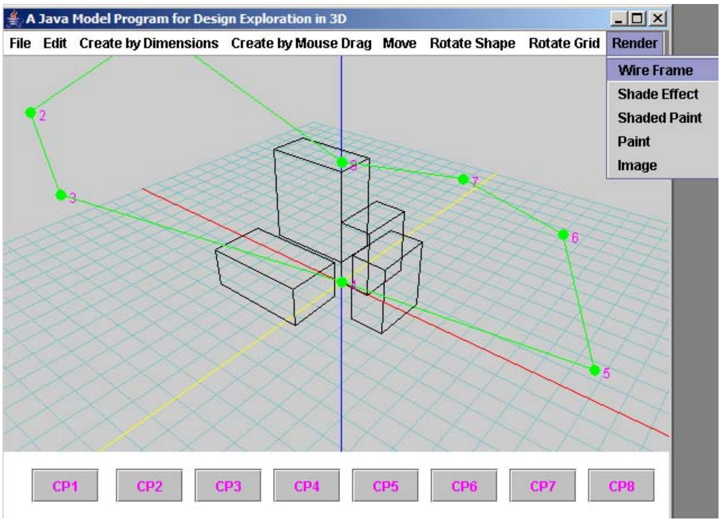
The program displays eight camera positions that are located around the created drawing, with the option of controlling each position in z direction through mouse drag [Figure 2]. The users of the program can explore a drawing through: changing the position of camera from the selected eight positions, or rotating the drawing in one direction or all the three directions.

4.2. ADDED FEATURES OF THE PROGRAM

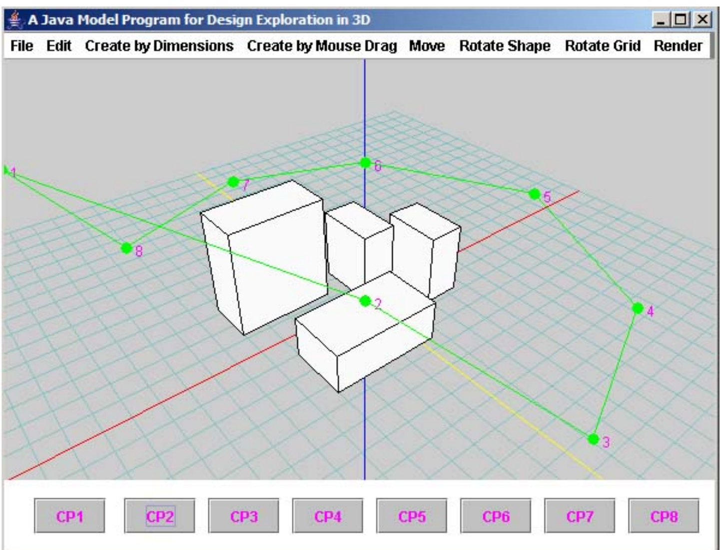
Functions of rendering, painting, controlling the light position, and shading, represent added features of the program, which have links to visual perception.

4.2.1. Render

Rendering functions encompass functions of wire frame and painting [Figure 2].



a- Wire frame drawing viewed from 4th camera at a higher position

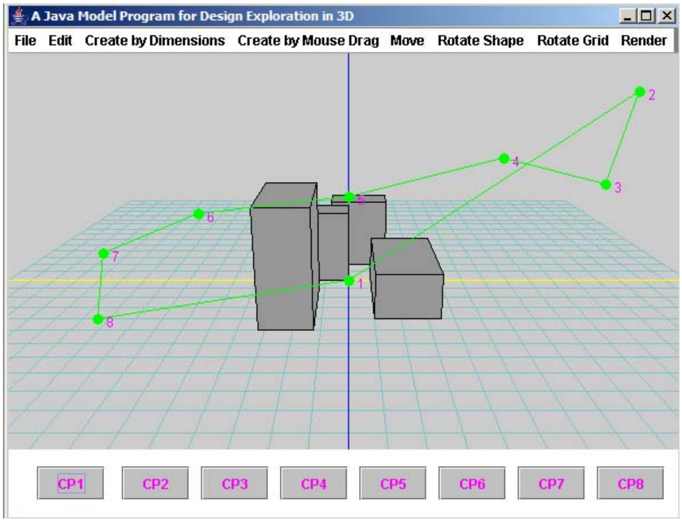


b- White painting drawing viewed from 2nd camera at a higher position

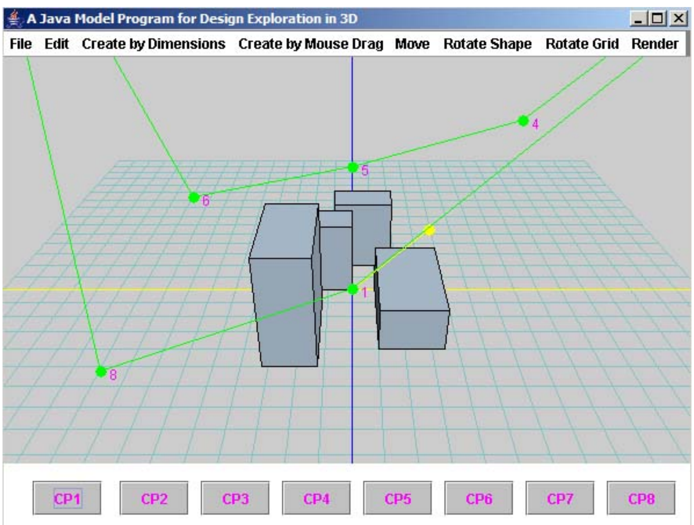
Figure 2. A four-mass combination of a design idea (the green circles represent the camera positions, the user can control each camera position in z direction by mouse drag).

4.2.2. Shade effect

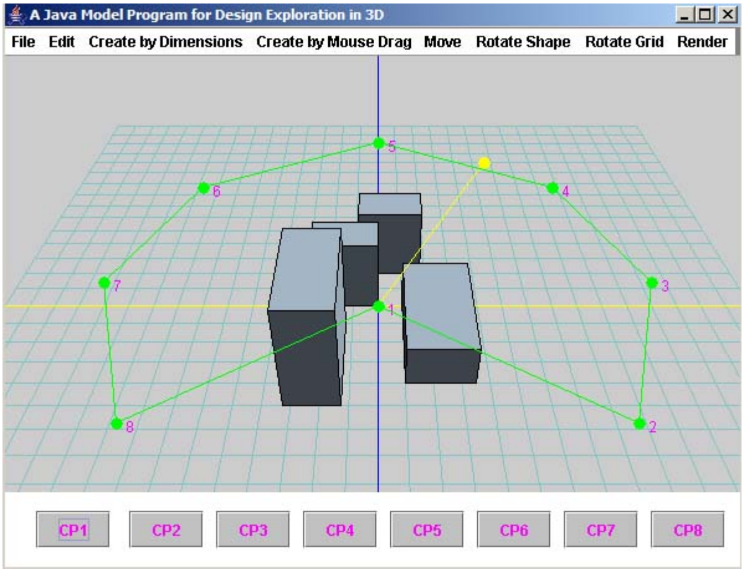
The program has functions of controlling the light position [Figure 3].



a- Grey painting drawing viewed from 1st camera of the default position without the shade effect



b- Light-blue painting drawing viewed from 1st camera at a higher position after adding the shade effect



c- Same drawing viewed form 1st camera at a higher position after changing the light position

Figure 3. Controlling the color of the whole combination, and the light position

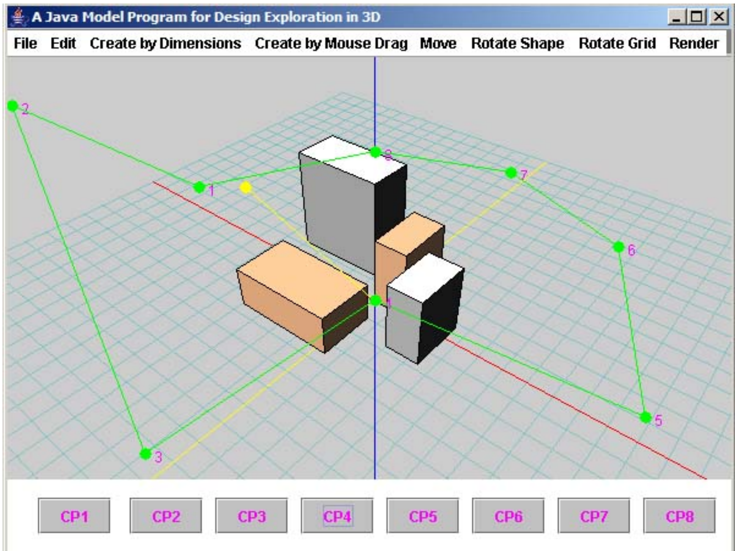
4.2.3. Shaded Painting

The program has a function of controlling the color of a form or the whole combination [Figure 4].

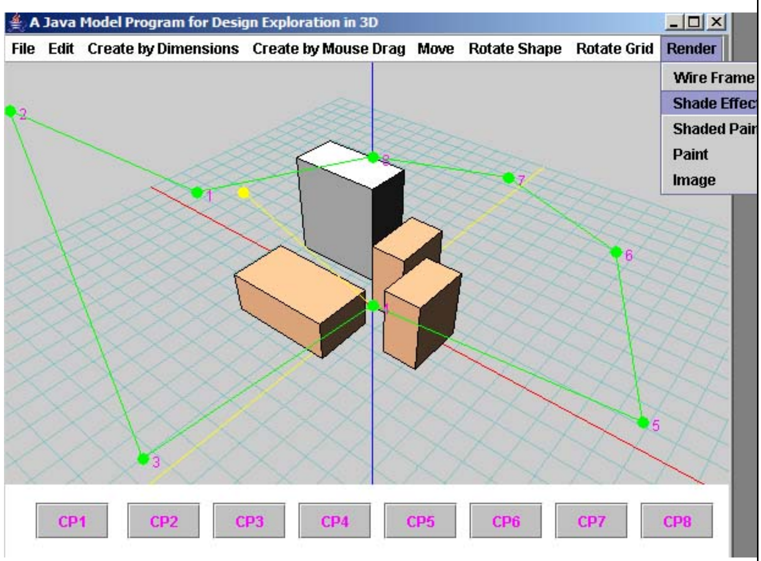
5. Conclusion

The research has highlighted the correlation between Visual Perception and Design-Idea Exploration. The main factors of visual perception processes, which are used through the act of imagining and visual design thinking in three dimensions, are color, light position (shade, brightness), and position of seeing (shape or site).

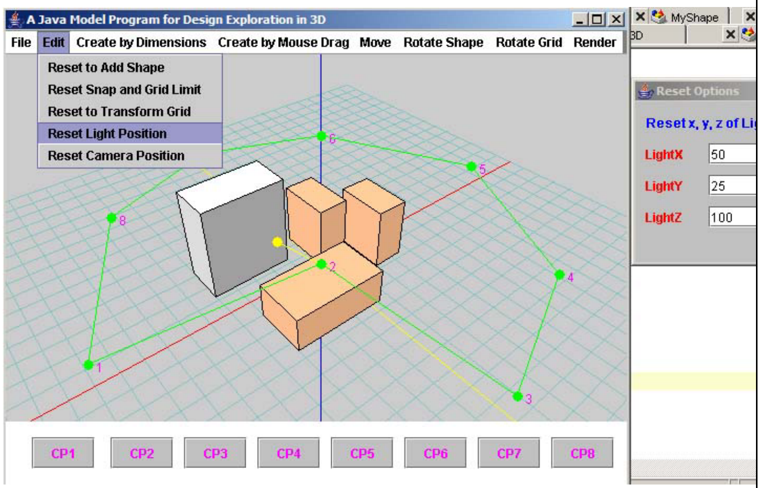
The research has applied the investigated previous factors in functions of the Java program model, which is used in mass exploration process. The presented program with its added functions can be applied in creating and exploring initial three dimensional shapes of design ideas.



a- Changing a color of two forms viewed from 4th camera at a higher position



b- Changing a color of one form viewed form from 4th camera at the previous position



c- Changing a color of one form viewed form from 2nd camera at a higher position, and the menu of controlling the light position

Figure 4. Controlling the color of form, and the menu of controlling the light position.

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Section II

Design Data Management and Sustainable Buildings

DIGITAL BUILDING SURVEYING AND PLANNING IN EXISTING BUILDING

Capturing and structuring survey information

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Abstract. For planning in existing built contexts, the building survey is the starting point for initial planning proposals, for the diagnosis and documentation of building damages, for the creation of objectives catalogues, for the detailed design of renovation and conversion measures and for ensuring fulfilment of building legislation, particularly by change of use and refitting.

An examination of currently available IT-tools shows insufficient support for planning within existing contexts, most notably a deficit with regard to information capture and administration.

In ongoing research at the Bauhaus-Universität Weimar (SFB524-Collaborative research center 524 “Materials and Structure in Revitalization of Buildings”) methods and techniques of revitalisation are being investigated (SFB 524, 2004). A special branch of SFB524-D2 entitled “Planning-Relevant Digital Building Surveying and Information Systems” is investigating possibilities of computer-aided building survey and communication platforms for architects and civil engineers.

This paper discusses the concept for a modular surveying system (basic concept, structuring of collected data, separation of geometry from semantic data, and separation into sub-systems) and the prototypical realisation of a system for the complete support of the entire building surveying process for existing buildings. The project aims to contribute to the development of a planning system for existing buildings.

The project is funded by the German Research Institute "Deutsche Forschungsgesellschaft (DFG)".

1. Building in Existing Built Contexts in Germany

After the period of reconstruction following World War II and the expansion of the built environment in the last 20-30 years a process of consolidation and renewal within the existing built context has begun. A variety of factors contribute towards this development, e.g.

- Dwindling population figures are leading to a decrease in demand for living space
- Population drift away from the former industrial regions
- New approaches to working, telework, decentralised services etc. have reduced the need for dedicated production spaces
- A steadily increasing need to renovate existing buildings

In 1997 the ratio between new building and renovation work was 53.7% : 46.3%. In 2001 prognoses estimated a change in this ratio to 43,8% : 56.2 % (BMBF, 2002).

Building in existing built contexts is becoming ever more important and the proportion is set to increase still further in the coming years.

The loose title “building in existing built contexts” covers a wide variety of different aspects. These include measures for maintaining and increasing the value of a property. They also include measures such as renovation, modernisation and conversion of existing buildings for new uses very often in combination with new buildings. In future planning tasks look set to include a variety of parallel tasks e.g. new building and conversion as well as renovation measures (BMVBW, 2001).

In contrast to new building, planning within existing built contexts necessitates more complex interactions with existing built substance and infrastructure with their own special and specific requirements.

Not least the actual presence of the building including its prehistory and amendments made during its lifetime are a central aspect. Existing building substance is characterised by a high degree of information with implications for the planning process, for the functional use of the building and particular building elements and the coordination of renovation measures. Typically new information comes to light and new questions arise during the actual renovation works with implications for the rest of the planning process and building measures. The existing building substance is in all cases the basis for planning tasks and building measures.

Planners are often confronted with new and different planning tasks which depend upon the respective form of the building and the planning aims of the particular project.

The planning and realisation problems of such renovation works have as yet not been researched in detail and tools for managing these problems are insufficient. A variety of initiatives funded by the German Government are currently investigating these aspects, e.g. “Bauen und Wohnen im 21. Jahrhundert” (Living and Building in the 21st Century) (BMBF, 2001) or the special research area at the Bauhaus-Universität Weimar SFB524 “Materials and Structure in Revitalization of Buildings” (SFB 524, 2004).

2. The Building Survey: The basis for building in existing built contexts

During the process of building works in and around existing buildings it is not uncommon that the actual situation on-site does not tally with existing planning documentation. Very often these mean additional costs as a result of planning amendments made during the building process or interruptions to the building progress.

Reliable, informative and accurate planning documentation is a prerequisite for efficient and economical planning in the context of existing buildings and can reduce the need for potentially costly ad-hoc decisions made on-site. Very often existing building documentation is non-existent or insufficient (not to scale, archive plans not kept up to date or even preliminary plans that do not reflect the actual situation as originally built).

Typically a building survey is only commissioned when existing building documentation is not available or cannot be used. Despite the cost, a building survey is the best means of obtaining reliable and accurate planning documents, either through a survey of the building in its entirety or parts thereof, of in some cases as verification of existing building documentation.

The building survey is therefore an essential part of the planning process and provides the information basis for all further planning activities. Existing information such as sketches, plans, measured geometric data and newly surveyed information must be combined and organised in a structured manner so that they can serve as useful parameters for the actual design and planning process.

3. Computer-Supported Building Surveying: Current situation

Architects typically produced measured drawings of individual building elements and measure such elements on site using conventional equipment (measuring stick or computerised optical distance meters) or using more complex surveying techniques (tacheometry, laser scanning and photogrammetry) (Figure1). The individual measurements are then combined in a second stage in the office to produce a single large 2D CAD plan from which sections, elevations and details are then derived (Figure 2).

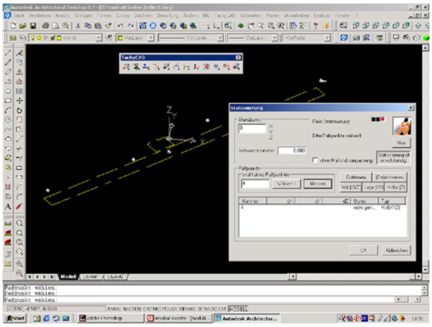

Figure 1. TachyCAD

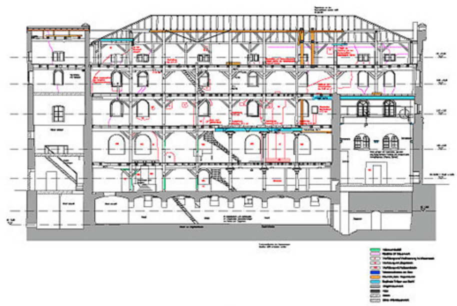

Figure 2. Result – CAD drawing

Typically IT-support during the building survey is limited to the saving of individual measured points in space, the CAD production of drawings or for specific individual tasks (Figure 3). IT-support is characterised by:

- A sequential isolated approach
- Geometric surveying without further semantic (building specific) information
- Few and disconnected visual representations of non-geometric information
- Software and hardware solutions adapted from other fields
- Insular solutions with information exchange only as geometric data file

	Callidus	CASOB	Curamess	CYRAX	Elcovision	ELTheo	ILRIS-3D	MENSI	Maxmess	miniCASOB	Minolta	MOBI	MobileCAD	PHIDIAS	PhoToPlan	Riegl	Rolleimetric	TachyCAD	TheoCAD	VITRUVIUS	Z+F: Imager 5003
Manual surveying									x	x		x	x							x	
Tacheometry		x				x						x						x	x	x	
Photogrammetry			x		x							x		x	x		x				
Laser scanning	x			x			x	x			x					x					x

Figure 3. Commercial surveying systems typically only support selected surveying techniques

The result is a collection of separate and usually disparate geometric and non-geometric information such as photos, room log, field book and 2D drawing.

4. The Research Project “The Building Surveying during the Planning Process”: A possible situation

The essential difference between planning new buildings and planning within existing built contexts is the necessity of capturing and evaluating the actual built situation. The current situation can be described as the original built situation taking into account building damages and changed conditions as a result of material fatigue and wear and tear. This depends largely on the previous level of maintenance carried out on the building. Building technology in existing buildings varies considerably depending upon building style, age and materials. Likewise, planning tasks vary greatly from project to project. It is therefore difficult to define standard solutions and approaches to the building survey and structuring system (building model, data interchange formats etc.)

Based upon an empirical examination of existing computer-assisted planning software and IT-solutions as well as geodetic tools, the following requirements for planning-relevant building surveying have been identified. Briefly put they include:

- All data capture tools and methods (such as tacheometry, photogrammetry, vectorisation etc) should be viewed as tools within an integrated toolkit which can be used in combination,
- The degree of information detail (density) should be flexible and extendable on demand as not all information is required at every stage of the planning process. A sketch-like overview is sufficient for elaborating basic planning intentions, for other areas a high degree of detail is imperative,
- An organisational structure for data should be provided which is standardised for particular building types but whose structure can be dynamically modified to fit the specific requirements of individual surveying requirements and buildings,
- It should be possible to collect, survey and combine different forms of information, such as formal data (descriptive), informal data (multimedia information) and structured data,
- The captured data must be presented to the user in an adequate form to enable the user to “explore” the building digitally.

Planning activities in the context of existing buildings involve: the step by step collection of building-relevant information; rule and parameter based solution development; combination of classic and automatic surveying methods and equipment which contribute to the creation (survey) and editing (planning) of a building model i.e. which enable access to the building as a container of information; the consideration of the entire process (building survey); intensification of information density to be captured (from the sketch to detail); the attribution of planning-relevant characteristic values; the provision and modification of ordering systems; and the free combination of different input techniques (surveying methods) in a single system.

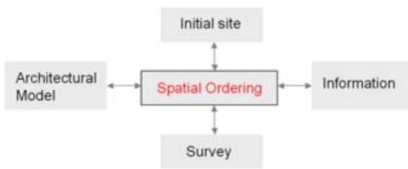

Figure 4. Sub-systems of the concept

Figure 5. The relationship between the building survey and the planning process

Based upon these requirements a software concept was developed and realised in prototypical form to provide suitable tools for the respective phases of the building survey. The tools are applied to a central model organised in a model management system (Figure 4 and 5).

4.1 THE INFORMATION CONTAINER – TYPES OF BUILDING INFORMATION

The computer-supported building survey is not simply a geometric description of a building. It should also provide a multitude of features and characteristics relevant both to the buildings future use and to its later CAD planning processing. In addition to its geometric form, the software concept allows each building element to be further described by specific properties: formal-descriptive attributes (building parameters), informal-descriptive attributes (text, images, videos, sketches etc.) and relational attributes (inferred structural connections) (Figure 6).

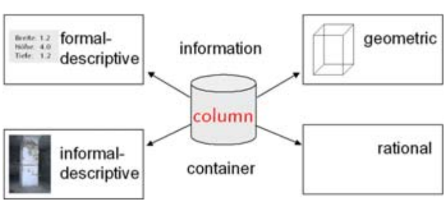

Figure 6. Information container

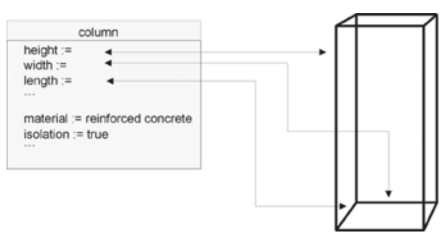

Figure 7. The relationship between user class and geometry

This data is ordered within a semantic structure (structure elements of the building construction / user class).

An user-class – a spatial, building-element or project class – is described by formal, informal, geometric and relational properties (attributes). Geometric properties are only linked to elements within a geometric structure. The geometry is “just an attribute” of an element (Figure 7).

A link between parameters of the geometric structure and formal properties (attributes) of the user-classes can likewise be defined, and this forms a central concept of the system employing the adjustment algorithm to mediate between different sources of information (Thurow, 2004a).

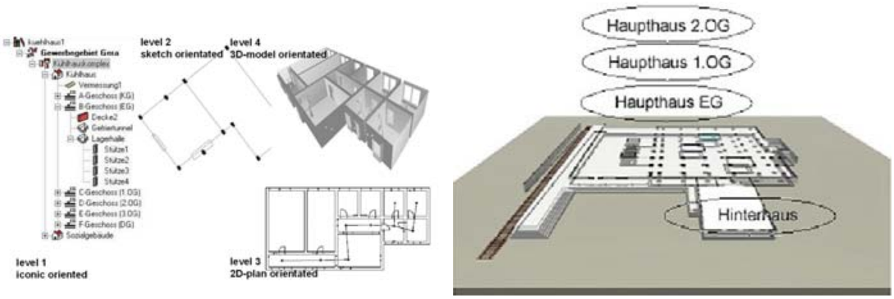

Figure 8. Different levels of detail

An essential aspect of the concept is the surveying and capture of building-relevant information with regard to its use in the planning process and the necessary intensification of information-density. Different levels of detail can and should be able to occur simultaneously within the same model depending upon planning progress (Figure 8).

4.2. BASIC PATTERN – STRUCTURING THE BUILDING

An essential prerequisite for planning activities, particularly when a project is undertaken as a team, is the structured provision of information. For the planning survey this means that information should be surveyed from the outset in a structured form.

How is a building experienced and described?

A typical problem when surveying existing buildings is that a large amount of information is recorded without an overview of the overall situation. The tendency is to concentrate on details, whereby simpler structural connections within the building are overlooked.

As buildings and projects are more or less unique, pre-defined organisational structures for building models have only limited application. At present there is no comprehensive ordering system for describing all existing buildings.

How could a building and the information contained within be structured efficiently with a view to its later processing using computer-aided tools?

The concept employs an open, flexible, adaptable and extendable organisational structure which is based upon the process of the building surveying.

A building survey is typically undertaken room-by-room. Buildings are perceived as a series of different rooms, each room conceived as a functional unit in itself.

Rooms are defined, at least in visual terms, by their spatial characteristics. The room can therefore only be described by the form of its enveloping boundaries, its perceived surfaces. Thickness is not an identifiable parameter. In this case building elements (walls, pillars, columns etc.) can be interpreted as 'material rooms' and described by their actual surfaces.

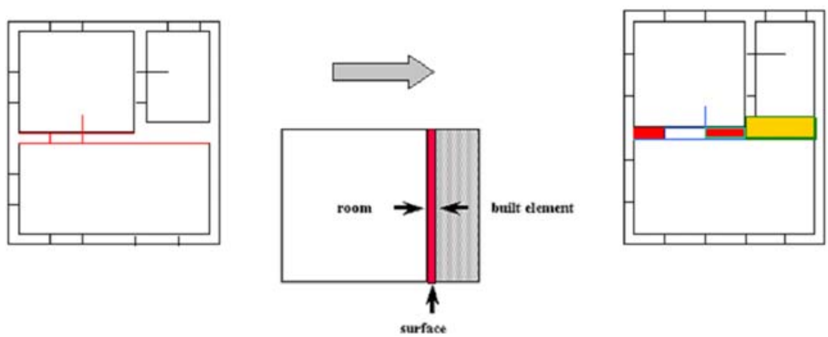

Figure 9. Relationships between building and room elements

The concept envisages a comprehensive organisational system with the ability to be extended flexibly. With regard to representing an existing building, three primary structures are relevant when describing an existing building:

- The Project Structure – a database for project-relevant characteristic values,
- The Spatial Structure – a summary of all spatial objects used to classify the building, and

- The Building-Element Structure – a hierarchical classification of all building (construction) elements (Figure 9).

The user is able to define their own specific ordering structure based upon typical abstract elements relating to the project, spatial and building elements such as wall surface, ceiling surface, columns etc. These abstract elements can be adapted to fit the specific building characteristics and project requirements through the addition of user-classes e.g. specific attributes, geometric parameters etc. These can then be exported, imported and adapted for use in other buildings and projects with similar characteristics. Pre-defined ordering systems (basic pattern) can therefore be created for particular building types and adapted to fit specific situations (Figure 10 and 11).

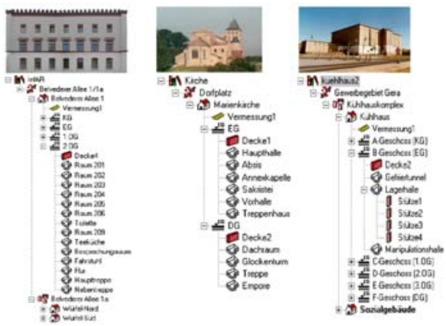

Figure10. Basic pattern

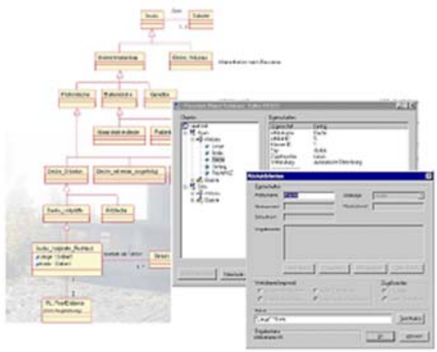

Figure 11. Flexible building model

4.3. THE PROCESS OF SURVEYING–COMBINING DIFFERENT TECHNIQUES

In order to maintain the free choice and flexible combination of surveying techniques for the user, the techniques have been linked to one another with the help of geodetic algorithms used in surveying e.g. different adjustment methods. As a result, the values required for the geometric digital image are indirectly determined, supporting both the deliberate use of verification using several methods to ensure higher accuracy, as well as an estimate of the representational accuracy.

One approach is to work from sketch to a 3D model (Figure 12). The creation of a sketch at the beginning of the process is not an absolute requirement.

Figure 12. From the sketch to a 3D model

Another approach is to reconstruct surveyed spatial boundaries. This involves taking a collection of measured values and through the provision of supplementary information to create the topography and geometry of the space-defining surfaces (Figure 13).

Figure 13. Reconstructing surveyed spatial boundaries

4.4. CONCEPT AND PROTOTYPES FOR A MODULARISED SYSTEM AND RELATED TOOLS

The system concept follows a modular principle. Oriented around the process of surveying the following sub-systems were conceived:

"Initial site visit" – supports the creation of a building model and definition of the spatial ordering system. The core functionality includes tools to describe the essential elements of the building in a sketch-like or iconic form, both spatially as well as the building's constructional elements. The capture of both formal and informal information is possible in this phase.The result of this phase is an approximate sketch-like organisation of the spatial structure of the building not necessarily to scale. It can serve as the basis for initial cost estimates or viability analyses.

"Survey" – supports the non-destructive and structured capturing of geometric data and relevant parameters on site. The survey can be undertaken conventionally in two dimensions or in 3D dimensions for use in a 3D model. Input devices include traditional measuring equipment such as measuring stick, distance meter and measuring tape as well as more complex equipment such as theodolites. The survey records the perceived surfaces of rooms and elements. The data captured is therefore often incomplete and not necessarily contiguous. The result is a structured 2D or 3D building model of spatially defined elements, enriched with further planning-relevant information.

"Build-element structuring" – supports the description of a building construction through its structural (load-bearing etc.) building elements and their interconnections. The module provides tool, with which surveyed surfaces can be grouped to form building elements of the building's construction (Petzold, 2001).

In addition to these modules further aspects must be supported, for example sufficient tools to enable the architect to evaluate and prepare the collected data:

- **Documentation, presentation, transfer to other applications** (for example the creation of room and building logs) (Tonn, Wolkowicz, Thurow, Ruth and Donath, 2004)
- **Navigating and information module** (Wender, 2004)

Each of the modular sub-systems provide the user with individual tools.

Selected aspects of the concept as described have been realised in a prototypical system. The prototype with the name "experimental platform FREAK" consists of a series of extendable tools which access and work with the same database (Figure 14).

Taking the process "from sketch to building element" by way of an example, the process and tools can be described as follows. More detailed information on mathematical techniques, algorithms etc. upon which the prototypes are based is described in Thurow (2001).

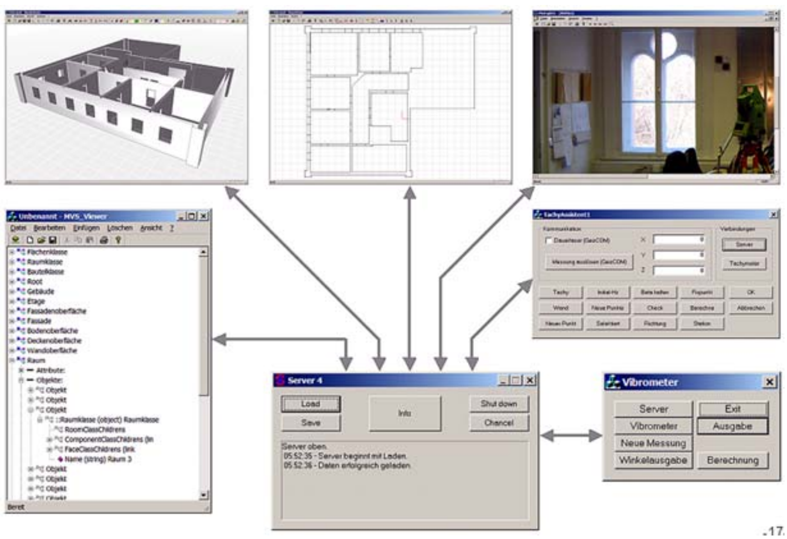

Figure 14. Server and different applications in the experimental platform-3D and plan-oriented views of a geometry model using the tools "OpenGLviewer" and "PlanarViewer", showing an example of a manually measured survey of the chair building.

The tools allow the sketch-based, plan-oriented creation of simple building geometries and their adaptation to fit measurements as captured (Figure 15). After the building geometry has been entered in sketch form the system looks for likely geometric abstractions, see Thurow (2004a). Using various different tools manual measurements or measurements obtained through tacheometry or photogrammetry (Luhmann, 2000) can be introduced into the model. The geometry is then adapted accordingly, based on computational adjustment algorithms (Figure 16).

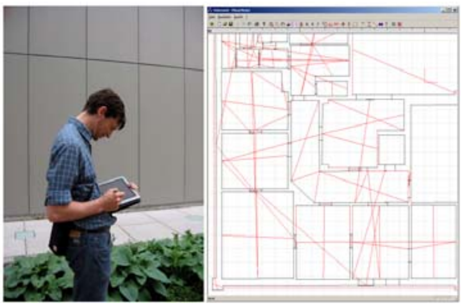

Figure 15. Plan-oriented survey using a Tablet-PC

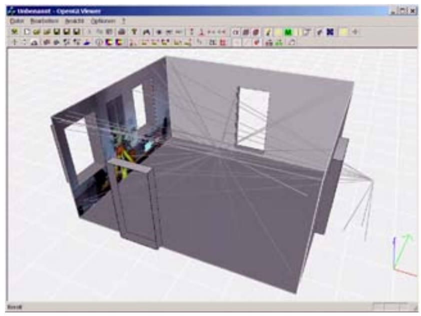

Figure 16. A room containing measurements obtained through manual measuring, tacheometry and photogrammetry

Through the use of a motorised tacheometer with visible laser beam it is possible to compare model and reality in real-scale. The tacheometer rotates to show the location of points in the geometrical model as a laser-beam point in the real building. Another method is the visual comparison between a distortion-corrected photo and the geometry model (Figure 17).

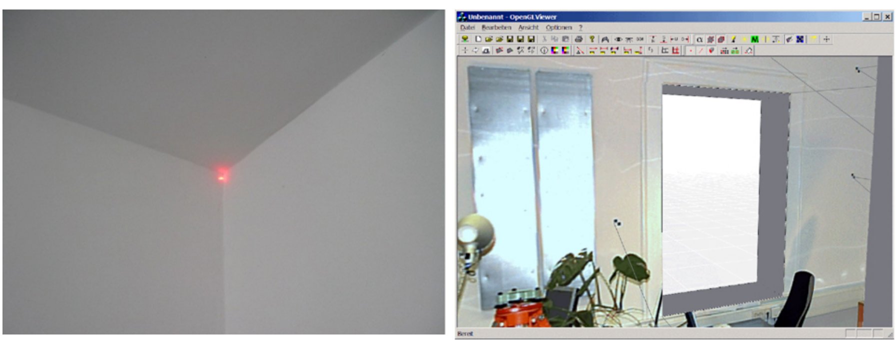

Figure 17. Comparison of coordinate point in the model with the real situation:

a) using a motorised tacheometer with laser beam

b) using a distortion-corrected photo as model overlay

As previously noted, a geometric model of the building surfaces is only one aspect of a building survey. However, through the survey of indoor and outdoor surfaces of a building, it is possible to infer the geometry of most of the building even if all building elements cannot be surveyed (i.e. hidden beneath other materials, unreachable etc.)

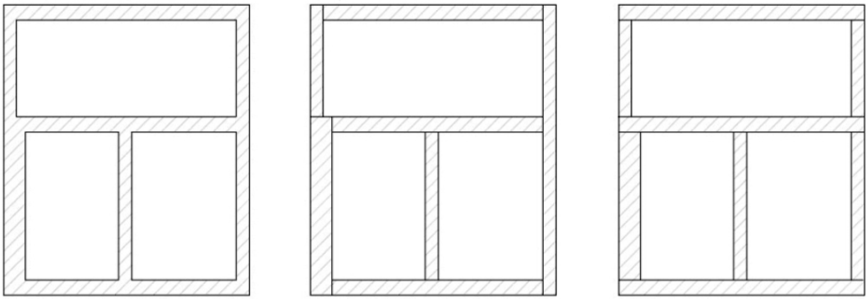

Figure 18. Surface model Different interpretations of a wall

Using the geometric data collected and background knowledge of different construction techniques, the historical period of the building and the techniques typically employed at that time, it is possible to largely infer how the building is organised in detail and so to minimise surprises during the actual building process (Figure 18).

A further tool "building element extraction" allows the semi-automatic recognition of likely building elements through their surfaces (walls etc.) This results in an abstract building-element oriented architectural model.

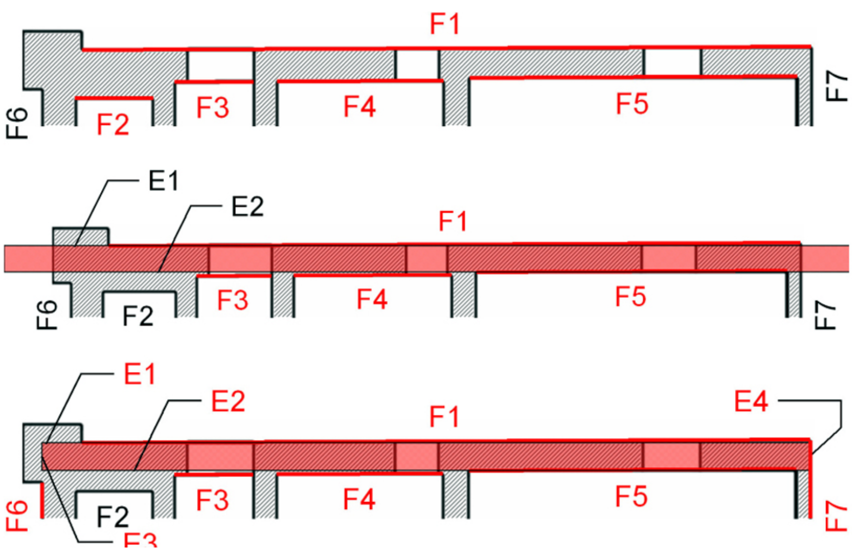

Figure 19. Building element extraction

The information gathered through this process of building-element extraction is, however, somewhat vague in nature and cannot always be applied. Certain structural building elements with differing geometries are not materially separate from one another and cannot strictly be defined as separate elements. The surveyor is able to define where one element begins and the next ends but in such a case this is of arbitrary nature.

For these reasons the following approach has been taken: The identity and geometric description of building elements are separated in their implementation and defined instead through relations (Figure 19). A particular building element is defined in a building class by establishing relations to available surfaces in the model. In order to allow a building element to have its own geometric parameters such as breadth, depth and height, observation objects are introduced. These observation objects examine geometric dimensions from the geometric model of the building and represent these as geometric parameters of the building object. As a result building elements can be created that are defined by a relation to the original model but can be utilised as individual objects e.g. in CAAD systems (Thurow, 2004).

5. Conclusion

An economically viable project realisation necessitates the capture of a particular amount of relevant information. The principal means of obtaining this information is through an initial building survey – an initial site visit – (i.e. room and building-element oriented recording of a building and access routes) and through research into historical documentation and basic geodetic, geotechnical and other basic information regarding the immediate relevant surroundings. All this should be recorded with a view to the envisaged future use of the building and the associated planning requirements. (Kohler, Hermann and Schloeßer, 1999; Kalusche, 2002; Xbau, 2004)

Future research will focus on assessing the data captured. Of particular relevance are modules for supporting financial viability, for supporting the design process and an adequate information presentation module (Petzold, 2004).

The concept described in this paper, as well as the experimental platform discussed here, confirm the relevance of this approach in developing a use-oriented model and information container for planning within existing built contexts.

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ISSUES OF INTEGRATING BUILDING CODES IN CAD

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Abstract. In this age of information revolution, design professionals are looking forward to exploring new methods and tools that could help them in delivering better designs and particularly understanding and incorporating of code-compliant design provisions in their projects. Automation of building code analysis is a vital factor in leveraging building codes from what is as a textual legal document to more graphical interactive source of building criteria. The argument of the paper will be based on the International Building Code (IBC) which is issued by the International Code Council (ICC) and considered as the most comprehensive and coordinated national model code in the US and is currently commonly used and enforced in 44 states. The paper will also examine and report on the purpose, types, interpretation, understanding and use of building codes applied in the United States; evaluation of recent research activities on automation of building code analysis; evaluation of current building code analysis tools; and a conceptual framework of a Computer-Aided Analysis of Design (CAAnD) program for building codes that could assist design professionals during project design development.

1. Introduction

Not so many years ago, all of the documentation in architectural design practice was produced manually. However things started to change and computer technology becomes more and more fully incorporated into the practice of building design. Although there is a widespread availability and variety of CAD software for each project design phase, complete computer integration are still far from perfect. For instance, in comparison with other architectural design factors, the "Analysis and Evaluation" issue is considered the currently least served and integrated design aspect in CAD systems (Khemlani, 2001). Designers are obligated to check the compatibility of their architectural design with locally adopted building codes and other requirements preferred by the owner (e.g. energy, cost, circulation, egress and lighting).

It is a tedious process to manually search for building code provisions. Designers read a relevant code section, interpret the intent of the code and then try to visualize any code problem in their design. There are no illustrations in building codes to help designers visualize what is described in the text. The building permit-issuing body checks the drawings and may have a different interpretation. The consequences of this process are costly and time-consuming rework, costly last minute design changes and delays during construction.

It is the time for design professionals to demand more than simple 3D model CAD software that provides geometrical representation with textual support. The concept of the Building Information Model (BIM) as a 3D digital database of the building should extent beyond properties, prices and manufacturers of building elements to support the creation and extraction of graphical and non-graphical characteristics of building components that support the analysis of design data and the next generation of smart building models that will transform the CAD industry from the era of computer-aided design to computer-aided analysis of design.

In order to understand the issues of integrating building codes in BIM and before evaluating the current efforts in the subject of automation of building code analysis, it is crucial to explore the nature of building codes and how they are applied during various design phases. The structure of the paper will start with exploring what are building codes and their application during the design process; evaluation of current research activities and software used in building code analysis; and will conclude with the conceptual framework for automating building code analysis process during various design phases.

2. Building Codes

2.1. WHAT ARE BUILDING CODES?

The Webster's Third New International Dictionary defines a building code as: "A collection of regulations adopted by a city to govern the construction of buildings" (Gove, 2002).

2.2. PURPOSE OF BUILDING CODES

The purpose of having building codes "is to establish the minimum requirements to safeguard the public health, safety and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from fire and other hazards attributed to the built environment and to provide safety to fire fighters and emergency responders during emergency operations" (IBC, 2003).

However, designers are expected to challenge those minimum requirements and to implement higher standard. In addition to what was locally adopted, designers might be obligated to apply other codes in their designs such as the American with Disability Act (ADA), Federal Fair Housing Act or NFPA 5000 which is developed by National Fire Protection Association and mostly used in the design of federal and hospital buildings.

2.3. TYPES OF BUILDING CODES (PRESCRIPTIVE VS. PERFORMANCE)

A prescriptive code describes the criteria, technical guidelines and possible detailed solutions. It mostly focuses on creating specific and prescribed responses to recognized problems. All the codes prior to the IBC are considered prescriptive in nature (IBC, 2003; Ching and Winkel, 2003).

On the other hand, a performance code sets specific goals, and reference approved methods and requirements that can be used to achieve compliance. The emphasis of performance code is on how a building and its components must perform in preference to how the building must be designed and constructed.

As an example to clarify the difference between the two code systems, a prescriptive code section might state that "travel distance to the nearest exit shall not exceed 200 feet (64 meters)", while a performance requirement might mandate that "means shall be provided to evacuate, relocate or defend in place occupants of buildings for sufficient time so that they aren't exposed to instantaneous or cumulative untenable conditions from smoke, heat or flames" (IBC, 2003).

The advantage of the performance-based design (PBD) option as it offers more freedom and less restricted solutions to designers. However, it involves greater sophistication in comparison with prescriptive design. By adopting a performance code, the designer is obligated to prove scientifically that a building's design meets the code's goals and objectives. This process might incorporate the use of scientific methods, computer and physics models and testing various expected fire-hazard scenarios. In addition, both designers and building officials should demonstrate advanced knowledge, skill and expertise using performance code (NFPA, 2002).

2.4. UNDERSTANDING OF BUILDING CODES

The key word to understand codes and standards and how they were developed is "intent". The intent of the code-writer is to solve a specific design problem with prescriptive words. Based on certain experience, upon construction or a life safety issue, the problem was identified. Accordingly, the code writer defines the performance criteria and then various acceptable solutions are articulated in a "code section". Therefore the "Why" is more important than "What" when it comes to interpretation of codes (Ching and Winkel, 2003).

IBC - Section 104: Duties and power of building officials, states that "The building official is hereby authorized and directed to enforce the provisions of this code. The building official shall have the authority to render interpretations of this code and to adopt policies and procedures in order to clarify the application of its provisions. Such interpretations, policies and procedures shall be in compliance with the INTENT and PURPOSE of this code. Such policies and procedures shall not have the effect of waiving requirements specifically provided for in this code."

The building code provides the designer with the flexibility to visualize the spatial requirements, develop applications and search for alternate means and methods to those given in the associated code provisions. The above code section also recognizes the ongoing innovation in building materials and construction technologies. It describes how building officials should proceed in the approval of alternative design solution. The proposal should comply with the intent and be at least equivalent with what is prescribed in the code in terms of quality, strength, effectiveness, fire resistance, durability and safety.[2]

2.5. INTERPRETATION OF BUILDING CODES

Building officials and designers are having different views concerning code interpretation based on their functional responsibilities. The role of building official is defined in IBC as "to clarify the application of code provisions" while the designer aims primarily to satisfy the building owner's needs; functionally, economically and aesthetically. Verifying compliance is the prime task of building officials while demonstrating compliance is what designers must do. The difference of opinions may occur as both sides' work on applying general code statements to a specific project. Similar projects may have a different interpretation in different jurisdictions. In order to resolve these differences, designers must work with building officials to bridge any gap between the intent of the design and the interpretation of the intent of the code. If no agreement is reached between both parties, the designer can appeal the ruling of the Authorities Having Jurisdiction (AHJ) to a prescribed civic body in the jurisdiction.

The construction documents prepared by the designer should incorporate minimum code analysis items such as occupancy classification, type of construction, building height and area.

In addition, as stated in IBC - section 106.1.1: "Construction documents shall be of sufficient clarity to indicate the location, nature and extent of the work proposed and show in detail that it will conform to the provisions of this code and relevant laws, ordinances, rules and regulations, as determined by the building official."

2.6. USING BUILDING CODES

The following procedure outlines the steps for code analysis. These steps are used in multiple codes such as the Uniform Building Code 1997 (developed by ICBO) and California Building Code 2000. It applies to a majority of situations that involve an analysis of code requirements for a specific use and anticipated construction type (CBC, 2001).

1. Classify the building:

   A. Occupancy: Determine the occupancy group according to the intended uses of the whole building or the portion it most nearly resembles. Calculate the gross floor area and the allowable occupant load of the building.

   B. Type of Construction: Determine the type of construction of the building by the building materials used and the fire resistance of various parts of the building.

C. Location on Property: Determine the location of the building on the site and clearances to property lines and other surrounding buildings. Determine the fire resistance of exterior walls and wall opening requirements based on proximity to property lines.

D. Allowable Floor Area: Determine the allowable gross floor area of the building. Verify the basic allowable floor area based on occupancy group and type of construction. Compute the allowable increases in floor area based on location on property and the installation of approved automatic fire-sprinkler system. Determine allowable floor area of multistory buildings.

E. Height and Number of Stories: Determine the height of the building and the number of stories. Verify the maximum allowable height and number of stories based on occupancy group and type of construction. Determine the allowable height and story increase based on the installation of an approved fire-sprinkler system.

2. Review the building for conformity with occupancy requirements.
3. Review the building for conformity with the type of construction requirements.
4. Review the building for conformity with exiting requirements.
5. Review the building for other detailed code regulations.
6. Review the building for conformity with structural engineering regulations and requirements for materials of construction.

Although the steps mentioned above seem sequential, in practice it is more interactive and requires back and forth process of review to achieve an optimized compliant design solution (CBC, 2001).

3. Building Code Analysis during and after Project Design Phases

All design projects proceed through certain phases that are common in most designs. Each design phase characterized by its defined activities and requirements although there is slight overlap between the sequential ones. The sequence of these phases is not strict and may slightly vary depending on the size and nature of the project, which can range from a simple extension to an existing building to a completely new building. Each design phase will be defined and discussed in relation to building codes requirements (CSI, 1996).

3.1. PLANNING/PRE-DESIGN PHASE

Every project begins with an idea or a need. The owner will then perform or demand the services of a registered design professional to perform or assist in the preparation of planning/ pre-design phase activities such as feasibility studies, facilities planning, site analysis, budgeting, or environmental impact analysis. If the project includes remodeling, the existing condition of the facility should be explored in the study. The objective of this phase is to determine whether or not the idea is economically sound and whether the return on investment will satisfactory cover the projected construction cost, operating expenses and generate the projected level of revenue. The designer will investigate basic building code and Zoning Ordinances related items through this analysis, such as zoning restriction, pedestrian or vehicular accessibility and the existence of local amendments to building codes. (Ching and Winkel, 2003) This investigation will lead to preliminary design decisions at the project level.

3.2. DESIGN PHASE

The design phase consists of four sub-phases.

1. Conceptual design phase
2. Schematic design phase
3. Design development phase
4. Construction Documents and specifications phase

3.2.1. Conceptual Design Phase

After reviewing and evaluating the owner's building program and budget requirements, the designer provides the owner with alternative approaches to the design and construction of the project. The designer prepares various design schemes and a detailed design program listing all the spaces, functions, estimated areas, preferred adjacencies and inter-relationships. The results will be in a form of small-scale preliminary sketches of overall form of the building, the massing, relationship diagrams and an outline of the building in relation to the site and possibly a simple sketch of the key sections and elevations. The designer presents these conceptual drawings to the owner in order to obtain his/her approval of a design scheme for development during the next phase (Khemlani, 2001).

During the preparation of design schemes, the designer should examine and revise the decisions taken during the previous phase and extend the analysis to the building code related issues at building and major space level.

3.2.2. Schematic Design Phase

The design scheme selected by the owner is detailed during this phase. The designer will start identifying the criteria for the building materials and products, for exterior elevation finishes and for structural, mechanical and electrical systems based on the approved design criteria. Based on the design program and overall shape and form, the designer begins to locate and dimension major spaces at an abstract level. The designer presents the development of design to the owner in a format of plans, elevations, sections, renderings, perspectives, 3D models and basic detailing of particular areas. The owner also receives written documents, which provide preliminary project description, outline specifications and cost projections (Khemlani, 2001; CSI, 1996).

During the schematic design phase, the building code analysis process continues in revising former building design data and checks all design decisions at floor and space level.

3.2.3. Design Development Phase

The design development phase follows the approval of the schematic design and any necessary modification to the budget or the design program. During this phase, the design is further refined and detailed plans, sections, elevations and construction details are developed. The designer determines the type and size of equipments and focuses on technical issues, such as, constructability and integration of building systems and components. The space layout is now finalized to include its physical characteristics (length, height and depth) and material properties of walls, doors, windows, floor and ceiling. The outline specifications are revised after update of all of these design elements.

Before preparing the construction documents, the design has to be intensively checked against locally adopted building code and other design criteria related to circulation, energy, lighting and others preferred by the owner. (Khemlani, 2001; CSI, 1996)

The intensive building code checking process covers every building code related items and details. The design data at this phase are considered “Exact” and “99% Final”. These data includes but not limited to:

1. Occupancy and construction type of all spaces.
2. Construction details that reflect the relation and connection between building materials and components.
3. Layout and height of the building.

4. Number, height and area of floors.
5. Circulation routes including location, type and size of elevators, stairs and ramps.
6. Intensive occupant load analysis.
7. Number, type and size of exit doors.
8. Travel distances to exit doors and areas of refugee.
9. Locations, sizes and types of openings in exterior and interior walls.
10. Level of fire hazards between adjacent spaces
11. Topological information (i.e. spatial relations between building components, such as separation, adjacency, connectivity & intersection)
12. Zoning Ordinances and ADA related items.

3.2.4. Construction Documents and Specifications Phase

The construction documents and specifications phase is considered the final design phase and it is based on the approved design development documents. The objective of this phase is to provide graphic and written information necessary for bidding, construction and future building management. All the documents produced during this phase in the form of drawings and specifications are considered as legal documents and should clearly illustrate the work, rights, duties and responsibilities of all parties involved in the construction process. (Khemlani, 2001; CSI, 1996)

The designer is obligated to explicitly prove the project compliance with various adopted building codes by graphically presenting and textually affirming the description of every building component or detail related to issues addressed by the building code.

4. Automation of Building Code Analysis Process

4.1. INTRODUCTION

An observer of the CAD market could simply notice the widespread availability and variety of CAD software for each design phase. Everyone may agree that computer technology has become more and more fully incorporated into the architectural practice. However, complete computer integration and automation are still far from perfect.

"Why does software for building design and construction continue to imitate manual procedures?" This question rose during the International Symposium on "Building Systems- Automation and Integration." (Building Systems, 1993)

Unfortunately, little has been done to tackle this crucial subject. No substantial development will occur without the transformation of AE computer-based technology from the era of Computer-Aided Drafting and Design (CADD) to the stage of Computer-Aided Integration and Analysis of the Design process (CAIAD). The building design team is under pressure to use as much design tools for design analysis and building performance prediction as possible.

4.2. RELATED WORK

Very little research was made and few papers were published about automation of building code analysis. Among those papers which directly addressed this issue was "A client/server framework for on-line building code checking" (Han et al) which aimed to develop an on-line automated building code checking system to service both designers and permit-issuing bodies.

4.2.1. A Client/Server Framework for On-line Building Code Checking

The paper focused on developing a framework for handling architectural building code issues by initially investigating handicapped accessibility requirements in building designs. Several issues were explored as major elements in the study:

1. The criteria of the building model.
2. The representation of code provisions.
3. The relevance of the provisions with respect to design components.
4. The encoding of component-based provisions.

In order to facilitate design data exchange, the study recommends that the client should use a standard product model such as the Industry Foundation Classes (IFC) and the Standard for the Exchange of Product Data (STEP). The plan was developed using an "IFC compliant CAD package" to create an IFC EXPRESS file from an architectural design. The file would then be sent to a code-checking program (CCP) located on a remote server. The program examined the IFC data file and posted the results to a web page. The web page presents the building model graphically with the "redline" information and hyperlinks to the review comments and the building code related provisions. The study has only applied to those issues related to door accessibility as an example that could extend to accommodate others associated with a building code or ADAAG.

A simple AutoCAD-to-IFC translation module was developed to generate the building class attributes and relationships required by the code-checking program in order to perform the building code analysis. Since AutoCAD natively does not support IFC building model format, an additional layer was created of building component objects with semantics compliant with the IFC hierarchy. An AutoLISP routine extracts and converts the IFC information from the enhanced AutoCAD database into an IFC EXPRESS file.

The paper studied the following ways applied in examining the relevancy of a building design to certain building code provisions:

1. Determine the provisions applicable to a specified building component or system of building components.
2. Determine building component or system of building components applicable to a certain provision or set of provisions.
3. Resolving exceptions within a provision.

4.2.2. Conclusion

This paper is considered as an indispensable contribution in mapping the directions in the field of CAIAD. I think there are fundamental issues that the paper either failed or avoided to address relative to building code checking. These issues include:

1. Although the study was titled to handle building code issues, it applied only one example of the disabled persons' architectural design requirements, which do not represent the core, and body of building codes. (Refer to the Purpose of Building Codes).
2. The study assumed without providing factual indications the similarity between the application of handicapped accessibility issues and other building code essential subjects. The generalized solution proposed by the study applied one case only (i.e. door clearance) and therefore it lacks behind in demonstrating enough evidences for generalizing the on-line framework.
3. The study did not address some basic subjects related the automation of building code analysis. For instance, it did not establish the relation

between the study and the building code analysis process during various project development phases.

4. IFCs are still under continuous development by the IAI and still lack the consideration of the requirements of the building code model and the building data model. The paper in this case may help in the continuous development of the IFCs and object model.

5. The target groups, as defined by the study, were design professionals and permit- issuing bodies. Although they may collaborate with each other in particular after the construction document phase, the two entities have different role and responsibilities. Therefore the proposed framework may best fit designers after the construction document phase. What about the preliminary building code analysis process during the design phases those are ahead of the construction document phase?

6. The study focused on the framework without defining and explaining key elements in the success of the proposed system such as:

   A. Which “IFC compliant CAD package” was used to create an IFC EXPRESS file from an architectural design?

   B. What is AutoCAD-to-IFC translation module and how it works within AutoCAD design environment?

   C. How and what program was used to develop the link between the building components, code comments and code sections?

   D. How building codes or ADAAG were organized to achieve their research goals?

7. The paper described the functions of the framework without much detail on how those functions work.

8. The study did not discuss other possible valid scenarios about on-line building code checking.

4.3. AUTOMATED BUILDING CODE CHECKING SOFTWARE

4.3.1. Plan Analyst-IBC 2000 (PA-2000)

Plan Analyst-IBC 2000 is stand-alone software developed to be an easy and affordable tool to streamline the plan checking process during the early stages of the design process. Three types of projects can be checked against the IBC using the software; commercial, single family dwelling and open parking garage. The software provides a customized check list and a code compliance report that shows code deficiencies based on user textual inputs. Other building code-checking software such as “Build2Code” with features and procedures has similar limitation to Plan Analyst which was developed to offer designers various benefits, as indicated by the software developer such as:

1. Improve in efficiency and quality of code checking process.
2. Convenience in the plan checking process.
3. Elimination of simple math errors and inconsistencies.
4. Reduction in plans checking time and elimination of hours of code study research.
5. Customization of code requirements.

4.3.2. How Plan Analyst Works

To use the Plan Analyst software, the designer extracts the required building code related information from the drawings and enters this information as textual into the software interface following particular steps:

Step 1: Enter basic description of the building

Step 2: Enter the basic description for each floor

Step 3: Select the use of each area and enter its floor area.

Step 4: Enter site description

Step 5: Indicate the type of construction and fire sprinkler info

Step 6: Select additional building features.

Step 7: Select customized Checklist.

Before viewing the analysis report, the user may select the question groups to use in completing the code checking process. The user will select whether each item/question was addressed or not on the plans. If the answer is not, the user will be asked to enter the location of the problem on the drawing to be added to the final correction report with reference to the applicable code section.

Step 8: Analysis Report

When the project description finished, automatically the analysis report is generated to include:

1. The relation between the project description and code requirements by referencing the description to the applicable building code section.
2. Explanation of where and where not the design does comply with the IBC with reference to building code section.
3. Indication of missing information

4.3.3. Conclusion

The Plan Analyst Software can be considered as a vital but immature step towards complete automation and integration of building code checking practice into the architectural design process. This statement could be seen more evident if we regarded the following conclusions:

1. It is also regarded as a rudimentary tool and could only be used in early design phases. (Khemlani, 2004)

2. The steps of plan checking as described above is a strictly linear process and it does not conform with the conventional design process which sometimes requires search of minor building code issues.

3. The nature and procedures of plan checking as adopted by the Plan Analyst software requires the user to have a comfortable knowledge in order to benefit from it. That's mean designers with no code checking experience could hardly use the tool.

4. The application of Plan Analyst software is based on tedium procedure of textual rather than graphical input besides calculating manually the area of different building components. (Khemlani, 2004)

5. Plan Analyst could not be integrated into any other CAD tools. That means it is still far away from becoming desirable by the mainstream of designers.

6. It doesn't provide users with very important information/service such as:
   A. Updates on building code sections
   B. Inquiry tool to search various code issues.
   C. Graphical support that interprets code sections.
   D. Limited scope of projects could be checked using Plan Analyst.

7. Although the checklist covers a lot of issues, it doesn't clearly explain how to comply with the requirement addressed in the question. This means that the user will still need to go back to the building code book to search for answers.

5. Conceptual Framework of a Computer-Aided Analysis of Design (CAAnD) program

Considering the nature of building codes and their application during different project design phases, the conceptual framework of automating the building code analysis process should consists of three digital development areas which based on the transformation of graphical representations and textual information into data that could checked using computer-analysis program. (See Figure 1)

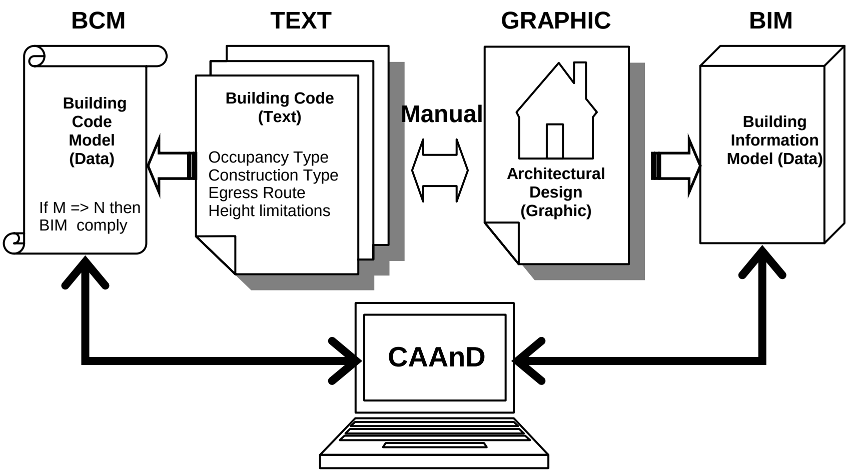

Figure 1. Conceptual Framework for automated building code analysis of design

These transformations include:

A. Building Codes	►	Building Code Model (BCM).
B. Architectural Design	►	Building Information Model (BIM).
C. CAD systems	►	Computer-Aided Analysis of Design program (CAAnD)

5.1. OBJECTIVES

This framework aims to:

A. Correspond to the functions, attributes and structure of a BIM that conforms to the requirements of building codes.

B. Reorganization of building codes in relation to an automated code check process and design practice. The reorganization will assist in leveraging the code from what is now a textual legal document to more graphical interactive source of building criteria.

C. Provide designers with a program that will assist them in the analysis of project design and to inform and advise them on how to understand and search various building code aspects related to project design.

5.2. MODEL CRITERIA

The subsequent criteria define the capabilities of the automated building code analysis program.

5.2.1. Building Code Model (BCM)

The BCM should correspond to the following:

1. The nature, development and application of building codes.
2. The building code compliance checking process at each design phase.
3. The type and subjects of building code.
4. The need to use building codes as Design criteria and an opportunity rather than a constraint.

5.2.2. Architectural Design and Building Information Model (BIM)

The hierarchy and relationships of various objects in the BIM should maintain and facilitate the tasks to:

1. Identify and classify building information objects or entities requested for building code compliance during various project design phases.
2. Extract and categorize the classified information.
3. Structure building information in a data model that's compatible with the nature of the building code and based on each design phase and each design level.

5.2.3. Computer-Aided Analysis of Design Program (CAAnD)

The CAAnD program should be to accomplish the following tasks:

1. Search the building code database by subject.
2. Sort various building codes encoded provisions and highlight those applicable to a particular project type based on input data.

3. Sort various building information and identify those required by the building code.
4. Evaluate the values extracted from building information against the conditions set by building codes. The structure of program should be based on steps followed in building code analysis. (Refer to the section titled "Using Building codes")
5. Associate the outcome of step "4" with the equivalent encoded building code section.
6. Link the encoded building code sections to the original text-based ones and vise versa.
7. Produce a final analysis report on the compliance of building design.

5.3. POTENTIAL IMPACT

The above listed objectives and model criteria will have significant impact on the following:

1. Hierarchy structure of the building information model (BIM) that represents the building design information related to building code requirements.
2. Hierarchy structure of the building code model that symbolizes the building code analysis process.
3. Reorganization of building codes.
4. The future development of BIM and IFCs in relation with the area of computer-aided analysis of design.

5.4. CONCLUSION

The further development in architectural practice is embodied in the progress of computer-aided analysis of design programs and building code checking is an essential element of this progress.

This paper highlighted some of the issues of integrating building code checking in CAD that has become more critical in shaping the criteria of the next generation of architectural software. The paper outlined the conceptual framework that will advance the automated building plan approval initiatives and inspire the continued interest in architectural design analysis.

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A CASE BASED ARCHITECTURAL DESIGN APPLICATION FOR RESIDENTIAL UNITS

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Abstract. Case Based Reasoning (CBR) is an AI approach that is widely used in many fields. When it's applied in the design field, it is frequently called Case Based Design (CBD). Its main idea resides in drawing analogies between past cases and the new case to be solved so that the user can make use of past experiences when solving a new problem. The work presented here describes a prototype application under development that makes use of CBR in the field of architectural design. The application is to act as a helping tool for architects in the pre-design phase by supplying them with an adequate number of similar past architectural cases to the design problem they have at hand. The different modules of the application will be presented and discussed, as well as the tools used to develop them.

1. Introduction

1.1. WHAT IS CASE BASED REASONING?

One of the frequently used applications in the AI field is CBR. What made CBR systems a big success is that they are based on the human way of thinking, reasoning and learning (Aamodt and Plaza, 1994), which was proved by the work of Schank (1982), Anderson (1983) and others. According to Riesbeck and Schank (1989), the human thinking is not based on logic but on retrieving and processing the right information at the right time. A typical CBR application has to deal with the following processes:

first, to identify the current problem situation, then search the case-library and select the case that is most similar to the current situation, use this case to solve the current problem, evaluate the solution, and finally update the case-library with the new case solved (Figure 1).

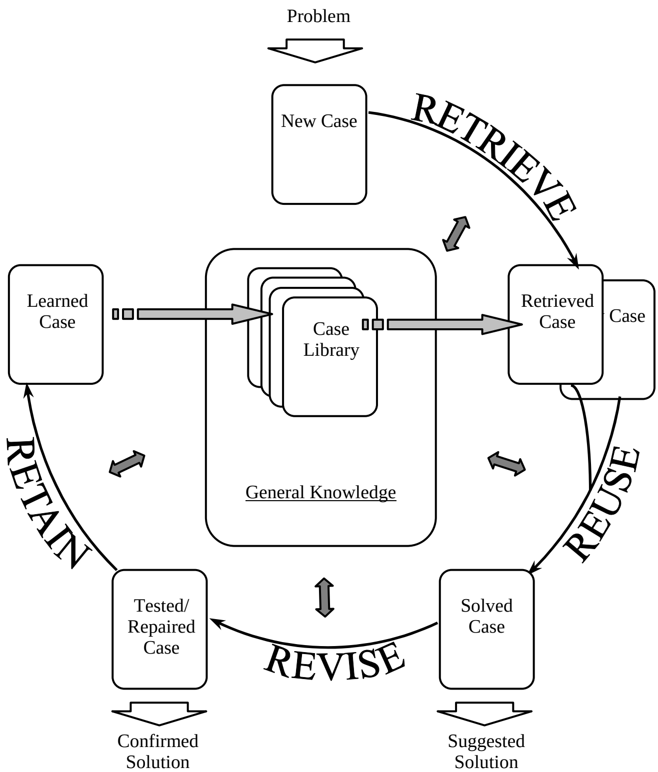

Figure 1. The CBR Circle (Aamodt and Plaza, 1994).

Watson and Marir (1994) state that the CBR cycle rarely exists as described above, but usually the human role takes part within the cycle. They state that many CBR tools act primarily as case retrieval and reuse systems, with the adaptation part being undertaken by managers of the case base. They believe that not being totally automated, and involving the human role in the decision making process should not be considered as a weakness in the system, a point of view which matches the assistant systems' argumentation (Brooks, 1996).

1.2.WHY DO ARCHITECTS NEED SUCH AN APPLICATION?

"The education in architectural design relies heavily upon the use of cases as a vehicle of discourse between the teachers and the students; the hope being that particulars in the given cases offer a holistic view of design issues that are difficult to articulate or view if they were taken up separately" (Dave et al., 1994). The process of using past knowledge to solve new design problems continues from being used in the education process to being widely used in design offices. In order to substantiate that, we performed a survey among a sample of architects. We prepared a questionnaire that addressed several issues such as how architects deal with past experiences, where they look for them, how much time they spend in searching for similar designs, how much time they spend in analyzing them, …etc. The questionnaire was sent to a sample of architects that represent the international community (Egypt, Germany, and USA). Fifty responses were received and it was found that 100% of the architects who participated in the questionnaire stated that they reviewed previous design cases in one way or another. 59.5% of them stated that they *always* or *most of the times* reviewed previous designs either made by themselves or by others, whereas 40.5% stated that they reviewed previous cases only *sometimes*. It was also clear that a significant percentage of the pre-design phase total number of hours was spent in searching for past cases. In particular, 216 hours were spent in searching for cases, while 345 hours were spent is studying and analyzing them (38.5 % and 61.5 %, respectively).

1.3. AIM OF THE WORK

This study aims at developing an architectural application to aid architects in the pre-design phase. The application is meant to reduce the time architects spend to look for similar cases to the problem they have at hand. It leaves the case adaptation process to be manually carried out by the architects themselves, since this is a process that needs the architect's creativity, not the system's efficiency. Since architects prefer graphic representation, and usually develop their conceptual designs using different sorts of diagrams and simple sketches, the developed application uses graphical description of the architectural cases instead of textual. With queries represented as bubble-diagrams, the application checks its case-library and retrieves those cases that are similar to the given query.

Such a system can be of direct benefit in housing design for large population groups where the traditional white table approach cannot yield user-specific designs, especially if there is limited time and financial resources committed to the architectural design. And which might result in duplicating inappropriate prototypes in hundreds or thousands, not suited to varying user profiles (Raduma, 2000).

2. How Does this Application Differ from Previous Ones?

During the Second International Conference on Artificial Intelligence in Design the issue of how CBR techniques can facilitate the design process was raised. Researchers were divided into two main categories, the first attempting to develop systems that *do* designs, while the other group was aiming at developing *tools* to assist the human designers (Domeshek and Kolodner, 1993). In the coming section, we'll present some of the existing systems, review their components and functionalities, and recite how our application differs from them.

2.1. ARCHIE-II

Archie-II is the product of collaboration between architects, computer scientists, design researchers and environmental social scientists at the AI lab of Georgia Tech's College of Computing. It is a *case-based design aid* (CBDA) that provides access to past experience so that human designers can adapt the cases for use in a present situation (Zimring, Bafna and Do, 1996; Heylinghen, 2000). It supports architects during the conceptual design phase through three means: (1) raising design issues, (2) proposing responses to design issues, and (3) identifying pitfalls and opportunities (Domeshek and Kolodner, 1993). This is accomplished by not only collecting successful cases, but also by having some cases that didn't work out as was hoped for. Cases were not just described, but the case materials have been drawn from post-occupancy evaluation studies, which were collected for example from the builder, concerning the difficulty of construction; the user, concerning the difficulty of living within certain parts of the building; or even from the maintenance staff. Evaluations of the current buildings serve to highlight the good and the bad features of the design (Domeshek and Kolodner, 1993; Heylinghen, 2000).

The case-library of Archie-II contained at the beginning only cases about courthouses and libraries. Later, tall buildings and handicapped access cases were also added. Since libraries and courthouses were regarded as very complex cases, they were broken down into several pieces of proper size and content (called stories). Each story was represented by: (1) a set of text strings (a title, citation, summary, and full story text), (2) a bitmap graphic intended to accompany and illustrate the story's text, (3) descriptive information including some indication of the major building systems involved and the major outcome, (4) a list of annotation points locating the story on relevant blueprints, (5) links to other related stories, (6) links to relevant guidelines, which suggest ways of thinking about certain problems instead of giving ready-made solutions, and (7) a list of descriptive indexes that provide access to the story in response to user queries.

Users can retrieve design cases by two methods. They can search for a specific design issue in addition to one or more of the following features: building space, functional component, stakeholder, and building's life cycle (i.e. safety in courtroom, glare in reading zones, etc.). Or they can browse the different cases through the bi-directional links embedded by the authors of the stories that link different stories that have some features or guidelines in common (Zimring, Bafna and Do, 1996; Heylinghen, 2000).

Archie-II is another system that applies what Watson and Marir (1994) referred to as systems that rarely exist -as described previously- with all four phases of the CBR-cycle made available. Also here, the manipulation phase is left completely to the user. The architect is supplied with the past stories that are related to the design task at hand, and he bears the responsibility of understanding and applying (or ignoring) the information presented (Domeshek and Kolodner, 1993).

2.2. CADRE / IDIOM

CADRE, and afterwards IDIOM are two systems developed at the Swiss Federal Institute of Technology in Zurich (ETH Zurich) and in Lausanne (EPFL) as an interdisciplinary work between architects and computer scientists. They belong to that category of systems that aims at automatically generating the complete design.

The focus point in CADRE has been on the adaptation of design cases to new environments (Heylighen, 2000). Each case in the case-library was presented as a complete 3-dimensional geometric model. For each case there is a graphic thumbnail as well as several representations that can be useful for the designer. Representations might be geometry-based (i.e. a CAD model), topology-based (i.e. a graph of adjacency relations between the different spaces) or grammar-based; these could be stored with the case or computed on demand. Each case can also be presented in one of four levels of detail. (1) All details: showing all available information about the case; (2) aggregate (or zones): showing groups of spaces (i.e. showing all public spaces); (3) center-lines: showing the geometry of the spaces without details; and (4) bounding box: displaying the smallest bounding volume of the case.

The user browses the case-library, and manually selects the case he prefers to be adapted to his own design program, or he selects multiple cases to be combined together to compose the final design. He also specifies the new problem context, which usually is a site description in addition to a design program. The new site layout and orientation and the specific program requirements result into a set of constraints that is derived from the discrepancies between the selected case in its original context and after its insertion into the new design context. Dimensional and/or topological modifications are automatically carried out to adapt the selected case to the new context. Dimensional adaptations change the values of the numerical parameters that describe the geometry of the design, without removing or adding spaces or elements. On the other hand, topological adaptations alter the layout of the case by adding, removing, or rearranging spaces and elements. In case that all constraints are resolved, one or more design solutions are obtained and displayed to the user. Otherwise the user either has to alter his set of constraints or choose another case to be adapted (Dave et al, 1994; Heylighen, 2000).

IDIOM stands for Interactive Design using Intelligent Objects and Models. The idea behind this project -as Lottaz (1996) describes it- was to develop a prototype of a design tool, which shows the usefulness and convenience of the paradigms of CBD together with constraints, preferences and models in architectural design. It integrates several ideas aiming to assist architects during their design task such as: CBD, constraints to represent knowledge, constraint solving, models to represent domain-knowledge, activation and re-activation of preferences, interactive adaptation of solutions, as well as hints and critique. As previously stated, IDIOM comes from the same working group as CADRE. And through the experience gained from CADRE, there were major modifications in IDIOM. It was noticed that architects rarely reuse a whole design case, as was presented in CADRE. Therefore, the case-library of IDIOM is built up of parts of designs. Cases are divided into five groups: living rooms, kitchens, bedrooms, bathrooms, and hallways. Each case holds geometrical information as well as a list of constraints that needs to remain fulfilled after combination with other cases. There are three types of constraints that control the output: (1) case related constraints, (2) user related constraints, and (3) model related constraints. In addition to these several constraints, the system also accepts preferences with priority. Preferences are sort of constraints, which the designer would like to be fulfilled, but in case they contradict with other fixed constraints, they are deactivated.

As in CADRE, the user browses the case-library and selects the cases he wants to insert into his previously given site, and it’s the system that adapts the selected cases to the new environment, trying to fulfill all fixed constraints and as many preferences as possible. IDIOM calculates the feasible solution space through conflict resolution with preferences and dimensionality reduction, and selects a solution that involves minimal changes to the case and to the current design. The result is meant to be nothing more than a proposal to the architect, which he may accept as is, or modify (Lottaz, 1996; Heylighen, 2000).

2.3. SEED

SEED stands for Software Environment to support Early building Design. Its purpose, as stated by its developers, is to provide support at the preliminary design of buildings in all aspects that can gain from computer support (Flemming, Coyone, and Snyder, 1994). The system should not only analyze and evaluate solutions, but should also be able to rapidly generate designs. SEED is divided into three modules, where each module offers the user several generation capabilities ranging from stepwise construction under the designer's control to the fully automated generation of design alternatives. The first module is concerned with the architectural program. By getting the building context and the overall function and size of the building as input (e.g. elementary school for 300 pupils), it generates an architectural program or design brief. The second module -The Schematic Layout design Module- takes the specifications of the functional components, the context, the budget, and the architectural program as input, and generates a layout of the functional units (e.g. the distribution of the zones over different floors). The last module -Schematic Configuration Design Module- takes the schematic layout and programmatic requirements as input, and generates a 3-dimensional configuration of the building (Flemming, Coyone, and Snyder, 1994; Heylighen, 2000).

2.4. FABEL

FABEL is a joint research project supported by the German Ministry for Research and Technology (BMFT) and is carried out by six different organizations and universities in Germany. It is a hybrid system, which applies case-based, rule-based, as well as model-based reasoning. It contains a collection of tools, called *specialists*, each of which addresses one of the CBR processes (Heylighen, 2000).

Objects in FABEL don't only have a position and a graphic representation as in classic CAD systems, but they also have a type. As described by Gebhardt et al (1997), design objects may be concrete elements of a building like columns, walls, doors, and windows, or they might be abstract elements, such as zones of certain use or climate. Each element is presented by the following: (1) coordinates: the spatial position of the object; (2) aspect: the subsystem to which this element belongs (i.e. construction, façade, heating element, etc.); (3) morphology: which describes the function of the element (i.e. pipelines and beams have a 'c' connection function); (4) precision: elements are divided into three levels of precision: zones, bounding boxes and elements; and (5) size: which distinguishes the level of concern being the whole plant, the whole building, one floor, a single room, or an area within a room.

Cases in FABEL can be manually selected from the case-base by the user, or automatically retrieved by the different *specialists* of the system. They are afterwards automatically manipulated through different tools. Some tools are for topological manipulation, such as TOPO, while others are for dimensional manipulation, such as AAAO and AgentEX (FABEL-Report, 1994; Coulon, 1995; Gebhardt et al, 1997; Heylighen, 2000).

2.5. THE DESIGNED APPLICATION

Regarding the CBR processes included in the application, unlike IDIOM, where the user manually selects the cases from the case-library while the application automatically manipulates the selected cases to generate the solution, our application makes use of the automated retrieval and retaining phases of the CBR-cycle, but leaves the manipulation phase to be carried out manually by the user.

While systems like Archie-II use textual case representation in building their case-library, our targeted application uses a simple graphical representation. This graphical representation enables the user to conduct his search via a simple bubble-diagram -which is widely used by architects- while in Archie-II the user searches the case-library by strings. The simple case description enables the user to easily update the case-library with his newly solved design problem, so that the case-library reflects new designs. On the other hand, in Archie-II due to the sophisticated case representation, adding any cases to the case-library is a time consuming and complicated task for the system developers let alone for the users. This leads to a static case-library with a limited number of cases.

Cases in IDIOM as well as in Archie-II are no complete buildings, but just separate rooms, zones or functions. It is thought that it's not the room itself that can be successful or not, but it's the room within its context that counts. Using parts of cases as in IDIOM, or describing selected functions and zones as in Archie-II should not for sure tune with all users of the system.

3. Why Residential Units?

As stated earlier, the application is intended to be a helping tool for architects during the pre-design phase. For the first prototype, low-income and middle-income residential units are chosen to build up the case-library. This is due to several reasons:

1. Residential units are typical buildings with a *finite* number of possible layouts (specially when we limit them to low-income and middle-income units). That makes it feasible to create a case-library that contains almost all possible residential layouts.
2. Also being a typical building-type permits a certain level of repetition, especially in early conceptual design phases (Chandrasekaran, 1990). That encourages architects more to view old cases and analyze how some design problems were tackled in them.
3. The more limited the budget for any design project is, the more an important role time plays. Since low-income and middle-income residential design projects are usually low budgeted and limited in time, we considered an application that reduces the amount of time spent on such projects to be useful and appreciated.
4. Last but not least, the more design constraints there are, the easier the design task is. While developing our first prototype we wanted to choose a simple building type, which consists of a limited number of elements and relations to simplify the system design. Residential units were the most appropriate building type, especially when we limited the application to low-income and middle-income units. This ensures a limited number of spaces and connections. We also added the constraint that all spaces should be within one level. Duplexes and multi-level residential units were excluded from our case-library.

4. How Does the Application Work?

4.1. GENERAL IDEA

While designing this application, we always had the processes architects go through in consideration. Architects may differ in their methods of developing designs, but still, there are some broad lines they all apply. As Domeshek and Kolodner (1993) put it: "the designer needs to learn about the client's problem and about prior art; unfortunately, this is a time consuming, costly, and omission-prone step in design. In architecture, common methodology calls for a special team - the programmers- to gather data on requirements and prepare a program that makes all requirements concrete. The designers then work to satisfy the client's concrete needs as made explicit in the program." They also state that designers tend to visit buildings, survey existing literature, and try to relate their current design task to famous precedents. And these are the same lines we tried to follow through the design of our application.

4.2. FIRST MODULE

Any design project starts with writing down the program. In some cases, this program is made available to the architect at the start of the project, and in other cases the architect develops it with the client. This program includes what types of rooms should be included, their sizes, the (connectivity) relationship they have to each other, and any special requests the client might express.

Our application also starts with writing down the design program. A user-friendly form (Figure 2) was designed, giving the architect a simple way to fill out the clients' needs.

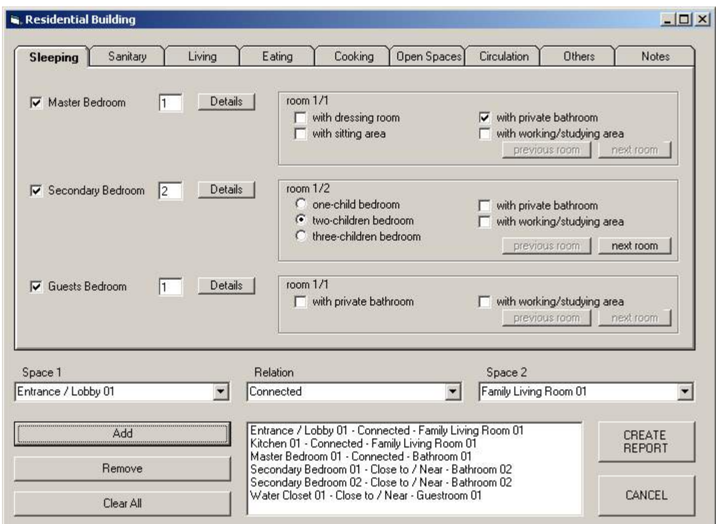

Figure 2. Filling out the form.

Using Visual Basic 6 © (VB) a multi-tab form was designed. The several tabs stand for the different room-types a residential unit might include, such as sleeping rooms, sanitary rooms, living rooms, etc. Using this form, the architect decides the types and the number of rooms the design should include. Some of the rooms have a *details button* that enables the architect to specify special features for each specific room. For example, secondary bedrooms might be for one child, two children or three children; they might include a private bathroom, or have an extra playing/studying area. These details are used to compute the area of each room. An extra tab is added to allow both the architect and the client to specify any special wishes or ideas. The form also allows the user to specify the (connectivity) relationships between the different rooms selected (i.e. the guestroom should not be adjacent to the master bedroom, etc.). It gives the user the possibility to add, revise and remove any notes or relationships whenever he wants to.

After completing this form, different reports and files are automatically generated. The first report is intended for the client to revise to make sure that all his requests are mentioned on paper; it acts as a contract between the client and the architect. Two other files are generated from that form, which will be used by the second module of the application.

4.3. SECOND MODULE

Based on the selections the architect made in the first step, a bubble diagram is automatically generated (Figure 3). This bubble reflects only the specific rooms with the calculated areas, as well as the relationships between the different rooms. The current position of the rooms doesn't play any role in the retrieval process in the third module. That's why we don't generate all possible solutions for the bubble diagram, but only the first possible solution that satisfies all relationship conditions.

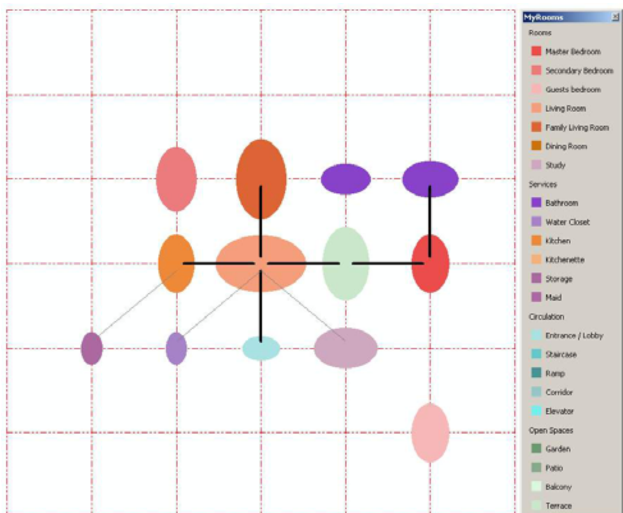

Figure 3. The generated bubble diagram.

This module was realized with ArcMap ™ 8.2 by customizing it using Visual Basic for Application © (VBA). In this module we make use of some features widely used in Geographic Information Systems (GIS) applications (such as topological relations). So instead of spending much time in developing those features from scratch, we decided to save time and make use of the available features in ArcMap, especially that it allows customization with VBA.

The two other files that were generated by the fist module are used here. The first file is a tab-delimited file that includes each room and its area, while the second file includes the different (connectivity) relationships generated from the VB form. Within ArcMap, several functions and routines were written that make use of those two files to specify a location for each room that satisfies the relationships conditions. Using these locations, a bubble diagram is generated. At this point, the architect might accept the bubble diagram as is, or he might modify it according to his views and concepts. He's allowed to change room sizes, add and/or remove rooms, alter room-connectivity, and specify room-orientation if he likes to. To make this process simple, the bubble diagram is generated using graphics, not features (feature is an ArcMap terminology that describes an element - may it be a line, a point or a polygon- that has a link to the database; while graphics are elements drawn on the screen with no linkage to any tables). After this diagram is finalized, the graphics are transformed into features, so that each element (room or connection) has a record in the database, and its record is updated with the modifications the architect might have introduced. This module ends by generating the query that will be used in the third module. The query is automatically generated from the final version of the bubble diagram the architect has modified. It represents the different rooms, their sizes and orientation as well as their topology.

4.4. THIRD MODULE

It's in the third module, where we search the case-library for cases that are similar to the generated query. Again, for not reinventing the wheel, we used a commercial system as a base for our application. As stated in CBR-Works' reference manuals (tec:inno GmbH, 2000): "CBR-Works by tec:inno is a software development package suited for intelligent solutions in a variety of domains and environments. It supports the user to design complex knowledge models. Concepts, types, similarity measures, weights and filters can be created, edited and maintained." For our application we had to use the development version of the program instead of the commercial one, to be able to adjust the similarity measures. This is due to the complexity of the model and the tailored similarity measures that an architectural object requires.

Since our aim is to develop a system that is based on graphical representation of the cases, we had to develop a model that can handle such representation. The developed model (Figure 4) represents the residential unit by the following objects:

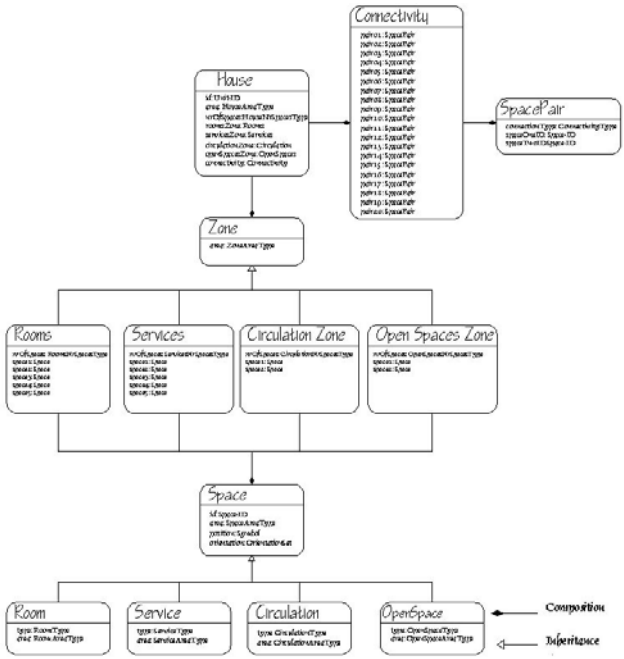

Figure 4. The developed Model.

Each residential object has a set of simple attributes (ID, area, and number of spaces), as well as a set of complex attributes (rooms-zone, services-zone, circulation-zone, open spaces-zone, and connectivity). Complex attributes are in fact other objects that have themselves different attributes. For example, rooms-zone is an object with two simple attributes (area and number of spaces) and other five complex attributes representing five spaces that this zone might include. Each space is represented by five simple attributes (ID, area, position, orientation, and space-type).

Each attribute is limited to a certain data type and a range. Some attributes have a simple data type such as integers, symbols or Booleans; but in most cases enumerations and sub-ranges are to be used to limit the value any attribute should have. For example, a space within the rooms-zone has its type limited to: master bedroom, secondary bedroom, guestroom, living room, family living room, dining room, or study; while a space within the services-zone has its type limited to: kitchen, kitchenette, bathroom, water closet, maid's room, or storage. This limitation helps reducing the number of comparisons made while comparing the query with the different cases.

A default set of weights is given to the different attributes that describe the residential unit. The architect will be given the possibility to adjust those weights according to his needs. While some attributes are used to compute the similarity between the query and the cases, other attributes are used as a filter to reduce the number of cases that are taken into consideration.

4.5. FOURTH MODULE

After calculating the similarity between the query and the cases in the case-library, the user is presented with those cases that are mostly similar to his query. The architect might use these cases to develop the design at hand. Then he should update the case-library with the new solved case. At the time of writing this paper, this fourth module for updating the case-library was not yet developed.

5. Evaluation and Conclusion

The system will be tested by giving two groups of architecture-students the same design assignment. While one group will be trained to use our developed application and given access to it, the other (control) group will only use the traditional methods. By comparing the performance of the two groups with regard to the quality of their designs, the time they needed to fulfill the task, and the simplicity of using the application, we will be able to assess the impact of using this application on the efficiency and the creativity of the designers.

6. What Else Can Be Done?

For the time being the cases are compared simply by checking the room area, orientation, type and connectivity. It is planned to introduce more special cases within the comparison phase. For example, adjacent rooms could be integrated into one bigger room, and big rooms could be divided into several smaller rooms (i.e. a small dinning room, which is adjacent to a small living room, could be compared to a big living room with a dining corner).

It is also intended to apply the system over the Internet, so that the case-library could be updated by several architects with diverse styles, instead of being a stand-alone system with a very limited case-library.

Acknowledgements

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COMPUTER AIDED SUSTAINABLE DESIGN

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Abstract. One of the most important aspects architects need to consider fairly early on is that of energy saving, cost, thermal comfort and the effect on the environment in terms of CO_2 emissions. At present, during the early design stage of a building, different options are assessed using simple tools (tables, graphs and software) that contain a large number of assumptions the very nature of which can bias choice or possibly lead to an inappropriate solution. It can be argued that the only way to provide a rational assessment of options is to use calculation methods that represent in detail the physical processes involved; this usually involves the use of dynamic thermal models. Furthermore if this tool is also used during detailed design it would introduce a consistency that is normally absent from the analytical design process. Many designers are of the opinion that, because not all details are known, then such tools are not suitable for application at early stages in the design. This view can be challenged because, even at the concept stage, a great deal is known about a building. This paper aims to show that a general description of a building can be used to generate sufficient data to drive a valid analysis using a detailed thermal model at the early sketch stage of the design process. The paper describes the philosophy, methodology and the interface developed to achieve this aim. The interface guides the user through the input process using a series of screens giving options for keywords used to describe the building; comprehensive default data built into the software are then attached to these keywords. The resulting data file is a building description that is the best possible interpretation of the design intent. This can then be used to assess options and guide towards a final design.

1. Introduction

In the early stages of building design process, architects need to assess various design alternatives and choose the one which best represent their design intent. One of the important aspects that architects need to consider fairly early on is the aspect of energy saving and thermal comfort.

In this paper, we report on the collaborative work that took place between the School of Architecture and the School of Computing at The Robert Gordon University, which aim was to develop an (online) interface, called Computer Aided Sustainable Design (CASD), that will guide the user through a series of input screens to allow him/her to describe the building and select various environmental and energy saving options. The interface is to be accessed by students at the School of Architecture to allow them to integrate environmental aspects in their designs.

A selection of building specifications from a database is used to generate numerical information that will be used by a calculation engine that uses sophisticated thermal models (CIBSE guide, 1986).

One of the projects main objectives was to develop a tool that assisted in reducing the number of design cycle iterations (revisions). This fits with government policy to improve the effectiveness of the design process and to make procurement of buildings cheaper and more efficient (Bennadji et al, 2002).

In the past people have resisted the use of such simulation programs for a number of different reasons. They felt that it was time consuming to input the necessary data and that the program was not user friendly enough. The team aimed to reduce the amount of input required for each building with the use of extensive, intelligent defaults. To make the program more user friendly, an implementation of a pictorial based input system was used with a minimal amount of data required to describe a building. Users also felt that programs could not be trusted, perhaps because of their complexity and the fact that they could not understand them. The above goes along way to solving this.

At the concept stage of any project the design team already have a significant amount of information regarding the building such as location, number of floors, occupancy, preferred glazed areas, insulation standards, thermal mass and required internal environmental conditions.

This information may seem quite standard but can prove to be invaluable when used along with the correct program and suitable dynamic thermal model. Indeed, there is no reason why such a tools should not suitable for application at early stages in the design process.

2. CASD's Features

CASD is a whole building energy prediction method and a program that allows users to enter a minimum amount of data to produce an energy analysis file. The analysis of this file is performed by a third party analytical program. It is intended to be used to compare the performance of different building's design that the building's actors can choose the best option regarding the thermal point of view.

The originality of this software is that the inputs and the outputs are generated in a building actor's understandable language and it's not necessary that they have good computer skills.

The basic features of the software are as follows:

1. Simple method for evaluating energy performance of alternative plans, section, elevations of a building at the sketch design stage. It is a means to estimate relative energy performance of different options.
2. CASD uses energy performance data from a mathematical model, in which values have been assumed for heating, cooling, lighting energy (data that would not be available at the sketch stage). The user manipulates only a few design variables, mainly related to building form and façade design.
3. CASD is not a precision model for accurate estimation of performance of an actual building. CASD is used to evaluate relative energy performance of a number of options for comparison purposes. In fact, a tool for assessing the environmental quality of a building should be able to deal with two distinct types of reality:
    1. The physical reality of phenomena, expressing the links between sources and environmental effects.
    2. The reality of the progress of a building's operation, with its phases, actors, decisions.

CASD has been deigned to capture all the data needed by any thermal model, and as such can be plugged-in any software that uses thermal models to predict annual primary energy consumption as a function of:

- Local climatic conditions
- Orientation of façades
- Area and type of glazing
- Obstructions due to adjacent buildings
- Occupancy and vacation patterns
- Lighting levels
- Internal gains

Examples of such software include, Energy2 and Energy10.

3. CASD's Interface

The interface has been developed using HTML in the Macromedia Dreamweaver MX environment. ASP (Active Server Pages) code was used to link the Web pages with a MS Access Database containing all the data entered by the user, and other default (standard) values related to the building regulations in the U.K. ASP allows you to dynamically edit, change or add any content of a Web page, respond to user queries or data submitted from HTML forms, access any data in the database and return the results to the browser. The images and icons have been manipulated using Adobe Photoshop.

The interface (see Figure 1) is comprised of a sequence of screens (Web pages) in which the user can freely move forth or back. The user is free to start from any screen after completing the first one which relates to the project description. The user can stop at any stage, save his/her work and resume at some other time.

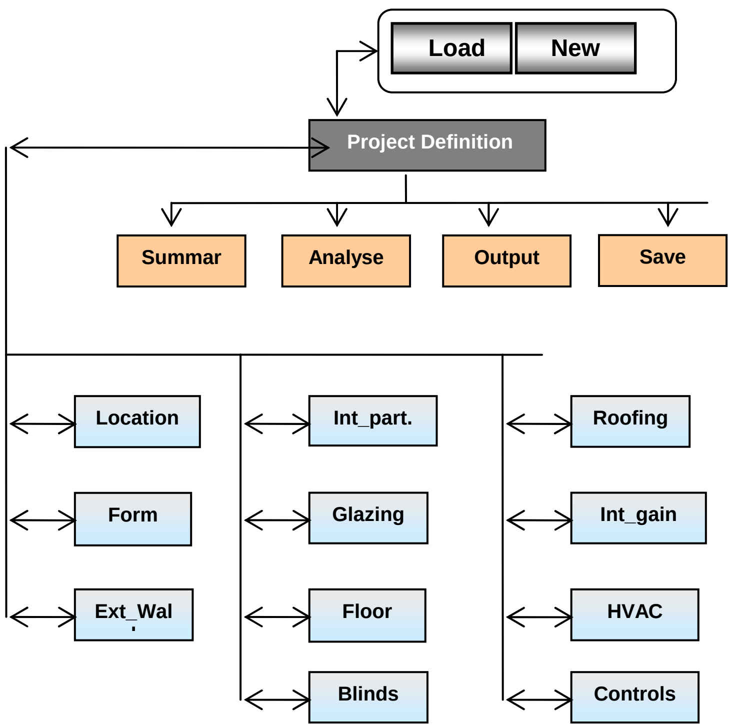


Figure 1. CASD's Interface.

In the following we provide a summarized description of all the screens with some of the options that the user is called to choose from.

3.1. PROJECT SCREEN

This screen enables the user to load an existing project (from the database) or create a new one. For newly created projects, the user can specify a project's name, description and the air conditioning function (standard or prestige), (see Figure 2).

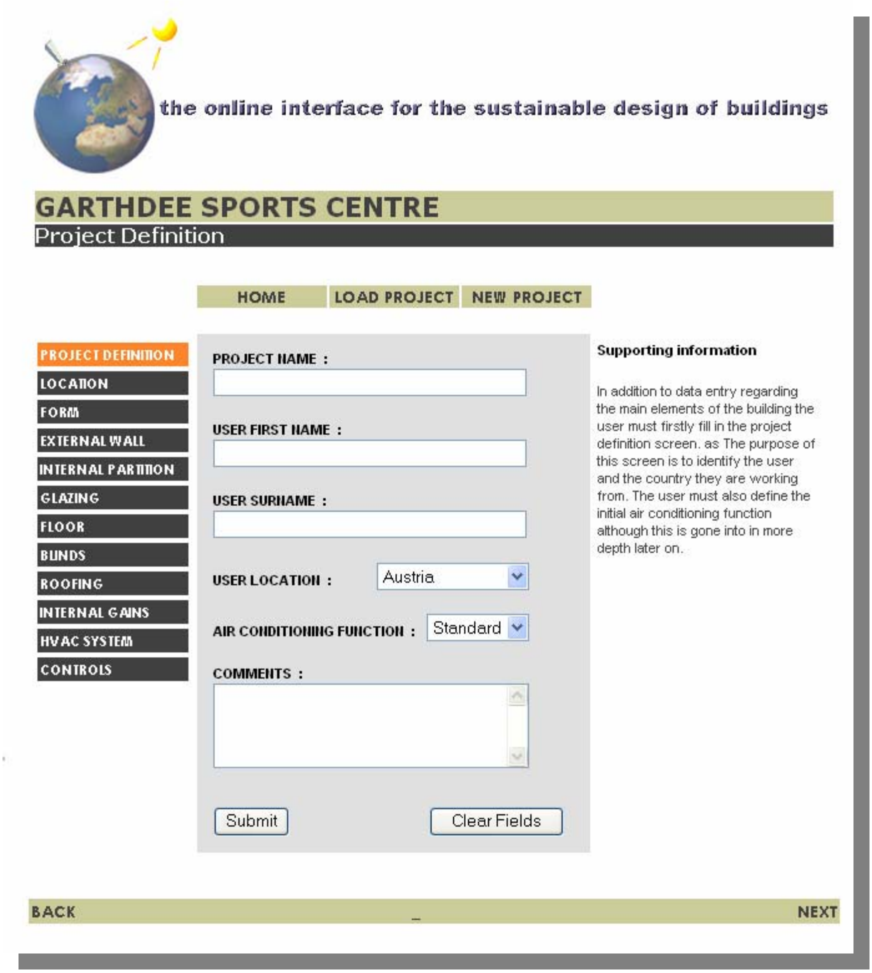


Figure 2. Project Definition Screen

3.2. LOCATION SCREEN

It enables the user to select the country in which the building will exist (at the moment restricted to the U.K.), then select an area within that country, given that in many cases (such as in the U.K.) building regulations differ from place to place. And finally, the user can enter the terrain in which the building is to be built, i.e., normal, severe or sheltered (see Figure 2). If one of the two last options is selected, the user will be asked to specify further whether the terrain is "rough open", "farmland", "urban" or "sub-urban", (see Figure 3).

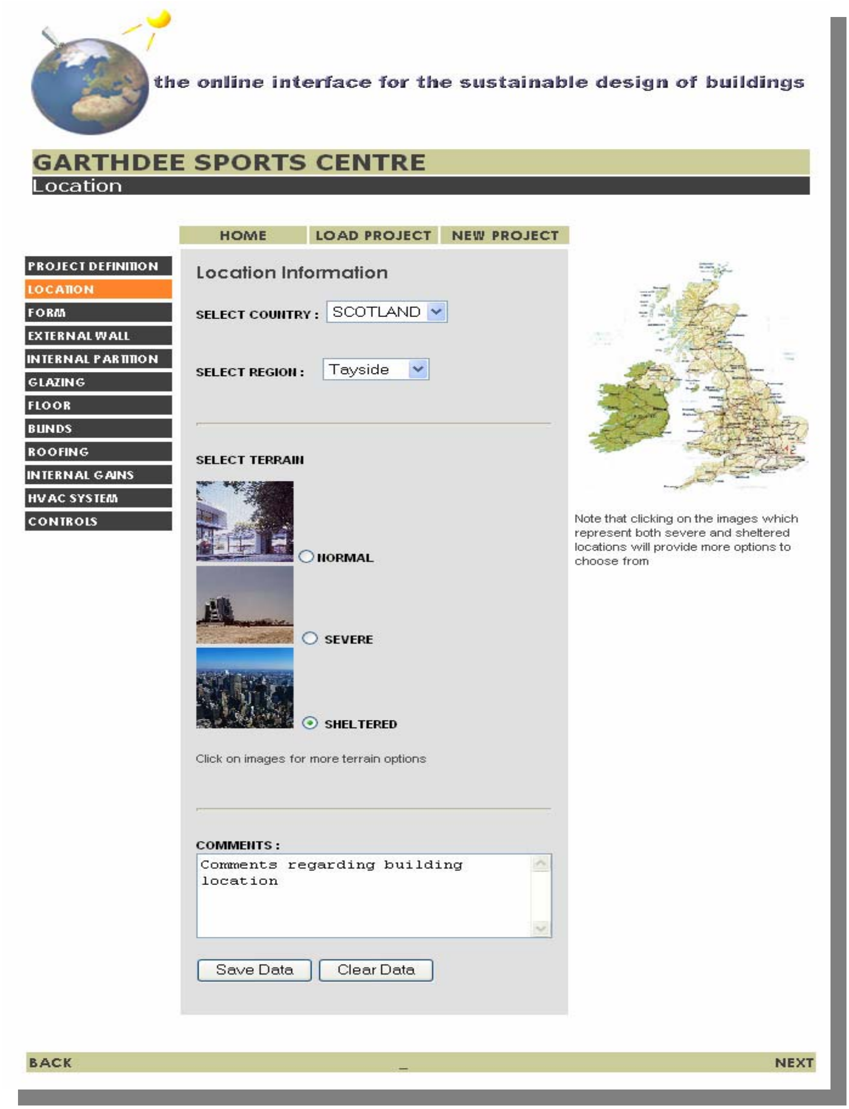


Figure 3. CASD-Project location

3.3. FORM SCREEN

The user describes the building's size (length, width, floor to floor height, floor to ceiling height, number of floors…), orientation (using a diagram that the user can rotate) and to describe the façades (in particular, the percentage of façade area that is glazed).

3.4. EXTERNAL WALLS SCREEN

Here the user describes the building's external walls. The user has three different ways of completing this section: Standard, Custom or load other walls. We describe here the first method, which is to simply choose from the standard specification shown for thermal response time and insulation standard.

There are three possible values for the thermal response time:

- Slow: corresponds to a lightweight external cladding with insulation in the centre and a solid internal wall.
- Medium: corresponds to a solid external cladding with insulation in the centre and a solid internal wall.
- Fast: corresponds to a solid external cladding with insulation in the centre and internal plasterboard finish.

The insulation standard provides the user with three choices:

- Standard UK building regulations value
- 20% better than building regulations value
- 50% building regulations value.

3.5. INTERNAL PARTITIONS SCREEN

Here the user is to describe the building's internal partitions and layout. The description includes the type of internal partition (high mass, medium mass or low mass internal wall) and the type of cell structure (mostly open plan or mostly cellular) for each of the sides of the buildings.

3.6. GLAZING SCREEN

This screen enables the user to describe the building's glazing. The user is offered two options: standard or custom specification. The standard option prompts the user for the number of panes of glass (two or three), the type of glass (clear, heat absorbing, reflecting or low E). If the user opts for the custom option, he/she needs to provide the U-Value of the glass, the short and long wave shading coefficients and the light transmission, (see Figure 4). Some specificity needs more than one screen to be clearly described, the glazing description is one of them, (see Figures 5 and 6).

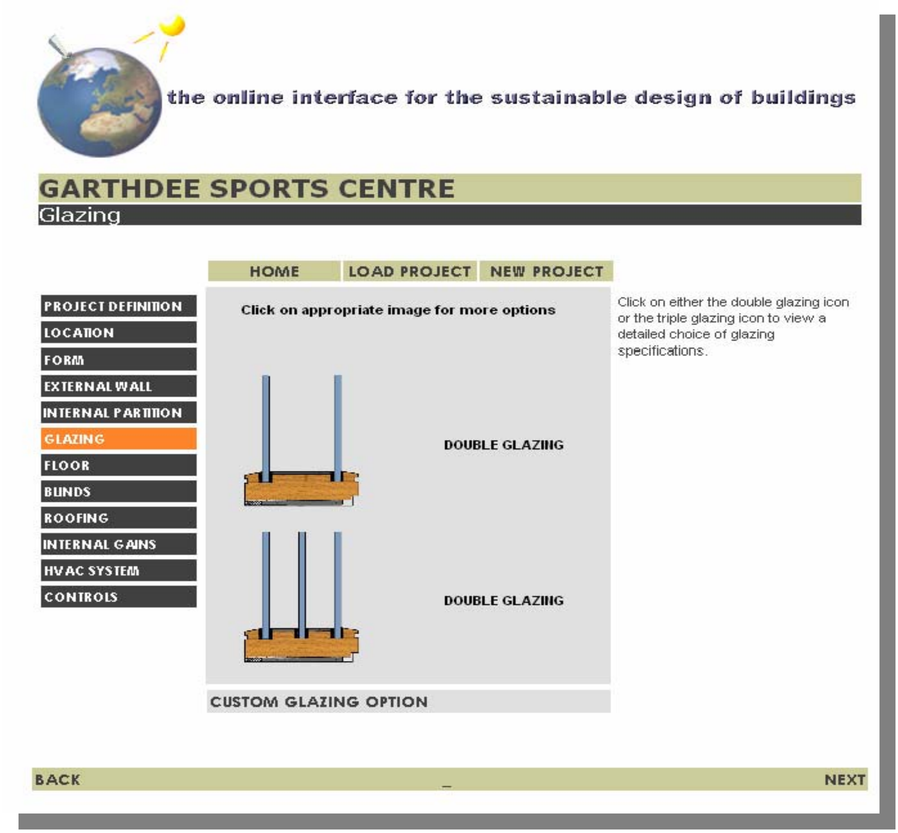
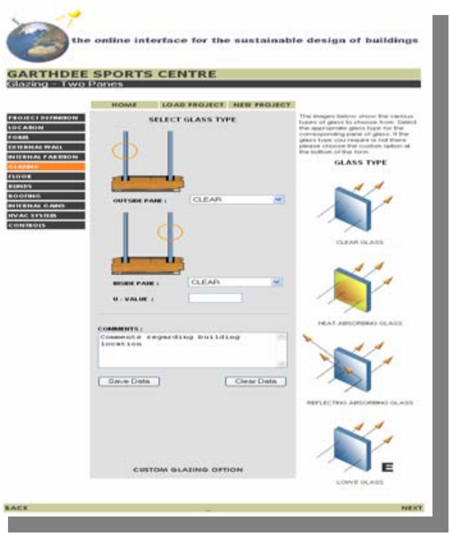


Figure 4. CASD – Glazing screen



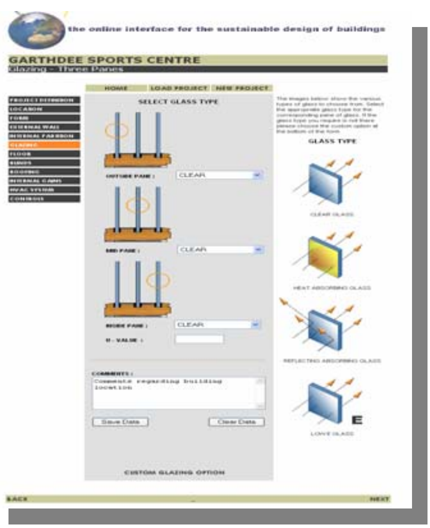


Figure 5. CASD - Double glazing *Figure 6.* CASD – Triple Glazing

3.7. FLOOR SCREEN

It enables the user to describe the building's floors. Again, three options are offered: standard, custom or load other floors. The standard option, for example, prompts the user to select the weight of the internal floor (light or heavy), the type of the internal floor and the type of the ground floor (solid or suspended). The custom option, however, requires the response time, insulation, solar absorbivity, external and internal emissivity and the internal reflectance.

3.8. BLINDS SCREEN

The user can describe the building's blinds and shading devices. The type of blinds includes external blinds, internal blinds and mid-pane (between two panes of glass). The shading devices include overhangs, side protection, outlook protection, loggia, roof protection to protect not only the glazed areas but the exposed walls as well. The dimensions of these devices are illustrated in a diagram within the screen to allow the user to visualize the device and input the dimensions.

3.9. ROOFING SCREEN

It enables the user to describe the roofing specifications of the building. Again, three options are on offer, namely standard, custom and load other roofs. The standard option requires the selection of the type of the roof (solid, solid with suspended ceiling and lightweight with suspended ceiling) and its insulation (the default option is set to comply with the building regulations, and if needed the user can select a better U-value).

3.10 INTERNAL GAIN SCREEN

This screen enables the user to input data which determine the internal gain of the building (Brown et al, 1991). There are two sections in this screen, occupancy and loads. For occupancy, the user must input the schedule showing when the building is occupied (this determines the heating or the cooling schedule and its intensity). The user selects an entry from a list of five choices:

- Very high occupancy: 24hrs, 7 days/week
- High: 12hrs, 7 days/week
- Medium: 12hrs, 6 days/week
- Low: 12hrs, 5 days/week
- Very low: 8hrs, 5 days/week.

The density of the building should be given in terms of number of people per square meter:

- Very high density: $5m^2$ per person
- High: $7m^2$ per person
- Medium: $8m^2$ per person
- Low: $10m^2$ per person
- Very low: over $15m^2$ per person.

The loads section of the screen describes the power used in the building, and the power used to run the machines inside the building. Again, the user can select from a range of “very high” to “very low”.

3.11. HVAC (HEATING, VENTILATION AND AIR CONDITIONING) SYSTEM SCREEN

It enables the user to input data which determines the type of heating, ventilation and air conditioning system to be used within the building. For example, the user selects the type of frost coil, the type of heat recovery system, the type of cooling coil and the type of humidifier.

3.12. CONTROLS SCREEN

Here the user can describe controls related to elements within the building including blinds, lighting, temperature, boiler, perimeter heating and electrical equipment such as computers. Talking about the blinds for example, the user selects how the blinds are operated (profiled, automatic or manual), and if the profiled option is selected, the user chooses from: blinds up all of the time, blinds down all of the time, or blinds down during the day.

4. Conclusion

CASD is being designed to suit the following aspects of building design: the iterative nature of the ‘real-world’ design process, the language of actors involved, and to supply results which can be interpreted by a multi-professional team.

The assessment criteria of the method, which consider the actors’ point of views, are related to the thermal performance of the building. The development of a method for assessing the thermal performance of a building is a difficult task because of the complex requirements to be met. The final output profile, which represents the building’s performance according to different criteria, can then be useable by architects and other consultants.

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OVERVIEW OF INTELLIGENT ARCHITECTURE

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Abstract: The concept of intelligent architecture started as an interest in the latest integrated building systems operating a single building or facility, so that systems can communicate and exchange information. The communication among these systems allows the right responses and decisions to operate buildings in a productive, economical and convenient way. Communication and information sharing prevents decisions from interfering with other systems' responses or operation. Systems' decisions and responses form the responsive architecture that is represented by systems outputs.

If intelligent buildings need to receive, analyze, and react according to such processes, responsive ones are required only to receive and react to only one input parameter. Technology and communication systems make it possible to combine several parameters by using system integration and computerization. Technology and computerized systems have enhanced and changed the manner of responses and provided a variety of decisions according to different sources of information.

Receiving, analyzing, and reacting are the key criteria of intelligent building that this paper will explore. The input (reception) category covers information detection devices such as temperature sensors. The second category will be the category of analysing devices. The third category, decisions and outputs, will cover both output of sensory devices and forms of reaction and response that emanate from these systems. As a result of the third category, this paper will survey the forms of responses to determine whether or not the kinetic response is a viable choice. The paper will discuss if these three criteria are the only criteria creating intelligent building or if there are others.

The paper will give an overview on intelligent architecture and explore in the main criteria determining intelligent building. The paper will then discuss when "responsive" and "kinetic" architecture becomes "intelligent". The paper will also redefine the intelligent architecture in the light of available technology.

1. Introduction

Since the 1970s, computer and telecommunication technology have been changing human life. These changes have outpaced the theories guiding such technologies. In the1990s, social and personal life has been affected by computers and telecommunication by making distance irrelevant. Physical spaces and their definitions, as human aspects, have also been affected; meeting rooms, for example, have become virtual as their physical elements have been computerized. This is simply integration between the computer's abilities and the physical world. Through this integration, physical objects and spaces considered as intelligent. Integrating computer to the physical world gives the physical world computer thinking ability. Computers have the abilities to receive information (input), communicate with other machines, transfer information, process information, calculate, and produce results (output); in short, computers can "think."

Buildings are technology, they accommodate technology, and they use technology. Buildings as objects become intelligent in the moment of gaining computer ability. The first intelligent building used technology to provide a comfortable, secure, and energy-conscious environment. The intelligent building concept offers the connection and integration of HVAC, access, lighting, security, monitoring, management, and telecommunication. Integration gives these systems the ability to communicate and transfer information. Communication among these systems allows output decisions to happen without conflict. Outputs or systems' decisions, on the other hand, are systems responses for input information coming from different sources. Outputs or systems' decisions are the basic needs in architecture to be considered as "Responsive Architecture".

This paper gives an overview on intelligent architecture, in general, and discusses when "responsive" and "kinetic" architecture becomes "intelligent". The paper will also redefine the intelligent architecture in the light of available technology.

2. Definitions of Intelligent and Smart buildings

The concept of intelligent building presents the strongest level of communication among a building's systems. The term "building systems" refers to all systems that operate a building like HVAC, mechanical, structural, access control, safety and security, building management, lighting, maintenance, local networking, and energy management. The intelligent building concept presents control and management by a building's systems and users using computer abilities to achieve users' needs, which may include productivity, efficiency, energy savings, entertainment, delight, and comfort, return investment, and low life cost.

So, defining intelligent building should not be related to specific achievement because required achievement can be changed from party to party. The intelligent building should have the same operation concept that has the ability to be adjusted according the different needs.

Scholars have defined "intelligent building" in terms of a building having the latest technology, so they consider a building to be intelligent when it has the latest building systems. Although innovation is very important in intelligent building; it doesn't mean that there is the necessary communication and integration among systems that can render a building intelligent. For example, the International Symposium, 1985, in Toronto, states that "intelligent building combines innovations, technological or not, with skilful management, to maximize return on investment." This definition contains, in addition to innovations and technology, needed achievement that is "maximize return on investment". It is an achievement that may be needed by commercial and office buildings, but it may not be needed by houses, unless we consider people's delight and comfort as an investment. In addition, other achievements that are important for commercial/office buildings, like users' productivity and comfort, are not mentioned in the definition. Defining by stating the needed achievements is clear in EIBG (European Intelligent Building Group) definition that says "the intelligent building is the one that maximizes the efficiency of its occupants and allows effective management of resource with minimum life costs." Efficiency and productivity are intangible; they can be determined by comparison of other or previous records, and minimizing costs is an achievement that can be reached by operation systems.

Bob, 1996, on the other hand, defined a smart building as "a building which can include the technology to allow for devices and systems to be controlled automatically." This definition shows basic process in operating intelligent building that is transferring information between controller and controlled devices. operation process is clear also in (DEGW), (1998) (the architecture of Duffy, Eley, Giffone and Worthington) definition that says "intelligent building is more responsive to user needs and has the ability to adapt to new technology or changes in the organizational structures." The definition mentions very important criteria and operation process. "Responsive" in the definition represent systems' outputs; "to user needs" in definition presents the ability to know "the needs" by inputs sources "user". "Adapt to" shows the ability to adapt either by itself or by others.

Atkin (1988) defines intelligent building as a "building that knows what is happening inside it and outside it and can decide the most effective way to create the right environment for users on time." Atkin in this definition is adding to the ability to know (input) and the ability to respond (output), the time factor. Responding on time is essential in an intelligent environment; most outputs or responses needed in certain time and it will be invaluable in any other time. "Knows" in Atkin definition covers the received information (input) and the media by which this information (input) is received and collected. “Decide” covers all types of responses, like adjusting temperature and adapting building form that represents the system’s “output”.

The evolution of telecommunications and electronics has expanded the capabilities of intelligent building systems. Integrating learning ability that includes the adaptability mentioned by DEGW definition, (1998) of intelligent systems should make systems able to learn from their experiences with similar cases reaching to optimum solution. In addition to the learning ability, information transferred between systems should be processed and analysed in Building Control System (BCS) that woks as building brain. The goal should be reaching to an optimum solution.

Accordingly, the basic criteria by which the building needs to have to be considered as intelligent are:

- Input system that receives information by means of information receiver.
- Processing and information analysis
- Output system that reacts to the input in form of a response.
- Time consideration that makes the response happen within the needed time.
- Learning ability

The definition of intelligent architecture should therefore include all of these criteria and systems. These criteria will be discussed in order to clarify their contribution to intelligent architecture.

3. Inputs

Each system in the intelligent building should have a means of collecting input information. Systems can obtain information in four different ways: sensors (real time), internal backup and restored information, manually entered information (programming and reprogramming) by users, and by being connected online (Internet).

3.1 SENSORS

Whenever we discuss intelligent architecture, we should start with sensors. They are the means of getting all type of data and information to systems. Sensors are simply detection devices that collect information and data internally and externally. Internally where they allow system to perceive even its condition and externally where they detect and receive information from out of system environment in real time.

Sensors are divided into three groups that cover both interior and exterior environment. Detection solar radiation, security and surveillance, noise pollution, and façade optics and colour change, for example, are some of exterior sensors controlled systems. Systems like energy, air control, lighting system, and air-condition controlling use interior sensors to reach intelligent architecture goals. The three groups are:

3.1.1 Security and Safety Sensors

Security, safety and surveillance sensors serve interior and exterior environment.

a. Fire and smoke detection
b. Photo optics
c. Access
d. Acceleration, shock, and vibration
e. Motion and human presence

3.1.2 Weather and Space Quality Sensors

f. Temperature
g. Humidity
h. Solar Radiation
i. Pressure
j. Light
k. Flow (Liquid and Gas)
l. Air Contents
m. Moisture
n. Chemical measurement

3.1.3 System Monitoring Sensors

o. Structural system monitoring
p. Mechanical system monitoring like (HVAC system)
q. All other systems that require monitoring

Sensors work as a nerve system for a building so it can feel and determine the reaction to internal and external conditions.

3.2 INTERNAL BACKUP AND RESTORING

Any system within intelligent package should have the ability to back up and restore cases and information. Restore covers, for example, scheduling scenarios in meeting room where the room needs to be connected online and air-conditioning needs to be set at 75 degrees Fahrenheit at a specific time, so the system should be able to able to recall previous settings and reset them. Internal backup system should work as memory in the intelligent system.

3.3 MANUAL PROGRAMMING

Systems are supposed to accept manual programming by users. At any time, a user (authority/administrator) should have the ability to reprogram the main system according to new circumstances.

3.4 INTERNET

Connecting all systems to internet gives them the ability to be updated and get online information from different companies. Most computer systems and drives have updates and companies provide these updates online, so for system to be updated and perform well, it should be able to communicate with different companies to update their drives. All data collected will be delivered to the data processing application.

4. Information Processing Application and Analysis

Information processing is performed in the building control system (BCS). BCS controls all systems as one unit and controls each system individually. It is the place where all systems integrate; it is called building system integrator (BSI). For systems to be integrated, they should have addresses that other systems recognize.

5. Outputs (Responses)

Outputs of BCS come as orders to the systems according to the decision. These decisions form systems' responses and can take at least two different classes: internal and external response. Internal and external responses are related to system. The internal is the class of response that covers all internal reactions and responses. Calculation and internal programmatic responses within the system are examples. Another example of internal response is an intelligent structure that can react to wind load by internally changing its tension. External response is the result of internal responses formed according to processed information.

An external response can take two forms: static and kinetic. A static external response can be in form of temperature, visual, audio, or/and light change. A kinetic response, on the other hand, comes in the form of movement; when a system decides to open or close a door, for example, it is considered as a kinetic response; “responsive architecture” responds to its users. In the following paragraphs I will discuss the kinetic and responsive architecture concepts.

5.1 RESPONSIVE ARCHITECTURE

Responsive Architecture is any architecture that has the ability to respond to users needs. It does not have to be intelligent unless the responses are result of an intelligent process. An adobe wall, for example, responds to outdoor temperature where it keeps cold air in the house when it is hot outside. It is a material property; it is not out of an intelligent process. The result should be according to information and data received and processed to be considered intelligent.

Some of the definitions of responsive architecture show that the term presents a specific form of response that is (kinetic respond). Fox (2003) says that “the core in responsive system is that the mechanical structures and how to implant them with interactive and intelligent behaviors.” But what if the responsive system response statically like in temperature or color change. Sterk (2003) also defines responsive architecture as “a class of architecture that demonstrates an ability to alter its form, to continually reflect the environmental conditions that surround it.” While altering the form is just a response type, the responsive architecture term is missing the term “intelligent” to represent this type of response (kinetic) and it should cover all types of responses in architecture.

So, intelligent responsive architecture is all spaces/architectural elements that have the ability to respond intelligently to the exterior and interior environment and to users’ needs.

The type of response that is represented in Fox and Sterk definitions for responsive architecture (kinetic response) is taking intelligent architecture a step further. The next paragraph discusses this type of response.

5.2 KINETIC ARCHITECTURE

The kinetic concept originated in art. Artists at the beginning of the nineteenth century started to make their sculptures that reflected movement. The “wooden merrier” by Daniel Rozin in 1999 is an example of kinetic art that uses electronic technology. The kinetic art has been also introduced in architecture as art pieces in building and sometimes within the building; Ralfonso (2004) (Figure 1) gaves examples of kinetic art that merge in architecture; a sculpture like ExoCentric Spirits that is suspended in indoor space (http://www.ralfonso.com/exocentric_spirits.htm).

Figure 1. ExoCentric.

In architecture, kinetics has been used by nomadic tent-dwellers. The tent is a kinetic structure since people can fold it up and carry it. The kinetic structure as a folding and portable system is still seen in kinetic architecture. Fox (2000) for example, defines kinetic architecture as “a building with variable location or mobility and/or variable geometry or movement.” He was describing various types of kinetic systems; one of which was the folding system. So the kinetic concept is not originally an intelligent one, but it represents the ability of controlling the structure by moving part or all of it.

The new direction is to introduce the kinetic concept to the intelligent as one of the responses that may alter the form of the building. Calatrava gave some examples to apply movement to building. Regardless of the function of Calatrava’s kinetic applications, his contribution shows the possibility to have moving form; the roof of the Milwaukee Museum, for example, can be moved and changed (www.calatrava.com).

The next step starts with the definition by Oosterhuis (2003), which states that kinetic architecture “refer[s] to a building that [is] controlled by sensors-actuators system to be able to respond according to the data received in form of movement.”

5.2.1 Control Mechanism in Kinetic Architecture

To understand intelligent kinetic architecture, I will explore different types of controls and how manual/traditional control can become intelligent. There are three main control mechanisms for kinetic architecture: inner, outer, and composite. The system, in inner control, is divided into small parts that give it the ability to alter its parts; a folding system is an example. The outer control is the ability of the system to be moved either by itself or by the power of other source. It can be seen in partition walls that can be installed and removed. Composite control merges the inner and outer ones to have a system that is able to alter its form internally and to move its mass as whole. The inner, outer, and composite controls are mechanisms that give any structure the ability to alter its form; they are supposed to be controlled manually. Manual control can be intelligent. The following are

1. Direct Control:

   Movement and control come as a result of direct source; the source includes all energy outputs like electrical motors and human energy. Moving a skylight by direct on/off source and portable partition are examples of this type.

2. Input Control:

   Input device is needed in this type of control. The movement comes as a result of this device feedback; sensors and programmed system are examples of these means of devices. The sensor, for example, should affect the system directly in a singular self-controlled response.

3. Multi Input Control:

   The control and the movement in this category should come as a result of multiple input devices; multiple sensors can be these devices that receive data from different sources to get the optimum decision.

4. Ubiquitous Multi Input Control

   Many autonomous sensors/actuators acting together are required in this type of control. The movement will be a decision of analyzed input out of sensors (input device) reflected on actuator (output device) to respond (output). The whole surface can be dynamic in such control; the surface can be building envelop.

5. Intelligent (Multi-input) Control

   The system in this category integrates learning ability in its control mechanism. The system will learn from experiences in trying to reach the best solution.

Time consideration is one essential factor that should be available starting from direct control. Depending on advanced computer control technology and the ability of manufacturing high quality kinetic part, intelligent kinetic architectural solutions can be both effective and feasible.

5.2.2 Sensors in Kinetic Architecture

Kinetics in architecture can be as simple as opening a door or window and it can be as big as moving a structure. Kinetic response is one of the possible decisions in BCS responses. To refresh room air quality, for example, the system may decide to start filtering or turn ON an air-conditioner, but it should be available as option to open window and get some fresh air if it is appropriate. Building envelop can use sensors and actuators to respond by movement. The Hyposurface by dECOi is an excellent example for kinetic envelope and inner controlled architecture element where a faceted metallic surface (wall) deforms physically by responding to the surrounding environment. It responds to movement, sound, and light as a result of real-time calculations (Figure 2) (Oosterhuis, 2003).

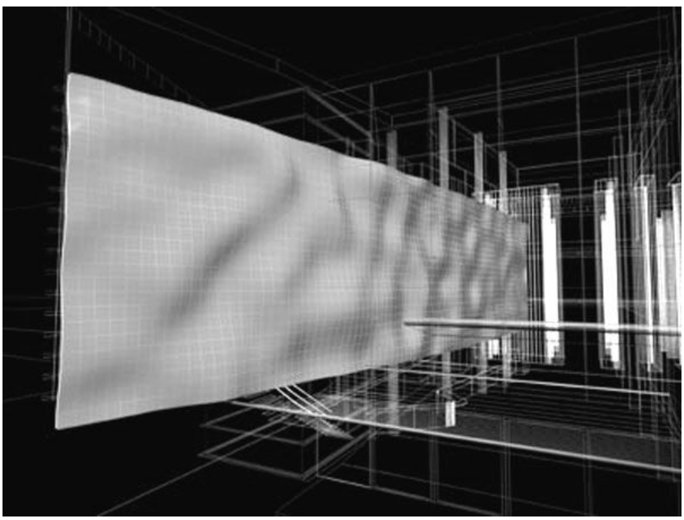

Figure 2. Hypersurface, 1999.

A structure can also use sensors to report its conditions and maintain problems like standing against wind load by increasing its internal tension using actuators. For example, chemical and physical data in concrete can be collected now by micro-electro-mechanical systems (MEMS) sensors. This sensor can be embedded in concrete to measure pH, moisture, temperature, and concentrations of chloride, sodium, and potassium ions (Snoonian, 2003). Some electronic companies like SIMENS use micro-electro-mechanical system (MEMS) to control systems.

6. Time Consideration

As intelligent criteria, time is critical for an intelligent system, where all responses and decisions must happen at or within the required time. For example, fire alarms should start on time, maintenance systems should report problems on time, and buildings should rotate to avoid sunlight on time. Sometime the system underestimates, during the analysis stage, some received information that may delay the response. Smoke from a fire, for example, may analyzed as cigarette smoke at first, but the system recognizes it is fire smoke after a while; at this point, the system must be able to adjust its sensitivity and analyzing process to respond to fire smoke next time. This can be called learning ability.

7. Heuristics (Learning Ability)

Heuristics can be defined as a set of rules that increases probabilities of solving a problem. Conceptually, it is about the ability to learn from experience. Adjusting decision time is an example of reprogramming and adjusting the system sitting on the basis of new information; information can come from people or sensors. In a meeting room, a system can feel the increasing number of people, so it reduces the temperature from 75 to 65 degrees Fahrenheit to overcome the heat of 20 persons and then the authorized person reduces it to 58; the system should realize that its calculation was not very accurate. With 30 persons, the system should calculate the heat of each person according to the last experience. The ability to learn is very critical in case of fire and maintenance.

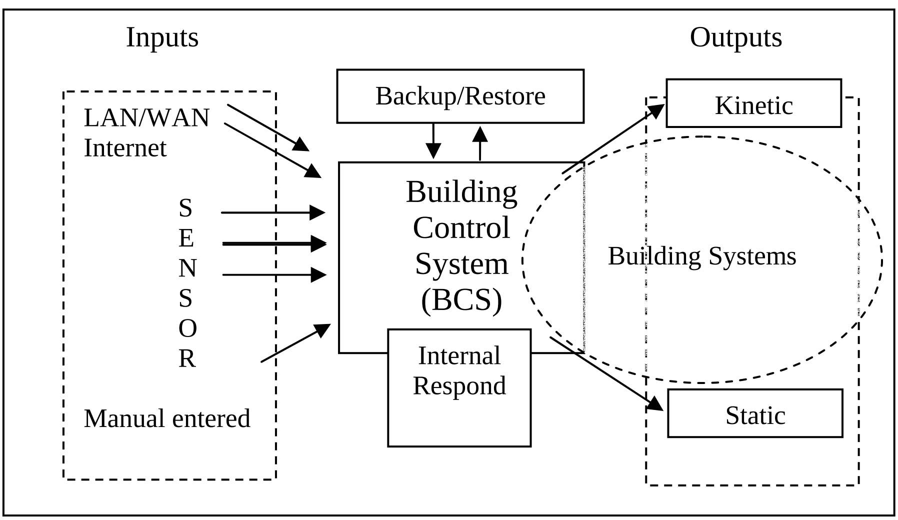

Figure 3. Intelligent System Anatomy.

Learning ability is the fifth criterion of an intelligent system and gives the opportunities to discuss some architectural examples of the new generation of intelligent architecture. Figure 3 shows intelligent architecture anatomy that combines most intelligent criteria.

8. Kinetic Architectural Examples

It is very interesting to discuss available buildings using the kinetic concept.

8.1. ROTATING HOME

The first one is called "Rotating Home"; it is exploring kinetic envelop as outer control. The building can take any shape in design; using a motor, the building rotates 360 degrees. It works in direct control concept where rotation starts and stops using an on/off switch. Conceptually, all walls in this house can change their location. The reason for rotation is to change the view. It rotates 100 times in one direction and 1000 in the other direction with all utilities fully functioning (Figure 4) (Johnstone, 2002).

Are there sensors in the building?

There are sensors in this house to detect leaks, thus notifying the home owner prior to any fluids or gases mixing (Johnstone, 2002).

Figure 4. Rotating home.

Whenever the owner needs any exterior view, s/he can get it; the problem will be direct control that can be enhanced to be fully intelligent by planting sensors to get the input information to respond to users' needs. Sensors rotate and change bedroom location to avoid sun, heat or light; noise on the other hand can be avoided and view at certain time can be seen from specific spaces in the house. Such a house needs 24/7 follow up and check for control systems; mechanical, plumbing, and electric system, in addition, to other systems should be fully integrated to report any shortage on time.

8.2. REVOLUTIONARY (SUNSPACE) DOMES

Patrick Marsilli started the idea of the revolving dome in 1986, and developed the first dome as a basic idea for others like Albert Warson to develop.

The dome (Figure 5) can be built out of wood, lightweight concrete, or steel, so it rotates 300 degree. A one-horsepower (745-watt) motor drives the turntable. All mechanical systems rotating the dome are grouped in the central area. The rotation can be controlled by direct control that may be reflected by on/off switch. It can be controlled by programming the systems to avoid sunlight (Warson, 2002).

Figure 5. Revolutionary Dome.

The example promises to have kinetic architecture. By input control, the building change orientation; this building is more solid in its idea in terms of reason. The reason of rotation for the builder is sun radiation and heat avoiding. The shortcoming in this project comes out of rotation range and mechanism. The range is only 300 degrees that may reflect the reason of rotation. The rotation mechanism is programmed into the system; having a device to detect the sun’s movement and heat will make the movements of the building more accurate. Devices can detect the sun and determine whether or not the building needs to be rotated.

8.3. BLUR BUILDING

Discussing kinetic architecture should recall the attempt of Diller and Scofido to have a building constructed of different materials, a building called 'blur pavilion'. They constructed a metal building that sprays countless tiny drops of lake water from thousands of jets. The fleeting sculpture will be even in rain by high-pressure spraying technology as mass of fog that changes from minute to minute (Figure. 6) (Scofidio & Diller, 2002).

They gave the basic idea of liquid form in architecture that is supposed to respond and be formed according to its and users' needs. They used computers to adjust spray strength according to the different climactic conditions of temperature, humidity, wind speed and direction.

Figure 6. Blur Building

9. Conclusion

An intelligent building is therefore a building that has the ability to respond (output) on time according to processed information that is measured and received from exterior and interior environments by multi-input information detectors and sources to achieve users' needs and with the ability to learn. Having specific achievements in mind to reach by intelligent building is very important to know before programming the system. The actual need of intelligent building can clear by looking to the result and requires needs that can be accomplished out of such system. Productivity, for example, is essential need for all companies; the environment in the office spaces can determine large factor of being productive as employee or not. As very simple example, in my office, I can't work for more than 3 hours continuously just because of low temperature. Feeling cold to a degree of leaving the office to an outdoor area to gain some sun heat for ten minutes and then go back to office. The maintenance decided to send the technician almost daily to check with people and higher the temperature. The waste in work time because of air conditioning is decreasing the level of productivity in the work that is wasting resources of any company.

The achievements that can be reached by having intelligent system cover most human life aspects. Productivity, efficiency, energy savings, entertainment, delight, and comfort, return investment, low life cost, and increase building life are some examples of these achievements.

Intelligent building should have nervous system consisting of embedded sensors and actuators that control most real time information. Accordingly, the building will have the ability to react statically and kinetically. So, altering the form and maintaining building body internally and externally will be some examples of building abilities. The nervous system represents integration among all systems, so intelligent building will be liquid form that changes according to surrounded environment or/and its current mode. As human, users should able to know if the building happy, sad, sick, or relaxing. The building, on the other hand, should be able to recognize users' mode and act according to their modes.

According to definitions of deferent used terms, it should be clear that Responsive architecture include any spaces, building and architecture elements that respond to users' needs. Responsive architecture should not be limited to one or two forms of responses; it should cover all forms of responses static, kinetic, internal, and external. Additionally, the Responsive Architecture is necessary an intelligent architecture unless that the respond is a result of intelligent process.

Kinetic Architecture is not intelligent unless that the kinetic is a result of intelligent process. The tent is kinetic shelter that can be folded and transferred. The new intelligent architecture should have all type of responses that serve its function.

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ARCHITECTURE

Section III

Electronic Architectural Education and Future Architecture

NO MORE FEAR OR DOUBT: ELECTRONIC ARCHITECTURE IN ARCHITECTURAL EDUCATION

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Abstract: Operating electronic and Internet worked tools for Architectural education is an important, and merely a prerequisite step toward creating powerful tele-collabortion and tele-research in our Architectural studios. The design studio, as physical place and pedagogical method, is the core of architectural education. The Carnegie Endowment report on architectural education, published in 1996, identified a comparably central role for studios in schools today.

Advances in CAD and visualization, combined with technologies to communicate images, data, and “live” action, now enable virtual dimensions of studio experience. Students no longer need to gather at the same time and place to tackle the same design problem. Critics can comment over the network or by e-mail, and distinguished jurors can make virtual visits without being in the same room as the pin-up—if there is a pin-up (or a room).

Virtual design studios (VDS) have the potential to support collaboration over competition, diversify student experiences, and redistribute the intellectual resources of architectural education across geographic and socioeconomic divisions. The challenge is to predict whether VDS will isolate students from a sense of place and materiality, or if it will provide future architects the tools to reconcile communication environments and physical space.

1. Historical Background

1.1. DISTANCE LEARNING AND ARCHITECTURAL EDUCATION

There are many definitions of distance learning as general; however, all have one common characteristic. The instructor teaches and the student learns at different locations. Although the term distance learning has been receiving a lot of attention at the institutions of higher education during the last ten years, it is not a new concept. In fact distance learning has been around since the last century.

In the late 1800's the University of Chicago began the first major correspondence program in the United States. Correspondence programs were designed *"to provide educational opportunities for those who were not among the elite and who could not afford full-time residence at an educational institution,"* but they were sometimes perceived as *"inferior education"* (McIsaac and Guanawardena, 1996).

At the same time, technology has provided education with new delivery methods. During the past decade the development of computer networking and tele-video conferencing has expanded and enhanced distance learning. Satellite and microwave delivery systems have revolutionized distance learning, but although they are effective, they have become increasingly expensive and are beginning to be replaced by asynchronous transfer mode (ATM) service. The Internet has opened a variety of new opportunities for communication and distance learning.

On the other hand, the creation of flexible time / place distance learning is the basis for asynchronous class communication. This system allows students to address courseware at a convenient time and place. Examples of this form of distance learning are printed-media courses using mail correspondence, E-mail and chat, video-based tele-courses, and Internet based courses.

1.2. ARCHITECTURAL PROFESSIONALISM AND EDUCATION

Over the last few years, due to the social and technological development, major changes occurred in architectural practice. These changes were accompanied, especially in Europe and North America by a noticeable client's dissatisfaction. Governments, construction and architectural organisations, and schools of architecture commissioned numerous reports aiming to assess the current state of the construction industry.

Assuming that the status of architectural education in the west can be used as an indicator for its counterpart in Egypt, a readings on the work of David Nicol and Simon Pilling who ran a thorough review of architectural education in the west, the main trends and problems in the construction industry and the propositions offered for schools to cope with the change are truly significant and problematic (Nicol and Pilling, 2000).

Accordingly, students first should develop more effective communication and interpersonal skills, so that they are better able to appreciate, understand, engage with and respond to the needs of clients and users. Secondly, students should acquire a foundation in team-work in order to prepare them for the inter-disciplinary working relationships that characterise professional life. Thirdly, there is the challenge of preparing students for a changing society where knowledge is growing at a rapid rate and the needs of society and the construction industry are continuously evolving. For this, students need to acquire skills and attitudes that are transferable across contexts and enable continuous lifelong learning.

1.3. INFORMATION TECHNOLOGY IN ARCHITECTURAL PRACTICE AND EDUCATION

The use of computers in architecture is mistakenly evaluated in isolation, as a matter of technical competence only. The revolution of information technology (IT) represents a large phenomenon that as it changes all disciplines, may ultimately change, the design/build processes, organisational structures and design cultures. IT effects on both architectural practice and education cannot be overlooked. A better understanding of these effects can be reached by documenting the account of IT and the different trends of computer usage in practice and academia (Abdelfattah, 2002).

2. The Effects of Information Technology on Architectural Practice

Professionals, generally in all industries, use IT to improve their effectiveness in practice. Technology affects architects on two distinct areas, firstly at the skills' level and secondly at the level of work processes and professional culture.

Alfredo Andia classifies the effects of IT on architectural practice into two major areas: professional skills and work processes (Andia, 2002).

2.1. THE EFFECTS OF IT ON ARCHITECTURAL SKILLS IN PRACTICE

The major effect of IT from the 1970s to the mid-1990s was at the skills level only. During this period of time, computer mainframes, PCs and CAD transformed architects' manual skills used in documentation, drawings, specifications, and written reports. But the transformation process, which lasted for twenty years, was not simple. Architectural firms' adoption of technological skills went through three distinctive phases, namely, according to Andia, the CAD on mainframe era, the CAD operator era, and the high computer literacy era (Andia, 2003).

2.1.1. The CAD on Mainframe Era

During the 1970s in the United States and the 1980s in Japan, large architectural firms adopted in-house CAD systems. They invested heavily on large systems, in-house programmers, independent information technology groups, and software. Their aim was to reach the latest and best total solutions they could pay for. The prohibitive cost of purchasing and maintaining CAD's mainframe hardware and software, which averaged from 50,000 USD to 200,000 USD per seat, limited the affordability of such systems to very few large firms. Examples of such systems include ARK2 from Perry, Dean and Steward, AES from Skidmore, Owings and Merrill (SOM), and HOKdraw-HOKimage from Helmut, Obata and Kasabaum (HOK). The average percentage of CAD usage in projects during this phase was 5% to 10% (Andia, 2003).

2.1.2. The CAD Operator Era

In the mid-1980s, as faster and cheaper PCs entered the market, and better off-the-shelf software was available, large in-house systems became obsolete. Another era of skills' change emerged in the second half of the 1980s in the United States and early 1990s in Japan, when the information system departments and their mainframes were replaced with PCs and CAD operators.

Before long, architectural firms recognised the downsides of their new approach. Information was drawn twice, first by the architect's hand and second by the CAD operator. During this phase, firms using computers in general drew only 10% to 20% of their projects using CAD (Andia, 2003).

2.1.3. The High Computer Literacy Era

As time passed, IT literacy began to propagate, allowing cheaper PCs equipped with easier software to take place on the architects' traditional drafting desk. The new transition, ironically, was easier and faster for smaller firms; larger ones were reluctant to replace their high-priced large CAD systems.

In the late 1980s and early 1990s, in the United States, a major change occurred. Modern customers, also IT literates, began to require drawings in digital format. This had forced upper management in architectural firms to consider CAD technology in their strategies and, consequently, to disseminate IT skills between all their professionals. By 1995, 75% to 100% of drawings produced by large and medium U.S. firms were executed using CAD.

2.2. THE EFFECT OF IT ON WORK PROCESSES IN PRACTICE

After the successful introduction of CAD in the eighties and early nineties, the next important change came with the implementation of network technologies, a development that continues to affect the industry till the moment.

Although CAD has transformed architectural drafting radically into a more efficient process, centuries-old design/build processes did not change. The new technology offers a potential to alter the way designers, engineers, contractors and their customers collaborate. Andia mentions two phases of impacts from network technology on the architectural practice everyday work processes; the data networks era, and the concurrent design era.

2.2.1. The Data Networks Era

Architectural firms in the United States adopted the data networks trend, from 1993 till 1998. Network technologies, like LAN, WAN and the Internet, were introduced into firms to improve computation capabilities such as document management, printing and plotting sharing, system maintenance, and software administration.

The data sharing course of action did not only improve work efficiency, it also signalled new possibilities for interdisciplinary collaboration. But practitioners misinterpreted the new potentials. They thought that faster and efficient connection to information increased the competence and productivity of their organisation. Slowly, they discovered that the efficiency of the work process was more likely related to the efficiency of the design-build process rather than the quantity and speed of data sharing, and the automation of existing tasks.

2.2.2. The Concurrent Design Era

The data networks era has triggered a new vision of the use of information technology in architecture and the whole construction industry. The use of IT by itself will not improve the performance of organisations unless accompanied by a fundamental change in the way work processes are perceived.

3. Models of IT integration in Architectural Practice

Alfredo Andia mentions that construction firms in general, are constantly applying IT solutions in their practice. Most of these implementations are directly due to the settings of a particular project; nevertheless, they often take a long time to be diffused into the main core of the firm’s total practice. However, two models of practice suggest a full integration of IT in the design-build process, namely, the digitally integrated construction system and the digitally integrated building system.

3.1. THE DIGITALLY INTEGRATED CONSTRUCTION SYSTEM

This model uses a more digitally integrated system that promotes a more efficient design process and challenges traditional practices and legal conventions. This system resembles systems adopted in other industries such as manufacturing and aerospace. According to the model, new designs are originated by hand, then, the architect develops a digital model of the design using modelling software (Figure 1). Next, the building is designed from *skin-in* and another physical model is produced to check against the original model (Figure 2). Hybrid techniques like stereolithography or 3D printing and laser cut paper pack models are used to produce accurate models supplemented with the tangible feedback of working directly with materials (Figure 3).

Usually three digital models are produced: a surface model describing the exterior surface, a wire frame geometry model describing the structural grid and organisation, and an interior surface model. When the design process is complete, the final model can be used in various roles to test and evaluate the various engineering options of the building, for example acoustics, lights and the flow of air, etc.

3.2. THE DIGITALLY INTEGRATED BUILDING SYSTEM

With the gradual application of artificial intelligence inside buildings, the worlds of construction and technical systems have witnessed revolutionary changes. Development in electronic technology and the growing collaboration between the fields of information and telecommunication technologies have led some firms to make the most of the possibilities offered by centralised control systems. With the development of electronic technology, centralised control systems, from energy management systems to those for vertical transport, were possible.

In the 1990s, all networks that carried digital information (computer data, telephone signals, and signals for environmental control and security) were integrated. In the year 2000, the paradigm of the Internet and the possibilities of connecting through a PC are separating the networks' functions from their infrastructure. At the same time, new digital technologies have opened the way for virtual configurations previously unthinkable. The phenomenon has produced several new synonymous terms like building automation, smart building and computer integrated building.

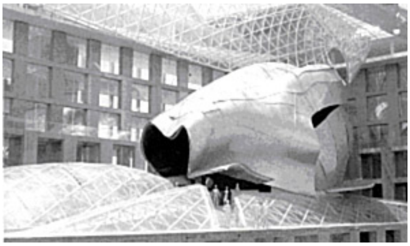

Figure 1: The check model for DG Bank, 1995-2001, Berlin, Germany (Lindsey, 2001).

Figure 2: DG Bank, Interior courtyard with horse head conference centre, nearing completion (Lindsey, 2001).

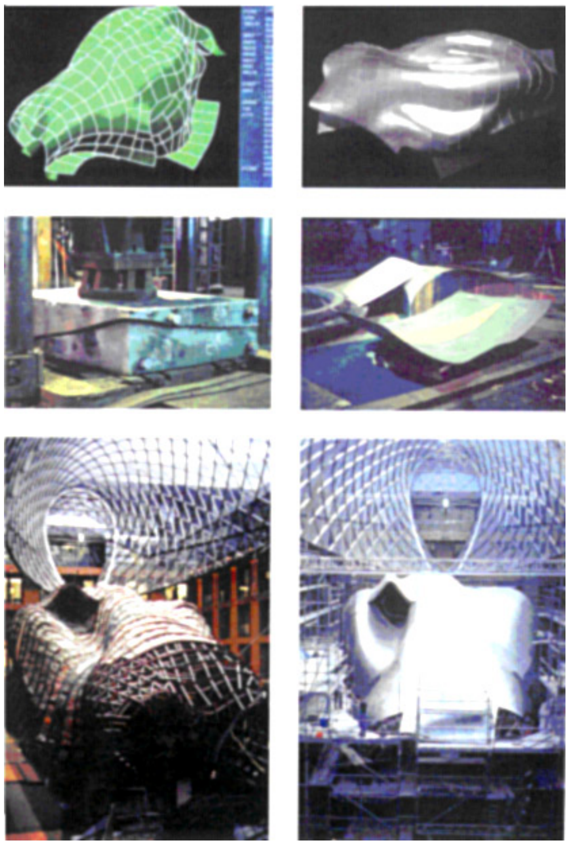

Figure 3: Top: CATIA model, physical model. Middle: hydraulic forming of skin panels. Bottom: horse head under construction (Lindsey, 2001).

4. The effects of Information Technology on Architectural Education

In most western architectural schools, the use of IT is aimed to challenge the traditional role of computers in practice: to produce CAD visualisations and to digitally record and share drawings and documents. Schools has become, according to Andia, experimental laboratories for creating design machines, new architectural imagination, exploration of materials, and extending the architectural realm to cyberspace. In the coming sections, it will be seen that IT continues to affect architectural education till the present moment.

Andia conducted a survey on the effects of computers on architectural practice and education in the United States, Europe and Japan, through the past three decades. He identifies five trends of discourse developed in the architectural academic community. The five trends are design methods, CAD visualisation, paperless architecture, information architecture, and virtual studios (Antably, 2004).

4.1. DESIGN METHODS

Early attempts to bridge the gap between technology and architecture started in the 1950s, when the design methods movement emerged. Most of the pioneering efforts were born inside academia as direct line of the problem-solving or systematic methods tradition that dominated the computer science community at the time. This was followed, in the 1960s and early 1970s by intensive research on the computability of architectural design in the architectural academic community.

After almost two decades of increasing expectations, the design methods theories and gurus quietly retreated to a small number of courses in architectural schools. The minute number of courses that survived was the foundation for some of the first commercial CAD systems.

4.2. CAD VISUALISATION

Between mid-1970s and mid-1980s, cheaper PCs and commercial CAD emerged and gave birth to a second discourse of computerisation in academia. CAD proved to be a key tool for project documentation and the digital visualisation of architecture. But this did not go without critique. Professionals criticised the simplistic nature of CAD systems, while academics, both in architecture and computer science fields, argued that CAD lacked the informational potential of software design. Numerous design studio professors banned the use of CAD from their studios in fear that it will hinder students from acquiring traditional drafting skills.

From the early nineties, CAD courses became widely accepted and started to become part of the core curriculum of architectural education. Tutors and students developed practical realism as they had to cope with change in practice. CAD proficiency became a prerequisite to employment after graduation. The most widely used software of the time was AutoCAD, Microstation and 3D Studio on PC platforms. Computer station per student ratios rose from 1:50 or 1:100 during the mid-eighties to an average of 1:20 to 1:10 in the nineties (Andia, 2003).

4.3. PAPERLESS ARCHITECTURE

Despite the booming development of computer software and hardware, and the dissemination of CAD visualisation in the nineties, many argue that the conventional design methods did not change. Architects still produce plans, elevations, sections and models almost in the same way. This has led the architectural academic discourse into another debate: computer implementation in architecture.

The School of Architecture at Columbia started a paperless design studio to eliminate conventional design methods. It used high-end software, originally designed for the movie industry to produce animation and special effects, such as Alias/Wavefront, Softimage and Maya. The software ability to create special effects was used to produce studies of building circulation, mobility, and program variations (Antably, 2004).

In conventional design studios (Figure 4), instructors normally rely on discussions and rationalisations to inform the student about what is not portrayed in his drawings or models. The learning process grounds on the tutor’s expertise and credibility. This hypothesis is shaken by the paperless architecture paradigm, as visualisations can be tested immediately and decisions are made spontaneously (Figure 5).

According to Antably, digital pioneering firms such as Greg Lynn FORM, Reiser+Umemoto, Denari, Lars Spuybroek at NOX, and F.O.A., led the way for new architectural imagination by publishing their unconventional designs as quickly as they could invent them. They created a whole range of new ideas, but at the same time, they provoked resistance on two fronts.

The first criticism came from the professionally oriented practitioners and academics, which criticised these eye candy projects and unbuildable utopias. The lack of built projects was the biggest intimidation for this generation of academic architects which motivated the School of Architecture at Columbia to react. In 1999, the school hired Frank Gehry, the most productive non-Euclidian contemporary architect, as a distinguished professor. Today, many amorphous structures are built or under construction around the world.

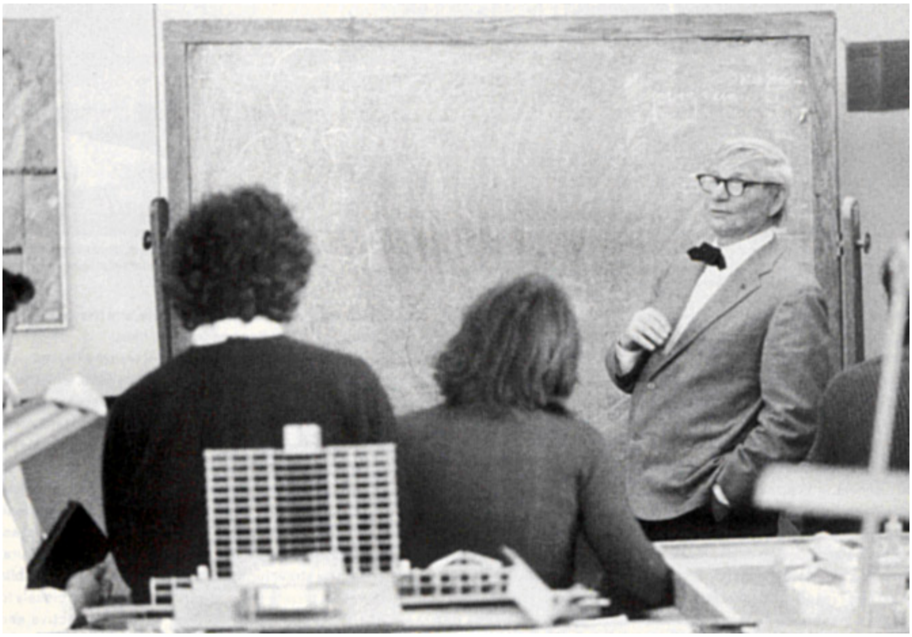

Figure 4: Louis Kahn's studio at the University of Pennsylvania, in 1974 (Architecture Magazine, September 2000).

Figure 5: Hani Rashid's studio-in-progress with Columbia University students at the 7th Venice Architecture Biennale (Architecture Magazine, September 2000).

The second and more serious front of criticism claims that these efforts are far from pushing architecture theory and practice into new directions. They merely lock architecture into endless loops of aesthetic experimentation along with a disregard of the human user of both the physical and virtual space.

4.4. INFORMATION ARCHITECTURE

In the mid-nineties, many academics were proposing different alternatives regarding the implementation of information technology in architecture. They argued that the introduction of IT may create a parallel way of practicing architecture, creating not only physical space but also a communicative and psychological one. A new architectural drift, that goes beyond exclusive concerns for buildings toward a mixed urban reality, both real and digital.

Many building types such as banks, shopping centres, office buildings, schools and academic campuses are radically changing. The type of activities that was characterised by a need for a pure functional physical building now migrates to more distributed cyber-real spaces. Jargons such as e-commerce, Internet banking, Internet shopping and e-learning, are not unusual to our vocabulary. Ironically, the business community in the United States now describes companies that engage in virtual commerce as click companies, while conventional physical companies are labelled brick and mortar companies (Prasarnphanich, and Gillenson, 2003).

4.5. VIRTUAL STUDIOS

In 1997, Mary Lou Maher, Simeon Simoff, and Anna Cicognani wrote a landmark paper and subsequent monograph, Understanding Virtual Design Studios, on VDS experiences at the Key Centre for Design Computing, Faculty of Architecture, University of Sydney. According to them, virtual design studios surfaced as the fifth trend of information technology in academia in 1993, when the first VDS project started. The existence of this academic model is largely due, according to Mary Lou Maher, to the development and availability of the Internet and telecommunication technology. (Maher, Simoff and Cicognani, 1999) (Figure 6).

The design collaboration may be single-task, in which each participant "has his own view over the whole design problem, and the shared conception is developed by the 'superposition' of the views of all participants," or multiple-task, in which "the design problem is divided among the participants in a way that each person is responsible for a particular portion of the design."

Figure 6: Architecture student Tom Carajevski at the University of British Columbia presents his design proposal to a critic at Kumamoto University in Japan. Photography courtesy Dr. Jerzy Wojtowiczp.

Similarly, communication may be synchronous, implying "the simultaneous presence and participation of all designers involved in the collaboration," or asynchronous, in which "designers may work at different times, often on different parts of the design, and do not require the simultaneous presence of all team members." Asynchronous communication has modest technical needs—typically e-mail and file transfer protocol (FTP)—while synchronous communication imposes high bandwidth and technology requirements for video conferencing, shared electronic whiteboards, and specialized groupware.

Simoff observes that an ideal shared design representation for VDS "would incorporate the designers' goals, descriptions, reasoning paths in their design steps, partial solutions to the design task, design communications, and information exchange." But he notes that no CAD system or interoperability scheme among CAD systems currently supports all these data. Therefore, the typical VDS employs an informal hypermedia approach, presenting information as text, tables, images, 3D models, animated images, and Web links to other information.

When implementing these principles, Nancy Yen-Wen Cheng, AIA, who taught at UHK during the mid-1990s when VDS took root there, favors structuring well-defined tasks and interactions "because of the difficulty of a true artistic collaboration between people who have never met." In local projects at the University of Oregon, where she now teaches, Cheng observes, "Where students can supplement mediated communication with face-to-face talk, they see their contributions become part of a useful repository." In remote projects, such as a recent collaboration with the University of Stuttgart, "students see that though their distant peers may have different values and approaches to design, many fundamental aspects of the design process are unchanged around the world. The enlarged pool of students involved [in a VDS] allows us to identify different models of excellence. While face-to-face interaction is more direct for conveying complex aspects of architecture and urban design, even through the haze of the mediated connection we get to glimpse a wider world."

The virtual design studio is the fifth trend, which explores the potentials of communication in the digital era. It opens a window on an extraordinary cultural exchange in the traditionally protected environments in design studios.

5. The anatomy of the virtual design studio (VDS)

A conventional design studio typically includes studio instructors, students and possibly a client or an engineer. Studio instructors collaborate to carry out the aim of the project and constant communication exists between students and their instructors. Communication is a key factor in the design studio. Designers sketch, draw and model in order to communicate their ideas. They can explain their ideas verbally or textually at any time. According to Ernst Kruijff, 87.9% of the total time in a design studio is spent on communication. (Kruijff, 2001)

At the same time, there is a swift change in the toward globalisation and long-distance design collaboration. This change is supported by a rapid pace of development in computation and telecommunication. Schools of architecture have to respond to such change.

Architectural education cannot be seen any more as a technical process only but also as a social one, where communication and collaboration are fundamental. Two main stream line effected the design studio and architectural profession as follow:

5.1 NETWORKS

Many academics, like Maher, Schmitt and Andia, report that network technology is the most influencing technological factor in a VDS. The development of the Internet has extended the network to computers around the world. This subtle distinction between establishing a network of computers, to connecting to the Internet, has implications on the way we perceive computers, information, and space. This is the most remarkable feature of Internet technology; studio participants view the Internet as simply one unified space in which any computer can communicate with any other computer. All we need to know to initiate a working session is a partner's Internet address.

5.2. DIGITAL MEDIA

Digital design media is the basis on which design information can be shared across a network. It is a representation of design descriptions.

Digital media that are most commonly used in a VDS are images, CAD and 3D models, text, e-mail, Web pages, video conferencing, and lately, immersive virtual reality (VR). There are other media, such as sound and movies that are also relevant to the representation of a design description.

5.2.1 Images

Normally, images are used to represent design concepts and geometry in both virtual and conventional design studios. Digital images can be created by scanning a drawing or sketch on paper into a file. This process implies that anything that we can put on paper can be stored and manipulated as a digital image. Alternatively, there are other computer generated sources of digital images which include: rendered 3D models, digital video, etc. The increasing availability and use of digital images means that anything can become part of the information available in the VDS.

5.2.2 CAD and 3D Models

CAD drawings are an essential part of the representation and communication of design information in a VDS. The design development is represented as CAD drawings. In order for the students to collaborate on the development of a design, they need group access to the CAD drawings.

The realism of visual simulation allows the comparative evaluation of design alternatives based not only on technical and functional criteria, but also on the aesthetic impact and user's needs. Where the clients and expected users of a building were previously shown drawings of plans and elevations, the use of realistic 3D models provides the ability to understand a design without requiring an understanding of the notation of technical drawings.

3D models are the data source for creating walk-throughs, thus designers have the ability to explore design solutions both from outside and inside. This technology is filling niches in a spectrum of fields connected with designing spaces from architecture, to the design of game and educational environments and even to movie production. In design, such a facility allows the designer to go beyond the stage of documented ideas to simulate the use of their design configurations.

5.2.3 Text

Designers who use text to augment their images are able to communicate their ideas and meaning associated with their design, where others who rely entirely on the images rely on the viewers' interpretation of the design.

Text-based information communication is used in the VDS for the introduction to the studio, the description of the design brief, the site analysis, the understanding of the design problem, the description of the student's design concept, and for the annotations of the images and drawings.

5.2.4 Web Pages

As part of the move toward integrated information management, considerable efforts have been taken towards development and implementation of standards for exchanging information. The Internet’s World Wide Web (WWW) has provided the solution. The basic idea is to separate the content of a document from the document structure and presentation style. Documents can be described in a way that is not dependent on any hardware, operating system or application software, which complies with the standard. This approach is currently used in creating the documents that are stored as Web pages.

5.2.5 Video Conferencing

Video conferences have broadened the nature of computer-mediated human and inter-organisation communication patterns. As an interactive communication medium, two-way video stands out in a number of ways. A videoconference can improve retention and appeal to a variety of learning styles by including diverse media such as video or audio clips, graphics, animations, computer applications.

In the VDS video conferencing sessions are scheduled regularly. The early sessions are planning sessions in which tutors discuss the studio's organisation and the brief. The later sessions are used entirely by the students to get to know each other and to discuss problems in getting information from one site to another. The final video conferencing sessions are used for work on particular portions of the design.

5.2.6. E-mail

The students use email to communicate with each other and with the client, studio tutors, and studio teachers. To promote interpersonal communication, the virtual design studio provides an e-mail tool to allow messages to be delivered to an electronic mailbox which can be read by the recipient at any time. This allows e-mail messages to be archived centrally and be available on the Web. This system also provides a way of navigating through the messages according to date, subject, or the person who sent the message.

5.2.7. Virtual Reality (VR)

The use of VR techniques is becoming increasingly popular in design education, as Andrew Roberts discusses when he summarises the benefits of VR as a teaching tool. He describes VR as experiential, that it allows students to have real life experiences with the built environment. Some of these experiences may not be possible in real world because they are too expensive, too dangerous or excessively time consuming. VR offers immediate feedback on design decisions and, in the presence of adequate networking infrastructure, VR is a superior tool for CSCD. It can help in the conceptualization of abstract ideas and if the user uses a head mounted display (HMD, Head Mounted Display) or a projected CAVE interface, it can provide a real sense of scale, particularly in architectural and urban design projects.

Lately, VR was introduced in the VDS, creating what is referred to as the virtual environment design studio (VeDS). In a VeDS, participants use VR in the design and the design evaluation of spaces. The space experience can also be shared in both synchronous and asynchronous modes depending on the network speed available.

6. The Communication structure of the VDS

In a computer mediated environment, communication is still the key factor but communication tools are largely different. The choice of these tools can highly affect the ease of communication in the studio.

All design information can be handled in a digital form which results in a large amount of computer files. In the absence of the appropriate communication tools, these files are typically bouncing between individual desktops, reducing the server technology to its most primitive and elementary operations of data storage and sharing. In such environment reports of loss or unnecessary and ambiguous duplicates of files are very common.

Maher defines the term VDS environment as the set of software tools installed in a computerised and networked studio to support VDS activities. At the start of any VDS, it is imperative to spend time setting up the VDS environment. This setup should be clear and transparent to all VDS participants (Maher, Simoff, and Cicognani, 1999).

Maher and Schmitt distinguished two modes of design collaboration, namely asynchronous and synchronous. In an asynchronous mode, the simultaneous presence of all design members is not required. Members work on different parts of the design at different times. Information is shared through the Internet or a local intranet using a variety of computational tools.

Contrastingly, in a synchronous mode, all design team members are simultaneously present. This implies the existence of real-time communication systems, real-time data sharing and shared drawing applications. This type of instantaneous collaboration is hindered by the computational and networking infrastructure available and the Internet traffic.

Maher notes that each participant in the VDS occupies a node (desktop) in the networked studio. The setup of each node depends on the setup of the VDS environment and available software and hardware. The degree of integration between a node's tools and other nodes can be the base to assess the possibilities of a VDS. Integration deals with, following Maher's description, the compatibility of hardware platforms and networks, the common applications running in the VDS environment and the interface metaphor that unifies the accessibility to files and applications.

Figure 7 illustrates levels of integration and autonomy in a VDS environment. Rectangle A represents a VDS environment where all nodes use the same computer platform. Rectangle B represents the case where different platforms are used within the VDS. Both A and B have all software tools installed at each node, reaching a high level of autonomy. Rectangle C represents a VDS with a unified platform but the same software tools are not installed at each node. In such a case, each node (or group of nodes) is assigned a specialized task. Rectangle D is similar to C with the exception of the diversity of platforms installed at each node. This diversity may offer more flexibility and potentials to the VDS. The limited number of software licences in scenarios C and D represents an economical advantage over scenarios A and B.

VDS environments can be therefore classified, according to the levels of integrity and autonomy, into a distributed environment or a centralised environment (Figure 8).

Lately, Sadik Artunç, introduced a diagram on the VDS components and level of integration in which they state that Establishing an interdisciplinary distance-learning centers within the College of Art and Design will provide schools of architecture, art, interior design, and landscape architecture with opportunities to offer online education courses to their students to enhance

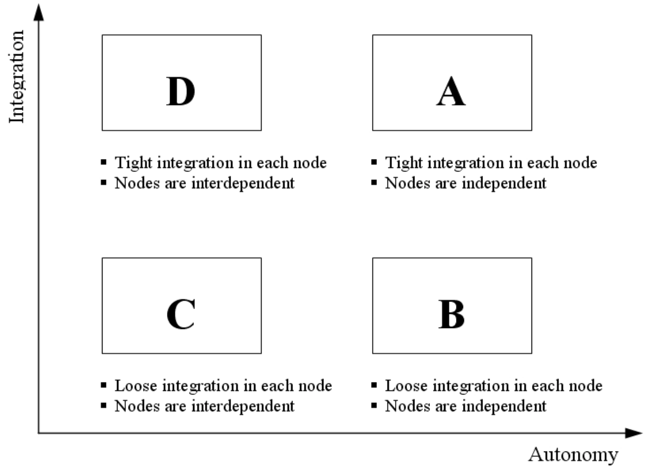

Figure 7: Integration levels in a VDS (Maher et al. 1999).

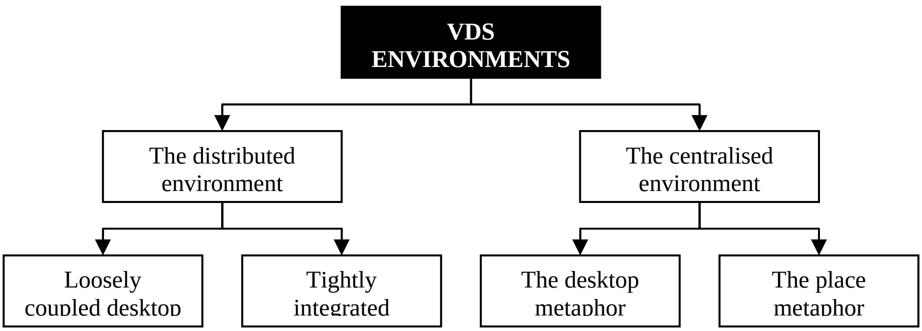

Figure 8: VDS environments (Antably, 2004).

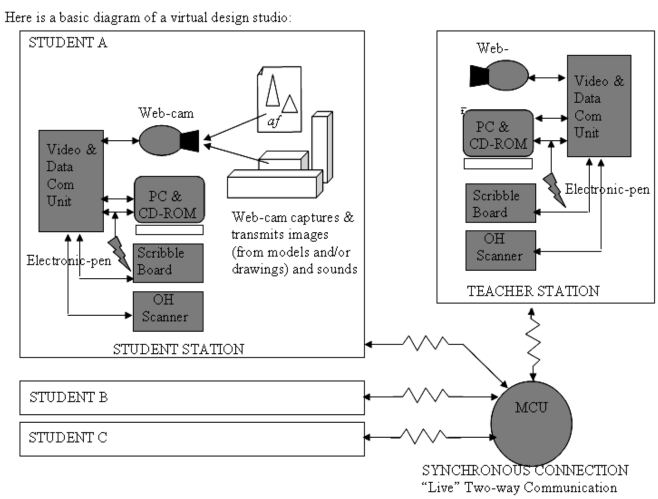

Figure9: Model of VDS environment (Antably, 2004).

their level of design. According to their model of VDS, student and faculty have a virtual meeting. Images of the student's work in the form of models and/or drawings are captured and transmitted through a web-cam to the faculty station. Faculty member sees the images on his/her computer screen "live." The student may present the work with the audio connection to further illustrate the ideas. Following the student's presentation the faculty member will provide a virtual-desk top critique by drawing directly on the computer screen of the faculty station with an electronic pen while the student hears the comments and watches the faculty member's drawing superimposed to the previously captured images of his/her own work. The faculty member's comments and drawings may be captured as a separate layer to document the progress of the work and critiques for future teaching purposes (Figure 9) (Sadik, 2003)

7. TDS or VDS

A VDS, as described by Maher, enforces communication, collaboration and team-working between participants. Schmitt also claims that a VDS can lead to a breakthrough in collaboration and team-working, but only if participants are willing to learn and to share their knowledge. Branko Kolarevic and others note that, as opposed to the professional practice, the diffusion of individual authorship encouraged less competition of the negative side. Shared authorship produced better and more developed design solutions. They even state that a VDS can improve project development and project management (Kolarevic et al, 1999).

But on the other side, Kvan mention that communication and collaboration were disappointing in most VDSs, and asynchronous mode of collaboration overwhelmed the VDS. (Kvan, 2000). Another point of debate is the technical aspect of the VDS. Maher points out that a VDS provides training for students on computational tools. However, Andia records that the digital burden placed on the student's education during the VDS is "one of the greatest negative comments, this type of experience has received". He mentions that the learning of IT tools usually occupies 20% to 30% of the students time. He also notes that the current collaboration tools are not satisfactory and need further development.

Andia approaches another aspect of the VDS when he observes that this new mode of collaboration can blend the traditional distinctive design biases of architectural schools. This blend of design cultures, which has previously evolved slowly through the years, is a rich source of ideas. According to Kolarevic and others, the intense exchange of ideas was one important skill acquired by students (Kolarevic et al, 1999). Another important observation is made by Kruijff when he declared that the focus of all VDS projects until now is on the preliminary design phase (Kruijff, 2001).

Although the VDS is a fashionable trend feverishly adopted by universities around the world, it is clear from the above literature that no agreement exists between academics on the outcomes of the VDS. However, scholars who expressed negative opinions about their experiences are still running VDSs in their design studios. The cause of this disagreement may be due to the use of different VDS settings, which Maher described as paramount to the success of the VDS. Another reason may be the participants' willingness to learn and to share knowledge, which Schmitt considers paramount for the VDS, and which can differ among different cultures.

8. The Egyptian Case

The status of Egyptian professionalism bears a resemblance to its western counterpart. It suffers from the same problems. The profession changes and the scope of architectural activities are contracting.

There is a lack of collaboration and communication between designers and their clients. This is due to architectural education which promotes an inferior and disgraceful image of a business-led architect.

All of the issues of concern in architectural education exist in the Egyptian context. Schools of architecture do not have a strategy for developing communication and team-working skills in the design studio which is isolated from the real practice. There are problems with developing lifelong education and the learning climate in schools of architecture does not enhance students' learning.

This paper presumes that, unless radical change to the way IT is seen in design studios, Egyptian practitioners will be incompetent in the foreseen global world.

9. Conclusion

The study of architectural professionalism shows that there is an increase in complexity in practice. There are too many stakeholders in design decisions while, on the other hand, too many design decisions are left to vendors. The architect does not play the role of a master builder anymore; he is now expected to be an integrator.

Accordingly, the role of the schools of architecture is to prepare students for practice. However, conventional education, the design studio being at its core, lacks a clear and methodological development and assessment of interpersonal skills.

The key challenges for architectural education can be identified as the need to develop more effective communication and interpersonal skills, and a foundation in teamwork between students to introduce the no fear and no doubt in students personality.

The use of IT in architecture is an essential trend. However, schools of architecture have another interpretation of the introduction of IT in architecture; they use it to change centuries old design methods. While almost every school around the world has infused computer courses in their curricula, very few of them have structured strategies that support computation in design. The unplanned introduction of IT in education was criticised by many. While conventional education does not enhance team-working and communication skills, computers and telecommunications seem to weaken them. Among many trends of IT usage in design education, only one stands out as a premise to develop these skills, namely the virtual design studio (VDS).

The VDS premises to develop collaboration and team-working skills of its participants. It also enhances their technical skills which may reflect on the design outcome. These skills may be significantly influenced by several educational, cultural and technical factors. Being relatively new, most of the research on the VDS focused on its technical and design characteristics. Although the technical aspects of the VDS have proven feasible, not much research was done on its social outcomes.

To conclude this paper, the paper has found that the changing architectural profession in both the Egyptian and western contexts has revealed a need for architects to acquire communication and interpersonal skills. The development of these skills is an issue of concern in architectural education. Contrastingly, the conventional design studio is promoting individual attitudes. The VDS is still in its early stages of development. More research needs to be conducted on its different social aspects and design outcome. A VDS arguably develops the collaboration and team-working skills of its participants. It also develops their technical skills which potentially contribute to their design outcome. The interpersonal and technical skills acquired in the VDS may be significantly influenced by several educational, cultural and technical factors.

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REFLECTIONS ON E-DESIGN: THE E- STUDIO EXPERIENCE

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Abstract. For two academic years I have been involved in teaching what has been called the e-studio. The e-studio is part of an effort to integrate digital media in the design studio and to raise the quality of studio instruction at Department of Architecture, Jordan University of Science & Technology. The primary goal of the e-studio is to teach students how to think and design using mainly digital media. This paper reports on the e-studio experiments and discusses the pedagogical implications of the studio. It contributes to the understanding of the relationship between digital media, and design practices and education. Observations revealed that digital media as used in the e-studio bring dramatic changes to the architectural design process, the design studio praxis, the design outcome, and the position of the designer in these processes. The e-studio also showed the need to reconsider our traditional understanding of the design studio culture.

1. Introduction

The influence of digital media and information technology on architectural design education and practice is increasingly evident. The practice and learning of architecture is increasingly aided by and dependant on digital media. Digital technologies not only provide new production methods, but also expand our abilities to create, explore, manipulate and compose space.

In contemporary design education, there is a continuous demand to deliver new skills in digital media and to rethink architectural design education in the light of the new developments in digital technology. During the academic years 2001-2003, I had the chance to lead the efforts to promote an effective use of digital media for design education at Department of Architecture, Jordan University of Science and Technology (JUST). Architectural curriculum at JUST dedicated much time for teaching computing skills. However, in this curriculum, digital media was taught in the form of "software use" education. In this context, digital media is perceived and used mainly as a presentation tool. Furthermore, Computer Aided Architectural Design and architectural design are taught in separate courses without interactions between the two.

In an effort to move from "software use" education toward integrating digital media into the design studio, the "Digital Media Integration Initiative" (DMII) was proposed by the author and adopted by Department of Architecture. Among other issues, the Initiative proposed to establish a digital design studio (the e-studio) in which digital media will be the main tool for creating and exploring design ideas. This paper reports on our experience in the e-studio experiments and discusses the pedagogical implications of the studio.

2. E-Studio Experiments

E-studio is part of an effort to integrate digital media in the design studio and to raise the quality of studio instruction. The primary goal of the e-studio is to teach students how to think and design using mainly digital media. In this studio, students learn how to go beyond the tools by shifting their attention from the tools themselves to their effective use in architectural design. The main media used in the studio include 3DS Max as well as other supporting packages such as AutoCAD and adobe Photoshop. Digital media were used not only as a presentation tool but also as a tool for design generation and exploration.

Beside exploring the digital medium as a design tool, the e-studio promoted new design agenda. Students were encouraged to rethink the conventional architectural design processes and conventional design products. The aim was to develop a pedagogical model that emphasizes e-design practice and theory. Beside exposing students to various ways of using digital media in architectural design and enabling them to develop skills in this regard, it was hoped that the e-studio would provide a valuable opportunity to critically evaluate current design discourse and to reconsider current understandings of design studio and digital design practices.

The e-studio was offered once a year and it was a compulsory studio for architecture students. A third year design studio, ARCH 312-Architectural Design 4, was chosen for implementing the e-studio model. It was expected that third year design students reached an acceptable design maturity that enabled them to experiment and deal with advanced design issues. The prerequisites for this studio included a digital media course in which students take AutoCAD, 3DS Max, and Adobe Photoshop. Most students also undertake an elective media course which covers advanced topics in digital media including the above mentioned packages. Thus, students enrolled in the e-studio already had a good efficacy in using the tools.

3. Reflections on the E-Design Process

The digital media offer an opportunity to architectural design education, not only as a convenient design environment, but also as a means of inquiry into the nature of architectural design. Digital technology is often perceived as a mechanical replacement to old processes, or a means by which manual processes become more efficient. In the recent past, Computer Aided Architectural Design was seen as "automation" of the manual design processes. We learned from the e-studio that it is a very simplistic view to assume that computing is just automating or extending existing manual procedures. The e-studio provides some evidence that computers and digital technology are not just augmenting or extending manual procedures but also transforming and changing them.

It seems that e-studio students are involved in a reflection-in-action design process such as that described by Donald Schön (1987). Schön and Wiggins (1992) described designing as “a conversation with materials, conducted in the medium of drawing and crucially dependent on seeing." According to them, designing is a kind of dialogue with the design situation. In the e-studio, students seem to engage in a similar interaction or dialogue with the digital medium. A student constantly reviews his position, reacting to all new information and conditions. However, one can characterize main differences between the e-design process and the traditional design process as described by Schön.

All students tend to design in three dimensions from the beginning of the design process. Students went beyond the conventional design process in which they work using abstract conventions (2D plans, sections etc) and started to explore, manipulate and articulate space in 3D or even 4D, using movement in both time and space. Designing in 3D has several advantages among which greater fidelity to reality which permits the student to think more naturally. A modeling and animation software, such as 3DS Max, allowed students to explore and examine space, form, texture, lighting, and color, as they explore spatial and temporal movement.

Integration is another distinguishing feature of e-design. In contrast to the conventional reflection-in-action process in which the design act is segmented into several abstract views, e-design seems to be more integrative in the sense that design acts and decisions are represented in one digital model that can be seen and evaluated from various points of view at any point of time. Visualization tools, that include advanced modeling and animation capabilities, provide an integrative environment which enables students to represent, test and evaluate the various spatial and formal aspects of their design concurrently and from several points of view. This represents a holistic and organic design approach that provides students with simultaneous understanding and integral awareness of the design situation. For example, students are able to create and manipulate solids and voids while at the same time evaluating texture, lighting, color scheme, proportion and other anthropometric relations of the proposed solution.

Another aspect of e-design is **interactivity** or responsiveness. E-design seems to be more interactive in the sense that choices are being infinite and the results are ever more immediate. Using advanced modeling and animation tool such as 3DS Max, students interactively manipulate and explore their design artifacts. The effect of design transformation and change is seen instantly. According to Schön theory, the "reflective conversation" with the design situation involves actions such as externalizing design ideas through drawing, interpreting the consequences of the drawing act, and making moves to a new design situation. In e-design, the feedback in the conversation with the design situation is more immediate. The transformation of the "digital artifacts", the movement to a new design situation and the "back-talk" of the situation are more instant. In contrast, tactile media provide a passive or less interactive environment in the sense that changing representation and feedback on the consequences of a design decision take time.

Another characteristic of the e-design process is the degree of involvement or **immersion** in the process. Observations revealed that e-design is immersive in dual senses. On one hand, advanced parametric modeling tools provided a work environment similar to desktop-VR where students are able to interactively explore and navigate their digital model. In this environment, students immerse themselves in a designed space in a manner similar to the way in which it would be used. The feeling of immersion was improved through LCD projection on a large screen. On the other hand, the numerous and versatile design and visualization capabilities of the digital environment provided unlimited choices for design creation which put the student in a complete immersion state. For example, design student is immersed in a virtual simulation that allowed him to model, articulate, and animate movement throughout the design process. The involvement is very personal and indescribable mental state - almost immersive. Several students were engaged in creative processes that few others could comprehend.

Thus, one can say that e-design represents a new model of design that is immersive and dynamic (reflective, integrative and interactive). This model brings dramatic changes to the conventional/tactile design process and questions several values associated with it.

Since e-studio students already have the basic skills in using the software and know how to design, one may expect instant efficiency in e-design. Our observations showed the opposite. Efficiency in e-design did not appear immediately. A significant amount of time is needed to develop skills and techniques in e-design. At the beginning of the e-studio, many students found difficulty starting design. The first week or so was hard for many students. They were kind of confused how to start.

One explanation for this "time lapse" is that students seem to switch mode from the conventional/tactile design mode to the e-design mode. In previous design studios, students attained and developed conventional design skills in which they used to work using abstract conventions such as 2D sketches, plans, sections, etc. This process or mode of design is different in several aspects from the dynamic and immersive e-design mode. Difficulty and time required to switch to the e-design mode differed from student to another, depending on personal traits and learning style.

Since e-design process tends to be different from the conventional design, it would be interesting to examine if e-design applies and creates different forms of tacit and propositional knowledge. Although each student has developed his own e-design working method, e-studio students did not become experts in e-design. Through time and practice, it is expected that students will develop skills and techniques in e-design and thus it is possible for an intuitive e-design procedures to appear. Through familiarity, the most apparent tools (mouse and keyboard) will tend to disappear and e-design becomes the core experience. It would be interesting to examine if such e-design experts use and operate with a design cognition that is different from those who design using conventional/tactile technologies.

It is clear that the e-design is different from the conventional design in several aspects. Thus, there is a need to reconsider our understandings of digital design practice which is still dominated by the prevailing conventional/tactile paradigm. Proper understanding of the e-design process requires a new perspective that goes beyond the discourse of the current paradigm. Dealing with e-design from the current conventional design perspective puts great constraints on our understanding of the new media and limits the questions that can be asked.

4. Design Studio Praxis

Initially, the e-studio followed the same general lines of the traditional studio: each student is to develop a unique solution for a design problem, recording results in drawings and models. At intervals throughout the project, the instructor holds individual or group reviews with students. At the end of the project, a final jury is held by the instructor and a group of outside critics. However, a critical analysis of the e-studio practices during two academic years revealed major differences between e-studio practices and conventional studio practices

The e-studio, for example, required larger amount of one to one contact with students. Students tend to produce more work with larger amount of information and complexity which demand more time from the instructor to examine and discuss with students. This tendency applies to both design and pre-design stages.

The e-studio, in contrast to the conventional studio, has no classical drawing boards. Each student has a desktop computer only with extra desk space for A3 sketch paper. One characteristic of the digital medium is its intangibility. Digital media are intangible to us except through the aid of technology such as keyboard, monitor or plotter. Initially, digital design is created and viewed on a computer monitor. To view the digital design there is an extra step of outputting design material. To present their work for desk critique or for formal/informal reviews, students used varied formats: soft copy (on computer screen or projected on large screen), hard copy (paper prints) or hybrid of both. The dilemma of which presentation format to use is one characteristic of the e-studio that is not found in the conventional studio. Each presentation format has its own rituals and constraints.

Using soft copy alone, whether on computer screen or projected on large screen, has its own limitations, such as the serial nature of the presentation, which make cross referencing and moving back and forth among various representations a difficult task. Also, students' work cannot be left on the "wall" so that other students can look at it for comparison and evaluation. In hard copy presentations, 2D images of the 3D model as well as sections through the model are presented. In hybrid presentations, 3D animations as well as hard copies of the digital model are used to demonstrate different parts of the design. Projecting animations or interactive models on large screen provided students with an immersive effect.

I usually ask students to have a printout during a desk critique so that I can mark out my comments. Outputting e-design is a demanding process that requires planning and time. Students have to render various views of the model, make sections through it, edit these images and use other applications to compile and print them out. Furthermore, the fact that what a student sees on the monitor is not necessarily what he gets on paper means that the student may re-print his work more than once. Thus, in e-design, it is difficult to conduct spontaneous pinup reviews or desk critiques. Enough time for outputting and editing design material should be allowed before a formal or informal review.

In the e-studio it is easy to identify the difficulties associated with tracking previous ideas during design development. Digital media enable students to create a large amount of design artifacts in a very short time. During the interactive e-design process, several artifacts are created and then destroyed or lost in a very short time. Some artifacts take a physical form for a very short time before they are destroyed or lost. Other artifacts are more instrumental for the design work and thus tend to stay for longer time before being lost. Students were encouraged to document the design process by keeping a record of important artifacts. Students tend to capture and save decisive ideas for future reference. However, during the design process, several students have lost record of important stages of their design. Observations revealed that this process is a demanding and not well organized process. Students' ability to move back and forth between design ideas/representations at different stages, whether for brainstorming, design development, communicating with others, or for other reasons is negatively affected by this limitation.

Digital media also change other aspects of the conventional design studio. Digital media, for example, redefine the boundaries of the studio. E-studio students are more outward looking. They engage with sources of learning beyond the studio boundaries such as the WWW. Some students tend to use pre-made elements or models available on the Web. This situation has legal, ethical and methodological implications. Also, compared with the conventional studio, there is more peer interactions in the e-studio. The students wander around the studio to discuss shared problems and solutions, to evaluate designs and how they did things, and some times to see what other students are doing. These practices reveal the importance of the social aspects of studio learning, where learning is created and changed by the social context. More research is needed to examine the relative importance of this aspect of the e-studio.

Furthermore, e-studio students tend to delay the contact time for the desk critique. One explanation for this phenomenon is that the integrative 3D environment enables the student to visualize his design and its problems and deficiencies better and thus he tends to be engaged in a continuous effort to develop and refine his work. Another possible explanation is media invisibility. To visualize the invisible design artifacts, the student needs extra time for editing and outputting design material in form of prints, screen captures, or as projection on large screen, each of which requires more planning and time management.

The above mentioned issues are clear anomaly and cannot be explained by or resolved from a conventional studio paradigm. The digital technology transforms the conventional studio and brings deep changes to its basic assumptions and practices. The e-studio experiments revealed the need to reconsider our traditional understanding of the design studio culture. The e-studio will remain experimental and discretionary to the extent to which we conduct it within, and think about it in terms of, the prevailing design studio practices.

5. E-design and Students Domain of Skills

To better understand how digital media affect and change the design process, it is beneficial to examine the effect of three independent variables on the e-design process: 1) manual artistic/presentation skills, 2) CAAD computing skills and 3) conventional design skills.

An evaluation survey was distributed after each e-studio and the results of the survey will be reported in another paper. However, some preliminary observations are worth mentioning here. The survey data showed that, in general, e-studio students feel better about their design skills. They express that parametric modeling and animation tools, such as 3DS Max, offer them a very convenient design environment.

Although digital media have proved to be useful in creating and presenting architecture, however, sometimes it was a source of “distraction”. While students with good architectural knowledge in terms of conventional design and manual presentation did very well in e-design, naive students with limited design and artistic skills tend to misuse the tool. Mislead or beguiled by the gimmicks of the digital media, they tend to rely on the art of "distracting". This uncritical attitude of such students resulted in very poor designs. Their products show very little assimilation or understanding of the underlying form. Such practices contribute to the anti-media sentiment that one may find among conventional design advocates.

Observations also showed that design students skilled in freehand drawing and tactile presentation methods, where less than enthusiastic for the e-studio experiment. Initially, it seems that there is little evidence to encourage them to use or explore the tool. However, later on they worked with the tool very well.

To examine the above observations, a co-relation test was conducted between students' performance in e-design and their skills in conventional design, manual presentation, and CAAD computing as reflected in their final grades in corresponding courses. In case there is more than one course representing the skill (as in conventional design and manual presentation skills), the average grade of these courses was used. The results of the correlation test (n=33) are as follows: Design skills and e-design r=0.83, artistic skills and e-design r=0.60, and CAAD computing and e-design r=0.31.

The low correlation between CAAD computing skills and e-design performance shows that computing knowledge alone is not enough to produce good design. Digital media cannot convert a bad designer into a good one. The high correlation between e-design performance and conventional design skills, and also between e-design and manual presentation skills, indicates the importance of basic architectural knowledge. Students who have good architectural craftsmanship (in terms of design and presentation skills) seem to be better equipped to extensively explore the medium and pursue its potential. In contrast, digital media seem to beguile and rock the focus of students with limited architectural knowledge. The final products of such students clearly offset the design content in favor of the image. The basic architectural knowledge tends to provide necessary constraints in a digital environment that appear to have no limitations. Thus, the basic studio and presentation skills, in terms of composition, materials, lighting, and color, tend to make all the difference in efficient e-design.

6. Media Limitations and Opportunities

The digital medium, as any other material, provides a medium with its own constraints, potentials, and aesthetic values. To enable students to explore the limitations and potentials of the new medium and to enable them to discover what the medium can do for them, two types of projects are offered in each e-studio. In the first type, the "Imaginative Leap", students are given a design project with flexible program. In the second type, the "Contextual Constraints", students are given a design project with specific constraints in terms of program and context.

The first project usually encourages students to think creatively and to discover innovative solutions. It also assigns a particular importance for rethinking and questioning the design process and the architectural form. In these types of projects students tend to create complex forms using complex operations such as several layers of modifiers, sub-object operations, and using NURBS modeling. They used these operations to generate various formal transformations that reflect their particular interest or conditions. These sophisticated modeling operations are used not only in design presentation but also in its generation and in questioning the various assumptions about design and architectural form.

These types of projects proved to be valuable to maintain the intrigue and investigation required to uncover the potentials of the new design environment. It was fascinating for students, who found it an opportunity to automat design generation and testing and to access the magical universe of complex forms**.** Some of the created forms transcended several essential issues such as constructionability, materiality, or the cultural and economical context. The complexity of the created forms questions the role of orthogonal abstraction conventions as a tool for architectural design representation.

After experimenting with the unlimited potential of the tool in the first project, the second project imposes some limitations in terms of program and design context. At the beginning, this was kind of disappointing for students – but later on they discovered that this condition is more likely to be enabling.

In one of the "contextual constraints" projects students were asked to design a "museum and cultural complex" at the Culture Street, Amman. One of the challenges in this project was how to deal with the peculiarities of the context. Creating and representing regional architecture, for example, entails a specific language of forms, expressions and material. Students had to relay on their experience to design and communicate the aesthetic and sensory influences of the physical context. This may be technically complex, but inevitable to represent and communicate regional identity. Particular e-design processes and techniques are needed.

One of the greatest challenges for students in the “contextual constraints” projects is how to impose a unique identity on the resultant digital form. Several students were successful in creating architecture with regional identity. I saw some real innovative approaches to reflect flavors of local/regional architecture. For example, some students used digital images of local stone styles, manipulated them in adobe Photoshop then used them in various channels of the "virtual material". Some students produced projects that jurors complimented as "Did not look like computer generated". Many architectural elements were simulated using "texture mapping" rather than modeling. Several students invented their own techniques. The nature of the project pushed students to seek to simulate the aesthetics and sensory qualities of the real world context. The issue of "material" here is not an issue of presentation; it is part of designing specific qualities of local and regional architecture. From my experience in teaching design, one can not ask students to produce what they cannot depict or represent on paper. These types of projects enabled me to engage in a deep discussion with students about critical formal and design issues.

On the other hand, some students were not that successful in designing with the contextual constraints of the project. They tended to produce generic forms that reflected a kind of common information-age culture. These forms were in complete contradiction with the context. Other students, however, provided a redefinition of local/regional architecture from a "techno" perspective. Challenges faced students in this project were reflected in their comments in the evaluation survey. One student mentioned that "digital media do not enable one to have his own "touch" or "to reflect his own identity". Another student mentioned that "computer do not provide a sensitive enough working environment to satisfy his particular demands". Another student mentioned that he wanted to reflect the "evocative nature of the place" but he couldn't. Thus, it seems that e-design not only affect and change the process of creating and teaching architecture, but also the qualities of the architectural product itself.

Observations showed that it takes time to realize the limits and opportunities associated with the media. These two types of projects, the "Imaginative Leap" and "Contextual Constraints", provided an appropriate vehicle to explore the new design medium and its potentials and limitations.

7. E-studio as a Locus of Culturalization

Digital technology is not a value free neutral tool that produces objective realties. Previous sections showed that digital media are dramatically changing the way we produce and teach architecture as well as the architectural product and the position of the designer in these processes. They also fundamentally alter the way in which we envision and describe architecture. It is worth examining if digital media and e-design influence students aesthetic values and their perception of the built environment.

Culturalization is the process by which individuals acquire their cultural behavior during the various contacts with the institutions of the groups in which they finds himself. As a result of "the culturalization process the individual assumes a definite set of conventional manners, ideals, knowledge, attitudes and habits." Thus, it seems appropriate to analyze and examine the inevitable outcomes of the e-studio as a culturalization process. It is necessary, for example, to examine how digital media affect new generations of designers and what are the social and cultural implications on architectural education and the profession as digital media become the dominant mode of designing.

It is often argued that a major disadvantage of digital media is their inability to communicate cultural and symbolic meanings. CAAD systems are usually described as being designed to create and compile value free elements (Al-Qawasmi, 2004). The argument is that CAAD systems and digital technology transform buildings into elements of global exchange and, in this way, support commodification and globalization of cultures. Another criticism is the tendency of digital media and CAAD systems to offset the design "content" in favor of the "image"; that is, the image substitutes the content in documenting and communicating architecture. In the century of globalization, this is a critical issue for developing countries, such as Jordan, where the search for a national identity is very crucial. As Manual Castells (1997) put it, in a world of global flows of wealth and images, the search for identity - collective or individual – "becomes the fundamental source of social meaning."

As new generations of design students are spending more time practicing e-design and participating in digital environments for communication and education, it is unknown as yet, what their aesthetic demands will be. In the e-studio, for example, the design products of the students seem to have different flavor or aesthetic taste compared with the products of the conventional studio. E-design products increasingly include a great deal of generic forms that reflect a kind of global architectural identity. Students tend to produce "techno designs" that transcend local conventions and constraints. Although it is necessary to prepare our students for a fast moving digital culture and to teach them how to respond to the various issues raised by the information society, we should be aware of the ambivalent nature of digital media and the inevitable outcomes of their deployment in architectural education and practice.

It is well known that different media "amplify" or "reduce" phenomena in various ways as a result of their own constraints and limitations. Postman (1993) has reinterpreted McLuhan’s statement that "the medium is the message" as meaning that “embedded in every tool is an ideological bias, a predisposition to construct the world as one thing rather than another, to value one thing over another, to amplify one sense or skill or attitude more loudly than another”. In the context of the e-studio, this suggests that digital media do not enable us without cost. In other words, some information or aspects of the design experience are becoming more important or relevant while others are becoming unimportant or irrelevant. As discussed before, many aspects of the conventional professional practices are no longer the dominant mode. For example, digital media eliminate the need to use physical models. The complexity of created forms upstaged the role of orthogonal abstraction conventions as a tool for architectural design representation. Also, students tend to use secondary data available on the Web rather than creating their own models or collecting their primary data, a situation that has profound ethical and methodological implications.

8. Conclusion

The e-studio provides a valuable opportunity to critically evaluate current design discourse and to reconsider current understandings of the design studio and the digital design practices. It enables us to gain insights into the architectural design process, the design studio praxis, the design outcome, and how digital media affects them.

Our observations showed that e-design appear to represent a new model of design that is immersive, reflective, integrative and interactive. This model questions several values associated with the conventional design process and brings dramatic changes to it. The digital technology also transforms the traditional studio and brings changes to its basic assumptions and practices. It introduces new studio practices that cannot be understood, explained or resolved from a conventional studio paradigm.

The e-studio highlighted the need to examine the social and cultural implications of using digital media in architectural education and the profession. There is also a need for more rigorous research to examine whether e-design involves different cognition activities than those used in conventional design.

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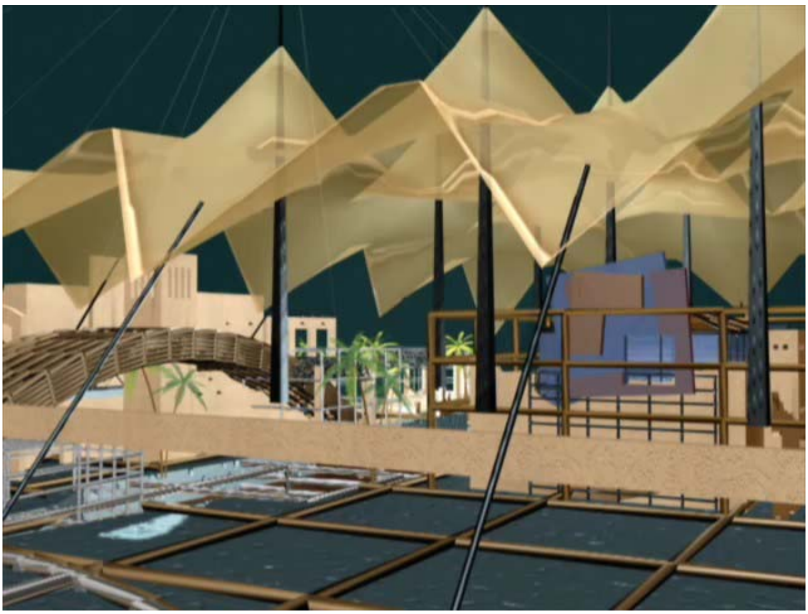

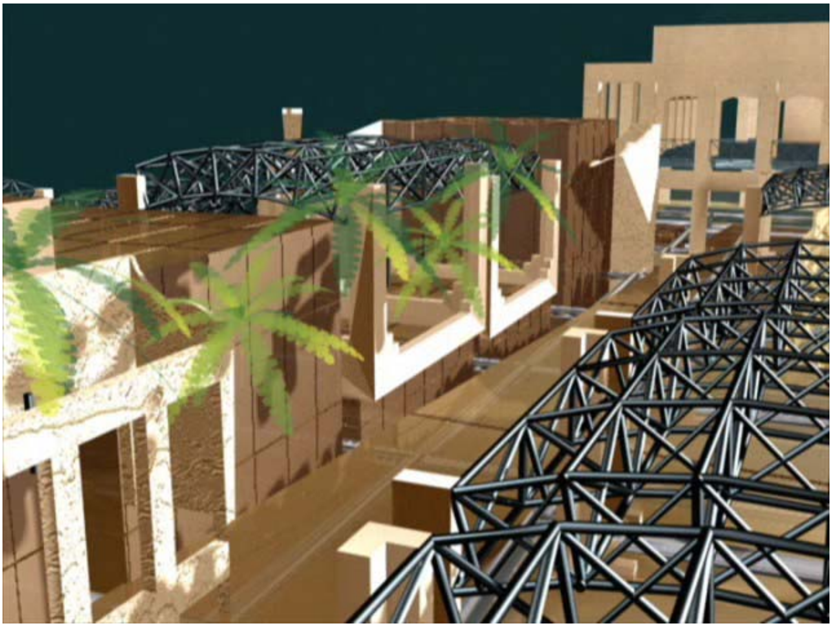

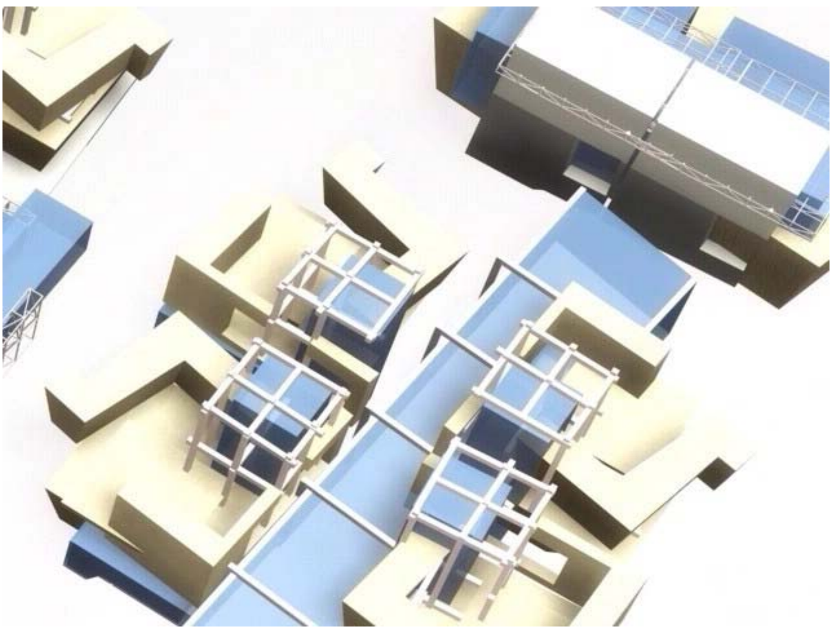

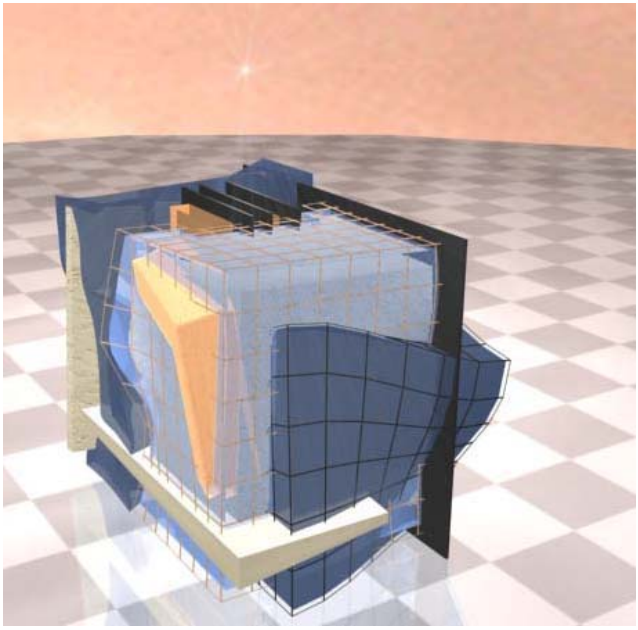

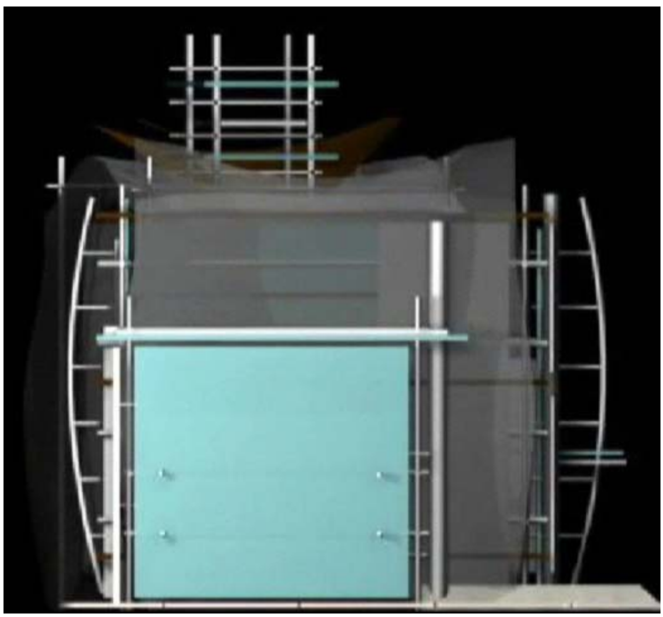

Examples of Student Work in the E-Studio

FROM HARD ARCHITECTURE TO SOFT ARCHITECTURE: ARCHITECTURE FORM IN THE 21ST CENTURY

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Abstract: The digital revolution is affecting not only the way we produce drawings, but also the way we think about architecture. Such expressionistic, neo-baroque forms would have been unthinkable without higher technology, which allows for customization at a massive scale. Three dimensional computation extends the architect's range, permitting a wealth of experimentation, any form seems possible, the architecture language, the vocabulary changed, and the way design thinking has various dimensions.

Within a short space of time the computer has become a widely accepted feature of architecture, both in the design process and in the everyday operation of buildings, and we are constantly aware that the computer's introductions into architecture will eventually have far-reaching consequences. After all, the current revolution is not just about the computer as a tool but about its role and effect on the form of architecture and thinking

This paper will discuss what form will architecture take in the next years? Will every future problem be anticipated, developing more efficient solutions? Will projects reflect meaningful architecture, for dynamic and contemplative environments and for aesthetic quality? And, how we will stand this unavoidable futurism?

1. Introduction

Since its creation, architects, artists, media designers and theorists have speculated about the ramifications of the computer. It is a theme that invites speculation, experiment and play - but that is not the only reason for the persistent questioning. Today we are aware that we cannot foresee al the implications of the technological revolution. We are aware that innovations and inventions need time to incubate, and that their effects on the organization of society can be completely unexpected. The radicalization of modernity that has been triggered by the computer means that it has become increasingly difficult to fall back on traditions: more than ever. We must reflect on what the future will bring (Figures 1, 2 and 3).

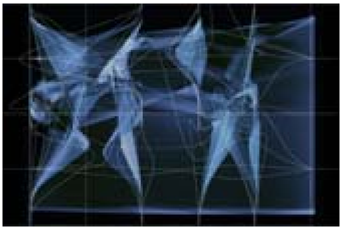

Figure 1. Computer model generation

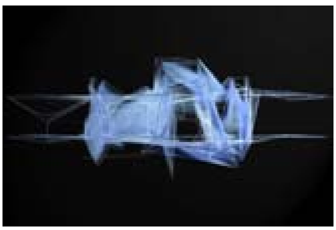

Figure 2. Model transformation

Figure 3. Model approaches

It presents a wide spectrum of approaches, from architects who incorporate the computers techniques into their working methods in a more efficient or exploratory way to practices that are based on the belief that the computer will dramatically change the nature of architecture, in terms of the design process, as well as on the levels of organization and experience. Digital architecture is not a movement - like many others that have been recently coined - but a way that helps us better understands and connects the many attempts to establish the computer's role in architecture, it makes us aware of the many opportunities that exist between and behind design approaches. Instead of trying to validate conventional architectural thinking in a different realm.

2. Evolutions and Transformations of new architecture

At the close of our century it is the information revolution that is metamorphosing architecture and urban design. Digital technologies are transforming the nature and intent of architectural thinking and creativity, (Figure 4), blurring the relationships between matter and data, between the real and the virtual and between the organic and the inorganic and leading us into an unstable territory from which rich innovative forms are emerging. It is in this context that today's experimental architects are deploying novel "hard' (manufacturing and material) and "soft" (digital) technologies to engender an architecture of incorporation and conjunction, to test the radical generative and creative potential made possible through computer application (Figure 5).

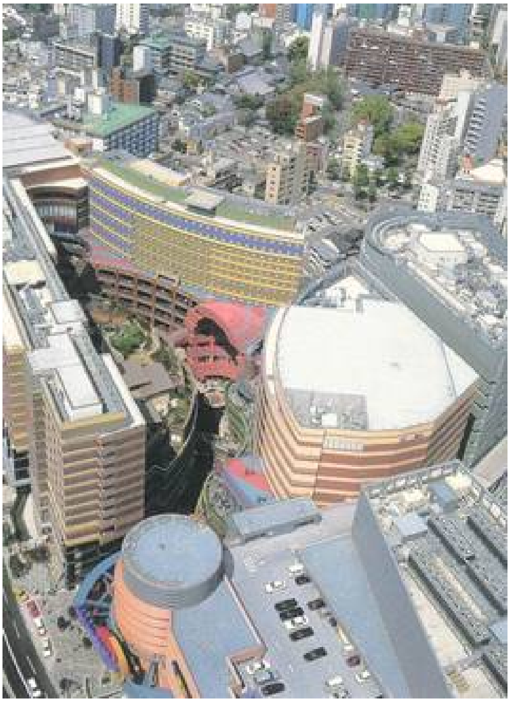

Figure 4. Digital technologies are transforming the nature and intent of architectural thinking and creativity

Figure 5. Reichstg Berlin-Norman Foster, 1999.

A new time-space vernacular is re-scripting the model of the city as cable and satellite connections span massive physical distances along a curved terrestrial geography, spatial description itself. Through visual and non-visual means of mobile cognition satellite-imaging, electron-scanning or heat-sensing -structures and buildings are being set free from a conventional linear viewpoint buildings can become less like icons of fixity and immobility and more like incursive fields of organized materialization.

Paradoxically, while architecture may at last free itself from the shackles of an over determined mode of visualization. The building user has become increasingly static, as human cognizance and transience reach around the planetary surface via telecommunications networks, we remain relatively fixed to our points of interface-our workstations, televisions and fax machines. The idea of place has therefore as instantaneous data exchange replaces traditional means of mobility. Buildings can now be seen from anywhere at once with the aid of a digital cognition, and strangely we are able to perceive everything at once by not moving at all.

If the seminal avant-garde of the early twentieth century designed an architecture for the Machine Age, then the architects are now devising transformative, poetic and pragmatic responses to the technologies urban networks and post-mechanical processes of the Information Age. They are developing spatial routines and urban coding for a world that is at once unfixed and fixed, here-there and there-here, dislocated and located. Theirs is neither revolutionary nor utopian architecture but an architecture of evolution, contextualization and transmutation (Figure 6). Their researches are triggering a phase-shift in our perception and comprehension of space, materiality and time at the start of a new millennium.

Figure 6. Disney Concert Hall, Los Angeles, USA, Frank O. Gehry, 2003.

Within our lifetimes we are watching unprecedented deviators from the basic outline of the city. The boundaries between urban conditions, between private and public space, natural and urban space, are blurring, while whole families of urban and architectural types-1950s skyscrapers and 1960s malls-are becoming marginalized or superannuated, urban forms like featureless information factories, gated exurban estates, anonymous strip malls and hopelessly tangled parking-lot complexes are evolving within the topographies and ecologies of our wired cities (Figure 7). At the never-ending edges of town, urban forms germinate and grow almost instantaneously, appearing in the world as if overnight, fully formed by the forces of global capitalism.

Figure 7: Webb Bridge, Melbourne, Astralia, Denton Corker Marshall, Robert Owen, 2003.

3. Virtual Versus the Real

The virtual is real but not actual, ideal but never abstract. Indeed, the two sides of this purported dialectic, the real-actual and the virtual-imaginary are not distinct halves but something akin to oscillating forces in a shifting field, existing not side by side but through and across each other. If we were to assign identities to the real-actual and the virtual-imaginary, we might say that they are at once singular and doubled. If they are entities at all, they share functions and space over coterminous territories, or overlapping regions of nor-exclusivity.

The twinning of the virtual and the real in architecture is not a phenomenon specific to our time or technologies (Figure 8). The notion of real spaces enriched by a virtual logic has existed since the seventeenth century, if not earlier. The puzzling forms of the garden maze, for instance, or the infinite reflections of the mirrored gallery, spaces in which vision and reasoning bend and warp according to a virtualized logic of reflection, simulation and distortion, were in many ways precursors of our intermingled electronic-virtual and material-real structures: the actual being recorded in a world network (data-maze) and the virtual as the points of interface (data-mirrors). If in the seventeenth century the real-virtual might have existed only in the mirrored halls and garden mazes of the privileged, todays intertwined real-virtual is more democratically shared across cities and social classes.

Figure 8. Reichstg Berlin-Norman Foster, 1999.

Time, perhaps once seen as an impediment to building, a source of delay and decay, has assumed a decidedly intimate role in an architecture that engages in a kinematical sculpting of space. Today, time and movement have been instrumentalized in architecture with the aid of powerful animation software's, which have enabled architects to develop dynamic, mutable and evolving design techniques and new spatial paradigms.

The use of animation software has inscribed duration and motion into static form rather than creating an architecture that is essentially the organization of stationary, insert forms, architects view spatial design as a highly plastic flexible art in which the building form itself continuously evolves through motion and transformation. With complex time sequences and simulations, forms are no longer defined by the simple parameters of scale, volume and dimension; multivalent and shifting external or invisible forces and inclinations can also affect forms (Figure 9). Employing software routines that track time-related factors, such as pedestrian and automotive movement, environmental elements such as wind and sun, urban conditions such as views or site density, these designers are producing buildings in which virtual and real media technologies are inextricably linked.

It suggests that mathematical models and generative procedures can be used to build models "derived from the particulars of the real world, from data and processes of the virtual world (Figure 10), or from numerous techniques of capturing the real and casting it into the virtual, motion-capture, for instance. Since time is a feature of the model, if the model is fed time-based data, the form becomes animate.

Figure 9. London City Hall-Norman Foster, 2002.

Figure 10. Fisher Center for the Performing Arts and Bard College, Annandale,USA, Frank O. Gehry, 2003.

4. Emergent Future Dimensions

A seamless virtual geography of informational interchange has replaced locale as an indicator of space and rearranged "natural" temporal sequences along the earth's surface The globalized liquid "soft architectures" of digital media from over, under and through the local, concrete and "hard architectures" of our contemporary cities, creating an indeterminate, "floating" environment, an interface between public and private, collective and subjective, symbolically rich and multidimensional world-space as an extraordinary context for architectural exploration.

Our international telecommunication networks have become characterized by agitated, irreversible super-corrections that operate outside conventional human understanding of time and space. We no longer communicate with friends, family or associates exclusively in a particular place; rather, we communicate both in the local context and across time zones and cultures. A seamless virtual geography of informational interchange has replaced locale as an indicator of space and rearranged "natural" temporal sequences along the earth's surface (Figure 11).

Figure 11. Guggenheim Museum, Bilboa, Spain, Frank O. Gehry, 1997.

Computerized design and manufacturing processes have brought about working practices that irrevocably affect the way buildings are assembled, function and behave. Little more than a decade ago, most offices reproduced their architectural drawings and schedules mechanically or by hand, documents were then delivered to consultants for review and updates, before revisions were painstakingly added to working drawings by hand. Today three-dimensional CAD models can be relayed between workstations or offices executed in different time zones and endlessly revised without ever leaving the electronic sphere. As computer processing power increases exponentially and advanced manufacturing software's become more available and less expensive, both large corporate offices and one-person studios will reap the practical benefits of the electronic paradigm shift.

Perhaps the most spectacular (and publicized) example of the extent to which these new technologies are influencing architects' production and aesthetic practices is the captivating use of complex-curve-generation software, digitization devices and numeric command-machining in Frank Gehry's Guggenheim Museum in Bilbao (Figures 11and 12). Using CATIA, an aeronautic and automotive design and manufacturing software, Gehry was able to produce precise three-dimensional models for every facet of the titanium and stone surfaces, as well as the intricate structure of the interior curtain walls and stairways, before directly delivering the design details to Spanish subcontractors in CATIA format.

Figure 12. Guggenheim Museum, Bilboa, Spain, Frank O. Gehry, 1997.

Architecture need no longer be generated through the static conventions of plan, section and elevation. Instead, buildings can now be fully formed in three-dimensional modeling, profiting, prototyping and manufacturing software's, interfaces and hard-wares, thus collapsing the stages between conceptualization and fabrication, production and construction, numerical data formations and spatial experience.

Architecture is becoming like "firmware" the digital building of software space inscribed in the hardware's of construction. Soft complex-curved surfaces modeled in data-space will be transmuted to real space as bent or torqued variable panels, as sheets in steel, copper or plastics, or glass-fiber skins: massive involutes elements designed in data-space will become milled, routed or turned elements in wood or aluminum, or cut as molds for quick-setting resins, rubbers or metals. Bridging the boundaries between the real-technical and the virtual-technical, firmware will favor a far more malleable relationship between bits of space and matter.

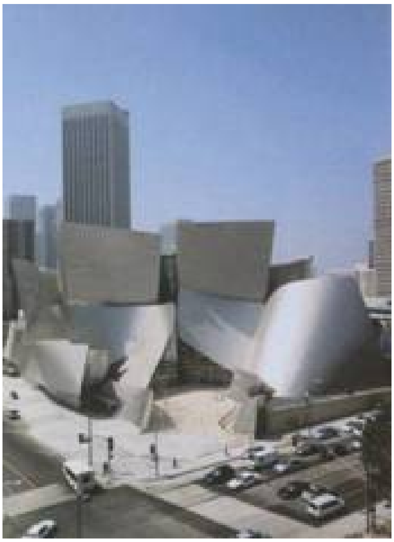

Figure 13. Disney Concert Hall,
Los Angeles, USA,
Frank O. Gehry, 2003.

Figure 14. Kunsthaus Art Museum, Austria,
Peter cook, Colin Fournier, 2003

As the French architect, technologist and theorist Bernard Cache has argued, architecture today should be understood as an electronic technical art." based less in the representation of ideal forms than in the scripting of machining codes and routines for numerically controlled (NC) routers, lasers and water jets. He suggested that the calculation of space, form and structure will usurp design altogether and eclipse the architect's previously deterministic role. The separation of entities corresponding to the productive division of elements is precisely what is being called into question. If there are any sacred cows to kill, it is not so much the strict geometry and standardization of components that industrial production has seemed to suggest, but the structures of thought itself, and in particular the linear and rationalizing tendencies that such divisions have championed."

The computer, then, will no longer be merely a production, engineering or facilitation tool under the command of the architect-user but a generating entity with its own virtual intelligence or "knowledge" of the design process: the computer will function as a partner (Figures 13 and 14).

Architecture is becoming a computational collaborative art based on the choreography of robotic manufacturing, while the architect, freed from the need to continuously invent a new is becoming more like a choreographer of space and material production (Figure 15).

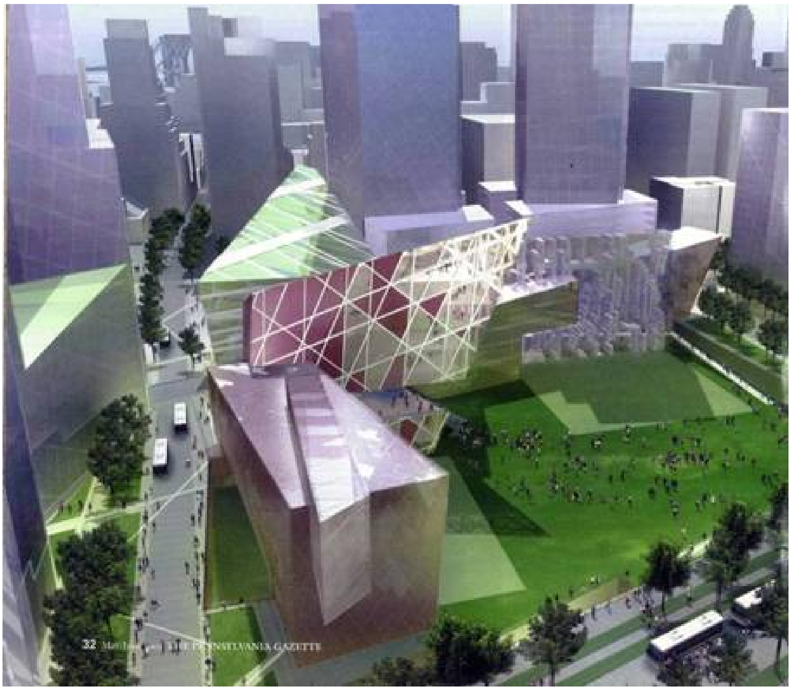

Figure 15. New York Gardens, New York, USA, Daniel Libeskind, 2004.

5. Conclusion

Architecture need no longer be generated through the static conventions of plan, section and elevation. Instead, buildings can now be fully formed in three-dimensional modeling, profiting, prototyping and manufacturing software's, interfaces and hard-wares, thus collapsing the stages between conceptualization and fabrication, production and construction, numerical data formations and spatial experience. The unique character of handwork and systemic mass production can now commingle in CADICAM mode of creation, which can produce series-manufactured, mathematically coherent but differentiated objects, as well as elaborate, precise and relatively cheap one-off components.

The shift in the twentieth-century image of architecture from the "hard" forms of industrial and military technologies (the biplane, the transoceanic streamliner and the automobile) to a more pliant investigation of broader techno-cultural conditions (the soft technologies of leisure and domesticity or the interface model of the computer) is an ongoing manifestation of the ethics of technology in the aesthetics of building, technology is ultimately society, and society cannot be understood or represented without its technological tools.

Nevertheless, the investigation and application of technology by architects must consider the ramifications of the potentially reckless and uncritical coercion of technology's powers into architecture. We must remain watchful of the machine's ruinous endgame played out as urban forms, spaces and relations. Recalling early modernism's utopian romance with machine form tells us much about the dangers of an addictive technology fix and the consequences of a technological overdose Indeed, there is something ominous that lies beneath modernity's play of sleek forms and pure surfaces under light. It was no accident that in the aftermath of the Second World War, Le Corbusier, once the champion of the engineer's aesthetic of cold, naked, polished steel, would reject the accelerated technologies of terrestrial movement and aerial flight, Witness to the spectacular violence brought into the world through the combined efforts of mid-century science and the war machine, Corbusier turned his architecture to the vernacular forms of the Maisons Jaoul (1952-56) and the sacred space of Ronchamp (1950-54).

Today, in a post-industrial age, we assume too easily that the more supple technologies of communication and computation are less threatening or less likely to drive us towards a total societal crash However pliant and mobile the technologies of the information age might seem real-time connectivity and interface may be only slightly more subtle in their potential for violence than their the brutal counterparts in the Machine Age.

With supercomputing speed estimated to achieve some twelve trillion calculations per second by 2005 and the sum of stored human knowledge to double every seventy three days in the year 2020, the heart of a highly technologized millennial architecture must lie in the critical relationship between technical speed and the architect's ethical concerns. Time and space may be at their most useful when not in use. Architecture may serve us best when it helps us to recognize the gaps, pauses and intervals or respite in an ever accelerating world. Sometimes speed limits us, and sometimes limits set us free.

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FUTURE SPACE CITIES@UNIVERSE: *DIGI-CITY VISION*

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Abstract. A template for the future city has been carved into the heavens. Ever since the beginning of humankind, we have looked to the sky for the opportunity to make a new start in our imperfect world. Between the stars and the darkness we have imagined utopias beyond the reach of our travel technologies, colonizing space with our fantasies.

Now we are in the first stages of an electronic revolution, but in the future 50 years later we will be in a mega-digital era which we have to predict, work and search for the reality of that future. Our planet is recently over loaded with different problems, such as pollution, population, nature disasters.

Our vast speed of technology and the curiosity of discovering the invisible, leads to study and find out the nearest Future Space Architecture. With the vast acceleration of technology and digital life, we should start to predict the future architecture on, into or behind the Earth. This paper is one of many perceptions of life and architecture behind the Earth in the digital era, Digi-City Vision.

1. Introduction

Until the 20th century, leaving the Earth's surface remained a fantasy. But with the advent of the space race and the first ventures into orbit in the middle of this era, this changed forever. Yet, despite the initial success and the resulting enthusiasm for space projects, few people are aware that space travel for ordinary people is imminent, and even when presented with the arguments, many seem unable to accept the idea. This reluctance to believe in extra-terrestrial living can be seen as a significant failing in modern society. It suggests disillusionment and lack of conviction about the successful future of humankind.

Yet it is important for a society to have ambitions for the future. The conquering of space is unique challenge that can help to unify the world and encourage us to collaborate as a species. In the emerging global society, this collective project is essential not just as a symbol of human unity, but for future economic progress. After all, the story of the human race through exploration and expansion into new territories and environments, and the eventual establishment of cities, is the essence of civilization.

Every age has produced a particular way of dwelling as a reflection of its specific conditions -social, economic and cultural- and technological developments In our own time, the new technologies of information and communications are transforming the home into a micro-city, a genuinely multifunctional environment (work, shopping, leisure, rest) from which to inhabit the global village. Within a few years the passive physical world defined by purely functional structures which give people shelter, and in which we consume products and interact with the world by way of screens, will be rendered obsolete by intelligent environments in which everyone and everything (people, objects, and spaces) will both generate and consume information and (ideally) transform it into knowledge.

Architecture, which organizes human activity by means of the construction of space, has the potential to play a key role in this new situation if we can transform it into the best interface for interacting in the new hybrid situation we will find ourselves inhabiting. This being so, the design of both physical space and digital space are going to have to take place at the same time, in a process of constant feed-back in which both worlds learn from their own and each other's potentialities and limitations. Matter and information will intersect in human activities. The knowledge society will develop a home geared towards knowledge, a place primed for the creation and representation of knowledge, in which the individual, the citizen, in relation with other citizens around the world, can live a life of quality (Metapolis, 2001).

This paper is trying to answer some questions such as:

- If the Earth is the place of life? How do we design buildings to live in a way from Earth? How do the natural, artificial and digital spaces interact?
- How can a building be designed to ensure a total flexibility of uses under new conditions?
- Does the space architecture have virtual environment in the form of natural or artificial landscapes?
- How is information ergonomics integrated as physical ergonomics?
- Can all of the components be connected to one another, without a hierarchy?

- Through which interfaces do we relate to "intelligent space cites"? How do we control the flows of information between the physical world and the digital world in these new cities?
- How does information reach objects and spaces? What new wiring does the house incorporate?
- How can this architecture be smart enough to updates new conditions such as gravity, air, and space attacks, etc?

2. Vision to the future: Beyond the Horizon

Norman Cousins wrote “What was most significant about the lunar voyage was not that men set foot on the Moon but that they set eye on the Earth. To be able, from a station in outer space, to see the relationship of the planet Earth to other planets; to be able to contemplate the billions of factors in precise and beautiful combination that makes human existence possible; to be able to meditate on journeying through an infinity of galaxies; to be able to dwell upon an encounter of the human brain and spirit with the universe—all this enlarges the human horizon. It also offers proof that technology is subordinate to human imagination; we can do this not just because of technology but because of our imagination” (NASA, 2003)

Space and Galaxies

The story of the human race through exploration and expansion into new territories and environments, and the eventual establishment of cities, is the essence of civilization (Armadillo, 2001).

3. Human in Space

Most objects in space give off energy in the form of electromagnetic radiation. This radiation can be in many different forms and often travels millions of light years before it reaches Earth. However, most forms of radiation are absorbed by the Earth's atmosphere and so cannot be seen from the planet's surface. Because of this, these types of radiation are best studied about space. There are many different satellites orbiting the Earth, allowing us to study radiation before it reaches Earth's atmosphere.

3.1 INTO SPACE

Of all the marvels and achievements of human race, the most incredible may well be our ability to leave our planet and travel into space. The drive for this came from two of the world's major superpowers, but it was not so much a desire for technological advancement as a battle for political supremacy. Nevertheless, sputnik's bold voyage into space in 1957 remains one of the most important milestones of science.

3.2 LIFE IN SPACE

We have put men on the Moon. Can people live in space? Can permanent communities be built and inhabited off the Earth? Not long ago these questions would have been dismissed as science fiction, as fantasy or, at best as the wishful thinking of men ahead of their times Now they are asked seriously not only out of human curiosity, but also because circumstances of the times stimulate the thought that space colonization offers large potential benefits and hopes to an increasingly enclosed and circumscribed humanity (Toroidal Colony, 2002).

The concept of human habitation in space is, of course, a very old one; in some form, it can be traced back to the early days of science and even earlier, to mysticism. It has been a theme of fiction and speculation. This century has brought the first real access to extraterrestrial space and, with it the architectural community is faced with the prospect of thinking the unthinkable about where we will live and the way in which we can best accomplish this.

In just 40 years, humanity has moved from dreaming of the moon and planets to landing on our satellite and sending spacecraft to all but one of our neighbouring worlds. Unless some economic collapse or popular backlash against space exploration cuts funding for the world's space programs, the coming century will certainly bring even more dramatic achievement and discoveries. Within several decades, engineers could be launching spacecraft toward the nearest stars.

To live in space humans must be protected from the fierce intensity and penetrating wavelengths of unattenuated sunlight, but this same energy is one of the primary resources of space. If this steady, ceaseless flux of solar energy is tapped its value may be very large. If the Sun's energy is converted with 10 percent efficiency to electrical power which is sold at a rate of $.012/kW-hr, a square kilometre of space would return more than

$14,000,000 each year. It is important for the colonization of space that an effective way be found to use this solar energy.

Space is extraordinarily empty of matter. The vacuum of space is better than any obtainable with the most refined laboratory equipment on Earth. This vacuum may be a resource in its own right, permitting industrial processes impossible on Earth. Nevertheless, there is matter in space and it is of great interest to space colonization (Toroidal Colony, 2002).

3.3 HUMAN NEEDS IN SPACE

Elementary essentials such as air, water, food, and even the sensation of weight all should be provided to the space colony. Engineering criteria to assure physiological safety and comfort are essential, but equally important is to provide for psychological and aesthetic needs of the colonists. The structure, mass, and shape of the habitat are sensitive to the choice of design criteria. Rather substantial savings in structural mass, and hence in cost and construction time, can be obtained by deviating from Earthlike conditions. Because the physiological effects of appreciable deviations from some of the terrestrial conditions are unknown, the living conditions in space are designed to be similar to those on Earth despite additional costs. The treatment of weightlessness is an example of this conservative approach.

Antigravity space – space center

3.4 FOOD AND WATER

Humans living in space must have an adequate diet; and food must be nutritious, sufficiently abundant, and attractive. There must be enough water to sustain life and to maintain sanitation. A diet adequate for a reasonable environmental stress and a heavy workload requires about 3000 Cal/day. It should consist of 2000 g of water, 470 g dry weight of various carbohydrates and fats, 60 to 70 g dry weight of proteins, and adequate quantities of various minerals and vitamins. The importance of the psychological aspects of food should not be neglected. The variety and types of food should reflect the cultural background and preferences of the colonists (Toroidal Colony, 2002).

4. Problem Definition

Our planet is recently over loaded with different problems, such as pollution, population, nature disasters. Our vast speed of technology and the curiosity of discovering the invisible, leads to study and discover the space with many questions: Space exploration, an active pursuit for less than two decades, has already displayed an extraordinary power to alter our viewpoints and stretch our minds. The concept of spacecraft Earth, a sphere of finite resources and ominous pollution, became pervasive and powerful at the same time we first received good photographs of our planetary home Human-made objects have already travelled millions of kilometres into the depths of space. The Pioneer and Voyager space robes have flown beyond Pluto, heading for the edge of the Solar System. However, in the vast expanses of the Universe, this is hardly any distance at all! Scientists and engineers are already working on new technology that will take the human race to the nearest stars, to neighbouring galaxies, and beyond.

The question, "**What is feasible**?" can be finally answered only by future historians. If in the 14th and l5th Centuries when new technology first made transoceanic voyages possible, European rulers had inquired what they should do with this new capability, no man could have been long-headed enough to perceive all the possibilities, nor persuasive enough to communicate his vision to others. We now realize that technology is but a part of any broad stride taken by man. A perception of advantage to be gained, resolve, organization, and a continuity of effort - some of the elements that must combine with technology to effect a major human advance - is indeed vital (Mitchell, 1998).

5. Building in Space

Space travel provides the ultimate challenge for designers and architects wishing to create an environment that is self-contained and can grow with, and is seamlessly integrated with, the human beings it protects and nurtures. One of the major challenges will be to identify substances that will be cheap and easy to assemble in space. Spacecraft and space stations will be assembled like Lego. The basic units will be manufactured from all over the world and will have standardized electrical circuitry, oxygen-carbon-dioxide-nitrogen-mixture carry capacities, internal pressure, etc, in order to prevent negative external forces ripping environments apart. The less human intervention and maintenance of space structure there is, the less costly habitation will be. Smart materials that are capable of self-repair will be needed, as the cost of sending up repair crews could prove prohibitive to future space stations. Not all materials will need to be artificial. Some organic materials that can grow, divide and mature in space, like bone, could be used to grow space stations from the culture of cellular 'seeds'.

To avoid disorientation, buildings able to maintain their own life cycles, mimicking the diurnal Earth patterns of sleeping and walking, and which can recycle water and organic products, will be necessary to pacify their inhabitants psychologically. The ideal architectural material to use in a vacuum is, of course, light. Laser highways, sculptures, artworks and advertising will be part of the information and architectural structure of colonized space. The concept of human habitation in space is, of course, a very old one; in some form, it can be traced back to the early days of science and even earlier, to mysticism. It has been a theme of fiction and speculation. This century has brought the first real access to extraterrestrial space and, with it, the architectural community is faced with the prospect of thinking the unthinkable about where we will live and the way in which we can best accomplish this (Raskar et al, 1998).

5.1 FASTER-THAN-LIGHT TRAVEL

Because the distance between stars are so enormous, we do not possess the technology today to be able to travel to another Solar System. Even the closest star to our Sun is too far away to reach in a single lifetime. To reach other stars, star-ships have to be able to travel faster than the speed of light-300,000 kilometers per second. But according to one of the fundamental laws of physics, Einstein's theory of relativity, faster-than-light travel is impossible. Even if scientists were to find a way to travel at the speed of light, it would still take over 300,000 years to get the centre of our galaxy (Armadillo, 2001).

5.2 INTERSTELLAR CITIES

One way of overcoming the need to travel faster than light is to build enormous star-ship that would act as portable space cities. Some scientists have suggested building colossal construction, several miles long, which would be able to carry thousands of people into space. These ships would not be able to travel as fast as speed of light, and the journey to find other plants would still take thousands of years. However, the number of people on board would mean that future generation would be able to explore far-off galaxies and planets. None of the original astronauts would live to see the far reaches of space, but their great-great-great grandchildren could!

5.3 LIVING OFF-WORLD

Space stations now allow humans to live in space for long periods of time. However, living in Earth's orbit is just the beginning of a new age of space habitation. Scientists all over the world are thinking of new ways to allow people to live in space and other planets-not just for years but permanently!

NASA deigns trials for space cities 2003

Space stations could become enormous homes in space as the population of Earth becomes too great for planet to contain. These giant homes could also be used for cruises through the Earth's atmosphere for those who would like a holiday in space! (Armadillo, 2001).

5.4 FOOD AND WATER NEEDED IN SPACE

Humans living in space must have an adequate diet; and food must be nutritious, sufficiently abundant, and attractive. There must be enough water to sustain life and to maintain sanitation. A diet adequate for a reasonable environmental stress and a heavy workload requires about 3000 Cal/day. It should consist of 2000 g of water, 470 g dry weight of various carbohydrates and fats, 60 to 70 g dry weight of proteins, and adequate quantities of various minerals and vitamins. The importance of the psychological aspects of food should not be neglected. The variety and types of food should reflect the cultural background and preferences of the colonists (Armadillo, 2001).

5.5 CITIES IN SPACE

Current space stations are usually quite small and cramped. They cannot hold more than a few people. Even the International space Station (ISS) is restricted to a staff of seven. Some scientists have suggested building much larger homes in Earth's orbit. These space cities would not just be laboratories for space science but homes for thousands of people. Although there is no gravity in space, this could be overcome by making the space city spin at a constant speed. This would create a false gravitational force that would push everything to the outer wall (Armadillo, 2001).

5.6 NEW HOMES

My personal vision to the future is a vision to the orbit Space city, it is possible in the electronic life we are going through, day by day we used to use the technology in every field of our life, so what will be tomorrow and next? This is the future vision. Our homes will be fully connected to an intelligent system which assist household doing and controlling every thing ….all furniture will act as intelligent objects work to make us feel comfortable in all our different modes, it's a new horizon, new lifestyle. How about our future space homes? Homes will be automatically recycled intelligent homes.

Every age has produced a particular way of dwelling as a reflection of its specific conditions -social, economic and cultural- and technological developments: The piping of water into the home led to the appearance of the kitchen and the bathroom; artificial light and electricity resulted in new forms of organization at home; domestic appliances allowed people to conserve food for longer periods and to do more in less time, and TV turned the traditional living room into a window on a world dominated by the mass media. In our own time, the new technologies of information and communications are transforming the home into a micro-city, a genuinely multifunctional environment (work, shopping, leisure, rest) from which we can inhabit the global village. Within a few years the passive physical world defined by purely functional structures which give people shelter, and in which we consume products and interact with the world by way of screens, will be rendered obsolete by intelligent environments in which everyone and everything (people, objects, spaces) will both generate and consume information and (ideally) transform it into knowledge (NASA, 2003).

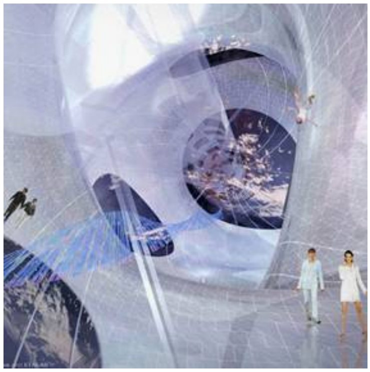
"Space colonization is likely to have a large favourable effect on communication and other Earth-sensing satellites. Already communication satellites play an important role in handling telex, telephone, computer, and TV channels. They provide data-links and track airplanes and ships as well as rebroadcast TV to remote areas. In the future even more of these data-link applications can be expected. Not only will planes and ships be tracked and communicated with by using satellites, but trains, trucks, buses, cars, and even people could be tracked and linked with the rest of the world continuously. Currently, the main obstacle blocking direct broadcasting of radio and TV to Earth from orbit is the lack of low-cost power in space. SSPS's would produce such power. In addition, their platforms could be used to provide stability. Currently, up to 40 percent of the in-orbit mass of communication satellites consists of equipment used to provide power and maintain stability. Finally, colonists could carry out servicing and ultimately build some of the components for such satellites" (NASA, 2003).

Architecture, which organizes human activity by means of the construction of space, has the potential to play a key role in this new situation if we can transform it into the best interface for interacting in the new hybrid situation we will find ourselves inhabiting. This being so, the design of both physical space and digital space are going to have to take place at the same time, in a process of constant feed-back in which both worlds learn from their own and each other's potentialities and limitations. Matter and information will intersect in human activities (Clark, WWW).

The knowledge society will develop a home geared towards knowledge, a place primed for the creation and representation of knowledge, in which the individual, the citizen, in relation with other citizens around the world, can live a life of quality. Now this technology leads us to land on Moon and Mars, it also can lead us to live in the space, building space cities with new life style, healthy environment. After this conclusion of NASA researches, how could we imagine our future space city? This is my dream which can be real one day, it’s a dream of the melting and mixing different environments using meta-technologies to gain new ways, new meanings and new quality of life in the future (NASA, 2003).

6. Building Virtual Worlds to Explore Signs of Real Life in Space

"Somewhere between reality and the unknown, science fiction has always flourished. The best sci-fi authors rigidly adhere to one principle: Make it as real as possible, given what's known. Now, as if lifting a chapter from an Isaac Asimov novel, NASA plans to create hundreds of "synthetic planets" that might represent real worlds orbiting faraway stars" (NASA, 2003). Discussions of the relationship of the actual to the virtual tend to polarize even more rapidly than discussions of morality, politics, or gender. Remnant of our predator/prey days, an exclusionary either/or mentality makes more detailed considerations difficult. In considering the urban implications of a transmissible architecture, we will have to set aside binary oppositions and establish continua between extremes that may well wrap around to meet at their most distant ends.



Interactions between virtual and real world

The **DIGI-City** will be suffused with intelligence. Sensors and effectors will be ubiquitous and will be linked everywhere with information utilities as common as running water. How can we begin to envision such a city? The problem of the design of "intelligent environments" can be instructive. Each term, and their relationships, can be replaced by "tuples". "Intelligence" can be replaced by Howard Gardner's seven types of intelligence: Visual, Verbal, Mathematical, Bodily, Musical, Interpersonal and Intrapersonal. "Environments" can be seen to be of at least three types: Actual, Virtual, and Hybrid. The loci of application of intelligence to environments can also be listed: in, on, of, and by. If we map these tuples onto a coordinate system, we create a space of possibility for:

- What intelligent environments might mean?
- What projects might be undertaken?
- What directions explored?
- What is the bodily intelligence of a virtual environment?
- How is intrapersonal intelligence exhibited by a hybrid environment?
- How can technologically augmented intrapersonal "intelligence" enhance an actual environment?

Once we have understood some of the features of this space, we can add dimensions. What is the range of urbanism? (Toroidal Colony, 2002). There is no question that urbanism as we know it will be altered, that our cities will become our interfaces to the net, that we will really be able to "reach out and touch someone" across the planet and as far as our transmissions will allow. As important as the understanding of those changes will be, we must not forget to see the larger change: a new, non-local urbanism is in the making.

This new urbanism, trans-urbanism, freed from a fixed geometry, will have to draw upon set theory and the physics of a quantum universe.

As distant as this may appear from the city as we know it, the trans-physical city or as I call it DIGI-City will not be the post-physical city. As the prefix *trans*- implies, it will be at once a transmutation and a transgression of the known, but it will also stand alongside and be interwoven into that very matrix. In order to develop **"the DIGI-House"**, which will include both; the design of spaces and objects and also the development of software, 20 different layers have been defined; the people responsible for supervising these layers will set out to define specific areas of development with the potential to take on a life of their own beyond the "DIGI- House". If remote control can change our understanding of TV watching behaviour – a form of activity that is relatively simple – imagine how extreme the effects which digitally enhancing a desk or work surface will have on space behaviour. Imagine the effect of 'remote control' furniture, objects, doors, lighting, and wall transparency. Email has already reshaped the people communications. But e-mail is just the beginning. How will life be restructured when we have an easy virtual communications tools?

And this is just the beginning. Computation is moving out of concentrated areas, such as computers, and into our walls, desks, ceilings and furniture in ways we have barely begun exploring. In a limited way in laboratories right now, rooms can sense activity, morph their appearance, and dynamically adapt to workflow or activity needs. We can collimate sound so that two people can speak across a room without others hearing them. We can project light onto walls or through translucent surfaces. And, of course, we can create shared virtual environments inhabited by digital libraries, software agents, avatars, and telepresent versions of ourselves which can assist in the creation of interactive information spaces – *three dimensional intranets* – which can help us manage the impossible increase in information now confronting us.

6.1 DIGITAL OBJECTS ARE NEW KINDS OF OBJECTS

The first step in integrating different materials is to understand the basic nature of each. This is especially true for our efforts to wisely integrate the digital with the physical. Two things should be kept in mind: ***Digital*** and ***Physical*** objects have different basic properties and so digital objects can be exploited in ways that are impossible with physical materials. Interactivity with digital objects can be defined by us, so the limiting factor in how we interact with digital objects has more to do with our imagination than with natural constraints.

Should we expect less from the design of rooms and buildings? If we just use digital technologies as substitutes for existing physical ones, we will fail. To make the best use of the additional functionality which the digital world can offer, we must think outside the physical box in two ways. First, we must think of how to use the digital in ways we cannot use the physical; and second, we must invent new forms of interactivity which liberate us from our conventional modes of relating to objects (Raskar et al, 1998).

Nothing helps free thinking more than reflecting on ultimate principles, in this case, the irreducible differences between physical and digital objects. It is at this point that we must free our thinking. Digital objects can be delivered at lightning speed almost anywhere. They can be duplicated essentially for no cost and they need next to no room to be stored. Indeed, there is no longer any real sense to the question of where they are stored since 'the network is everywhere' and systems are becoming increasingly distributed. One file, a thousand copies anywhere, just in time, and just the way you want it (big font, small font, annotated, read only, modifiable). Moreover, the very rooms in which these digital elements are embedded soon will contain thousands of sensors and small actuators. How shall we exploit this new found interactivity?

6.2 THREE DIMENSIONAL INTRANETS

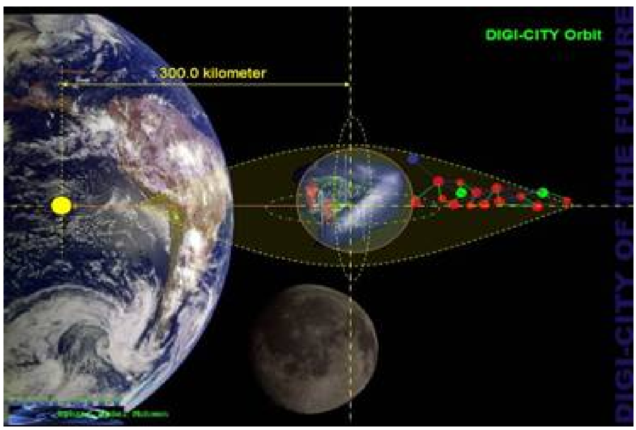
A second major change digital everything makes possible is three dimensional intranets and anytime, everyplace personal information networks. At present, corporate and personal intranets are accessed through computers. As these move out of laptop and desktop boxes to walls, windows, furniture, and ceilings, and as our means of interacting moves beyond the confines of mice, pointers, and tablets, we will interact using speech, gesture, and everyday objects. Sensors will be everywhere and processors will be devoted to making sense of this new level of context awareness. Perhaps this will take another five years in laboratories, perhaps it will take fifteen.

Even now, though, projection of information onto walls and work surfaces allows users to interact standing up and by touching and pointing, often on a writable surface such as a whiteboard. The extra space this provides for organizing information means that we now can massively increase the number of entry points to information we have in a room. Intranets and digital libraries can take to the walls. But with that increase in power comes the need to design the interface to all this information with the presentation parameters of walls and ceilings in mind. Information architecture will have to take account of physical architecture (Raskar et al, 1998).

In my vision to build the future healthful city, it's the reactions of the Era technology. According the vast acceleration of digital technology in the last 20 years, we can predict the fact of mixing the real into the virtual and vice versa. But the question that we have to think to solve and save our souls from new diseases, what equation or what Code we have to use to integrate the virtual into the real? I think the digital technology is going to control everything, so we need to protect our souls from its diseases (viruses) that might destroy the human nature.

7. The DIGI-City

DIGI-CITY is a Real Space City orbits the Earth, 300 kilometres above the surface of our planet. This structure orbits the Earth in the same orbit as the Moon in a stable position that is equidistant from both Earth and Moon, It has a Digital Infrastructure, its urban environments is a data transformation according to energy absorption of its users. It's the interaction between physical and digital environments.



DIGI-CITY proposed orbit; Author.

Abundant solar energy and large amounts of matter from the Moon are keys to successfully establish a community in space. Not only does the sunshine foster agriculture of unusual productivity, but also it provide energy for industries needed by the city. Using solar energy to generate electricity and to power solar furnaces that colonists refine aluminum, titanium, and silicon from lunar ores shipped inexpensively into space (Streitz and Holmer, 1998).

7.1 DESIGN SPECULATION GOALS

This system is intended to meet a set of specific design goals established to guide the choice of the principal elements of a practicable colony in space. The main goal is to speculate the design of permanent community in space that is sufficiently productive to maintain itself, and to exploit actively the environment of space to an extent that permits growth, replication, and the eventual creation of much larger communities. This initial community is to be a first step in an expanding colonization of space.

7.2 THEORETICAL FRAMEWORK

Houses, buildings and public spaces sensitive to the incidence of information and its development in mechanisms within and with which they relate and interact with one another. The innovation with which the digital world is constructed needs to be carried over into the physical world. Technological advances in effect makes it possible -and with ever increasing rapidly- not only to simulate models of growth but to animate structures, anticipate processes and generate flexible, interactive systems whose definition is based on fundamental patterns/programs and duly processed and transformed messages/data.

The digital world is ushering in -it is still in its early stages- a space rich in embryonic possibilities; a space open to new programs and new spatial definitions born of operative environments/systems ("reactive" mechanisms) that are capable of "reacting" to and "mutating" with reality, and thus capable of "tuning in" to and "acting" in and with it at the same time. This heralds a new period of architecture in relation to other spheres of production, a new phase that will in all probability see the introduction of previously unimagined -or at best vaguely intuited- techniques and formal concepts in every aspect of the construction -and the whole conception, representation, design and simulation- of a dynamic and changing, evolving and elastic space and its connection with the very development of techniques and technologies themselves. These dynamics affirm themselves as merely the "potential" of what is anticipated as a new "phase" among the last vestiges and reformulations of modernity, the most forceful manifestations of which can be envisaged as a new **"advanced architecture"** related to the extreme operativization-both **virtual** and **real** of the new technologies and the assumption of a multiple and as such more complex space-time-information, definitively linked to what has come to be known as the **"digital universe".**

This will be an architecture involved in the conception, organization and design of possible evolutionary systems capable of responding to the challenges of the new informational environment that is already being anticipated: the analysis and strategic reformulation of a city in equilibrium with and within the territory (and not only of its movements and growths, but also of its infrastructures and relational spaces); the definition of a technical development and an intelligent construction capable of interacting effectively with an innovative industry by means of versatile, combinable systems of production; the application of new operative concepts in the design of an "interface-habitat" (of the residential cell and the scenarios -interior and exterior- associated with it); the assumption of the new eco-media and the relation between these and an instrumental approach to the landscape -and to a possible "new nature"- associated with a (paradoxically) more radical because artificial ecology: the new possibilities of programming and computer animation translated into a possible digital "genetics" of form and a possible definition of simulated scenarios, real and virtual, etc.

How architects resolve the material with the virtual will shape our experience of buildings and enclosed space for the foreseeable future? The problem is not theirs alone. Fundamental concepts are in transition and it is the job of cognitive scientists, new media analysts, and computational scientists to understand the implications for human interactive behaviour (Popma, 1971). I have argued that the concepts of psychological space and place are changing; that the concept of enclosure is changing; that our idea of what is furniture and what is architecture are changing.

Architects, until now, have been able to concern themselves almost exclusively with the experience of spatial structure, functional effectiveness and aesthetic feel. But henceforth they will have to be concerned with information architecture too. That for how people navigate through information space. They will also be linked to how they move around their offices and use the shapes therein. Buildings will forever serve to support and house, but as the digital permeates our physical world the way we experience architected structures will have less to do with the material nature of those structures. The wired world is not the same old world (Kirsh, 2001). DIGI-CITY vision has been created according to NASA researches and studies as the present space technology source. But I have built out my view with the prediction of the future vast technology exchanges.

7.3 DIGI-CITY FRAMEWORK

It is a computer system that contains social and physical way of life. It is the digital and physical interaction environmentt.

7.4 DIGI-CITY DATA: "THIS IS A PROPOSED DATA"

Date of construction:	2050
City Volume:	24 Million cubic meters
City Orbits distance:	300 kilometres from Earth surface
Energy:	Nuclear + Solar Energy
Expected age:	500 years
Earthy Wight:	22 Million tons
Orbit Wight:	00 Million tons
Capacity-dwellers:	12 Million individuals (4 millions families).
Start Capacity-dwellers:	50 families = 200 persons

7.5 DIGI-CITY URBAN

New Method of Construction:

Constructing under zero gravity and with good vacuum it may be practical to form new shells and new materials. Using Robotized Labours we could build the dreams constructions.

Streets:

Light structure Streets are constructed whenever you go, connected

Landscape:

Fibre Optics, laser and virtual 3D. screens landscape structure connected also to the main frame, which leads users or inhabitants order the environment of landscape they prefer, and they will see what needs, and each person will see different view according to some signals from a personal microchip fixed to the human body, this means that you can fly by your car above the pyramids and the Nile river "Egypt" or you can dream that you are flying on the top of the Eiffle Tower "France". Real farm "forest" is an important part of the city; it's a highly controlled farm that produces every thing using the genetic science, even producing new products and new healthy vegetables and fruits. It has many kinds of trees and animals.

Vehicles:

Cars are flying such as "flying saucers" by nuclear power engine; which wireless connected to the main frame. People can move around the city in no time, they could also move out of city with some precautions and permissions to visit other cities around.

NASA space vehicle designs

Walking passages:

It is anti-gravity environment in general, but you can find the gravity = "Earth gravity" inside the buildings, you feel like in your Earth home with all the furniture and equipments, but in addition, all objects and furniture are intelligent and connected to a personal computer system which is connected to the city mainframe. DIGI-City is our future city, orbits in the space.

Recycled infrastructure:

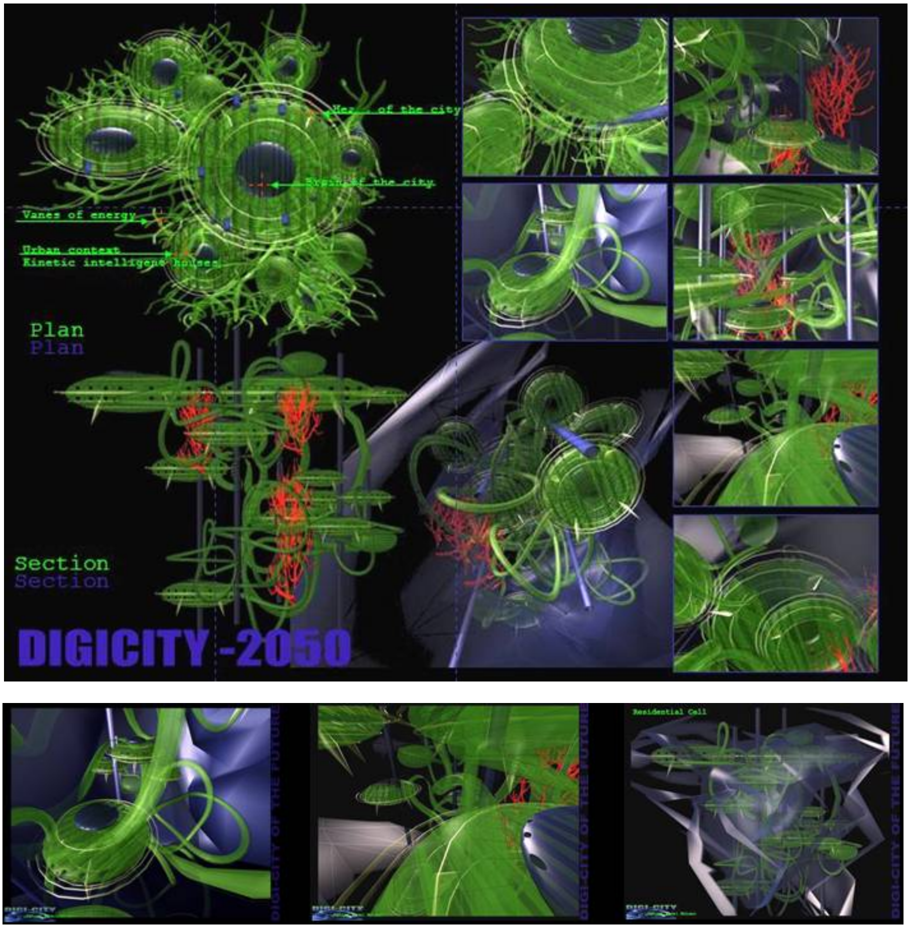
DIGI-CITY is a Recycled, Intelligent and Environmental City with an electronic Brain "Mainframe" that controls every thing. Water gained from evaporating absorbing solar energy using the Sun lighting and heat by electronic cells, drainage system is connected to recycled operation and reused for plants in the settlement. Oxygen is produced from the main part of the city "City Farm".

Industries and Agriculture:

The main Industries in our city are Medicines, Electronics and all technical industries for Earth people that need high degree of anti-polluted environment. They are all produced and controlled by technical robots, those industries will be exported to every country all over the Earth. DIGI-City Agriculture, produce the best healthful vegetables, fruits and beans all over the world in this time, it is production is controlled by a very accurate and sensitive technical system with the cleanest environment have ever gained.

Services and civic centre:

DIGI-City Civic Centre is mostly a virtual centre, it contains some physical buildings for social communication as: restaurants and cafes, cinemas and theatres, sports and social club. All services are connected to the city network which is connected to universe network UWL; Universe Web Link. One can use all services through the network and will be delivered to his accommodation cell or unit by another kind of Robots, those services include: shopping, registrations, official documents, entertainments, social relationships by connecting and viewing any point in Earth using satellites hyper technology or by moving to another city.



DIGI-City Architecture; Author.

City Governorate system:

DIGI-City Governorate is an electronic system controlled by another type of Robots connected to special system, updated automatically. This system has human administration, but they are working as technicians for that system, this system is empty of corruption but could be full of viruses that need technicians to avoid its attacks.

Community hierarchy and relationships:

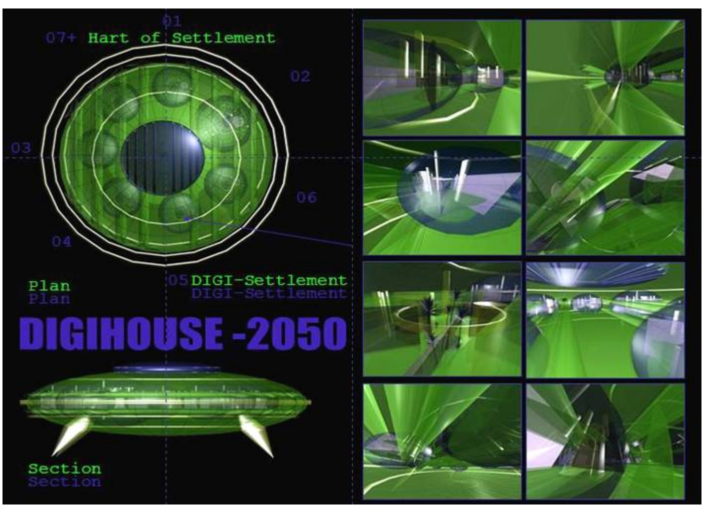
DIGI-City is a sort of community that has new rules and new kind of relationships not far away from the existing relationships of this electronic age. People now spend most of their time sitting in front of computer monitors, but tomorrow computers will control human beings, but they will never reach their hearts and brains.

Residential cells = neighbourhoods:

Residential complexes consist of many houses starting from 5 to 50 houses for each cell or neighbourhood, each cell have its heart < "civic centre" and it is Brain < "intelligent services control system". Houses are planned to move from one cell to another, from city to another. A house is a space vehicle that contains a local vehicle which people can use to walk or move inside the city. Cells are connected to each other by energy beams that change its colours from blue to red related to energy absorbed from the movement of people through the urban environment of the city. This energy is one of the energy supplies of the urban environment.

7.6 DIGI-CITY ARCHITECTURE

The "DIGI-City Houses" is thus conceived as an electronic cell, it is a technological environment, oriented primarily at objects, it is a new interaction between the physical world and the digital world, in order to lay the foundations of a new "art of dwelling"-future space city. The "DIGI-House" will not be "a house with a computer"; instead, the house will be the computer. As Neil Gershenfield says, architecture will never be inert again. Walls and ceiling are covered with one of the technological wonders of the 21st century: Phases array optics, it's an intelligent optics connected to the Personal Identification System (PIS). Here is my point of view to the future space house architecture, after solving all problems concerning the space extreme environment. They are three main points concerning Space, Technology and Society.



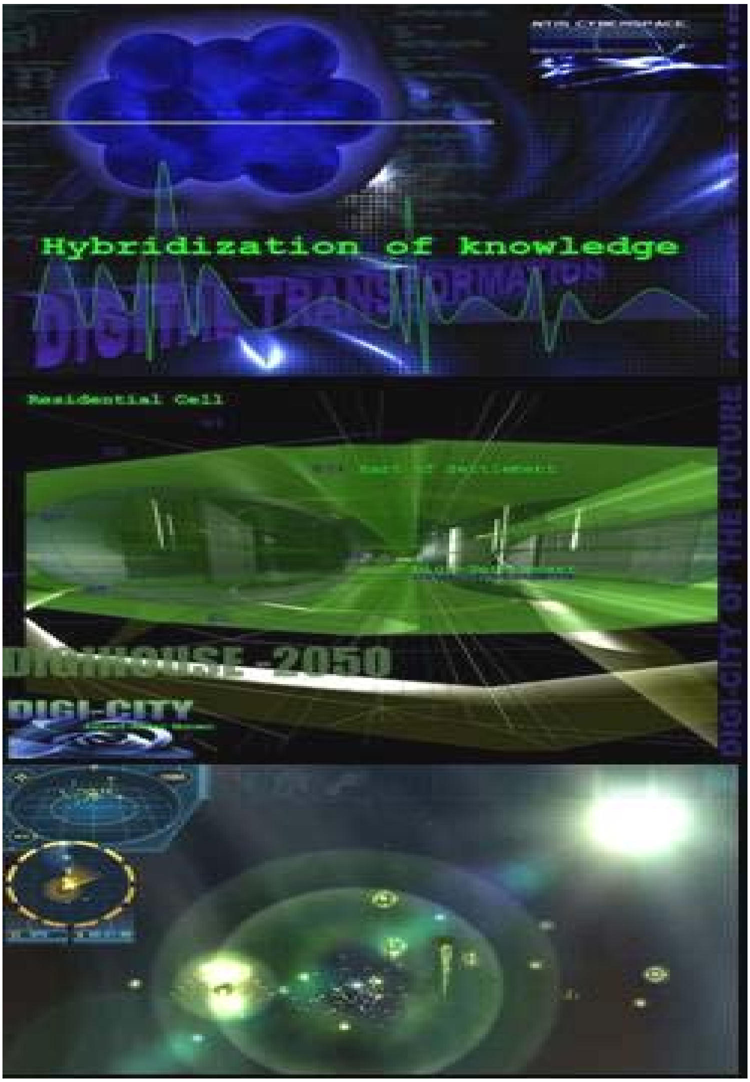
DIGI-House Architecture; Author.

7.6.1 Space

If the home is a place for work, leisure, shopping and rest, DIGI-CITY-House is a micro-city. It should be designed as multifunctional house. It's the real interaction of natural, artificial, virtual and digital spaces. It fits the physical requirements of human beings as it fits to carry out the personal dreams by the personal interaction of virtual world. That can be done by:

- DIGI-Houses "cells" should be designed to ensure a total flexibility of the future Era uses; it's a Data Use House.
- DIGI-Houses is the place where people Tele-work within the system network.
- DIGI-Houses is the place of Leisure, people can play at scale 1:1, virtu-physical playing tools.
- DIGI-Houses have a unique space for personal Vehicle "flying saucer", it's an intelligent vehicle connected to (PIS) and to the main frame, it could select the ways of moving according to the city traffic plan in that moment. It moves with a speed almost the speed of light, it has a nuclear endless power engine, and it flays or moves through light structure streets. All are connected to the city mainframe system.
- DIGI-Houses have off course an immersive. VS "Virtual Simulator" and conference space to live in any place on the whole world, or to connect with any persons or aliens all over the universe.
- DIGI-Houses Kitchen have to be connected to (PIS), all its components are intelligent recycled objects, they feel and obey house keeper "Robot" orders.
- DIGI-Houses Bathroom have to be connected to (PIS) and the Infrastructure Network System (INS), all its components are intelligent recycled objects, each house have one water treatment unit that leads to reuse the used water for planting and supplying the flash units .
- DIGI-Houses Bedroom is the deeming space, you can choose or control your dreams besides you could choose the romantic atmosphere you need to sleep in. All skin layers reshaping the sleeping space are intelligent enough to reflect what you need.
- DIGI-Houses have many real windows to the virtu-physical landscape, and it has also many virtual windows. LS "Land-Screen" leads you to select what you need to see over.

DIGI-House; Author



DIGI-House & Hybridization of knowledge; Author.

7.6.2 Technology

- UWL; Universe Web Link, DIGI-Houses are computers connected to the universe web link network < it's a new way of internet.
- PIS. "Personal Identification System" is the human house interface, which controls the flows of information between the physical and the digital world at the house (cell) or at the city as whole or even at Earth; it's connected to the city orbiting satellites.
- DIGI-Houses are wireless houses. Information's reach objects and spaces using a kind of infrared cells and radiations.
- IO. " Intelligent Objects" and furniture
- INS. "Infrastructure Network System"
- H2H. "House To House" a house does think by incorporate their IPS and incorporating genetic learning algorithms. Houses are related to each other, they could recognize and behave. For example if there is a fire in a house, all neighbour houses start to apply for the emergency proceedings such as: cut off electrical fields, start cooling the exterior skin of the house, collect all flammable objets to emergency case.
- HRS. "House Recycling System" = sustainable house, including water, drainage, oxygen, garbage, food and even electricity could be recycled by a way of reusing the energy of light.
- ILS. "Intelligent Layering Surface". House spaces could modify their size in relation to their activities and energy. It has an intelligent sensitive skin layering, some are virtual layers and others are real and they both construct the real house surface. Those layers could control the energy import or export from a house, it also save the house (cell) from any external environmental changes, besides it gives many types and kinds of meaning and feelings to space users.

7.6.3 Health and Society

- New social relations produced in DIGI-City, the technological systems such as UWL, PIS, IO, and city mainframe are the structure of the virtual social relations in this society. Besides the physical relations gained by the city civic centre.
- Health Care and Medical treatments is going to be natural treatments according to technical specific calculations of personal health evaluation data which stored each hour by (PIS) and then reacts as accuracy orders to the other systems specially the Kitchen system (healthy food and drinks needed in this sutation), besides some physical treatments will be done using the furniture system which it can do it in a specific period.

- Homesickness will disappear gradually by virtual treatments. A period of one age needed to free.
- Food and Water, are always fresh healthy. DIGI-City agriculture in the main farm, produce the best healthy vegetables, fruits and beans all over the world in this time, it's production is controlled by a very accurate and sensitive technical system with the cleanest environment ever existed.

8. Conclusion

This is my vision to the future space life that architects will face; it's a complicated virtual-real clean life. Technology is a vast growth field. Researchers should dream more and more to create new quality of architecture that match electronic media of life. Universe is endless, our minds and creations should be endless in the next era, I believe it will act as real one day.

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Section IV

Computer Visualization in Architecture

IDENTIFICATION, AND VISUALISATION OF CONSTRUCTION ACTIVITIES' WORKSPACE CONFLICTS UTILISING 4D CAD/VR TOOLS

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Abstract. This work addresses the problem arising on all construction sites: the occurrence of workspace interference between construction activities. From a site space planning context, this problem can lead to an inevitable roadblock to the progress of the scheduled construction operations. In real situations, when the spatial congestions occur, they could reduce productivity of workers sharing the same workspace and may cause health and safety hazard issues. The aim of this paper is on presenting a computer-based method and developed tool to assist site managers in the assignment and identification of workspace conflicts. The author focuses on the concept of 'visualising space competition' between the construction activities. The concept is based on a unique representation of the dynamic behaviour of activity workspace in 3D space and time.

An innovative computer-based tool dubbed PECASO (**P**atterns **E**xecution and **C**ritical **A**nalysis of **S**ite-space **O**rganisation) has been developed. The emerging technique of 4D (3D + time) visualisation has been chosen to yield an interesting 4D space planning and visualisation tool. A multi-criteria function for measuring the severity of the workspace congestions is designed, embedding the spatial and schedule related criteria. The paper evaluates the PECASO approach in order to minimise the workspace congestions, using a real case study. The paper concludes that the PECASO approach reduces the number of competing workspaces and the conflicting volumes between occupied workspace, which in turn produces better assessment to the execution strategy for a given project schedule. The system proves to be a promising tool for 4D space planning; in that it introduces a new way of communicating the programme of work.

1. Introduction

1.1. PROBLEMS IN VISUAL WORKSPACE PLANNING

Communicating the construction schedule and strategy of work among the project team members is a unique problem that takes place in most construction sites. This problem is even cumbersome as the built facility generates complex shapes of occupied site-spaces by the executed construction processes. The ideal solutions in traditional space-time planning techniques, have involved textual description, hand sketches with site layout templates, a number of graphical technologies, including bar charts, network diagrams, and 2D/3D scaled visualisation models Morris (1994). However, there are shortcomings of techniques in forming a visual representation of the construction execution workspace:

- Activity workspace execution: Considering the Gantt chart a favourable technique, planners are not capable of communicating visually the execution strategy and plan. In other words, the Gantt chart can be thought of as a '*what to do*' list and sequence of assignments concerning the construction activities. Cheng and O'Connor (1996) claim that, in field practice, construction planners have to interpret space information into poor visual descriptions. However, they do not seem to convey the dynamic behaviour of construction activities' workspace in 3D space and time.

- Mental rehearsal of site operations: Mawdesley et. al (1997) explained that Gantt chart technique does not furnish a *communication medium* on how the project activities on the construction site are to be executed. During the construction phase, the format of Gantt chart does not '*capture*' the visual interaction between the site operations. Consequently, the Gantt chart is not entirely adequate for rehearsing site operations, both in space and time.

- Loss of productivity: Productivity problems were investigated by Kaming et al. (1998) and showed that inappropriate workspace planning caused interferences between subcontractors. Many frequent visits by the workmen had occurred in some zones of the building, which resulted in work interruptions. There is evidence to suggest that workspace interference was a factor in decreasing productivity of work by 40%.

1.2. WHAT WAS NEGLECTED IN CONSTRUCTION WORKSPACE-TIME PLANNING EXERCISE?

Four important issues, therefore, were not highlighted in 4D workspace-time planning. They are:

1. Execution strategy representation: Traditional workspace-time planning methods, such as the space-time Chainage charts and layout motion diagrams, in their most general forms, are ambiguous. Construction planners often express the coordination of the planned schedules based on highly generalised conceptual space terms, such as North, South, East and West. Take an example of a construction planner conveying the execution of *Ground Floor Steel Columns* activity to begin from the East and progressing towards the West. The execution plan of such an activity is left to the workmen on the site. In such manner, work interruptions between site operations might occur Mallasi and Dawood (2001), especially in large complex construction projects, where the site space involves a number of constrained site operations.
2. Construction progress state simulation: The weekly visualisation technique used for the construction progress state is not realistic. Previous site layout planning applied such techniques from a factory/plant perspective that only featured linear patterns of direction for the produced work Zouein and Tommelein (1999). This research proposes a time-based 4D simulation of the activities execution workspace as the construction progress state changes dynamically.
3. Planning in three-dimension: Planning and analysis of construction workspace inside the building requires a three-dimensional approach. In some situations, for example, workspace conflicts could exist in different floors of a building project Cheng et al. (2002). Planners in some construction situations, such as the plant and equipment operation, need to analyse space three-dimensionally. External site layout techniques using the *Grid System* neglecting the analysis of spatial information in 3D, and applied 2D approach that only dealt with horizontal workspace conflicts.
4. Workspace-time connectivity analysis: In building construction, workspace-time connectivity analysis should be based on the intervals where activity execution workspace changes over points-in-time. Nowadays, the accepted view of most researchers is that space has properties related to things, explained Hillier (1996). Further, it is highly acknowledged that workspace behaviour is *'connected'* and relative to its defined properties. From one perspective, research in workspace planning did not provide workspace connectivity mechanism, so that to encapsulates the activity workspace behaviour at any point-in-time.

1.3. INCLUSION OF SPECIFIC VISUAL PLANNING FEATURES

Figure 1 indicates the two levels of project planning: strategic and operational. This study focuses on improving the conventional visual space planning features, utilised in the operational level. As revealed by Gardiner and Ritchie (1999), the planner systematically involves their technical judgment when making the decisions about what tasks will be performed, how the tasks will be performed, restrictions on how to perform them, and who will perform the tasks.

To some extent, these decisions are of a spatial nature and they do not appear to have the adequate visual representation in the traditional planning methods. There are four workspace planning tasks (Figure 1) that can be highlighted during project planning stages: (1) developing a space concept of the built facility (2) planning the workspace requirement based on the construction method and physical resources (3) the Critical Space Analysis (CSA) of workspace conflicts, and (4) the detail output of work execution strategy.

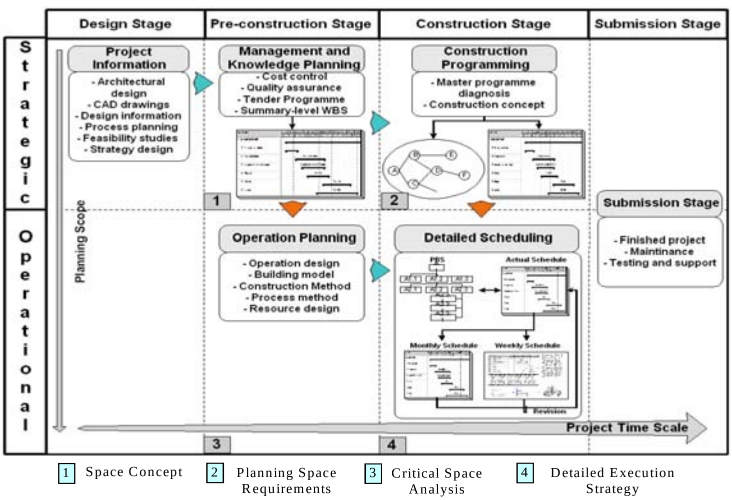


Figure 1. The two planning levels along the project stages including the four workspace planning tasks.

From the above, three main visual features are utilised to help in generating 3D visual representation of the activities workspace configuration. They are explained next.

1.3.1. Visualising Quantities of Work

Planners realise the importance of recording the progress of construction work at weekly intervals, then presenting it on a Gantt chart. This study, therefore, suggests three types for work rate distributions to be included in the 3D visualisation: *Uniform*, *High-Low*, and *Low-High* distribution. In this respect, the example shown in Figure 2 explains the significant correlation between the activity behaviour at a *point-in-time* (e.g. week six) and its completion, based on the three types of work rate distribution.

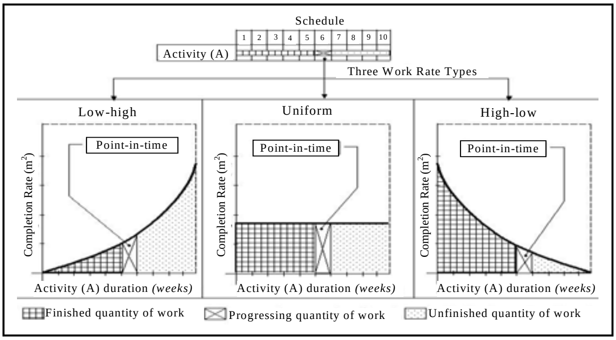


Figure 2. Activity-behaviour at point-in-time based on the three types of work rate distributions *(adapted from Mawdesley et. al (1997)).*

1.3.2. Workspaces Location and Overlap in Time

This concerns the representation of the physical location of workspace overlap between progressing activities across the horizontal and vertical space. This is a simple feature acquired from the Time Chainage overlapping method in one-dimensional space (1D + time). This representation, therefore, is suitable by means of giving an indication of where and when activities workspaces take place.

1.3.3. Execution Patterns (EP)

Planners analyse the execution strategy of work utilising Site Layout Motion diagrams Roberts (1998). This technique has been utilised in many literature to optimise the facility and site layout planning Zouin and Tommelein (1999). Equally, *EP* have been recognised by Riley and Sanvid (1997) as an important element in workspace planning. Visualisation of the motion diagrams technique and the *EP* is improved in this study by visualising the activity execution strategy in twelve *EP*.

This research project automates the above twelve *EP* in the 4D workspace planning. The overall combinations of these *EP* facilitate 4D visualisation of *'what-if'* scenarios based on *Progress of Work (PW)* direction and *Execution of Work (EW)* direction that are considered perpendicular to each other in Universal 2D Cartesian space (Figure 3).

Execution patterns are divided into two main categories. The first is the cardinal category (Figure 3, a), which occurs as a result of referencing the *PW* in the main cardinal directions and the *EW* perpendicular to it. This category produces four *EP* types (e.g. *PW* being executed from the West to the East, and the *EW* in both directions of North and South). The sub-cardinal directions are in the second category, which results in the eight *EP* types (e.g. *PW* being executed from North to South, and the *EW* being executed from the east-west accessed from northeast).

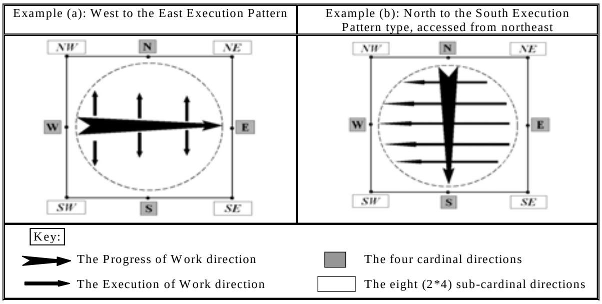


Figure 3. Illustration of two examples out of twelve EP types showing the mechanism of the PW and EW directions.

In this research, EP are divided into two main categories. The first is the cardinal category (Figure 3, a), which occurs as a result of referencing the *PW* in the main cardinal directions and the *EW* perpendicular to it. This category produces four *EP* types (e.g. *PW* being executed from the West to the East, and the *EW* in both directions of North and South). The sub-cardinal directions are in the second category, which results in the eight *EP* types (e.g. *PW* being executed from North to South, and the *EW* being executed from the east-west accessed from northeast).

2. Use of 4D Visualisation Technology

4D construction visualisation is becoming a popular technique in the construction planning. For the last fifteen years, both practitioners and researchers in construction management realised the great promise of such emerging visualisation techniques. Nowadays, the Construction Industry is becoming familiar with the uptake of 4D models to improve visualisation of construction schedules.

2.1. WHAT IS 4D-CAD VISUALISATION?

The most common about 4D-CAD visualisation is that it brings together the Gant chart schedule information (using any project scheduling software like MS Project®) and three-dimensional components of a construction project (using any CAD software). In 1987, the development of the first generation of 4D project scheduling were initiated by the engineering and construction firm Bechtel, in collaboration with Hitachi Ltd. and exploited the characteristics of the fourth dimension Rischmoller and Alarcón (2002). This firm, together with the Martin Fischer research team, from Stanford University, formulated the original technique and basis of visual 4D models, linking project schedule to the 3D CAD model to simulate the construction sequence.

Many researchers have addressed the concept of 4D-CAD in construction management. Although 4D visualisation does not quantify workspace conflicts between the construction processes, there were several research attempts in academia. Some examples can be found in the work by: Akinci et. al (2000a) who formalised construction workspace types and taxonomy; Akbas et. al (2001) identified 4D visualisations technique using *construction zone generation*. 4D-CAD space visualisation has also been identified throughout the Virtual Construction Site (VIRCON) project – a UK research initiative to develop a decision support system for construction project planning Mallasi and Dawood (2002); the technical survey of 4D-CAD research by Heesom and Mahdjoubi (2002) have benchmarked the construction knowledge, framework, and resources necessary to develop 4D models.

3. The Context for Workspace Competetion

3.1. RATIONAL FOR CRITICAL SPACE-TIME ANALYSIS (CSA)

The proposed CSA associates the visual features for workspace planning with the workspace competition. CSA deals particularly with analysing the space-time competition that occurs between construction operations. Therefore, CSA verifies the occupied workspaces by construction operation as competing together. The focus will be on how to quantify the nature of this competition, by assessing criticality of the workspace conflicts sharing the same space. The key assumptions are that the dynamic nature of workspace usage and change should be traced continually and so accommodate space connectivity in the fourth dimension. Once the space connectivity mechanism is established, it would then be possible to quantify the particular effect of critical spaces on the construction work progress.

Hence, the PECASO prototype was developed in this work to evaluate the outcome of the CSA. The 4D-CAD prototype integrates MS Project® scheduling application with the AutoCAD® ADT, via the MS Access® database. A graphical user interface (GUI) is built on top of AutoCAD, utilising the advanced features of Visual Basic for Applications (VBA) programming.

3.2. USE OF PAST CLASSIFICATION OF WORKSPACE CONFLICTS

For the purpose of analysing the workspace competition, the CSA mechanism must provide a reasoning mechanism, in order to minimise the criticality of a construction workspace. If a workspace conflict is expected to occur in a specific week, for example, questions, such as ‘which space-types are expected to interfere during that week?’ and ‘what is the severity and knock-on-effect of such interference on the construction progress?’ must be raised. By providing answers to these questions, the severity (i.e. degree of space-conflict) of the interference can be assessed and work execution adjusted, to allow increase in the productivity of workers on the job.

The theoretical approach for classifying the clash types, was developed by Akinci00a, space-time conflict taxonomy. The space-time taxonomy considers the conflicting space-types among the properties for classifying the clash types (Figure4). The outcome from this is a classification to include the main clash types like congestion, damage, and safety hazard. The result from this taxonomy is the detailed sub-clashes of the main clash types - because different level of congestion might exist on site.

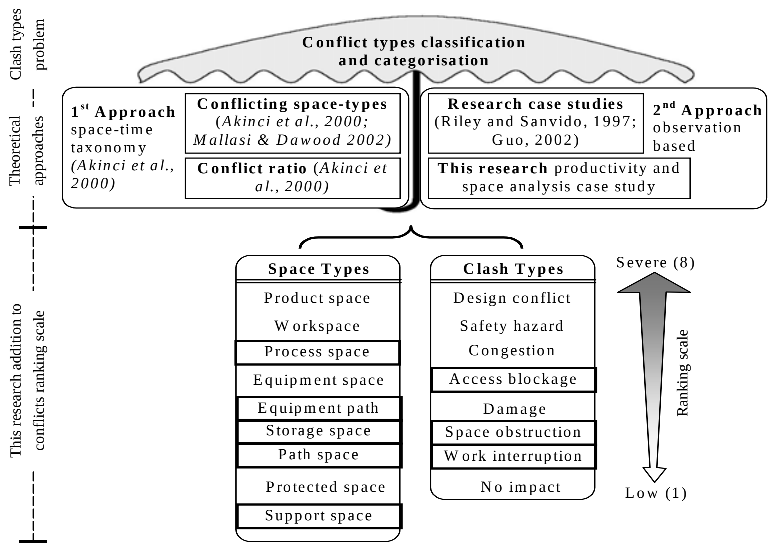


Figure 4. The theoretical approaches for classifying the ranking system associated with workspace conflicts.

As can be noticed in Figure 4, it has been practical in this research to rank the severity of workspace clash types. Some conflict types were added, such as work interruption, space obstruction and access blockage.

3.3. QUANTIFICATION OF WORKSPACE CONFLICTS

The immense amount of spatial data related with the analysis of activity construction workspace emphasises the importance of developing the CSA quantification approach. This is a complex issue and an on-going area of research that has started to receive some attention among the construction research community. The crucial point that is beginning to emerge is the determination of the variables associated with the measurement of space criticality, therefore minimising the severity of workspace conflicts.

This study developed the quantification approaches for CSA, based on literature survey presented in Table 1. The table shows clearly the gaps in the justification of an approach for obtaining the related space properties in critical space-time analysis; also in terms of linking the measurement of the space conflict to the criticality, or severity, of that conflict. As a consequence, there are currently no 'mature' benchmark quantification approaches to spatially analyse and enable a measurement of the performance of the construction schedule. The next subsection describes the proposed measurement and assessment for quantifying the workspace competition.

3.4. PROPOSED QUANTIFICATION METHOD

The proposed assessment of workspace competition quantifies the CSA value. In the interest of CSA, therefore, a multi-criteria evaluation function has been developed. The multi-criteria function will provide a measurement for CSA value, and so values the different criterion for the construction schedule and the workspace data. The multi-criteria function utilises weighting between the multiple criteria. Ramulu and Kim (2003) believe that multi-criteria function measurement is the first important step to formulating a solution to the problem.

The multi-criteria function comprises of the sum of five schedule and spatial related criteria, using various weight coefficients for each criterion. Figure 5 illustrates an abstract example for applying the calculation of the CSA value, based on Equation 1. This study has developed the multi-criteria function $f_A(scr)$ for the possible conflicts between A number of activities during monitoring period D (*per week*) as follows:

TABLE 1. The theoretical approaches for identifying space and clash types.

	Properties and quantification approaches								
Author(s) and date	Variables	Preserve CSA	Volume conflict analysis	Workspace types	Conflict details	Conflict ranking	Visualisation medium	Optimisation approach	Apply CPA criteria and priorities
Thabet and Beliveau (1994)	- Space Capacity Factor	No	Yes	No	No	No	CAD	N.A.	No
Akinci et al. (2000a)	- Conflict Ratio - Clash severity sub classification	No	Yes	Not all	Yes	Yes	4D-CAD	N.A.	Yes
Guo (2002)	- Interference Space Percentage - Interference Duration Percentage	No	Yes	Yes	No	No	4D-CAD	Manual rescheduling	Yes
Winch (2003)	- Spatial Loading	Yes	No	Not all	No	No	4D CAD/VR	Brute force algorithm	Yes

$$\underset{A}{f}(scr) = vw1.\underset{D}{f}(co) + vw2.\underset{D}{f}(r) + vw3.\underset{D}{f}(no) + vw4.\underset{D}{f}(st) + vw5.\underset{D}{f}(cr) \quad (1)$$

where $f_{(scr)}$ = the project schedule space criticality calculated value;
$f_{(co)}$ = the criteria function for the percentage of conflicting workspace.

where

$$f(co) = \frac{\sum TotVolConflict}{\sum TotVolOccupiedSpaces} \quad (2)$$

$f_{(r)}$ = the criteria function for the total number of workspace conflicts with respect to the rankings; $f_{(no)}$= the criteria function for the total number of conflicting activities; *f(st)*= the criteria function for the conflicting space types; *f(cr)*= the criteria function for the critical activities (1 for critical and 0 for non-critical); vw_i = the weighted coefficients for each criteria in the function $f_A(scr)$.

The weighting coefficients vw_i (sometimes referred to as variable weights) are an estimated measure for each criterion governing a priority scheme. By doing so, the performance of the value of $f_A(scr)$ function can be assessed. Although these coefficients could be obtained through trial and error, they could also be *user-defined* values from the project planner. This is most preferable, as explained by Chang et. al (2002), because the value for each weight will be given, according to the 'relative importance' of the criteria attached to it.

Generally, the sum of these weights should satisfy the following conditions:

$$vw_{(i)} = vw_{(1)} + vw_{(2)} + vw_{(3)} + vw_{(4)} + vw_{(5)} = 1 \quad (3)$$

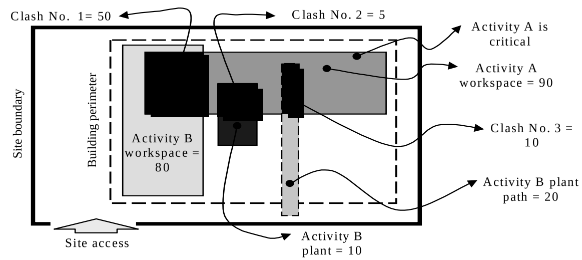
and

$$0 \leq vw_{(i)} \leq 1 \quad (4)$$

The values for vw_i in Equation (3) are the measures of priority for each criterion that is chosen by the project planner. These values range from Zero to One: more important criteria will get a higher weight, and less important criteria will get lower weights.

3.5. IMPLEMENTATION OF TIME-BASED 4D WORKRATE SIMULATION

A key concept in the visualisation of workspace competition is the technique for simulating construction product and processes in a time-based fashion. The time-based simulation mechanism involves the construction progress state in space-time and is done dynamically. Research by Kamat and



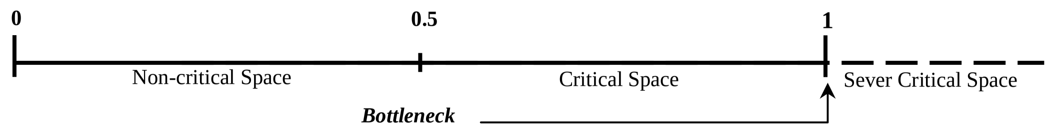
Clashes	Clash description	Total occupied volume	*f(co)*	*f(r)*	*f(no)*	*f(st)*	*f(cr)*
1	Workspace A and workspace B *(work interruptions)*	90 + 80 + 10 + 20 = 190	50	1	2	4	1
2	Workspace A and B equipment spaces *(space obstruction)*		5	2			
3	Workspace A and B path spaces *(damage)*		10	3			
Totals:		Final *f(co)* value = (50+5+10)/190 = 0.34		6	2	4	1
Applying user-defined (vw_i) weights to normalise each criteria:		0.34 * 0.8 = 0.27		6 * 0.1 = 0.6	2 * 0.1 = 0.4	4 * 0.1= 0.4	1 * 0.1= 0.1
Space criticality value $f_{(scr)}$:		0.27 + 0.6 + 0.4 + 0.4 + 0.1 = 1.7 *(severe critical space)*					
4) CSA scale range for the criticality values, and legend							

Figure 5: Examples showing the developed approach for calculating the CSA value of $f_{(scr)}$

Martinez (2001) confirmed that 4D time-based simulation was suitable and highly scalable in designing a generic 4D visualisation system. Arguably, representing the activity-workspace change in time is an abstract simulation mechanism to process the change of activity-workspace behaviour. This way, 4D time-based technique becomes a snapshot of time and workspace simultaneously. The mechanism utilises a visualisation clock as a controller (*dates and times*) for altering the time forward and backward (Figure 6).

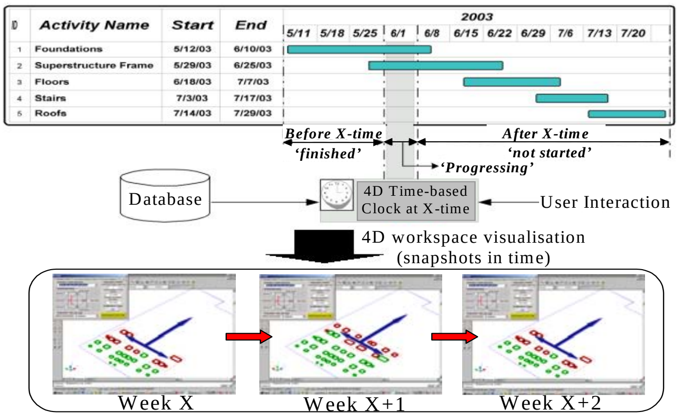


Figure 6. The 4D time-based simulation and the clock control at X-time.

The time-based concept simulates the *Quantities of Work per week* ($QW_{(prog)}$) during three time-based frames (or intervals). The first time-based simulation frame (Figure 6) visualises the '*progressing*' activity-workspace during '*X-time*', based on Equation (5).

$$QW_{(prog)} = QW_{(tot)} / AD_{(tot)} \quad (5)$$

Where $QW_{(tot)}$ = total quantity of work value obtained from the database; and $AD_{(tot)}$ = total activity calendar duration obtained from the schedule information.

The second time-based simulation frame obtains the *Quantities of Finished Work* ($QW_{(fin)}$) from previous week(s) '*before X-time*', which represent the state of completed work. Equation (6) is utilised in identifying this amount of $QW_{(fin)}$.

$$QW_{(fin)} = QW_{(prog)}\ (\text{thisMonWeek-Week}) \quad (6)$$

where $QW_{(fin)}$ = quantity of finished work calculated during *X_Monitoring_Week* (*X_MonWeek*)

The third time-based simulation frame deals with activities that have not started yet *'after X-time'*, and also determines any *Unfinished Quantity of Work* ($QW_{(unfin)}$) for progressing activities (Equation 7).

$$QW_{(unfin)} = QW_{(tot)} - (QW_{(fin)} + QW_{(prog)}) \quad (7)$$

where $QW_{(unfin)}$ = quantity of unfinished work calculated during *X_Monitoring_Week* (*X_MonWeek*).

4. Assignment of Workspace

4.1. EXISTING TECHNIQUES

Sirajuddin (1991) and Thabet and Beliveau (1994), propose that construction workspace is a combination of resource gangs, including their equipment and tools. This is a situation where resource gangs operate and manoeuvre equipment within the direct workspace at the activity location. Another typical case is similar to pouring concrete into pad foundations, using a concrete mixer and a concrete vibrator. Sirajuddin suggested that, to some planners, these workspace dimensions could be obtained either from their previous work experience, or from data, such as equipment and tools manuals. Similarly, Akinci et. al (2000b) incorporated a concept for assigning project-specific space requirements associated with a construction method model into the 4D WorkPlanner Space Generator. The positional information about space was modelled using an allocentric representation (such as, roof scaffolding outside or inside a building envelope).

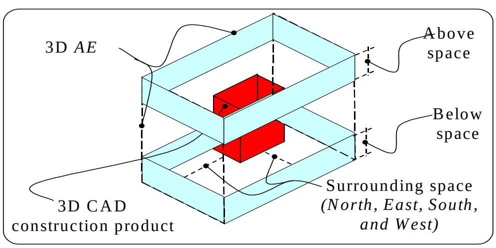


Figure 7. The three workspaces properties associated with the 3D *AE* around a construction product.

To specify the workspace requirement in a dynamic way, while satisfying a set of spatial dynamics and change of workspace usage over time intervals, is a difficult problem as there are many alternative space strategies to apply on the logic of work execution. Therefore, it was decided in this research to design the construction workspace based on the *Approximation Envelope*

(AE) that uses a 3D Box to represent the activity workspace (Figure 7). The *AE* technique improves previous research efforts, by including the characteristics of workspaces like: above, below, and surrounding (*North, East, South, and West*).

4.2. CAPTURE OF DYNAMIC REQUIREMENTS FOR WORKSPACE

The assignment of workspace based on the 3D *AE* provides the planners with generic capture of different workspace requirements, according to the nature of the construction activity. The application and concept of the 3D *AE* for workspace representation is provided in the example in Figure 8. The example shows two construction product groups 'A' and 'B', and the plant associated with them (Figure 8, a and b). Even when the location and position of the products associated with the construction activity are changed, the assignments of the workspaces are dynamically reconfigured utilising the 3D *AE* (Figure 8, c and d).

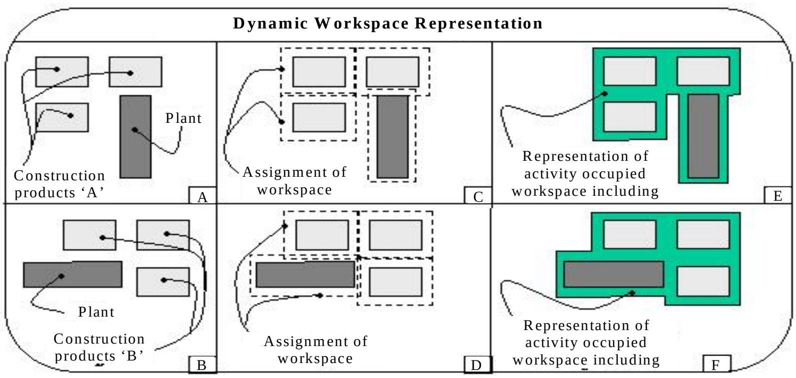
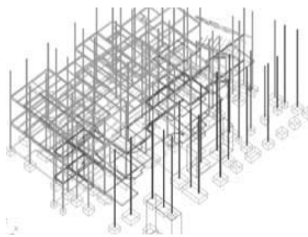
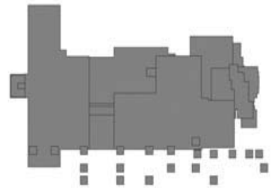
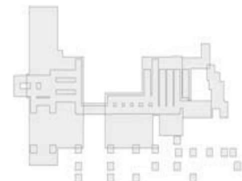
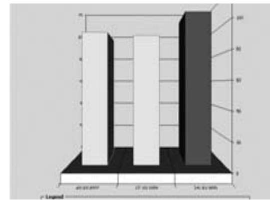
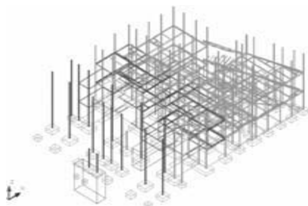
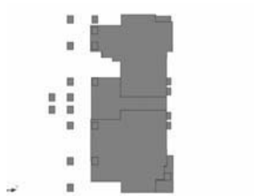
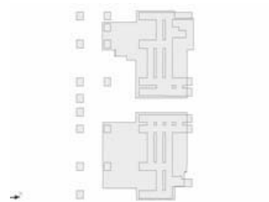
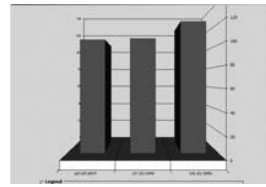
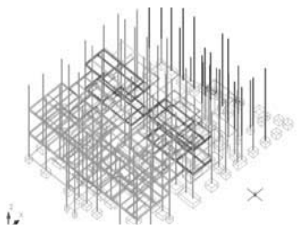
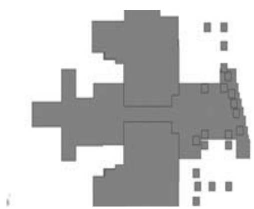
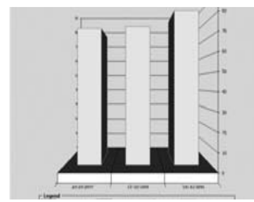


Figure 8. Representation of dynamic workspace configuration utilising the 3D *AE* concept.

5. Experimental Results of Workspace Competition

The author utilised the PECASO 4D tool to experiment with CSA results and hence evaluate the workspace competition concept. The CSA values are obtained after running three scenarios utilising the PECASO 4D simulation approach. It was important to consider in the analysis the occupied workspaces by the resources on site like plants, material paths, and storage areas. On a weekly basis, the simulation results were exported to the MS ACCESS database for future evaluation of the space criticality function $f_A(scr)$.

TABLE 2. Three weeks of workspace variation and minimisation of CSA values $f_{(scr)}$ for three experimental 4D simulation runs

Run No.	4D Visualisations	Top View pf Site Space Usage	Top View of Site Space Conflicts	CSA Chart Report
1) *EP*: North-South				 Original CSA ≈ 1.08
2) *EP*: East-West				 Max. CSA Value ≈ 1.21
3) *EP*: West-East, access South-West				 Min. CSA Value ≈ 0.83

A typical experimental illustration for minimising workspace conflict is shown bellow in Table 2 and applied on the School of Health project case study. The simulation began with a max CSA value of 1.08 representing the actual project schedule (run No. 1). The alteration of the above variables for minimising workspace conflicts indicates a reduction of CSA by 0.25 less than the original schedule (run No. 3). The reason for this minimisation is due to the variation in *EP* type for the Ground Flooring Concreting activity (North to South), while the rest of the activities were progressing from the West to the East. At the same time, the occupied workspace by the plant moved to a space free of congestions and reduced the total number of conflicting space types *f(st).*

6. Summary

This paper introduced the workspace competition as a new concept for minimising workspace congestions occurring on construction sites. Visual planning features like: twelve execution pattern types, three different work rate distribution types, and time-based QW simulation were identified and implemented in the developed 4D visualisation environment. The design of a multi-criteria function was the core of the PECASO approach for evaluating the CSA value. Based on the experimental results, the PECASO CSA approach is expected to increase the planner's awareness for workspace planning and become more confidence when using 4D visualisation for communicating the project plans. One could argue that the advancements in 4D space-time conflict analysis relies on capturing the dynamic nature of construction site operations. The results also suggest possible future use of the proposed technique in 4D workspace planning.

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COMPUTER VISUALIZATIONS IN PLANNING

Computer Techniques for Visualization of Development Scenarios for Historically Important Landscapes and Urban Spaces: The Case of Nablus

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Abstract. A wide range of visualizations have been developed and implemented as tools for urban simulations and visual impact assessment. These include: plans, diagrams, elevations, perspective sketches, renderings, modified photographs (photo renderings and photomontages), slide projections, scale models, movies, videotapes and computer graphics. In the last decade, graphical computer applications have proven to be an increasingly supportive tool in visualization and manipulation of graphical material. This study presents the state of the art of computer visualization in planning. More specifically, the use of web-based computerized visualizations for landscape visual simulation, with the aim to develop a system of visualization techniques as an aid to communicating planning and design scenarios for historically important landscapes and urban places, with particular attention to the city of Nablus in Palestine. This has led to the evaluation of possibilities and potentials of computer use in this field, and to the definition of the visual problems and challenges of the city of Nablus. This study will argue what extra one can draw from computerized visualizations, what is likely to be its impact on future planning and design research, and what this visualization experience really means for historical important locations as in Nablus. The study demonstrates that computerized visualizations can be a powerful tool in representing a cityscape in three-dimensions from different angels. Visualizations will allow better understanding of the components of the city, its landscapes, city features and the process of change. In this way it may provide new and better platforms for public participation in planning.

1. Introduction

In city and landscape planning and design there is in many cases a need for the ability to mix reality and virtuality. Or in other words; to understand the visual effects or impact from a specific development or project implemented in a local area you must try to imagine what the future physical elements, such as buildings, roads or trees will look like and how they will integrate in the area. This task can be done in many ways. Planners and designers used many classic analog visualizations tools for the representation of ideas. For ages planners and designers used the ability to create perspective drawings and paintings where reality is mixed with planned objects. An example illustrating the use of **perspective** sketches is the work conducted by Emmelin and Brueswitz (1991). They used hand made drawings sketches in order to view possible changes in the Swedish landscape (See Figure 1).

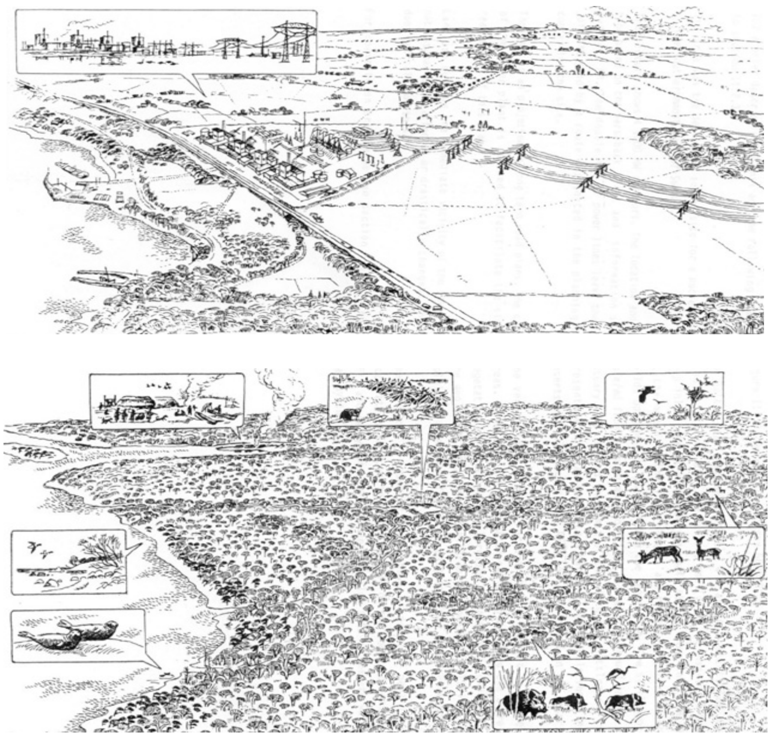


Figure 1. Emmelin and Brueswitz (1991), showing possible changes in the Swedish landscape through sketches.

Among landscape architects Repton (1803) can be seen as an early pioneer in visualization. In his Red Books Humphry Repton concentrates on the representation of proposed changes in the landscape in **perspective view** comparing the existing situation with his proposal. Two slides as Repton called them, were hinged at the bottom so that the slide depicting the proposed improvement could be flipped up to cover only those parts of the slide depicting the existing landscape that were to be changed (see Figure 2). Repton suggested this provided a more effective way than maps or plans to help his clients visualize the effects of proposed changes.

Figure2. Humphry Repton slides (1803), showing the landscape before and after the development.

Another option is to build **physical models**, which illustrates the terrain and the existing buildings together with the developments suggested in the project. A third option is to make **a photomontage,** by attaching the proposed scheme onto a real site photograph and give the impression of a completed situation within it's actual context. There is at least one big disadvantage with these conventional methods. It is almost impossible to change the plan without creating a new illustration or a new physical model. The flexibility you need when the conditions in the plan or the subject of visualization are changed is not there. Furthermore the ability to show visualizations of more abstract geographic information in perspective view is not there either. This may not be a major problem for the professional designers and planners, because they have learned and trained to interpret the planning documents. However, it is certainly a very tangible problem for the politicians and the common citizens in the area of interest. They have to trust their own imagination or the few illustrations and models that are made from the information given in the planning documents. Members of the general public who are not so familiar with the habit of planning documents may not fully comprehend the developments that they represent, and may find it difficult to comprehend how new developments would ‘fit’ into the environment. Stanley King and his co-authors (King et al., 1989) suggest that visualization is the key to effective public participation because it is the only common language to which all participants technical and non-technical can relate “*Visualization provides a focus for a community's discussion of design ideas; it guides community members through the design process, it raises their design awareness and facilitates better communication*”.

Therefore, there is a great need for new and better ways to visualize the effects of proposed developments, especially because the citizens of an area have the right to know how the implementation of this plan will affect the area they live in both visually and environmentally. In this way, visualizations will secure the opinion count of community groups, and it will work as instrument to communicate design and planning proposals between planners and the public.

2. The Case of Nablus

In a topic of a recent PhD-study carried out at Department of Landscape Architecture and Spatial Planning at NLH – Norway by Hassan (2002), Nablus is identified as an important geographical, historical and cultural city. Nablus lies in a valley between two mountains, Mount Ebal (940 meter) above sea level and mount Gerzim (870 meter) above sea level on the south. Most important is the fact that different planning strategies have determined the Nablus image and form in the last century. The developments that occurred in the last period helped the city growth, but there were no clear regulation and orientation to control this growth, which lead to several problems concerning the city’s visual appearance from both architectural and planning views. This development now leads to the destruction of the image of the two main hillsides of mounts Ebal and Gerzim. The result is a vast deterioration of the city landscape and environment. There is little respect for planning considerations that care for the aesthetic values of such an ancient city (See Figure 3). Based mainly on its distinctive physical, functional characteristics, and the development trends, the city of Nablus may considered to be composed of three main parts: 1) The Inner city - with the Old Town part: a district rich of historical evidence. 2) Mount Ebal and Gerzim hillsides (see Figure 4): two district areas, with fast city development activities. 3) The Eastern and Western plains: two districts, originally kept for agricultural and industrial uses, later they became place for refugee camps and new housing development projects. On the background of

Nablus' geographical and historical importance, and as the city continues to expand and more building activities are taking place, the study classifies two main visual challenges regarding the city appearance, which the city might

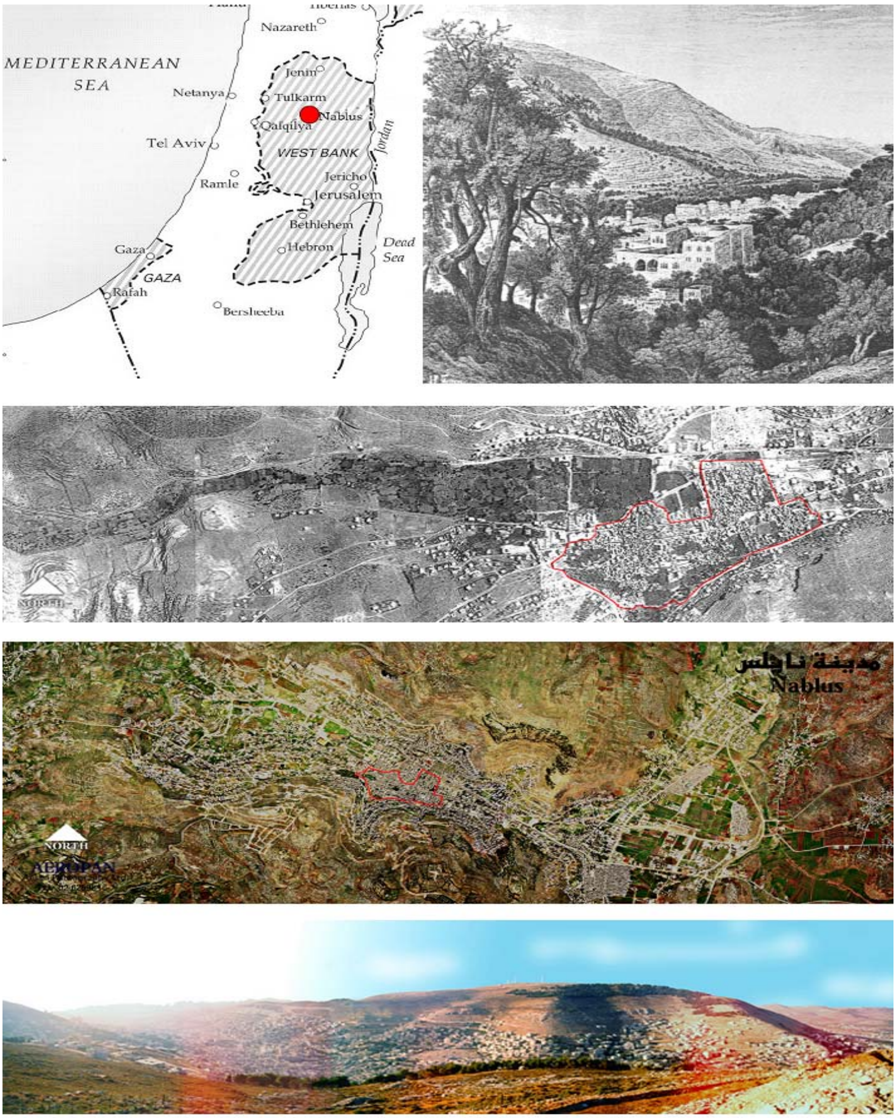


Figure 3. View on Nablus, from left side and down: Map showing location of Nablus; View of Nablus from19th century as seen by Wilson, C.; Arialphoto of Nablus from 1944 with the Old City in the center; Arialphoto of Nablus from 1999 with the Old City in the center; View from Mount Gerzim looking northwest, shows the typographical location of Nablus between two mounts.

face in the future: *The first* is the visual challenges on large city scale. This can be represented by the continuous developments on the hillsides of Mount Ebal and Gerzim, enhanced by the high visibility of the hillside, which represent a unique situation in which changes on the hillsides can be seen from almost any place in the city (See figure 5). *The second* is the visual challenges on district or local scales in the city. This can be experienced in the inner city part, where many open spaces and leftover archaeological sites around the Old Town are threatened by new building activities. This might have an effect on the Old Town and city appearance in general.

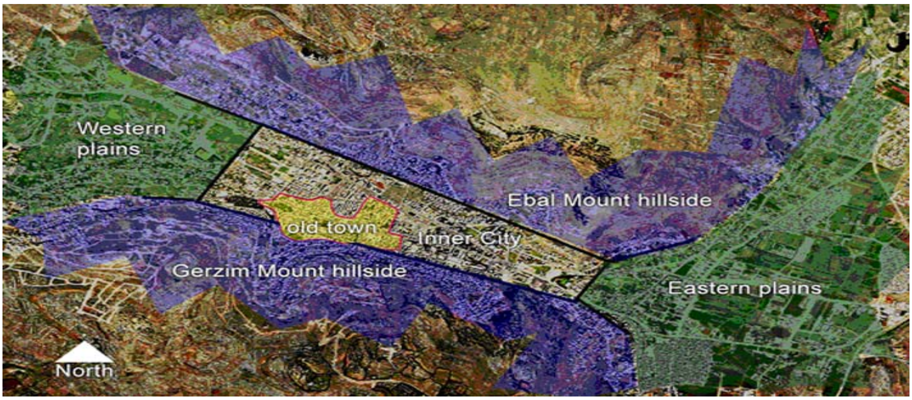


Figure 4. Illustration shows the main three zones that characterized the landscape of Nablus.

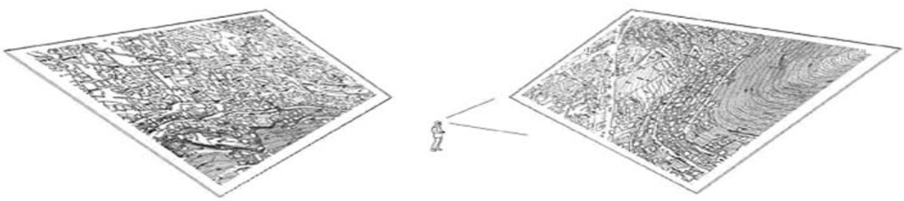


Figure 5. Illustration shows the typical layout of the two main hillsides of Nablus displayed against each other; showing the high visibility of the hillsides.

3. Visualization Techniques and Process for the Case Study Area

The study focuses on the technological aspect of visualization for urban simulation as an innovative tool for interacting with the planning process. Processes and techniques are discussed which all deal with aspects which are relevant for the visualization of the town of Nablus. The focus is not only on the visualization of the urban environments, but also on larger parts of the landscape. Specifically, the evolving modeling techniques for efficiently creating, visualizing, and managing virtual urban environments. Examples from the field of research and practice are investigated. Further, attempt is made to specify the types of visualization techniques that are applicable for the case of Nablus, which can provide a basis for interpreting the visual impact of new developments on the city landscape (See Table 1). As a result it was identified that the latest developments in web-based computer visualizations will provide opportunities to use digital techniques to view various development scenarios, which might encourage the public to interact with design proposals.

Table 1. shows the differences and different uses of different types of computerized visualizations.

Visualizations type		Pros	Cons
Pre-defined visualizations *(Video films & computer animations)*	DYNAMIC VISUALIZATIONS	- Gives an overview of the proposed conditions the form of animated film that can later be played back. - The visual quality of such visualization is very realistic, because of the pre-film editing possibilities of picture and sound. - Such visualizations can be distributed on video tapes or Compact Disks.	- Since the camera movement and the recording of the film are pre-determined, viewers are left passively to watch the film as they watch ordinary TV with no control over the contents. Similar to static visualization, they cannot change their viewpoints, for example, to see other parts of the model. - This technique could be misused to avoid some areas from not to be filmed, where there may be severe impacts on the overall environments. - Any changes to the proposed project, such as the shapes and textures of the objects, or its location changes, will result in the remodeling and re-filming to reflect the changes.

Interactive(VR) visualizations *(Geometric Model VR visualizations: VRML's)* + *(Photo-Realistic Media VR visualizations: QTVR's)* DYNAMIC VISUALIZATIONS	- Facilitates freedom of movement within the model, and the simulation of movement at ground level minimizes the dangers and misconceptions of bird's eye view perspectives, that scale models and computer-generated images very often suffer from. - Presentation and comparison of alternative schemes is simplified and building elements can be selected and investigated in greater detail if needed. - The ability to interactively visualize projects in context and the limited degree of visual manipulation the proposing team can enforce. - The design and evaluation circle can be significantly shortened since digital information is much more easily manipulated, edited and presented. - It facilitates the illustration of changes whilst minimizing the cognitive load to the recipient. - It can be argued that VR enables more substantial public participation, making information more accessible and comprehensible.	- A photo realistic visualization is difficult and labor intensive for some interactive visualizations. - Visualizing 3D interactive models of huge landscapes or cities needs advanced computing equipment,. - Viewing some types of 3D interactive visualizations need some special computing equipment like: 3D theaters or CAVE's, which are very expensive to install. - No standard system for constructing virtual models. - Interactive visualizations that are web-based, suffer at the time being from the restrictions of the Internet Bandwidth (the speed of transferring files through the Internet).
Computer based edit-images	- Their main advantage is that they show the development within the real landscape and from known viewpoints. - Advantages in speed and cost. - Computerized static simulations have the advantage that they can be performed in a photo realistic way.	- The creator of computer visualizations needs to have knowledge of various systems.

A pilot project was carried out to test some of the defined goals and objectives. The objective of this pilot project is to identify the opportunities and constraints of computerized visualizations for the intention to develop a visualization system that is able to support planners and designers in planning and communicating proposed developments with the public in the urban landscape of Nablus. This was done by showing examples of the visual effect of future proposed development on the appearance of city landscape. The visualization system is developed within the limitation of PC environments, which uses the web as main visualizations engine. A number of visualization forms and tools are used in the visualization system (See Figure 6), more specifically: 1) Visualization of proposed development in the form of static and dynamic simulation. This gives more depth to the visual impact of developments in the appearance of the city landscape. 2) Visualization of the existing environment. This to give a true impression of the existing surroundings before developments are taking place. 3) Visualizations of historical evidences of previous civilizations, which will shed light on the historical importance of the area. To enable the possibility to store, analyze and retrieve related data, a GIS system is suggested in such a visualization system.

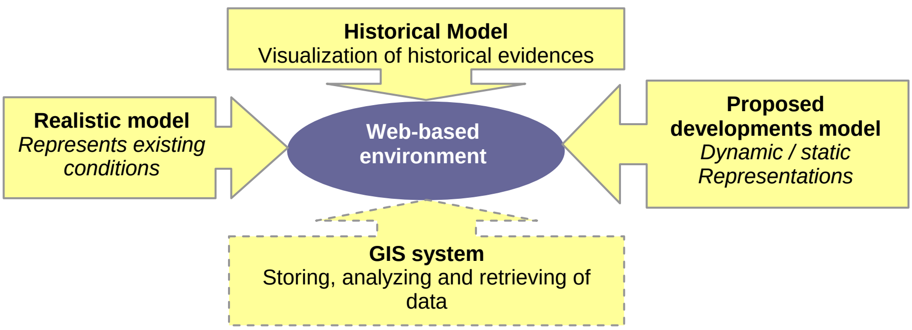


Figure 6. Basic concept of the visualization system.

The pilot project was planned and developed in three main stages (See Figure 7), starting with the definition of project scenarios and the visual analysis of selected project proposals, followed by the construction of the required visualizations for the simulation of new conditions, and then the representation of the findings and the creation of the visualization model.

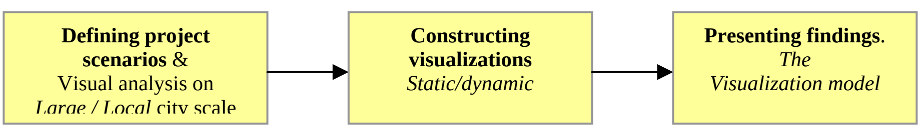


Figure 7. Development stages of the pilot project

3.1 ALLOCATING PROJECT SCENARIOS

In the attempt to provide examples that show how to operate visual simulations by means of computer visualization techniques, a decision was made to choose project locations and scenarios that might have a clear impact on the visual appearance of the city landscape of Nablus. Two project examples were chosen to represent the **large** city scale visual challenges. The developments on the *hillsides of Mount Ebal*, and the construction of a *bridge* connecting the two hillsides of Mount Ebal and Mount Gerzim. (See Figure 8)

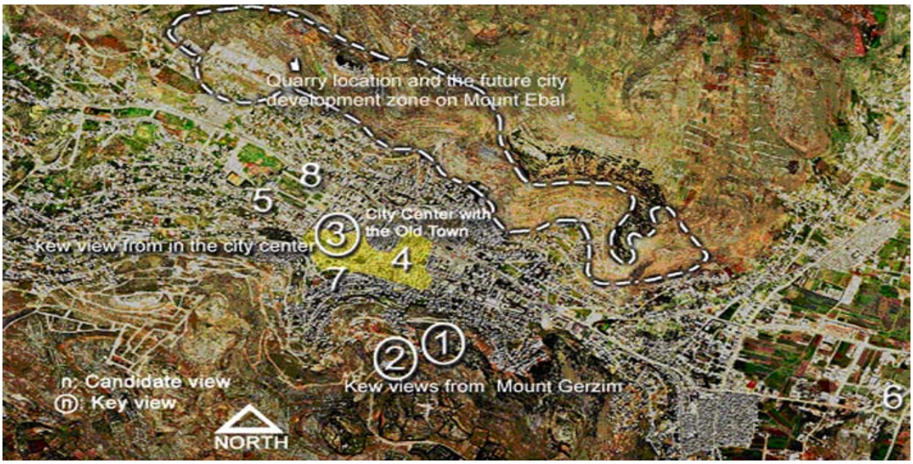


Figure 8a. Large scale project example: Ebal mount hillside development with main key views.

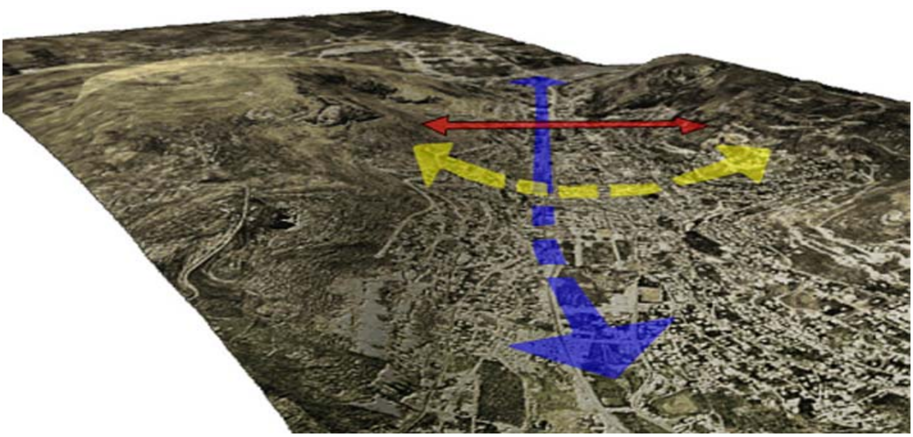


Figure 8b. Large scale example: Bridge project connecting the hillsides of Mount Ebal and Mount Gerzim.

On the **local** city scale, the development of the main city square was chosen as an example (See Figure 9). In addition, and as preparation for the construction of the required visualizations, a site analysis study of the project surroundings was conducted. The resulting analyses provided basic visual studies and representative views.

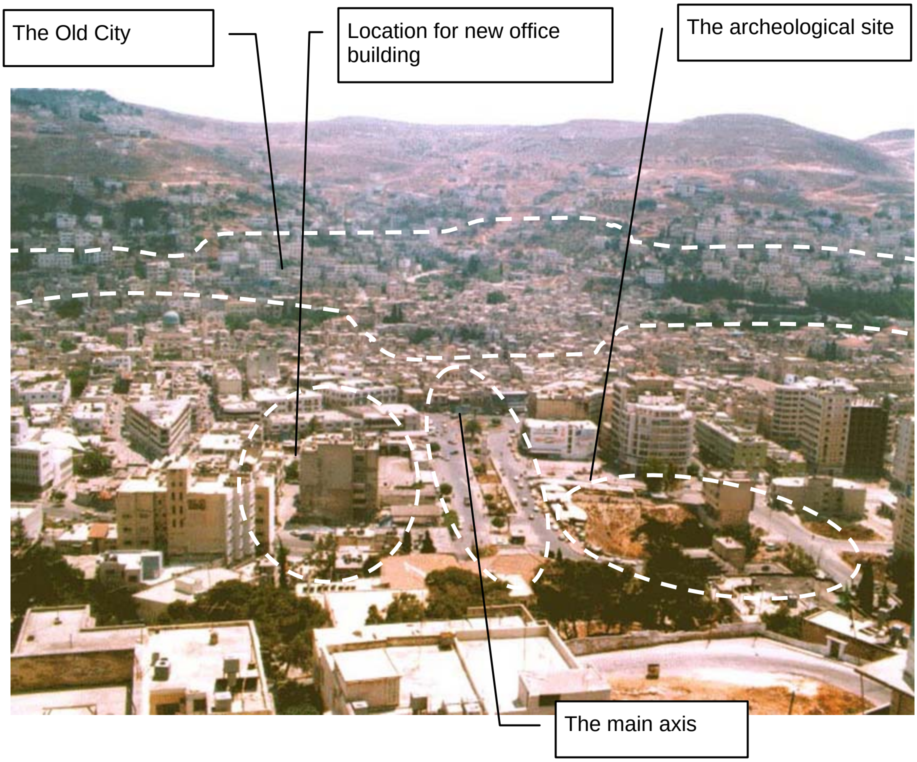
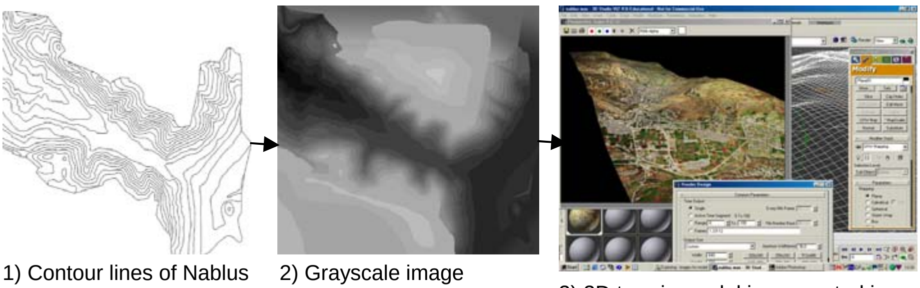


Figure 9. Local scale project example: the main square at the city center.

3.2 CONSTRUCTION OF VISUALIZATIONS

Two main forms of visualizations techniques are used to construct the visual simulations: static & dynamic visualizations. Static visualizations are represented by digital photomontage simulations of the various development scenarios. Dynamic visualizations are represented by the 3D VRML virtual models of the developments proposals with the historical 3d model, and the QTVR panoramic views for showing the project surrounding. The end product is a virtual model (VRML model) of the site, which could be navigated and distributed over the Internet. The visualizations were constructed according to the criteria that all models must be manageable for most PC platforms. In order to model the landscape form, a method to generate a 3D digital terrain model was identified (See Figure 10). Contour line map was used as a basis to generate a grayscale image that represents the topography of the landscape; this image is then used in a CAD system such as 3Dstudio VIZ to give the height and shape of a GRID terrain model. An aerial photo of the site is then draped over the terrain model. Through this method one is able to generate a digital terrain model of the landscape of the city with less polygon counts. This is of great importance when transferring 3D model to a VRML format for web-based visualizations. To achieve a good performance during the process of downloading and navigating of the virtual model on the web, a decision was made to use simple abstract features with lowest amount of polygons, and also texture bitmaps that do not need much time of computer calculation (See Figure 11).



1) Contour lines of Nablus Prepared in AutoCAD

2) Grayscale image represent the height-map.

3) 3D terrain model is generated in 3Dstudio-VIS

Figure 10. Procedure used to create terrain model for the city landscape Nablus using grayscale image.

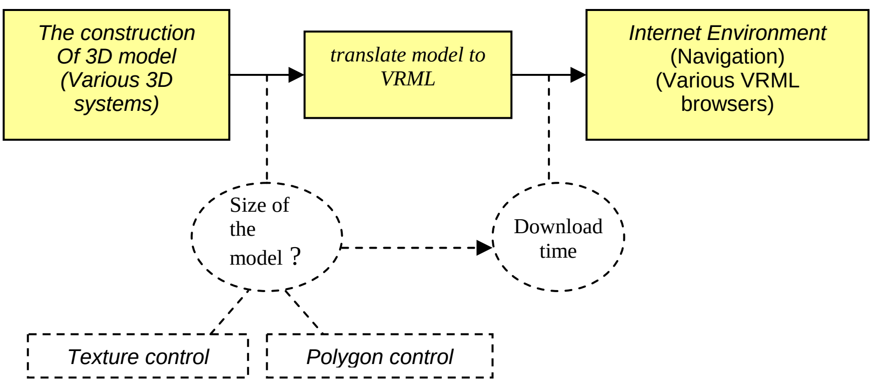


Figure 11. Process and steps to create the virtual model

Various modeling technique are used to construct the 3D models for the Ebal hillsides developments 3D model, the construction of 3D historical city (See Figure 12), and the construction of main square model.

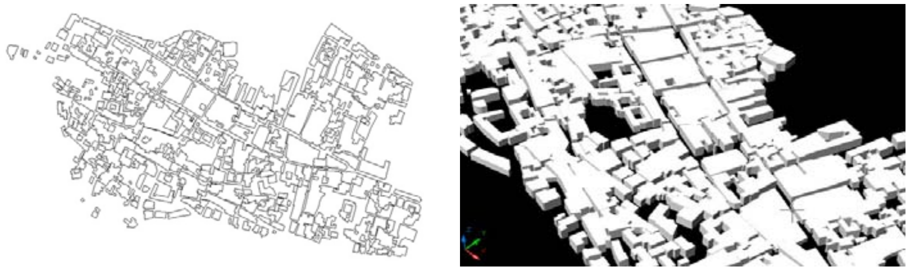


Figure 12. 3D model of the old city part of Nablus.

World Construction Set (WCS) by 3DNature was used to produce 3D renderings of the city landscape. WCS was found extremely powerful for landscape terrain renderings, designed specifically for creating landscape photo realistic images. The system allows the complete control over every aspect of the look of the land. With its 3D texture facilities, it is a pioneer system among other system commercially available. A resulting perspective views is shown in Figure 13. A drawback of WCS (at the time the study was conducted) is not having the mechanism within the system it to produce or to export VRML files. This problem is been solved in 2004 by the release of Scene Express for realtime navigation by 3DNature.

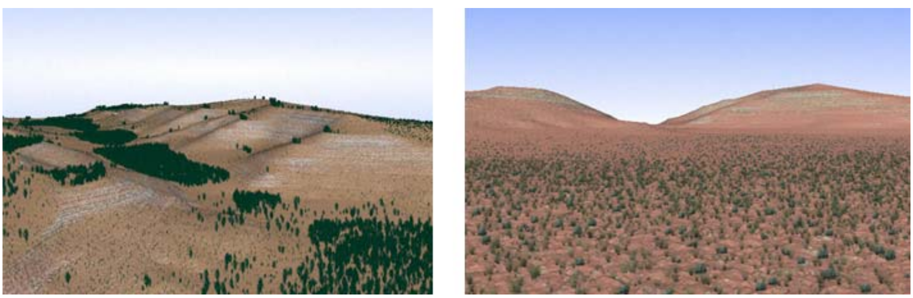


Figure 13. Two computer images of the landscape of Nablus made by World Construction Set.

3.3 THE VISUALIZATION MODEL

The visualization model as part of the visualization system demonstrate how various computerized visualizations can be combined together to form a model whereby city planners, designers, and community groups can get the possibility to visualize, evaluate and communicate possible future conditions and new developments in the urban environment of Nablus (See Figure 14).

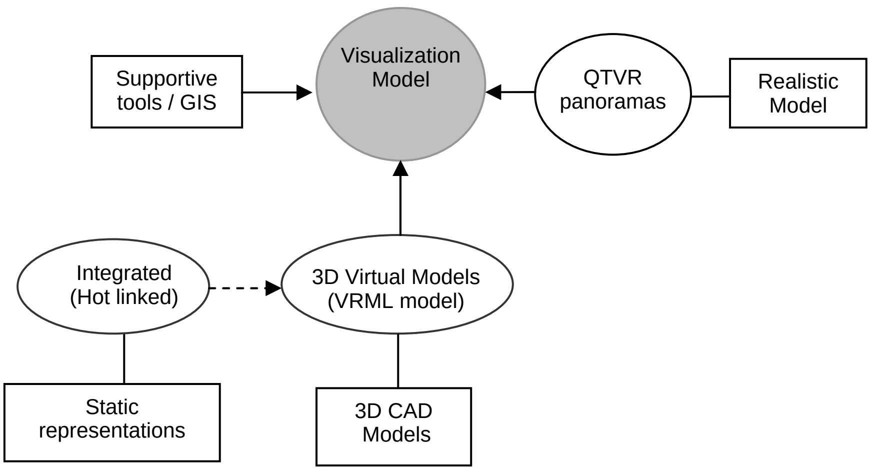


Figure 14. Components of the visualization model

The focus is on constructing a model for viewing and interacting with 2D-static and interactive 3D-dynamic visualizations, with a comfortable graphical user interface that will allow an expert and a layman to find their way and to understand the data easily. The interface and visualization software runs on the entire line of desktop platforms, allowing extensive use of real-time navigation. The visualization model interface uses the hyper-text markup language (HTML) Windows standard, and includes a well-defined set of functions that most users find sufficient for loading and viewing models and visualizations without additional programming effort (See Figures 15, 16 and 17).

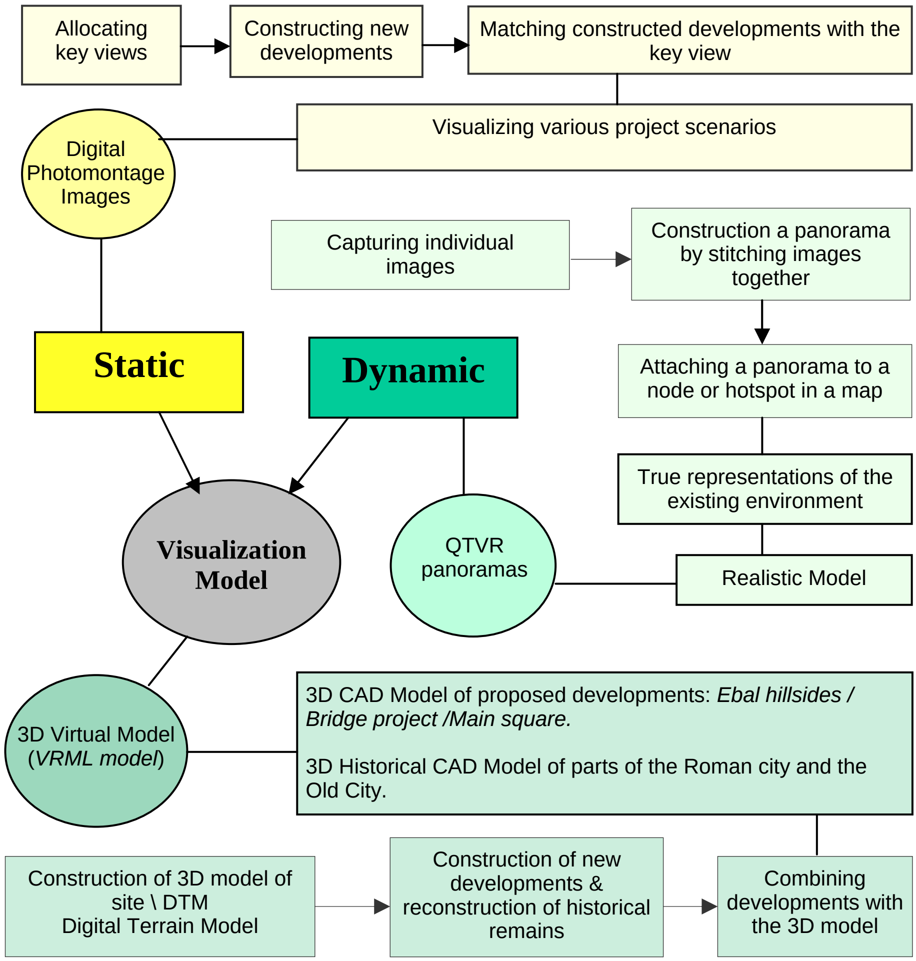


Figure 15. Detailed structure of the visualization system.

Figure 16. Some Images from the visualization model showing the visual experience of development projects at the city landscape Nablus.

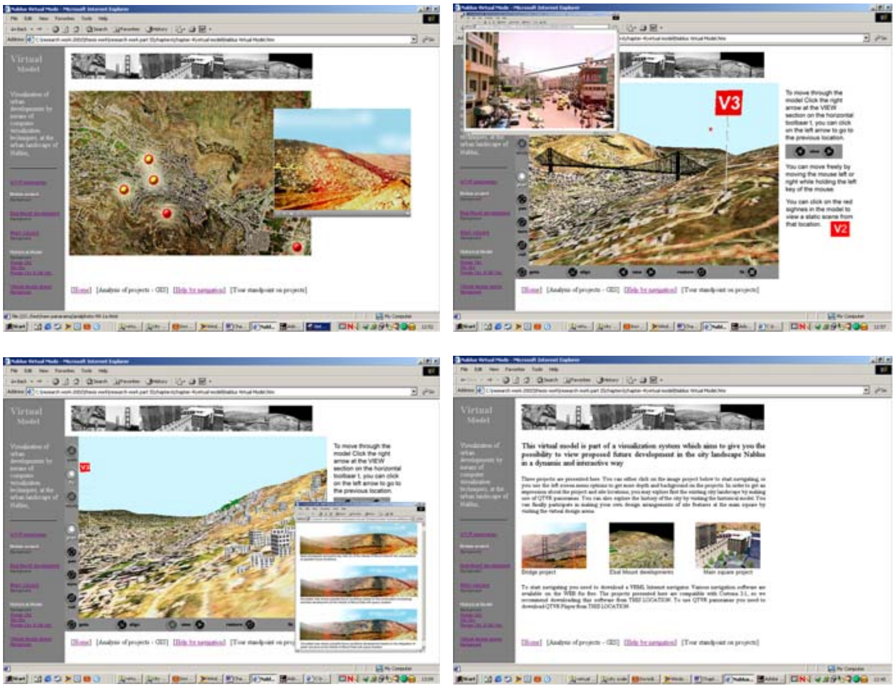


Figure 17. Screenshots of the visualization model.

4. Conclusion

The system highlighted the visual challenges, which the city of Nablus is going to face in the near future, by quickly exploring development proposals and alternative design solutions. The interactivity, flexibility, photo-realism, and adaptability of the visualization forms used, make this technology an effective tool for interactive design in the complicated process of the city planning. The system indicated the potential of building virtual reality environments with very low cost, by using relatively cheap PC hardware and commercially available software. The system has verified that real time web-based visualizations in the form this study used it are suffering from many restrictions. More specifically the following restrictions were identified:

- *The limitations of VRML* for large models and urban scale models in particular are very substantial. Current state of the art for VRML techniques demonstrates a focus on small-scale projects.

- *3D CAD modeling* of existing environment is still made manually. Much of the time needed to model virtual environments is spent on this stage by collecting data and constructing the 3D model.

With respect to the case study, the study has shown that the future shape of the urban landscape of Nablus will be determined by the way planning strategies and future development scenarios will take the historical, geographical and cultural weight of the city into consideration. Because of the high visibility and dominant character of the two main hillsides of Mount Ebal and Mount Gerzim, Nablus proves to be a case where development proposals within the city landscape requires more than the average level of planning.

As for the case of Nablus and the use of visualizations, the study concludes that this visualization experience brought together many integrated aspects: the historical evaluation of the city, the future image and appearance of the city, the cultural identity, and the technological innovation.

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EMBODIMENT AND ILLUSION

The Implications of Scale as a Cue for Immersion in Virtual Environments

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Abstract. This paper examines the extent to which the issue of scale impinges on our sense of immersion in virtual environments. We consider perception from the point of view of Merleau-Ponty's phenomenology, and describe a study involving extended interviews of a small number of subjects who were presented with static, moving and interactive images of spaces. We test a series of propositions about scale cues, and speculate on the wider phenomenological issues of expectation, metaphor and play.

1. Introduction

There are many factors that contribute to a sense of immersion in digitally mediated environments. We can be tricked into believing that the image or sensual stimulus before us is in fact “real,” but this is only a minor motivation in artistic production, according to Bolter and Grusin: “Trompe l’oeil [optical illusion], which does completely fool the viewer for a moment, has always been an exceptional practice” (Bolter and Grusin 1999, p. 31). Photorealism is not the only determinant in the experience of immediacy, nor is it even necessary. In fact the potency of immersive environments often derives from exaggeration, selective abstraction, hyper-realism, and the play of scale. Looking beyond the visual we also see that new media present us with opportunities for haptic interaction, either imagined or actual. Furthermore, as attested by the captivating power of computer games at various levels of visual abstraction and sophistication, digital spaces are engaging, immediate, and immersive to the extent that they provide us with something worthwhile and interesting to do.

Interactive digital media provide an excellent means of testing, comparing, validating and challenging theories about perception, in our case aligning the phenomenology of Merleau Ponty and Heidegger with contemporary researches into "embodied interaction" (Dourish, 2001). Digital media provides an opportunity to work with scale as a variable, an idea brought to our attention in a provocative paper by (Xiaolong and Furnas, 2003). Dynamically changing the size of a 3d model, such as a building, or changing our own size in relationship to it, is perhaps beyond our usual experience, and so presents as a challenge to our perceptual apparatus. We are familiar with the effects of perspective as we move through a space, variable zoom lenses, digital zooming, and objects that grow and shrink before our eyes, not least in movie special effects — but what of variable scale in 3d virtual environments? Such effects include: experiencing an urban model at human scale as a pedestrian, then changing scale to that of a giant, able to step over buildings, or hold the model in the palm of my "virtual" hand. Perhaps then we could shrink to the size of ant and explore the interstices of the city model normally invisible to human-scale investigation. What difference would such scale changes make to our interaction with the environment, and what possibilities do they provide for design?

This investigation leads us to examine the cues by which we determine our scale in relation to an object or environment. These cues include the coordinates and view angle of the viewer in relation to the scene, speed of movement, distance between eye positions (if stereoscopy is employed), aerial perspective (due to atmospheric diffusion), focal length, and depth of field. If the eye position moves then we take cues from speed, inertia and pattern of movement. If there is interaction then the distance of our reach and the mode of interaction are important. The sonic quality of environments is strongly influenced by their scale. We might expect small objects to emit higher frequency sounds than larger objects. The object in view is important. A close up, surface level perspective of a fountain pen might suggest that either I am very small or the pen is very large. The presence of grime, surface imperfections, material properties and behaviours are also determiners of scale. The effects of scale are strongly influenced by imaginative metaphorical relationship (Johnson, 1987). To suggest that I am an ant or a giant already colours my perception of scale. Scale perception is also mediated by the legacies of visual representation: classical and romantic painting, scale drawing, physical model making, photography, film, special effects, computer games, and digital manipulation. To change scale dynamically in relationship to our environment or image adds further complexity to the experience of scale, and is abetted by metaphors of growth, inflation, and fantasy scenarios.

How does scale and scale-change, affect our sense of engagement, immediacy and immersion in a digital environment? In this paper we explore the propositions that changing scale is a further mode of interaction that can influence immersive experience. We consider whether working in an immersive environment where there is a sense of being at different scales can be useful in accomplishing certain design tasks. More significantly we explore the proposition that the sense of scale is a strong determinant in our experience of engagement in a digital environment. The "god's-eye view" is concomitant with a sense of distance and abstraction. The eye-level view brings us into the environment. On the other hand, the slow movement of our increased size or elevation can give time to reflect and establish distance. The faster movement of the small-scale participant sometimes suggests engagement (as for the frenetic computer game player). The process of "changing scale" also induces a momentary sense of distance from the digital environment. With the issue of scale manipulation there is an interaction between the two conditions suggested by Heidegger, of the "ready-to-hand" and "present-at-hand." Ultimately, we maintain that the designer needs to be able to alternate between these two positions of immersion and distance while working on a project, and dynamic scale manipulation provides a means of abetting this process.

Our investigation takes us into the realms of the phenomenology of perception, spatial representation, the nature of digital media and embodiment. We illustrate our paper with examples from a student design project investigating scale in virtual environments, studies of user responses and attitudes to scale issues, and research using interactive 3d environments.

2. Phenomenology of Perception

Scale is an important element of our perception as it often contributes to the logic, or the absence of logic, of the relationship between the human body and its surroundings. The body is the centre of our interaction and our mediation with the world (Johnson, 1987).

The conscious experience of the human body, from the subject's point of view, is the focus of study for phenomenology: a division of philosophy that considers both the structure of conscious experience, and its intentionality. As a method of investigation, phenomenology offers a human-centred account of knowledge, based on experience. For phenomenology, experience is constituted by the interaction of our bodies with other objects, and provides the general frame for our actions (Merleau-ponty 2003, p. 235). The background of this frame is perception. We perceive the vast field of objects that surrounds us, being aware that, in turn, we are being perceived as objects by others.

The French philosopher Maurice Merleau-Ponty, in his *Phenomenology of Perception*, first published in 1945, emphasises the role of the human body in perception. He analyses different bodily attributes to account for this role: the body as object, the experience of the body, spatiality, motility, synthesis, the sexual being, and the body as expression.

As our body constitutes a first "frontier" when encountering the world, the way we structure space draw from it. Everything about our body is not only co-ordinated, but derives a functional value that we don't have to learn but is already known to us. His investigation leads him to assert that our consciousness is *embodied* in the world.

Merleau-Ponty maintains that "the perception of space and the perception of the thing, the spatiality of the thing and its being as a thing, are not two distinct problems." (Merleau-ponty 2003, p. 171). The determination of whether something is "real", to us, or not, is a judgment based on perception. He argues, that a perception of a relationship between:

- one object and another,
- one object and a memory of an experience whether related or unrelated to the object,
- two experiences that are related,
- two experiences that are not related,
- and two metaphors as a second level of relationship,

is neither purely sensory, nor the processing (reasoning) of facts. The decision of whether something is "real" or not is down to the perception of the relations between objects, a process of interpretation that is already embodied. Space features prominently in our narratives of who we are and our position in the world, and we tend to categorize spatiality as an element of our experience. Consciousness is a state that includes both sensing and reasoning. This state will draw on many experiences embedded in memory. For traditional empirical study (against which Merleau-Ponty positions his approach), it is only the pure sense experience that decides and gains our knowledge of every other thing in the world. For rationalism (to which he is also opposed), it is only reason that decides and gains our knowledge (Merleau-ponty 2003, pp. 30-60). Phenomenology attempts a way out of this problematic.

The German philosopher Martin Heidegger introduces two terms that are important to our research: *'ready-to-hand'* and *'present-at-hand'* (Heidegger 1962, pp. 135-144). The ready-to-hand refers to entities that we encounter first before any others, and those which are 'close by.' He offers the example of wearing spectacles. They are close in terms of distance, but they can also become immediate, available, inconspicuous and invisible. They are ready-to-hand. If something is present-at-hand, on the other hand, it presents itself in terms of functional values: with properties that can be measured (optical properties, weight, dimensions).

In a mode of interaction that is ready-to-hand we would expect scale to play a minor role. We just interact with, and react to, our environment as embodied beings. It is only in the event of some kind of perceptual breakdown that issues of scale come to light, and our encounter with objects has more the character of the present-at-hand. There are many situations in which space might present to us as alien, and fully present-at-hand: extreme sports, space travel, hazardous and life-threatening encounters, surreal landscapes, uncanny architectures, and digital interactions.

3. Digital Media

Interactive digital media enable advanced investigation on themes of embodiment and perception, providing an excellent means of testing, comparing, validating and challenging theories about perception. Computers introduce an interesting mode of interaction deploying space as a major metaphor. The Capability of creating a 3D world and filling it with artefacts from our more familiar environments is possible due to the ever increasing power of computer processing.

Our own investigation of embodiment in the world starts with a simulation of the physical world using software such as 3D Studio Max, Maya and Form Z. These programs offer capabilities that range from creating a simple shaded model to creating a full photo-realistic environment, deploying optical effects, and offering the ability to animate this world in different ways. Translating this world from physical form to software constitutes digitisation, creating representations through various algorithmic and mechanical transformations.

There is as yet no efficient procedure for recording and simulating all plausible interactions with a digital environment. So interpretive interventions are required to orchestrate navigation, interaction and behaviours. Multimedia authoring tools such as Macromedia Director, and its ShockWave 3D functions, facilitate navigation through virtual environments, and allow a degree of user interaction, such as being able to move objects.

In a sense we are working with two metaphors. The first metaphor is about a world or an environment that resembles a physical environment (computer model as physical model, digital world as material world), and the second metaphor is of the interaction between our bodies and the world (screen cursor as hand, digital avatar as body, virtual camera as eye). Metaphors work both ways. Our study into bodily interaction with the virtual world can inform our understanding of interaction in the material world. In the manner of action research, there is the potential to uncover many outcomes. Direct outcomes include insights into the way we understand and interact with space, and the way scale affects this understanding. Indirect outcomes include determining the importance of scale as a cue for immersion in virtual environments, and developing techniques for students to examine and investigate new aspects of their designs.

Space and scale feature prominently in narratives about everyday life, modulated by the spread of digital media to create ever-expanding narratives of communication, containment, boundaries, thresholds, and transgressions.

4. Perceptual Study

The study was conducted in two stages. The first focussed on a taught course for undergraduate students of architecture working for their first degree. The second stage involved research around the perceptions and observations of a small cohort of designers, using the undergraduate material as a resource.

4.1. STAGE 1

The first stage involved a course project on Multi-scale Virtual Environments, in which students were challenged to reconstruct a street of the city as a computer model. Then the unfolded printout of the street model was used to construct a scaled down physical model of the same street. Each student modelled a different street. So the models (digital and physical) could be assembled to create conceptual representations of the city. Students were then asked to use a version of the unfolded physical models to construct a means of transportation in the virtual model, a vehicle that they could use to navigate their virtual environment. The task of designing a vehicle was intended to provoke students to imagine mechanisms of transportation in a virtual environment, and the routes of travelling from one point to the other, and exploring techniques of spatial transformation: folding, bending and twisting surfaces, transforming an orthogonal street model into a folded origami vehicle. The digital models of the vehicles were put up for auction and shared throughout the group. The next step was to create a computer model of a multi-scale virtual environment suitable for displaying, garaging, accessing, testing and navigating the folded vehicles.

Each student was then was required to provide a simulation of movement through the multi-scale space. The aim was for the students to experiment with different ways of interacting with their models, vehicles and environments. The fact that students modelled physical streets in Edinburgh city, gave them a chance to look at the city in a new light, and to create simulations and animation that question scale and bodily experience. By the end of this stage we had a model of the central area of the city of Edinburgh and a series of animations and simulations.

Not only did this phase of our research provide resources for what follows, but it gave us an opportunity to develop a series of interesting scenarios about scale (a kind of design research in itself), and to develop a sense of how designers think of scale, challenge it, and play with scale. Our research approach fits within the framework of participatory action research (Argyris and Schön, 1989).

4.2. STAGE 2

The second stage was a pilot study using the material created in the first stage. The research comprised a presentation of the material to subjects with a design background, in a room set up for that purpose, and was then followed by a questionnaire and an unstructured interview.

4.2.1. The Presentation

We structured various visual scenarios using Macromedia Director (*Figure 1)*. The presentation contained four categories, each of which had sub categories. Each of the sub categories had an image, an animation, a Quick Time movie or a 3D flash virtual environment. The discussions were recorded to tape.

4.2.2. The Questionnaire

There were nine questions.

1- What do you think this is an image/movie of?

2- Which of the following best describes your impression?

(1= totally disagree, 2= disagree, 3= not sure, 4=agree, 5= totally agree)

2.1-The space is large

2.2-The space is small

2.3-The scale of the space is ambiguous

2.4-I feel lost in the space

2.5-The space is confusing

2.6-The space has a clear structure

2.7-I feel small in the space

2.8-I feel large in the space

The main issues canvassed in the questionnaire were: the scale of the body, the scale of the environment, and the scale of the body compared to the scale of the environment.

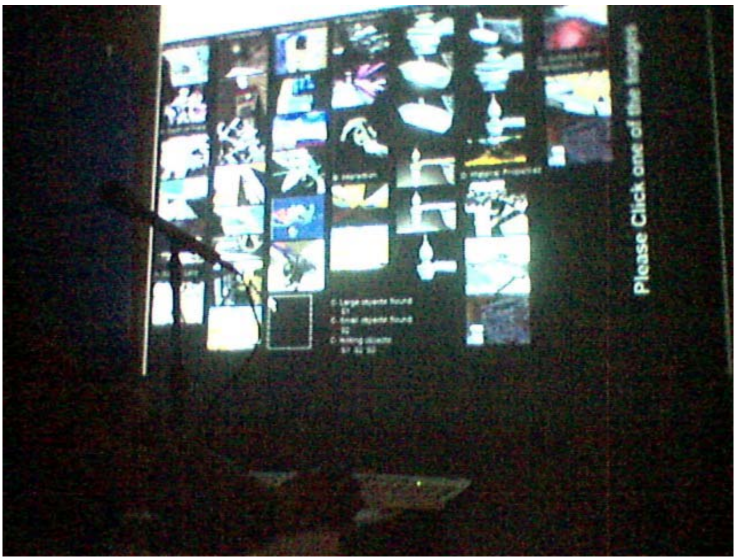


Figure 1. Various visual scenarios using Macromedia Director.
(Photograph by *Aghlab Al-Attili)*

4.2.3. The Unstructured Interview

The unstructured interview explored the motivations behind the answers in the first part, and the way designers articulate their narratives about scale. Below is an extract from one of the interviews, and the way it was analysed to extract codes. Figure 1 shows a frame from the animation presented to the user.

4.2.4. Extract from the First Interview

What do you think this is an image or a movie of?	
	I perceive it some how like a game environment.
But how do you perceive the depth of field?	
	I cannot understand the figures and the shapes, and all of that. I can understand that they are 3D objects. So I see the depth, but I do not recognise the space. So this is why I feel this is, more or less, a virtual space or a game Environment. I do not know something that I do not recognise. And I feel a little bet disturbed by the motion, because I cannot understand the space, and it makes me feel a little bit as though I lose my orientation maybe, and …
So you perceive the depth of field because of the objects basically, and because of that you feel that they are 3D, and therefore, they have to be in a 3D environment that has depth	
	Yes
How do you perceive the scale of your body? I mean, when you go across this motion (points at the animation) for sure, you move and you feel that you have a body, I assume. Do you feel that you have a body?	
	Yes. In the first part, mainly I feel that.
Do you feel this body is large or small?	
	It is both of them but mostly small.
Why?	
	I think because of the details of the environment. There are a lot of things.
How do they give you the feeling that you body scale is small?	
	I could not say.
What makes you feel that you are small?	
	(Pause). Maybe the way that the camera is moving, and the way it is left up and down, and the details of the environment. So I think that before the camera did something like that I perceive it as being my eyes. So I am down. Then and looking up.
So when the camera turn up you perceive yourself as looking at something that is higher than your view.	
	My height, yes.

And the level of your eye view? That is why you thought you were small? But why did not you perceive the objects as being large objects rather than your body being small?	
	Because I do not recognise the objects, I do not have a reference point for the objects.
What about the floor [texture]?	
	My eyes stopped at the flooring, because I could recognise it I suppose. It was familiar.
Still, the floor was not enough to give you a sense of scale. So what you are saying is, generally, because you are mostly looking from your eye level, and you were looking in front of you, or up, that is what made you feel small.	
	[nods agreement]

4.2.5. Extract from the Second Interview

Now you have seen this animation, do you think that the visual field is deep? Do you think it has depth?	
	Yes.
How did you decide so?	
	There are various objects in various parts in the environment.
And how do you perceive the scale of your body in this environment?	
	I am not sure. The way I walk through it, I appear to have a normal size, because I don't feel I am very high up walking over the ground, and I do not feel so close to the ground.
So you decided the size of the scale of your body is normal because of your point of view…..	
	Yes
While the depth of field did not affect your decision. What about the objects, the scale of objects in this visual field?	
	They appear large.
And why did you decide so?	
	Because when the movie enters and I go through objects, they appear to be at least twice the size of me.
Twice the height?	
	Yes, twice my own height.

<table>
<tr><td colspan="2">And that is why you perceive them as big objects and you perceive your body still to be of a normal size?</td></tr>
<tr><td></td><td>Yes.</td></tr>
<tr><td colspan="2">Did you try to have any frame of reference on this occasion? As though you can look at the ground and say that the texture of the ground is something I am used to and I can judge myself to be little bit smaller or a little bit larger. Or maybe it is the wall that is on one of the sides, the texture of the wall, relating to that texture.</td></tr>
<tr><td></td><td>Oh, I get dizzy.</td></tr>
<tr><td colspan="2">Why?</td></tr>
<tr><td></td><td>Because it is turning too fast.</td></tr>
<tr><td colspan="2">I see.</td></tr>
<tr><td></td><td>Well the floor, it has a pattern. But they could be any size to me. They do not make me change my mind. And the walls do not either.</td></tr>
</table>

5. Comparing Both Interview Fragments

Unlike many experiments that aim to detect patterns of interaction, or perception, without looking into details, this study was designed to elicit both. The study raises question about the nature of immersion and how some people report a sense of being immersed when their scale is changed, or ambiguated, in a virtual environment. As the subject of the experiment is a user of the environment, and scale cues are changing dynamically, issues of immersion rise to the surface. How much of what we do in our being-in-the-world entails continuous attempts to fit our bodily scale into the environment, or set our own dimension against the dimensions of other objects? In fact, considering the whole project, this could be seen as a commentary on designing a functional space on the one hand, and adapting the functions of a space to our particular uses on the other hand. Beyond that, the study examines issues of embodiment and interaction.

In the first case we play the role of the designer, and we create environments for exaggerated and fictionalised versions of our bodies. Although that might initially sound like a simple task, it is complicated by the fact that the designer must “re-invent” herself as multiscale inhabitant of different environments. Certain consistencies in these designed environments are called for. In the second stage, subjects were faced with surreal worlds. The usual spatial references to daily life embodiment were distorted or absent.

In the second part, the subjects were not specifically invited to speculate that they may be in some sort of distorted reality, but, like Alice in wonderland, they try to make sense of what is in front of them. During this process, it seems that they give up their basic perception of their embodiment and, step by step, they seem to develop fixations (or obsessions) with different kinds of embodiment. They rediscover their environment in new ways. We will examine these hypotheses through further studies. In the mean time our study provides evidence for the factors that influence our sense of scale, at least amongst spatial designers.

6. Elements Affecting Scale

The interviews corroborated the following scale cues in digital environments.

6.1. VISUAL ELEMENTS

6.1.1. The Oblique Perspective

Among the visual elements affecting perceptions of scale, the oblique perspective, or distant aerial view, has a strong impact. We may feel that our bodies are small and insecure, or huge and looking out over a vast landscape. Where there are familiar scale referents, the body draws on the metaphoric associations between objects and defines its scales depending on its relationship to them. In the absence of a clear frame of reference, there is a fine line between perceiving one's body as huge and overlooking a small environment under its control, and perceiving one's body as a small entity floating over a huge environment *(Figure 2)*.

Figure 2. Screen shots of frames showing an environment changing from an oblique view (right) to an elevation view (left). (Model and animation by *Masumeh Geranpayeh)*

6.1.2. Depth of View

When the visual field is extensive, subjects tend to believe that their scale is smaller than normal, while the size of the environment is very large, but the presence of a kind of reference for a scale in the environment will always enhance this feeling *(Figure 3)*. The absence of this reference on the other hand encourages the subject to think she is very large and is only observing a very small object.

Figure 3. The element of a stair case acts as a strong reference to the scale of human body and the environment, but when this element is repeated in various scales and in the middle of nowhere, it questions this sense of scale. (Model and rendering by *Armeet Panesar).*

6.1.3. Coordinates and View Angle

The proximity to the ground level is a cue for the subject to seem smaller as proximity to the ground is generally associated with shortness of stature *(Figure 4)*. It seems the reverse is not the case. Having an elevated point of view is insufficient to engender a sense of inflated scale, as elevation is mostly associated with flying, or being elevated on a plane. In most cases, it is sufficient to have a point of view close to the ground, to generate a sense of being small *(Figure 5)*, but it takes more than an elevated point of view to achieve a sense of being large.

Figure 4. A building from what seems to be an ant eye perspective (left), and a subject looking at it (right). (Model and rendering by Matthew Murphy)

Figure 5. A normal human eye view but with proximity to ground level (left), and a subject looking at it (right). The juxtaposition creates confusion of whether the scale of the viewer is small or big. (Photograph and digital processing by James Whitaker)

Figure 6. Familiar objects at exaggerated scale, like a cup or a beaker, give the impression that the viewer is small. (Model and rendering by *Elizabeth Westmacott*)

6.1.4. Focal Length

Many rendering programs can simulate variable focal length, from wide angle to telephoto. With the absence of a referent, subjects reported confusion about scale where a wide angled lens setting was deployed in the rendering. Yet, a wide angle lens with high curvature is more likely to trick people into believing they are small *(Figure 7)*. A narrower lens creates the feeling of being close to far objects, while objects that already have strong reference to scale appear larger than their normal size.

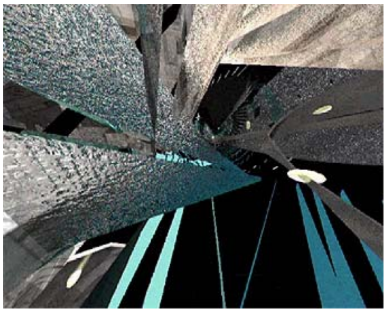
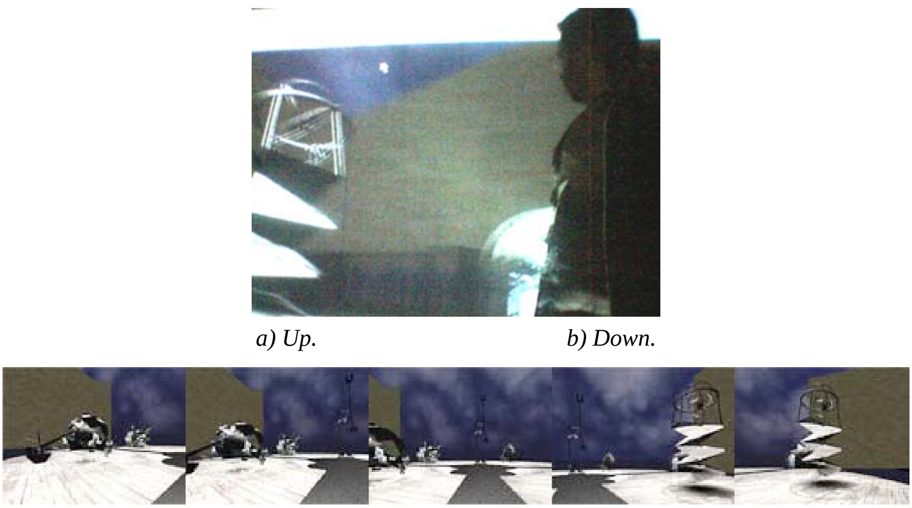


Figure 7. If the objects extend to the edge of the screen then the viewer tends to report that she is small compared to the environment. (Model and rendering by *Bonnie Chu*)

6.1.5. Speed of Movement

Speed of movement of the camera is stronger than many other elements in dictating the size of the subject *(Figure 8)*. Fast speed seems to suggest that the subject is large, but in the absence of other scale referents, fast movement can suggest that the objects encountered are large.



a) Up. *b) Down.*

Figure 8. A subject *(a),* looking at the motion described in the series of frames *(b).* (Model and rendering by *P. Wang)*

6.2. SONIC QUALITIES

6.2.1. Sound Emitted By Large Objects

Low-pitched sounds suggest that objects are large, but it still means that the subject might be small.

6.2.2. Sound Emitted By Small Objects

High-pitched sound in this case appears to be the best sonic cue for scale. Other low-pitched sounds perceived by the body from the surrounding environment suggest a small scale.

6.2.3. Sounds Giving Hints With or Against the Environment

All sounds that give hints by being associated in real life with large or small objects lead the subject to adapt his scale to suite the size of the object of the sound. For example, associating movement with the sound of scuttling encourages subjects to think that they are small.

6.3. DETAILS

6.3.1. Details of Grime, Rust and Dirt

They suggest equally being close to an object and being small in size. The subject decides his scale depending on the perspective *(Figure 9)*.

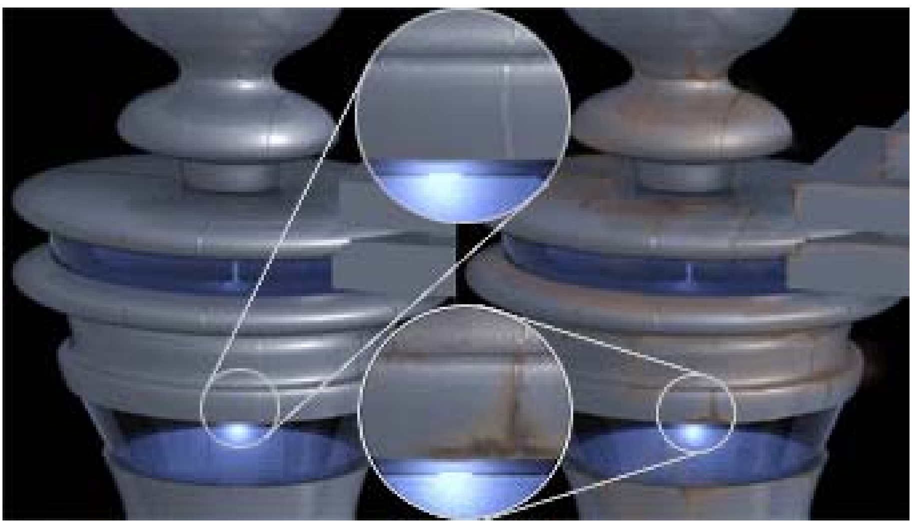


Figure 9. Grime, rust and dirt are not necessarily elements confusing to perception of scale. (Model and rendering by *K. Tong*)

6.3.2. Material Properties and Behaviour

With the presence of photorealistic materials, the subject seems to perceptive the details and properties of these materials. But with the absence of these material properties, the subject perceives the environment as a 2D flat image or a series of flat frames *(Figure 10)*.

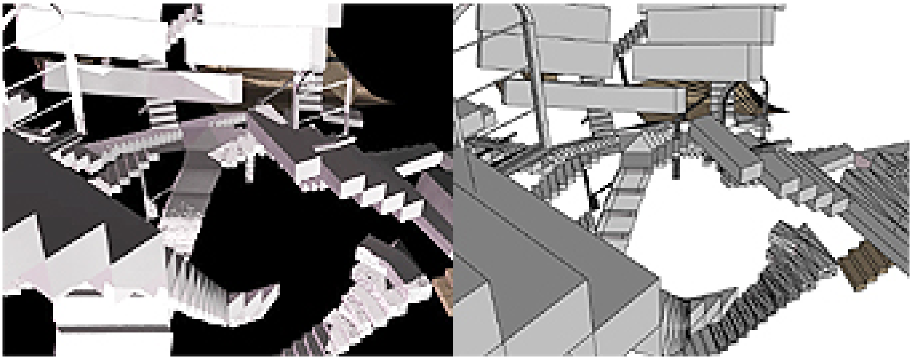


Figure 10. Material properties give the illusion of involvement in space and increases the sense of change to scale. (Model and rendering by *Armeet Panesar*)

6.3.3. Details of Surface Imperfection

Surface imperfection is a major source for confusion. Any details that cannot be seen by the eye at normal scale will be seen, but still not be recognised, if the size of the subject is reduced and the subject is interacting with it.

6.3.4. Details of Surface Level Perspective

Surface level perspective is again a strong cue if the surface is the ground, but if the surface is a wall, and unless coordinates of view take the wall surface as the lower part of the screen, it will not affect the scale of the subject *(Figures 11 and 12)*.

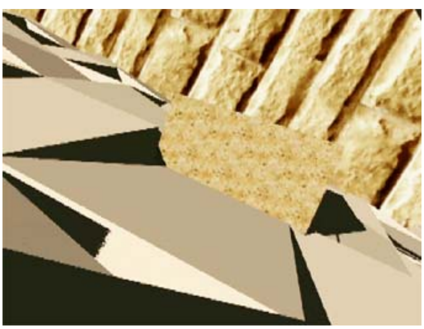


Figure 11. Surface level perspective of a wall. Yet the angle of view suggests movement perpendicular to the wall. This suggests a change in scale. (Model and rendering by Matthew Murphy)

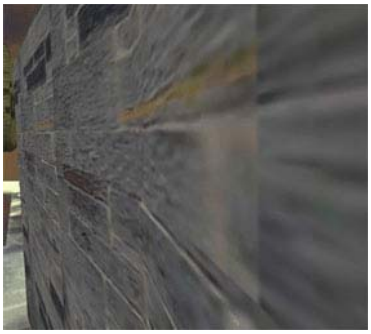


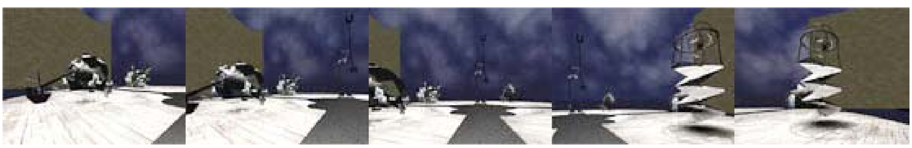
Figure 12. Surface level perspective of a wall but with no change to the angle or scale. (Model and rendering by *Naomi Harris*)

6.4. INTERACTION

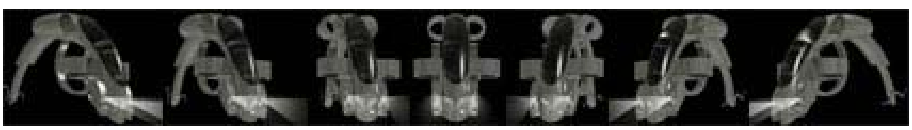
6.4.1. Interaction with Objects within Arm's Reach

Having objects within arm's reach is a major contributor to immersion. Once an object is felt to be touchable, it can affect the determination of the subject's scale. The fact that the object is within arm's reach, helps the subject judge the scale of the object accurately. This seems to reflect on the sense of scale of the object *(Figure 13 (a,b,c))*.

a) Moving around an object. (Model and rendering by *P. Wang*)



b) Looking around the space from one point (Model and rendering by *P. Wang*)



c) Having the object rotate in front of the viewer. (Model and rendering by *K. Tong*)

Figure13 (a,b,c) . Screen shots of frames showing the nature of movement

6.4.1. Mode of Interaction with Objects within Spaces

In this section, the subject had the chance to interact with objects in a virtual environment. The subject had the chance to get close to objects, far from them, look at them from different points of view, move in different speeds, and had different versions of the environment with different focal lengths *(Figure 14)*. This showed how the combination of all these elements could affect the perception of scale in virtual environments.

Figure 14. A Shockwave 3D interactive virtual environment of a physical space within the University: the Playfair Library, with small scale (right), and normal scale (left). (Model, rendering and programming by *Aghlab Al-Attili*)

7. Conclusion

This preliminary study indicates that perceptions of scale vary according to a range of factors, and these are interrelated. Presumably concepts of scale already have fairly sophisticated expression in the practices of architectural designers, draftspersons, geographers, and cartographers. Technically, scale is a fixed ratio between the dimensions of the representation and the object being represented: 1:1, 1:50, 1:100, 1:10,000, etc. It is most comfortably discussed in the context of orthographic projection (plans, elevations). In the case of perspective projection, however, scale refers more to the size relationship between the viewer and the viewed object. None of the subjects interviewed had difficulty discussing scale, and change of scale, in this context.

The background experience and training of the subject plays a major role in perceptions of scale. Expectation is a significant theme of perceptual studies in phenomenology. If an object that has the shape and texture of a beer glass or a slice of cheese enters the perceptual field then that triggers expectations about the size of the viewer in relation to the environment. But as attested by fantastical painting, from Hieronymus Bosch to the Surrealists, familiar objects in unfamiliar contexts create ambiguities that excite the senses in new ways. Most of the imagery presented to the subjects exaggerated the issue of scale in some way, provoked interest, and evoked interesting responses. Designers at least seem to enjoy, and are engaged by, visual imagery that presents ambiguities of scale.

Much of this engagement by the subjects had the character of play. Subjects enter into the "experimental" situation as if participating in a game. They played along with the theme of the study. According to one participant: "I feel like I could crawl into that piece of cheese." We assume that such assertions, and the expressions of feelings of vertigo or dizziness in some cases, were analogous to the putative emotions recounted in the case of watching an engaging film. We are not easily fooled into believing that the images before us are real, but we enter into the experience as in play. The play element was also evident as we observed how respondents would adapt their expectations according to what had already transpired. Each situation in the study further consolidated the rules of play for the next stage. The subjects spontaneously discussed issues, problems, misgivings, and confusions about the images being presented in terms of the theme of the study: scale. To a subject whose experience is being framed in terms of scale, everything becomes an issue of scale. On the one hand this vindicates the issue of scale as a major determinant of our immersion and engagement in digital environments. It is also testimony to the importance granted within phenomenological study to the roles of projection, metaphor, and imagination in perception.

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VIRTUAL REALITY IMPLEMENTATION IN THE ARCHITECTURE CURRICULUM

The experience of King Fahd University of Petroleum and Minerals

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Abstract. Following a recent curriculum revision, the Department of Architecture at the King Fahd University of Petroleum and Minerals (KFUPM) established a Virtual Reality (VR) laboratory to service its information technology courses and research. Two years after the establishment of the laboratory, utilization has not reached the level anticipated and the facility is yet to be fully integrated into teaching and research activities. The paper reviews the implementation of the laboratory with a view to identifying and examining the factors that account for its current utilization. Factors identified in the paper included inability to fully implement the proposal for the laboratory, inadequate implementation preparation, complicated procedure for producing visualization content, and computing resource compatibility problems. The paper concludes with general suggestions for schools trying to implement virtual reality in their curriculum and specific suggestions to improve the utilization of the KFUPM VR laboratory.

1. Introduction

Since the late 1980s, architecture and architectural education have witnessed an important transformation with the introduction of computers and information technology (IT) (Cuff, 2001). Computers and information technology have become pervasive in all aspects of architectural practice and education, challenging the traditional ways that architects have operated for a long time (Cuff, 2001; Laiserin, 2002). One of the most powerful changes brought about by computers is in the aspect of visualization. Computers enable the generation and experience of virtual environments with a profound implication on how we design and also interact with the product of design. The debate in the profession about the relative merit of the introduction of computers on architectural design that the transformation engendered has since given way to the exploration of its cognitive implication on design and to questions of whether it is engendering the emergence of new modes of thinking about architecture and space (Cuff, 2001). The pervasiveness of information technology in education and practice is also reflected in the growing proportion and importance of IT courses in the curricula of architectural schools. Many schools have increased IT content in their curriculum and are investing resources to acquire computing resources to ensure that they provide their students with the necessary skills and competitive advantage. In many schools investment in IT have also include the establishment of Virtual Reality laboratories to provide students with opportunities for enhance visualization aimed at improving design skills.

In the King Fahd University of Petroleum and Minerals (KFUPM), a recent revision of the architecture curriculum reflected the growing importance of Information technology in education and practice, and the need to position graduates with a competitive advantage in the professional field. The revision saw a change in the vision and mission of the department all emphasizing information technology. This emphasis was reflected in the course structure, where new information technology courses, including a virtual reality course were introduced. An initiative for the establishment of a Virtual Reality (VR) Laboratory was started to support the teaching of IT courses, studios and to support research activities. The Laboratory became fully operations in 2002. Two years after the establishment of the VR Laboratory, utilization is below the level expected and it is yet to be fully integrated into teaching and research activities. The paper reviews the implementation of the laboratory with a view to identifying and examining the forces that account for its current utilization. The paper is divided into three main sections. The first section explores virtual reality and its application in architecture and architectural education. The second section reviews the implementation process of the KFUPM VR Laboratory. The last section assesses the utilization level of the Laboratory and examines the factors that account for the observed level of utilization. The paper concludes with general suggestions for implementing virtual reality in architecture schools and specific suggestions for improving the utilization of the VR Laboratory at KFUPM.

2. Virtual Reality in Architecture

Virtual Reality refers to the act of generating and interacting with computer generated virtual environments (Vince, 1999). Virtual Reality refers to an attempt to create and convey a sensation of reality using artificial means, usually the computer. Virtual Reality is used interchangeably with Artificial

Reality, Virtual Worlds and Virtual Environment. The concept of VR presupposes the existence of material reality. Humans sense and interact with reality or the material world through their senses; vision, hearing, touching and smelling. Human beings have a vision that is coloured, binocular, stereoscopic and wide angled. In human vision, the individual is also enveloped by the environment or image he sees. In hearing, human beings are able to distinguish different range of frequencies, direction and volume, as well as associate sound with external objects and events. The eye is also used for equilibrium for the body. Tactile sensation resulting from the human touch enables the differentiation of different types of objects. The human sense of smell enables odours to be distinguished and to be associated with events and places. The use of the combination of the senses creates the human perception of material reality. Virtual reality creates an artificial sensation of reality through enabling human sensation. The degree to which a virtual reality presentation enables the use of many or all of the human senses determines the reality or degree of immersion of the presentation. Technologies of virtual reality are differentiated based on the degree to which they are able to simulate reality particularly in their display. The technologies vary from fully immersive technologies where the user becomes integrated into an artificial 3-dimensional world with almost all his senses activated, to non-immersive technologies, which provide limited sensation of reality. There are various types of virtual reality equipment prevalent in the market. Among the most popular ones are screen based projection systems, Head Mounted Display (HMD), the Binocular Omni-Orientation Monitor (BOOM), and the Cave Automatic Virtual Environment (CAVE) (Vince, 1999). Screen based VR systems provide visualization through projections on screens. This can be as simple as projection on a computer monitor to Domes and large screen based systems. Level of immersion varies from simple projection of animation to stereo viewing of multimedia presentations on large screens or Dome systems using 3D polarized glasses. HMDs are the premier immersive VR technology (Vince, 1999). The device is head mounted and the user interacts visually with the image. This is sometimes combined with tactile systems to create a true feeling of immersion. BOOM from Fakespace is a head-coupled stereoscopic display device. The CAVE was developed at the University of Illinois at Chicago Electronic Visualization Laboratory. The CAVE consists of a room with graphics projected from behind the walls. The images on the wall are projected in stereo mode to give a sense of depth. Users are surrounded by the image giving a complete sense of immersion. Several people can also be in the room sharing the same experience.

VR application has grown to almost a limitless level with the evolution of the technology. Virtual Reality has changed the way people interact with technology, offering new ways for the communication of information, the visualization of processes and the expression and communication of creative ideas. VR is used to represent 3-dimensional worlds either real such as buildings, landscape, spacecraft, archaeological excavation of sites, human anatomy, sculptures, crime scene, reconstructions, solar systems, and so on, or abstract such as magnetic field, turbulent flow structures, molecular models, mathematical systems, auditorium acoustics, population densities, and information flows. These virtual worlds can be animated, interactive, shared and can expose behaviour and functionality. Architecture, by virtue of its experiential nature and the importance of visualization to it is one of the prime disciplines where virtual reality is having a significant effect. VR makes it possible to simulate buildings and explore them at a virtual level, making studies of such issues as function, construction technology, performance etc possible. As a tool, VR provides architects with the means to improve design quality through prior study and assessment of the design product. The use of VR by architects also improves the communication of design ideas to clients and users without the requirement of their understanding the notations of technical presentation (Maher et al, 1999). VR also enables the comparative evaluation of design alternatives based not only on technical and functional criteria but also on aesthetic impact and user needs (Maher et al, 1999). For the student architect, VR provides an opportunity to improve design skills through better mapping of abstract representations with the reality of the experience of form and space. Also the design teaching process is improved through the use of VR, as criticism and comments which might be hard to fathom from traditional abstract representations become more easily appreciated when a simulation of the building is experienced.

The potential of VR application in design education has made the technology the focus of acquisition by many architectural schools. The development of the technology is in part driven by research in universities, particularly in the United States, where the technology is most prevalent. It is not within the scope of this paper to develop generalized criteria for evaluating or analyzing success in VR implementation by schools of architecture. In the case of KFUPM four criteria developed based on the mission of the facility have been used to judge level of utilization and success in implementation; integration into teaching and research activities, ability to support the VR needs of the university community and use of facility for VR consulting to the wider community. Using the KFUPM criteria for an overview of VR implementation in the architecture curriculum, it is apparent that VR has been successfully implemented in many architecture schools, particularly in the developed world. Examples of successful VR implementation in Universities in the United states include the Cornell graphics laboratory established in 1974 (http://www.graphics.cornell.edu), The MIT Media Lab established in 1985 (http://www.media.mit.edu), University of Michigan Virtual Realty laboratory established in 1993 (http://www-vrl.umich.edu), The NCASA

Virtual Reality Laboratory at the University of Illinois at Urbana Champaign established in 1991, and Columbia University Computer Graphics and User Interface laboratory (http://www1.cs.columbia.edu/graphics/projects/virtual-worlds.html). A review of these facilities appears to suggest certain common recipes for success. First of all, there is no single VR technology that predominates across all the laboratories. HMDS, BOOM, CAVE and projection system VR were found across all the laboratories. Most of the laboratories developed as a result of research initiative by either a department or a group of people. Almost all the laboratories use external funding usually from industries. The external funding allows the laboratories to acquire a broad range of VR facilities and to ensure that their facilities are updated. The laboratories all have a strong research focus, in addition to teaching. Almost all of the laboratories are at the forefront of the development of VR technology, both hardware and software. The laboratories are also situated to support multi-disciplinary research bringing together many disciplines such as architecture, computer science, engineering and manufacturing. Many of the laboratories have teams dedicated to research in specific areas and many have a core team of people that also manage their VR facilities. In the Gulf region, other than KFUPM, the other case of a prominent implementation of VR is that of the Department of Architecture at the United Arab Emirates University (UAEU) (www.engg.uaeu.ac.ae/a.okeil/uaeu-cave). The UAEU system is an immersive CAVE that was developed in-house. The project was initiated in May 2001 and the first student project and course taught using the CAVE were carried out in January and February 2004 respectively indicating that it has successfully taken off and is already being integrated into design studios and the courses of the Department.

3. Virtual Reality Implementation in KFUPM

The process for establishing the Virtual Reality Laboratory at KFUPM started immediately after the completion of the review of the curriculum of the Department in 2001. The process for establishing the VR Laboratory was initiated by the then Chairman of the Department to support new information technology courses in the revised curriculum. A proposal for the VR Laboratory was prepared and forwarded to the University administration. The proposal highlighted the mission and purpose and, equipment and staffing requirement of the laboratory. Included as part of the objectives of the Laboratory are to support teaching and research, to support the educational use of VR in other departments and to offer consulting services to public and private sectors of Saudi Arabia. The proposal called for the laboratory to be partially funded by the University and partly by a corporate chair endowment in Virtual Reality. The University ultimately funded the laboratory as the Department was not able to finalize the arrangements for the endowment of the chair. Prior to the preparation of the proposal for the laboratory, the Department had initiated a search for suitable VR technology to use. In choosing equipment, commercially available systems were opted for to ensure the quick establishment of the laboratory and because of the lack of internal capability and time to develop a system. Two companies offered products that were judged most viable; Imagetek corporation (www.3dimageteck.com) and Elumens (www.elumens.com). Both companies were asked for literature about their systems as well as for quotation. Imagetek Corporation offered a choice between a 3DI Telejector shown in Figure 1, and a 3D video encoder/decoder combination along with projector, stacker brackets and mounts, and a film screen. The 3DI Telejector has the capacity to project both stereoscopic 3-D video, watched using polarized glasses, and 2D video. The 3D encoder/decoder combo has the additional ability of encoding and outputting a single field sequential video signal from two cameras for recording, transmission or display of 3D video. It can also take encoded field sequential video and decode into left and right eye views for projection.

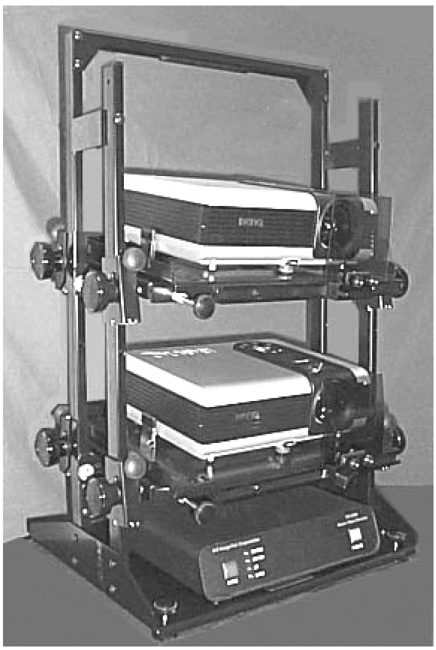

Figure 1. 3DImagetek 3DI Telejector

Elumens on the other hand offered a series of Dome VR equipment built on spherical projection technology. The Dome Series shown in Figure 2 are large spherical projection systems offering immersive VR through the use of a 180 degree field of vision. The Series consist of a Vision Station for a single user and the 3, 4 and 5 meter Domes capable of holding a larger number of people depending on Screen diameter.

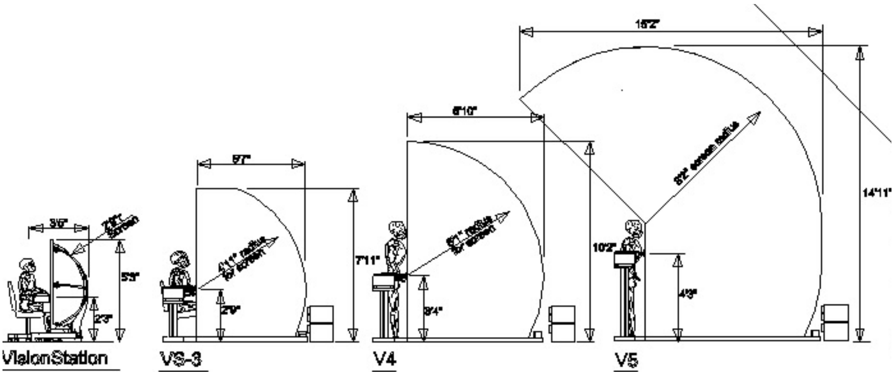

Figure 2. elumens Dome Products (Source- Elumens)

On assessing the submissions of the two companies, the Dome product from elements was judge more suitable. The dome products were scaled to enable us purchase a vision station which could be used in the Design studios, where students could generate animations and virtual display of their design products in the process of creation thereby improving the design process. The four meter dome was judged suitable for the laboratory by virtue of its ability to hold up to 10 persons viewing a virtual reality presentation. It therefore had the capacity to support student presentations to a jury of the department faculty. Factors which counted against the Imagetek product included the fact that it was a simple stack stereo projection system which meant that all content had to be recorded into a media that is compatible with the project system and then encoded to display both left and right eye which is viewed with polarized glass. The elumens system offered the opportunity of viewing with out any additional gadget.

Once the elumens system was selected, the vendor was invited to make a presentation of the technology to the school, which they did. The system was well received and there was a vivid enthusiasm for the implementation of the technology. The process of ordering the equipment was initiated in early 2002. A vision station was first ordered and situated in the design studios. Subsequently the four-meter vision dome was ordered and delivered. Computers were ordered for the laboratory, comprising of a Dual Xeon Processor IBM machine with Nvidia Quadro4 xgl graphics card to be used for running the 4meter dome and five single Xeon Processor IBM machines intended for networking to create a rendering farm to support content production for the laboratory. The Elumens 4-meter dome was installed by agents of the company, who also gave three days training on how to prepare and visualize content. This was attended by almost all the faculty as well as a core group of senior students who were selected to work on it.

4. Utilization of Virtual Reality Resources

By the October 2002, the VR Laboratory was up and running with all computers and visualization equipment installed. The visions station that was initially stationed in a design studio was later moved to the VR laboratory as it was found to have occupied significant studio space. Almost two years after the establishment of the Laboratory, however, assessment of its utilization points to a level far below anticipation. The Department was able to get the first core set of students who were trained during the establishment of Laboratory to master it and undertake a number of visualization exercises for university projects. They were also able to use the laboratory for the visualization of some of their past studio works. They were, however, unable to use the laboratory for the visualization of on-going studio projects. The Department was less successful with the next set of students co-opted to work with the laboratory. Only a few of them were able to master the process of creating content and the group was unable to undertake any significant visualization exercises. Faculty research using the Laboratory is yet to take off and there is still no attempt to formulate core fundamental research based on the Laboratory's facilities. The laboratory is also yet to be fully integrated into academic courses and design studios including the VR course and the computer based Design Studio. The proposal for the VR Laboratory to serve as the core of a multimedia service to other University Departments, though approved, has not generated the request anticipated and even if requests are generated, there is limited capability to undertake such task. The general assessment points to utilization that is below the level anticipated. The need to act to improve utilization calls for examining and understanding the forces that are contributing to the current utilization of the laboratory. A set of interrelated forces have been identified as accounting for the current utilization. These have been classified into five as follows.

4.1. INABILITY TO IMPLEMENT THE PROPOSAL FOR THE LABORATORY

One of the factors shaping the utilization of the VR Laboratory is the inability to fully implement the proposal for the Laboratory. The proposal called for the purchase of diverse VR equipment as well as dedicated staff support in the form of the holder of a chair in Virtual Reality and a Computer Aided Design Technician to oversee the running of the laboratory.

The dedicated staffs are supposed to be in charge of managing facilities in the Laboratory, scheduling use, providing training and courses in use of facilities etc. The inability to diversify equipment means that the performance of the Laboratory is hinged on understanding and using the single range of equipment in the laboratory. Absence of supporting staff has left the Laboratory without key people to guide its development and promote its use.

4.2. INADEQUATE IMPLEMENTATION PREPARATIONS

On hindsight, it also appears that the process of computerization and implementation of VR might have moved too quickly in the Department, combining the introduction of computers with the introduction of Virtual Reality. The quick and simultaneous introduction of information technology and Virtual Reality engendered a debate among the faculty on the relative merits of the digital revolution on design skills, the so called digital versus tactile debate taking place in many schools of architecture. The debate shifted focus from trying to understand and utilize the potentials of the facilities available to trying to justify the implementation of information technology in the curriculum. Such a situation, it appears, might have been avoided if implementation of information technology had been carried out in a gradual and sequential manner. Implementation was also not preceded by the adequate preparation of the academic faculty. Initial training offered by the supplying company was inadequate to impart the necessary skills needed to manage the production of content. Academic staffs were also constrained, by teaching, research and other activities, from devoting time to master the operation of the VR facility and in some cases, conflicts in computing platform interest precluded academic staff from investing the time to learn. While quick implementation was motivated by the availability of funding for the laboratory, a gradual implementation backed by a well though out strategy of implementation for both computing and virtual reality might generally have led to better earlier acceptance and a faster integration into the teaching and research process.

4.3. PROCEDURES FOR PRODUCING CONTENT AND LACK OF SUPPORT

The complicated procedure and requirement for generating content for visualization on the Dome has also been a major disincentive to the optimal utilization of the VR laboratory. The Dome series product uses the Spherical Projection Interface method, sometimes combined with stereoscopic vision. The preparation of content follows a particular set of steps or process illustrated in Figure 2. Content development starts with the modeling and assignment of materials for the object to be visualized. The model has to then be animated using software programs that support a four camera set-up. Elumens recommends 3D StudioMax because of its support for 4-camera setup. It appears, however, that only Maya is additionally able to effectively support a four camera setup for generating Dome content. The animation process produces four different images for each frame. The images are then stitched using the elumens proprietary TruFrame program to create a single image with 180°x180° field of view (FOV) for distortion free viewing on a hemispherical viewing screen. The stitching process also involves correcting the image for offset viewing and projection on the different Dome series. The projector and viewer positions are largely arbitrary and flexible in Dome projections. Elumens systems require very high-resolution playback to take full advantage of large screen area. The Vision Station displays at a resolution of 1024x768 while the larger systems display at a resolution of 1280x1024. The large display resolution means that the final visualization file is large, and has to be compressed. Elumens provides another proprietary product TruMotion for the compression and playback content files on the Dome. The complexity of the procedure means that adequate time is needed to address all process problems and prepare content for visualization. Significant computing resources is also need for content production particularly in the rendering and stitching of output from four cameras and also in the visualization of the huge files that are generated. The complexity of the process, inadequate computing power and excessive glitches that were face in the initial experimentation in the use of the laboratory appears to have served as a disincentive to the full utilization of the laboratory.

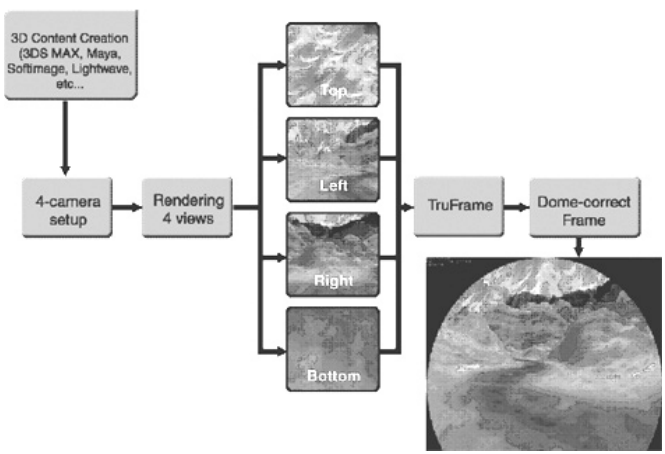

Figure 2. Content Preparation for Elumens Dome Series Display

The disincentive resulting from the complicated procedure for producing content was further exacerbated by the inadequacy of training manuals and support. The Domes were supplied without adequate training manual or step by step manuals explaining the procedures for producing and visualizing content. Support for the products was provided through a single web location, where users have to post their questions and wait for response or search for response to similar enquiries from other users. The situation expanded the learning curve for the operation of the Dome and discouraged people from utilizing the VR facilities.

4.4. DESIGN STUDIO SCHEDULE AND NEED FOR NEW COURSES

The structure of the design studio schedule of the Department also contributed in part to the level of utilization of the laboratory. Studios are structured so that students undertake 2 to 3 design projects within a fifteen weeks semester. This makes the average duration of a project to range from 4 to 6 weeks. The limited time given to design projects means that students are always under pressure to meet scheduled bench mark requirements and have little or no time for experimenting with new technology. The combination of a complicated content production process and limited project durations has combined to limit the utilization of the laboratory. Additionally also, the inability to offer new courses that explore the potential of the VR laboratory, means that students are not very clear about the benefits of the use of the VR facilities.

4.5. LIMITED COMPATIBILITY WITH OTHER COMPUTING RESOURCES

Part of the disincentive for using the laboratory also arises from the limited compatibility of computing resources. The Dome series equipment uses a four camera setup, thereby requiring that virtual models be compatible with the 3D StudioMax computing software. Prior to the introduction of the dome, however, FormZ was the most prevalent rendering software of choice among the students, and the teaching of IT courses dealing with Modeling, Rendering and Animation was done using FormZ. The lack of full compatibility between FormZ and 3D StudioMax meant that attempts to transfer virtual models from FormZ to 3D StudioMax, always resulted in glitches that required substantial time to resolve. This increased the time dimension needed to create content for visualization on the Dome and further discouraged the use of the Facility. There was also the question of appropriate browsers to use for real time virtual reality. The hemispherical nature of Dome display means that browsers have to have the capability of supporting spherical display at the large resolution required by the Domes. So far only one experimental browser has been identified and even that is at a rudimentary stage of development. This lack of compatibility of browsers with the Dome series limits the ability to cut the time of preparing content by engaging in real time virtual reality.

5. Conclusion and Recommendations

The paper reviewed the experience of KFUPM in establishing a VR laboratory and examined some of the forces that account for the less than expected utilization of the laboratory. From the literature, it is apparent that many universities have successfully implemented virtual reality laboratories. Schools have to be on the edge of technology to remain competitive and provide graduates with the skills necessary to survive in the professional industry. Introduction of technology must however be optimized to ensure the efficient use of resources. In KFUPM, VR implementation was driven by visionary leadership coupled with the availability of opportunities for funding. Such leadership is absolutely necessary for introducing innovative technologies. The KFUPM case has however shown that the introduction of such innovative technologies must be tempered by well developed strategies to ensure optimal success in implementation. Examination of the KFUPM experience suggest certain strategies that may generally improve the potential for success in introducing computing as well as virtual reality to the curriculum of architecture schools. To start with, computerization should be gradual moving from a systematic gradual introduction, acceptance and integration of computers into curriculum to investment and introduction of high end systems such as virtual reality. Gradual introduction should be complemented by training and faculty development and training on computer application in architecture. Virtual reality introduction should preferably be initiated by the academic faculty and a core team of dedicated people with technical know how should be identified prior to implementation. Virtual reality should not be implemented as a departmental resource but as a university wide resource integrated into teaching and research across different disciplines. New and specific courses that seek to explore VR and its applications have to be introduced along with VR adoption. Computer based studio projects should include dedicated projects aimed at using VR to explore and shape the design process. The Choice of systems for implementation must reflect technical capabilities and ease and ability to use systems. Research, especially basic research, and collaboration with industry is critical to the success of virtual reality facilities. It enables the generation of funds for modernization and provides the motivation for full utilization

In the case of the KFUPM VR Laboratory, concerted actions are needed to improve the utilization of the laboratory. There are several specific actions that are recommended to improve the utilization of the laboratory. Urgent action is needed to identify a core group of faculty and assign them the responsibility of developing strategies for incorporating laboratory into teaching and research activities. Such faculty should develop adequate technical knowledge of the available equipment. The University may also consider appointing dedicated staff for the laboratory as was contained in the initial proposal. There is also a need to develop a multi-disciplinary research framework which seeks to exploit the capabilities of the facilities of the Laboratory. Adequate training in the use of the VR laboratory facilities is critical to the optimal utilization of the laboratory. There is a need to develop user friendly training manuals as well as a proactive support regime to promote the use of the laboratory. This should be complemented by the introduction of special courses that seek to explore the potentials of the VR laboratory. There is also a need to link the VR Laboratory to design courses and to exercises in IT courses, especially the Virtual Reality course. Finally, there is a need to work on setting up the initial rendering farm intended for the laboratory as a means to ease the time required to produce content.

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Section V

Computers in Environmental Quality and Life Cycle

PLAUSIBILITY IN ARCHITECTURAL DESIGN
SOFTWARE SUPPORT FOR THE ARCHITECT-ORIENTED DESIGN OF COLOUR SCHEMES FOR INTERIORS AND BUILDINGS

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Colourful is my favourite colour. (Walter Gropius, 1921)

1. Introduction

The approach discussed here is part of research into an overall concept for digital instruments which support the entire planning process and help in enabling planning decisions to be based upon clear reasoning and plausible arguments.

The paper describes a plausibility instrument for the formulation of colour scheme proposals for building interiors and elevations. With the help of intuitively usable light simulations, colour, material and spatial concepts can be assessed realistically.

The software prototype "*Coloured Architecture*" is conceived as a professional extension to conventional design tools for the modelling of buildings. As such it can be used by the architect in the earliest design phases of the planning process as well as for colour implementation on location.

2. Colour as an Essential Design Decision

Architecture is "designed" space. The colour and characteristics of a space's surfaces play a significant role in the "design" of architectonic space.

Surface characteristics apply to both interior as well as exterior space, and are dependent upon the environment as well as mobile elements, fittings and extensions. The exploration of and determination of colour values and their application to different built surfaces is a complex and creative process which is part of the architectural design process. The selection, determination and application of colour is an aspect of almost all design phases and occurs in conjunction with other design decisions (form, function, construction) and is influenced by a number of factors (light, material, surface temperature, subjective perception etc. (Nemcsics, 1993).

A good knowledge of colour systems and their effects within particular spatial situations, in conjunction with particular materials and surface qualities and the influence of light on colour and atmosphere are only some aspects necessary for professional design of colour schemes. The tools and working methods are in principle relatively simple and have not changed significantly over the years: interior rooms or exterior elevations, perspectives or isometric representations are drawn to scale and coloured as a means of exploring (for the designer) and communicating (for other participants) colour schemes. Colour scheme variants, detailed vignettes, colour samples and colour collages form the basis for planning decisions. Very often such decisions are often made independent of other design aspects such as spatial organisation, environment, the atmosphere of a space, its use, material or construction (Philipp, 2003).

3. Colour in architectural design and its implementation in current CAAD systems

Modern-day design and planning in architecture should make exclusive use of CAAD systems. Architect-oriented colour scheme design is rarely or only poorly supported in currently available commercial CAAD systems.

Depending upon the manufacturer, different CAD systems support different colour palettes such as the RAL-system or the Pantone© colour system. (see Figure 1: Example of RAL colour systems in commercial CAD systems). These can be attributed to 2D or 3D objects as colour values in CAD systems. A variety of commercial modules or plug-ins are also available which integrate different colour palettes into various software tools (e.g. the colour atlas from www.dtpstudio.de). This add-on approach does not directly support the needs of the planner in an architectural planning environment. A comprehensive architect-oriented system is necessary which supports such design decisions from start to finish by providing colour experimentation, management and representational functions.

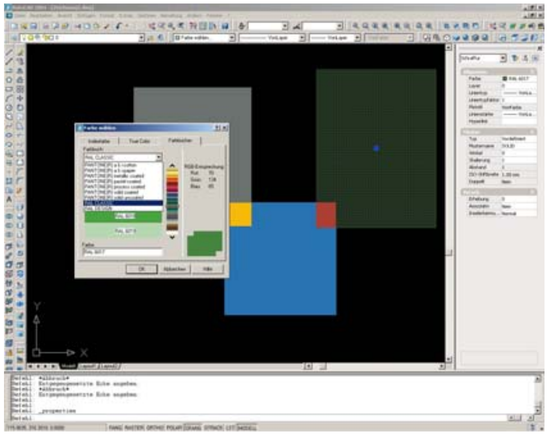


Figure 1a. An example of RAL colour palettes in commercial CAD software: here AutoCAD, RAL Classic colour palette, ©AutoDesk.

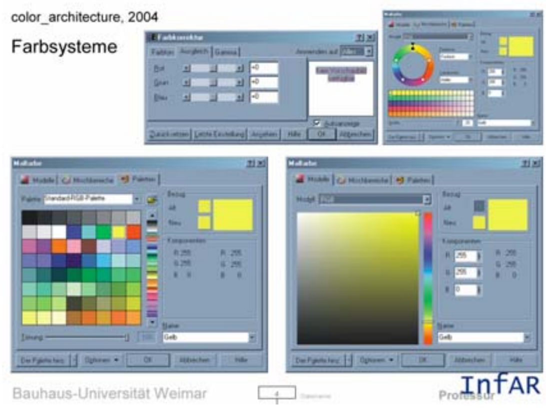


Figure 1b. different colour palettes in image manipulation software: here Corel Photopaint ©.

It is not important whether 2D drawings or 3D models are developed; the previously discussed colour considerations and final implementation are independent of this. The graphic product of CAAD supported working methods, “the drawing” (digital or otherwise), is used as a basis which can be ‘filled’ with colour appropriately. Current CAAD systems support the design of spatial geometry and can produce representations of this in the form of images, element catalogues or bills of quantities. Functions which support the plausibility of these representations are not available (Lömker and Donath, 2003). The integration of colour scheme design in the complex process of design is not supported whether with regard to the informational or structural CAAD models.

4. Colour experimentation using planning-oriented CAAD-based tools

CAAD systems offer the potential of providing the architect with comprehensive information which can help in the reasoned and informed development of planning solutions, not just the formal design aspects.

5. Coloured Architecture [C_A] – Digital colour development in design and planning

The planning concept supports all typical and necessary investigations, representation and realisation requirements for colour schemes in architecture.

The experimental system C_A [*Coloured Architecture*] is oriented towards the requirements of the planning process and communication of the results, and has demonstrated in experimental implementation that such a CAAD-based approach can be used for colour-scheme design and decision making. The use of the system enables the following:

- The exploratory and intuitive application of colour schemes for particular building surfaces.
- support for design-process dependent colour scheming, i.e. from a variety of 'unsure' design proposals in the first phases to the exact specification and colour catalogue for use on site.
- Support for particular colour combinations, i.e. project specific or 'favourite' colour palettes or colour combinations.
- Consideration of the architectonic play of material and light
- Incorporation of technical colour systems (RAL, DIN, CIE Lab, Munsell, CMYK, RGB, LAB, HSB etc.) as well as specific product-based colour palettes (Berns and Brinkmann, 2003).
- Avoidance of redundancy as a result of working in different geometric models and drawn representations. Colours are applied to building elements and objects in the CAAD model rather than projective representations thereof.
- The specification of colours on site (which walls and elements are to be painted with which colour) e.g. the transfer of CAAD-based information to exact specifications for the building site (colour charts for rooms, sample cards),
- Demonstration of the value of 3D CAAD systems in the support of design plausibility in the design process (Balaguer and Abderrahim, 2002).

The concept of the experimental system Coulored Architecture is oriented towards the needs of the planner and consists of three primary components:

A Colour attribution
B Colour evaluation
C Colour implementation

5.1 COLOUR ATTRIBUTION

Colours can be applied interactively to all spaces or elements defined in a CAAD model including their surfaces or parts thereof. Each surface of an elevation, each wall surface, each window frame or glazing bar that has been defined in a CAAD model is linked to a digital colour object with the respective colour information (saturation, lightness etc.) Spaces and elements can be grouped and combined to simplify and coordinate the application of colour schemes. A building element can be separated via different sectional levels into sub-areas and coloured differently as required. This can take place through the use of “working views” in CAAD systems and/or using the elevations, indoor room elevations, panoramas etc. generated from the CAAD model. (see Figure 2. Coloured Architecture: Part of the colour choice dialogue box for applying colour in the planning process.)

In addition to exact fixed values, value areas can also be defined (tonal value, lightness areas etc.). Each sub-stage can be defined as a variant and combined. Through the grouping of colours and colour variants, particular colour situations (lightness regulation by same tonal value) can be assembled and archived.

Following the object-oriented approach of CAAD systems (Beucke, 1995), the colours can be directly applied to the CAAD model elements as room or element properties in the form of attributes. A variety of colour systems (RAL, DIN, CIE Lab, Munsell, CMYK, RGB, LAB, HSB etc.) or product palettes according to the manufacturer can be used and translated (as far as is technically possible). To ensure that the digital colour used (screen, plotter) corresponds to the actual colour, a variety of different adjustment, calibration and proofing functions are available (see also Figure 1a: Colour palettes in different systems: here Corel Photopaint©).

A further concept takes account of the influence of light and material properties on surface colouring and the entire effect of colour in a building: Exact colour combinations, additive (light rays, monitor, RGB) and subtractive (CMYK, paint mixtures, printer), either through the specification or evaluation of “colorimetric coordinates’ such as RGB-values and further properties in relation to both architect-oriented and technically verifiable colour definitions.

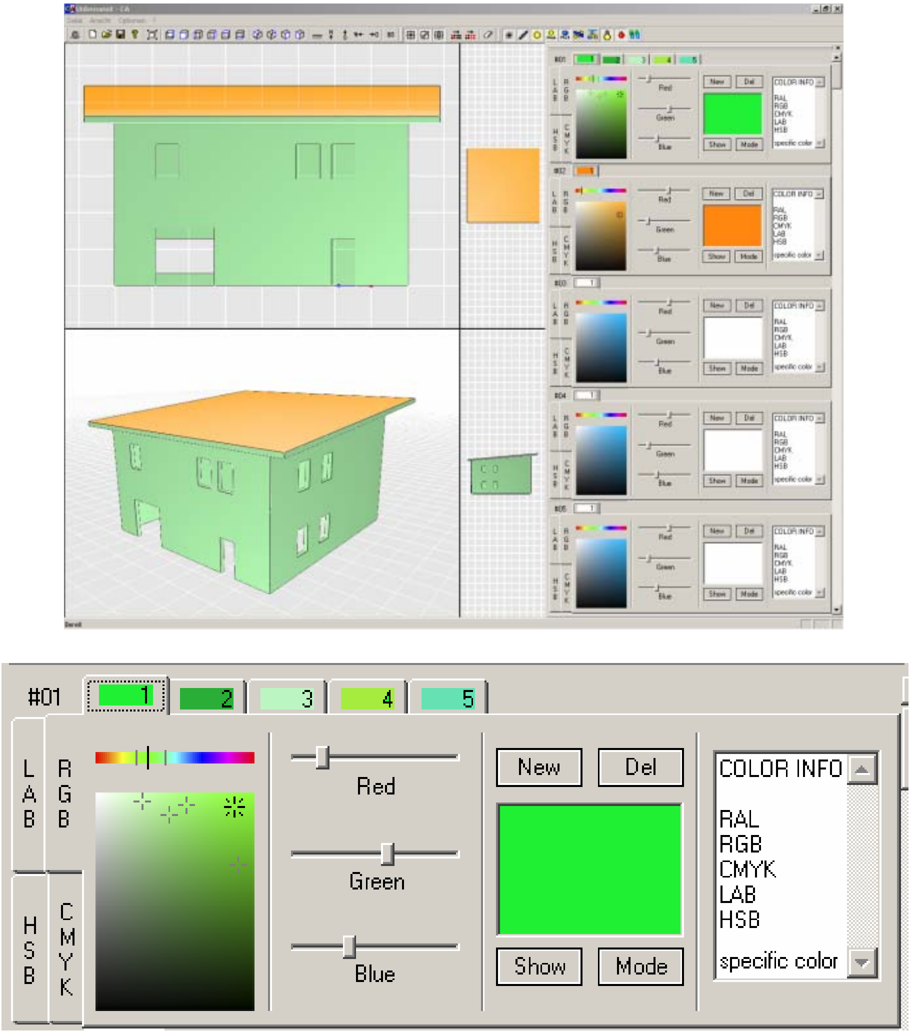


Figure 2. Coloured Architecture: Part of the colour choice dialogue box for applying colour in the planning process.

5.2 COLOUR EVALUATION

The evaluation of colour is largely dependent upon the so-called "subjective colour impression" and is based upon our psychological pattern of perception, our aesthetic response and individual character. In addition there are a number of conventions, traditions and restrictions with regard to the effect and interaction of colour in architecture. These aspects will most likely remain as valid as ever. The experimental system as discussed here should provide the necessary basis to transform these sensory-perceptive impressions into planned colour schemes (see Figure 3 Coloured

Architecture: comparison of colour scheme variants using 2D-views of a CAAD building model). The system supports the typical working method of architects and planners.

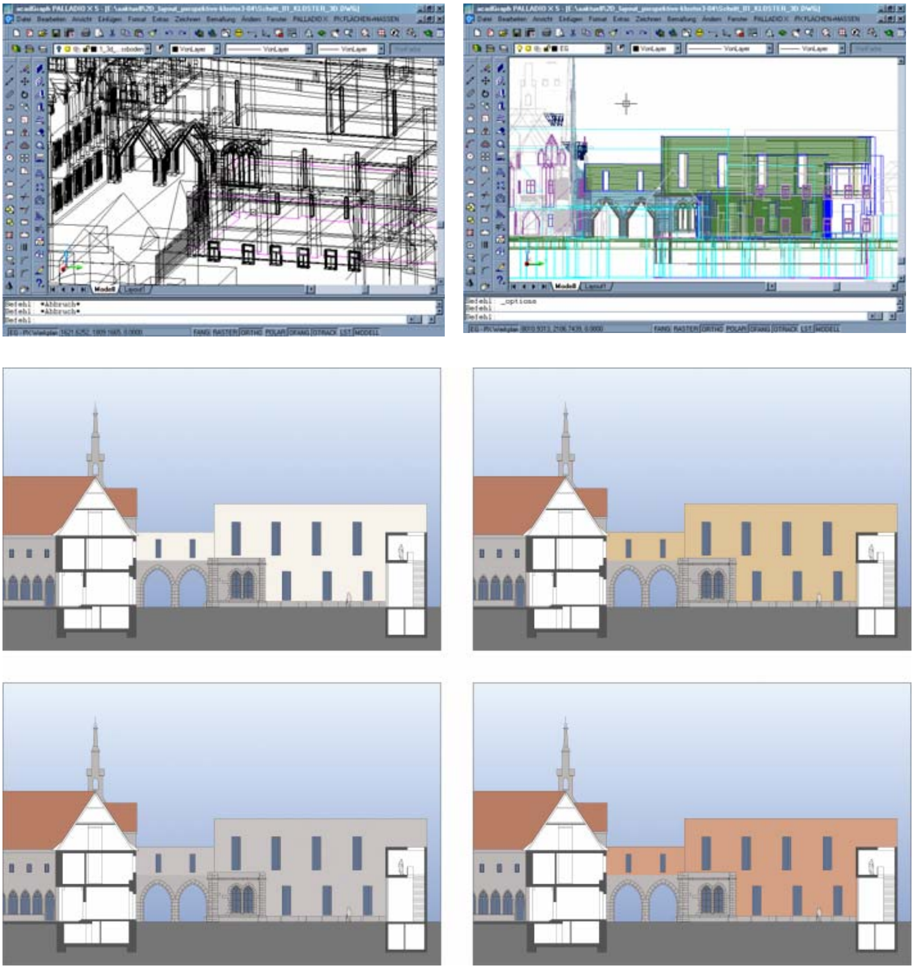


Figure 3. Coloured Architecture: comparison of colour scheme variants using 2D-views of a CAAD building model (Augustiner-Kloster Erfurt, Competition, 2004 © nitschke-donath architekten)

5.3 COLOUR IMPLEMENTATION

The comprehensive use of complex CAAD tools throughout the entire planning process also enables the results in digital form to be evaluated and edited on location before final specification.

A number of different systems for transferring working drawings and planning documents to the site have been developed in the last few years (see System OnSiteEnterprise, 2004). In the case of colour schemes it is equally useful as it is important to review the choice of colours on site. An evaluation of colour using swatches and samples (printed/plotted) requires correct colour management between all different presentation media i.e. monitor and digital output devices. The experimental prototype therefore includes classic colour calibration functions. In addition, a useful combination of classic colour scheme evaluation techniques is also part of the concept. Two typical techniques employed by architects are included:

- A room-by-room colour scheme output (indoor wall and floor/ceiling elevations) and
- The large-scale output of colour samples for trying out on site.

The derivation of colour-cards in the form of “space-colour-profiles” is a direct addition to the CAAD-generated room log and allows colour-schemes to be applied to wall and building-element surfaces room by room (see Figure 6 automatically generated wall and floor/ceiling elevations using colour profiling from CAAD model). In addition selected portions of the model can be rendered and output as so-called colour samples at a scale from 1:100 to 1:1 (see Figure 6 Definition of selection for rendering as a large-scale sample printout for evaluation on site).

To reduce errors or misunderstandings the sample printouts can be tried out on site. All samples include the details of colour properties so as to ensure the correct application of the colour envisaged (see Figure 7 Part of a room log including application of colour scheme and Figure 8 Coloured Architecture: Interior wall and floor/ceiling elevations).

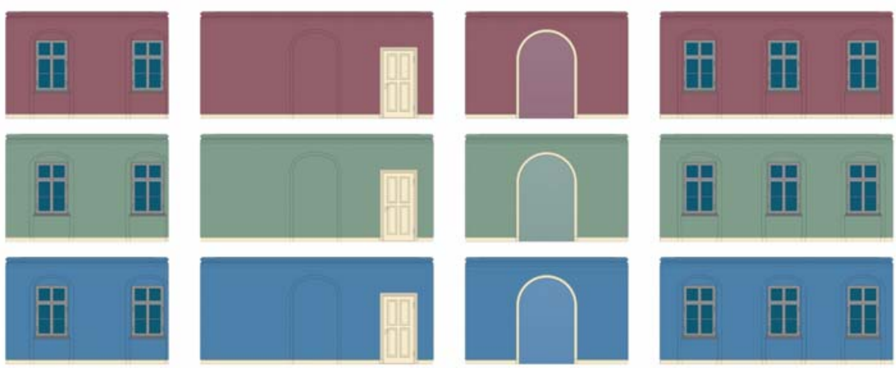
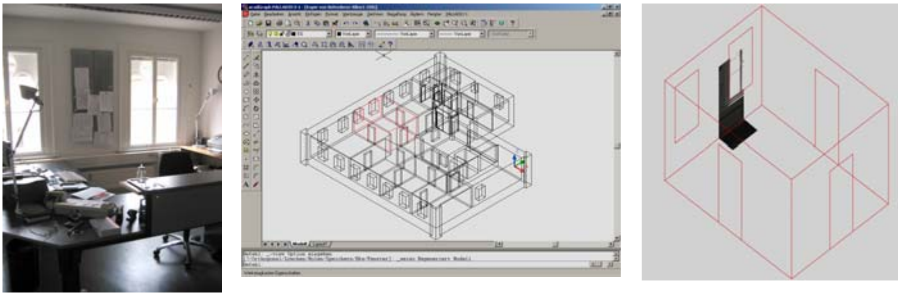


Figure 5. Coloured Architecture: automatically generated wall and floor/ceiling elevations using colour profiling from CAAD model (Wielandgut Osmanstedt, Ausführungsprojekt, 2004 © nitschke-donath weimar)



The room on site

Selection of room in 3D CAAD model

Selection of an area for a sample plot at 1:1 scale

Figure 6. Definition of selection for rendering as a large-scale sample printout for evaluation on site. Site: Belvederer Allee 1, Bauhaus Universität Weimar, 2004.

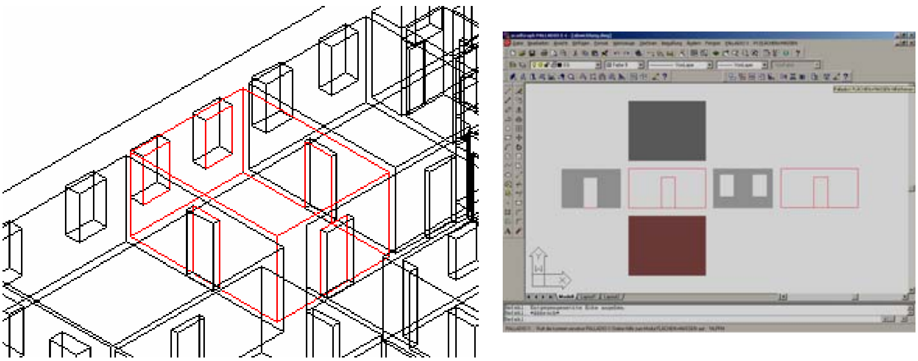


Figure 7. Part of a room log including application of colour scheme.

Figure 8. Coloured Architecture: Interior wall and floor/ceiling elevations showing different colour scheme proposals based upon predefined space-colour-profiles. (Belvederer Allee 1, Bauhaus Universität Weimar, 2004).

6. More Colour in Architecture

The potential of such digital planning tools lies in the "added value" of CAAD: many more planning aspects can be digitally supported using CAAD systems than solely building geometry.

The concept discussed in this paper is an example of a task-oriented extension of current CAAD systems, maximising the use of CAAD-characteristic object-oriented structured building models. Colour scheme design decisions can be made and specified using the building model. The effect of light and material is as yet not implemented and is very important in order to correctly evaluate the effect of colours in rooms or outdoor environments. However, even this experimental development prototype already demonstrates the added value possible through the consequent use of CAAD: function, construction and not least design aspects have equal status and can be worked upon in direct relation with one another under the control of the architect.

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A COMPUTER PROGRAM FOR LIMITING THE SUITABLE COLOR RANGE FOR FACADES

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Abstract. Limiting the suitable color range is considered as one of the important steps in the process of choosing color for facades. This paper aims at developing and presenting a rule based program that its main function is **L**imiting the **S**uitable **C**olor **R**ange (**LSCR**) for building facade. So, the paper presents the steps of color limitation process, its requirements and classification of different factors that influence color decision such as functional, climatic, environmental, social, commercial and political factors…etc. After this step, the paper presents a description of the supposed program, its components (the user interface, the knowledge base, the inference engine and the color palette) and the relationships in-between. Then the paper presents the running sequence of LSCR and a practical example for using it to limits suitable color range for a facade due to its circumstances.

1. Introduction

Computer became a necessary tool in all science branches including architecture. During the last years, it began to exist in all aspects of architecture. But there is a need to develop more applications that would assist architects throughout the different steps of design process.

Because color is one of inevitable visual properties of any material, the color selection of facade components is considered as one of the important stages in architectural design process. One of the particular steps in this stage is limiting the suitable color range depending on the factors that influence the building and the color decision.

In the past, architects used traditional color circles, solids and models as a color palette to choose the suitable colors through it. But with the recent possibility of computer to compose a large amount of colors (about

16.77 million), specification of the suitable color range became not easy with traditional methods. This fact leads to a question about the role, which computer can play in this step in order to avoid neglecting of any suitable colors for facade.

This paper presupposes that computer can plays a role in assisting in limiting the suitable color range for building facades depending on a knowledge base for all factors that influence selecting color. So the paper aims at presenting a rule based program for **L**imiting the **S**uitable **C**olor **R**ange for building facades **"LSCR"** in accordance with all circumstances and factors, influencing the building and the color solution.

2. COLOR LIMITATION PROCESS

It is important that becoming acquainted with the color terminology that is used in this paper, steps of the color limiting process, circumstances and factors that influence it.

2.1 COLOR TERMINOLOGY

This point presents a briefly overview for the terminology related to colors (as pigment), that are used in this paper.

2.1.1 Color properties:

Colors may be said to be the quality of reflected light from a surface or a light source (Isaac, 1971). The word "color" refers to a companion of three properties: Hue, Value and Saturation.

HUE is the property that distinguishes one color from another, the property that enables us to name the color.

VALUE/ LIGHTNESS is the darkness or lightness of a color.

SATURATION refers to the purity of color or the vividness of a color (Cleaver, 1972).

2.1.2 Color Attributes

From thermal point of view, colors are classified into Warm and Cold colors (Porter and Byron, 1976).

Warm colors are the colors of the warm area of the spectrum. It includes yellow, orange, red and in-between colors.

Cold colors are the colors of the cold area of the spectrum. It includes green, blue, purple and in-between colors.

“Complementary colors” is earned attribute (which color earns it through its relationship with other colors), the opposite colors in a color wheel are complementary colors. When two complementary colors mix together, they compose a neutral color (Arnheim, 1974).

2.2 STEPS OF COLOR LIMITING PROCESS

Like all other architectural design stages, an architect follows some steps that lead him to obtain the most suitable color range for the facade that is under design. These steps are:

a. The first step in this process is collecting the circumstances of the facade and all factors influencing it.

b. The architect begins to Study and analyze the circumstances of the facade and all factors influencing it

c. Depending on the studies in field the of color and building facades (which provides him with all necessary knowledge in this field to take the right decisions), the Architect begins to get out the rules that control the relation between these factors, circumstance and the suitable color range.

d. Consequently, he uses these rules to infer the properties of the suitable color range for every one of the influenced factors.

e. In this step, the architect gets the crossed color properties in all partial color ranges that inferred in the previous step. The result is the color properties of the suitable color range for the facade and its circumstances.

f. The last step is applying the result onto a color palette for deleting the undesired colors and leaving the suitable colors in the palette (Figures 1 and 2).

After addressing the color limitation as a process, it is important to study and analyze the inputs of this process that are represented in the influenced factors and circumstances.

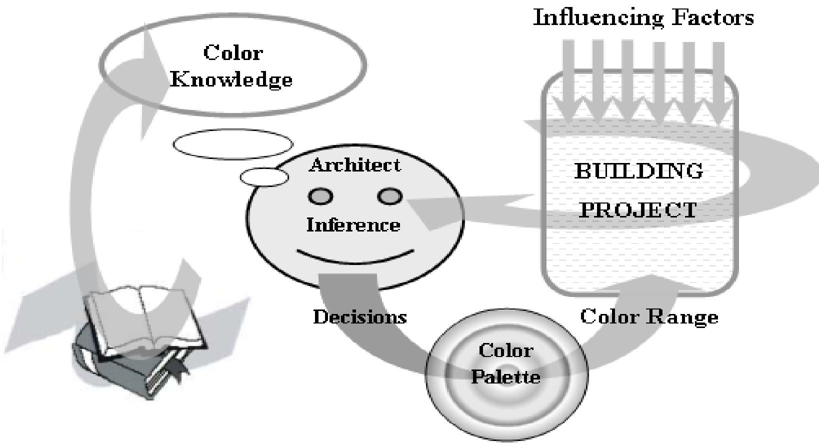


Figure 1. Method of getting the suitable color range for a facade

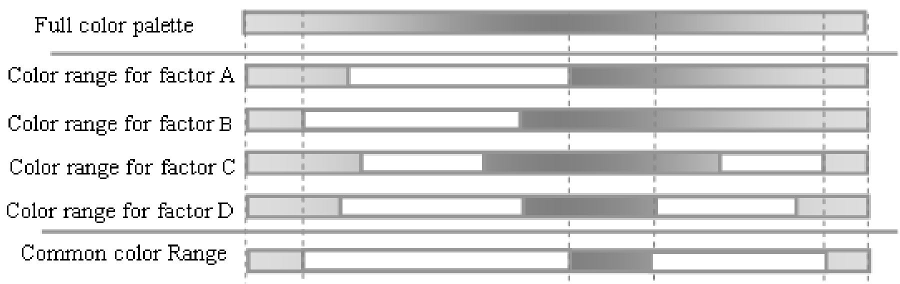


Figure 2. Method of getting the common color range for all factors

2.3 FACTORS THAT INFLUENCE THE COLOR LIMITING PROCESS

Factors that influence the design process are divided into three groups; the functional factors (requirements of building function), the natural factors (climate, material, environmental factor) and the human factors (psychological, cultural, social, aesthetical, economical, legislation and political factor).

Some of these factors don't influence the color limitation process and influence other stages in color selecting process. One of these factors is the material factor, which dealing with it is the last step in the color selecting process. The other factor is the aesthetical factor, which influences the way of organizing and distributing colors on the different components of a facade.

The human factors influence the desires and preferences of members of the architectural work (the architect, the investor, the user, the society and the municipality), and consequently influence the color limitation process (Abdelmagid, 2000).

These factors can classify into two groups; inevitable factors and commendable factors.

2.3.1. Inevitable and coercive factors

- **Legislation factor:**

The most inevitable factor is the legislation factor. It may cancel the limitation process if there are any laws that control selecting the colors of building facades.

- **Function:**

The suitable color range for the functional factor is tied to the emotions and feelings that the facade should present in accordance with the building function. Previous studies present the relation between colors and feelings, functions and feelings (AbdelMagid, 2000). The relation between building function and facade colors is derived and presented in Table 1.

TABLE 1. The suitable color range for the different building functions.

Building Function	**Color Properties**		
	Hue	**Lightness**	**Saturation**
Residential	All Hues	High & Medial	All
Governmental	All Hues	All	Medial & Low
Administrative	All Hues	All	Medial & Low
Trade	All Hues	High & Medial	High & Medial
Service	All Hues	High & Medial	All
Cultural	All Hues	High & Medial	All
Educational	All Hues	High & Medial	All
Health	All Hues	High	Medial & Low
Recreation	All Hues	High & Medial	High & Medial
Tourist	All Hues	High & Medial	High & Medial
Social	All Hues	High & Medial	Medial & Low
Industrial	All Hues	All	Medial & Low
Religious	All Hues	High	Low
Funeral	All Hues	All	Low
Sport	All Hues	High & Medial	High & Medial

- **Climate:**

Climate Studies in field of architecture confirm that color helps in thermal adaptation of the building. These studies clarify that hot climate requires light colors that can decrease heating penetration into the building. Also it requires cold colors that can realize sensation with coldness towards the buildings. On the contrary, cold zones require dark and hot colors (Zelanski and Fisher, 1989). The temperate zones don't require any color conditions (Table 2).

TABLE 2. Thermal circumstances and its suitable color range.

Thermal Factor	Color Properties		
	Hue	Lightness	Saturation
Hot Zone	Cold Hues	High	All
Temperate Zone	All Hues	All	All
Cold Zone	Warm Hues	Low	All

- **The sun shine**

Saturated colors in zones that have a strong and direct sun shine (like the tropical areas) vanish with time. So these zones don't require saturated colors. Otherwise, zones that have a weak and indirect sun shine require saturated or light colors that can resist effect of shades and the lake of the light (Zelansky, 1989). Table 3 presents the suitable color range for sun shine probabilities.

TABLE 3. Sun Shine factor and its Suitable color range.

Sun Shine	Color Properties		
	Hue	Lightness	Saturation
High	All Hues	Low	Medial & Low
Medial	All Hues	All	All
Weak	All Hues	High	High

- **Orientation:**

In the north of the equator, north facade s is shaded most of the day. Shades on this facades lead to decreasing the visual saturation and lightness of the color, so colors in these facades appears less in lightness and saturation. Such facades require saturated and light colors (AbdelMagid, 2000). East and west facades don't require any special conditions. Also, the suitable colors for a south facade (sunny facade) are the non saturated colors. Otherwise, dealing with the building that has multiple orientations, and in order to avoid the separation of colors of facades, it is good to ignore the effect of this factor in such case (Table 4).

TABLE 4. Orientation and its suitable color range.

Orientation	**Color Properties**		
	Hue	**Lightness**	**Saturation**
North	All Hues	High	High
East / West	All Hues	All	All
South	All Hues	All	Medial & Low

- **Pollution:**

Pollution leads to a visual decreasing for saturation and lightness level of colors. Also, the effect of pollution will appear fast and strong in colors with high and low level of lightness. So, polluted atmosphere requires using saturated colors with medial lightness.

Otherwise, Medial lightness level colors are suitable for the medial level pollution. The low level and no pollution don't have any special conditions (AbdelMagid, 2000) (Table 5).

TABLE 5. Pollution level and its suitable color range.

Pollution Level	**Color Properties**		
	Hue	**Lightness**	**Saturation**
High	All Hues	medial	High
medial	All Hues	medial	All
low	All Hues	All	All

- **Surrounded Colors:**

The surrounded colors - in the built environment - represent a reflection of some human factors (like the social, political and sometimes the cultural) on the color preferences of the society.

Taking this factor in consideration has three directions: The first is the similarity between color properties of facade colors and the surrounding colors. This direction means canceling of the limitation process.

The second is the negligence of its effect in case that there isn't a dominant surrounded color.

The third direction is considering the facade colors as a part of big colored image that includes facade colors and dominant surround color. This leads to deal with the color of the facade as a component of color schemes, where the dominant surround color is essential.

2.3.2. Commended Factors

Some of human factors like cultural, social, economical, technological, political and psychological factor are considered as commended factors.

Studies clarify that these factors are crossed, for example, it is difficult to separate the effect of the cultural factor away from the psychological factor or the technological factor away from the economical factor. Also it explicates the different forms of effects and its reasons.

Because these factors influence color preferences of members of the architectural work (architect, investor, user and municipality), the influence of them can replace by preferences of members of the architectural work. But some studies warn from the danger of obligation the human preferences because they may lead to a mill color choice (Mahnke, 1987). So, and as a principle, a human preference is respected if they belong to the suitable color range of the inevitable factors.

3. DESCRIPTION OF LSCR

After becoming acquainted with the steps of color limitation process and the influencing factors, it is clear that such program can depend on four essential components that represent all requirements to emulates and perform procedures of color limitation process. These components are Knowledge Base, Inference Engine, Color Palette and User Interface (Figure 3). For constructing LSCF and its components, the author used “Visual Basic” as a programming language.

3.1 THE USER INTERFACE

It is a means of communication between the program and the user (the architect). He inserts the inputs of the program (influencing factors and circumstances), which is necessary to the inference engine in order to work. The probabilities of each factor are presented as a pull-down menu that, and through it, the user selects the corresponded case.

Also and through it, the user receives the suitable color range for every factor and for the crossed range as a final result. Components of the user interface are shown in Figure 4.

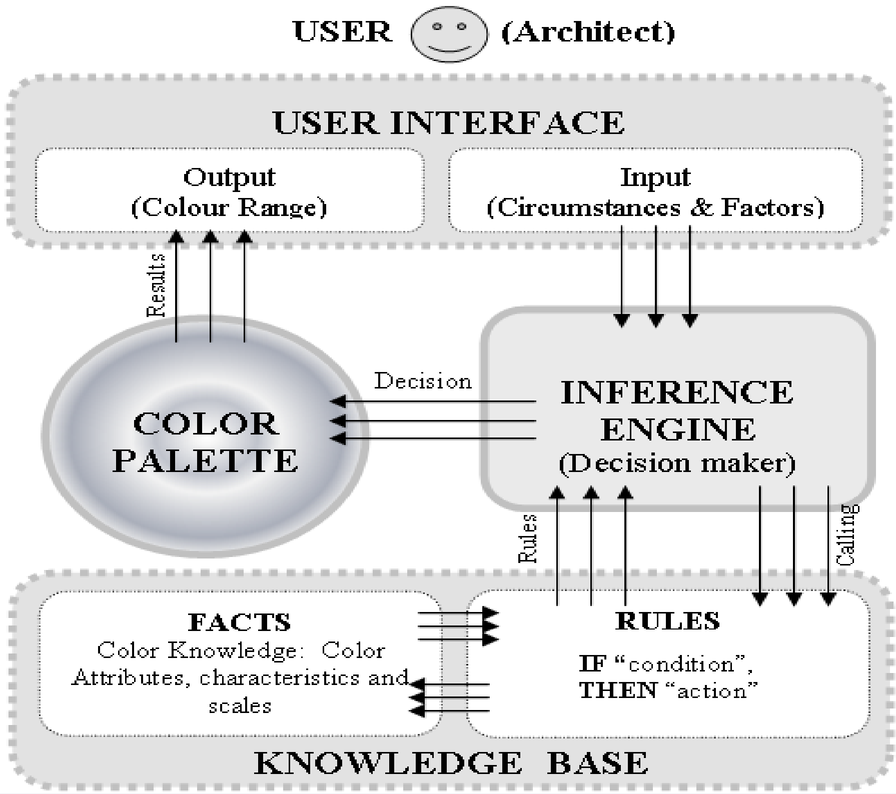


Figure 3. Structure of a program for limiting the suitable color range for a facade -LSCR

3.2 THE KNOWLEDGE BASE

That contains a representation of knowledge related to circumstances that may influence the process of limiting the suitable color range. One widely used representation is the production rule, or simply "Rule". A rule is composed of an IF portion and a "THEN" portion. The IF portion lists a set of conditions. The piece of knowledge represented by the rule is relevant to the line of reasoning being developed if the IF part of the rule is satisfied; consequently, the THEN portion can be concluded, or its problem-solving action taken.

LSCR Knowledge base consists of 27 rules that inference engine use to cover 1215 probabilities of inevitable influencing circumstances.

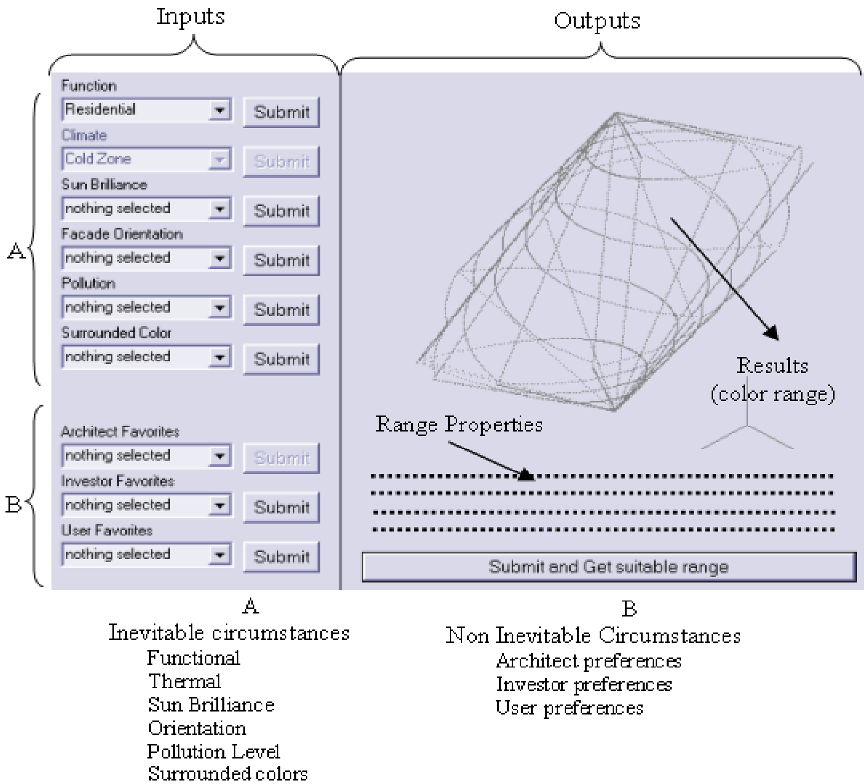


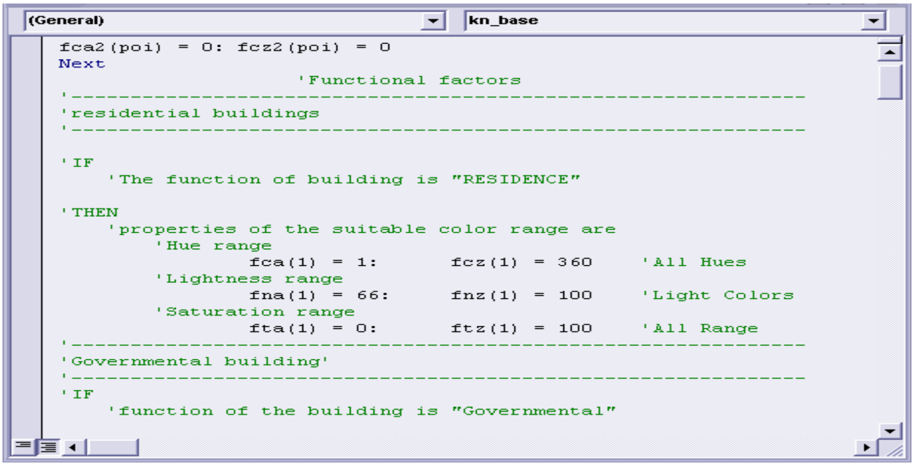
Figure 4. Components of User interface in LSCR

The following are examples of rules in knowledge base of LSCR.

RULE
IF
Building function is ***Residence***
THEN
Properties of suitable color range are:
Hues are ***All Hues***
and Lightness is ***Medial*** and ***High***
and Saturation is ***High***

RULE
IF
Thermal zone is **Hot**
THEN
Properties of suitable color range are:
Hues are ***Cold Hues***
and Lightness is ***High***
and Saturation is ***All***

A part of the encoded knowledge base of the program is presented in Figure 5.



```
(General)                                   kn_base
fca2(poi) = 0: fcz2(poi) = 0
Next
                    'Functional factors
'-----------------------------------------------------------------
'residential buildings
'-----------------------------------------------------------------

'IF
    'The function of building is "RESIDENCE"

'THEN
    'properties of the suitable color range are
        'Hue range
                fca(1) = 1:        fcz(1) = 360     'All Hues
        'Lightness range
                fna(1) = 66:       fnz(1) = 100     'Light Colors
        'Saturation range
                fta(1) = 0:        ftz(1) = 100     'All Range
'-----------------------------------------------------------------
'Governmental building'
'-----------------------------------------------------------------
'IF
    'function of the building is "Governmental"
```

Figure 5. A part of the Knowledge Base of LSCR

Beside rules, it contains encoded facts like the color attributes: Hue, Lightness and Saturation, color characteristics: hot and cold colors and color scales for Hue, lightness and Saturation.

3.3 THE COLOR PALETTE

That is the color model, which represents a source of colors in the program. It is also a source of the relations between colors and their attributes. The color palette receives the decisions from the inference engine in order to apply it and to get out the suitable color range as a result.

As a color palette, LSCR depends on PCM (Figure 6) as a suitable computerized color palette for the architectural field, which was been derived by the author in the end of 2002 (AbdelMagid, 2003; AbdelMagid, 2004).

PCM palette is belonged into a computer program that can call colors in correspondence with colors properties that the inference engine presents them in the decision.

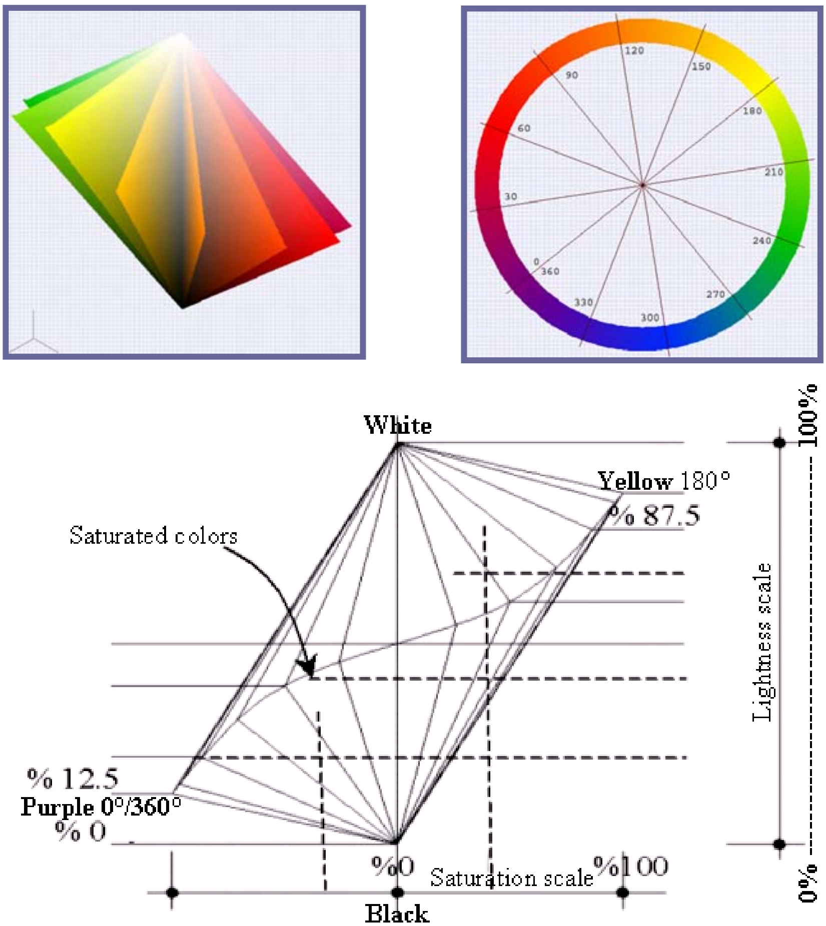


Figure 6. Properties of the Pigment Color Model "PCM" as a suitable color palette for the architectural field

3.4 THE INFERENCE ENGINE "IE"

IE is the head of the program. It receives the entered circumstances and influencing factors, and then it searches the knowledge base for necessary rules.

After collecting the needed rules, it selects a rule and then the actions of the selected rule are executed. IE selects another rule and executes its actions. This process continues until no applicable rules remain.

Through a treatment for rules execution results, the inference engine infers the decision that limits the properties of the crossed color range and represents the properties of the suitable color range for inserted circumstances.

4. RUNNING LSCR

4.1. LSCR Working sequence

The next steps present the work sequence of such a program:

a. The program receives, from the architect, the circumstances and the factors influencing the facade. These factors divided into two main groups. The inevitable factors: Function, Thermal, Sun, Pollution, Orientation, Surrounding colors. The second is the human factors represented in their color preferences. The program does this function through the Input part of the user Interface (Figure 7).

b. Using the Inference Engine (The Reasoning Engine), LSCR begins to collect the rules related to the inserted circumstances and factors.

c. IE executes the collected rules and shows the color range that corresponds to every rule in the output part of the user interface. Then it makes a reasoning process in order to get the crossed color range of the inevitable factors group and then to the human factors group (that is represented in color preferences of the architect, the investor, and the users of the building).

d. The IE makes a comparison between the results of the two groups of factors and then takes its decision.

e. LSCR passes the decision through the color palette to obtain the suitable color range as colors and properties.

f. LSCR presents the results to the user (the architect) in order to complete the color choosing process manually or passing it to another program that can do the next steps in this process.

g. The program presents a simple report that includes all the inserted information, circumstance, factors, the program decision and all data related to color range. The report file type is a text file beside a bitmap file that shows the color range into PCM color palette. Both two files are printable and saveable.

4.2. PRACTICAL EXAMPLE

After inserting circumstances that influence the building through the user interface, some hidden processes run and then the user receives the suitable color range for inserted circumstances.

4.2.1. Inserting circumstances

One of the 1215 case that program covers, is a residential building in a hot zone, medial sun brilliance with a north facade in a polluted atmosphere and the surrounded colors is light colors. On the other hand users prefer the green tones and the investor prefers light colors without any preferences for the architect. Through the user interface, the architect passes the previous circumstances in the correspondence place to every factor (Figure 8).

Inevitable Circumstances:

- The building is Residential.
- The climate is Hot.
- The sun brilliance is Medial.
- The orientation of the facade is North.
- The atmosphere pollution level is High.
- The surrounded colors are Light Colors

Commended Circumstances:

- The architect hasn’t any color preferences.
- The investor prefers the High Lightness colors.
- The user prefers the Greened colors

After inserting all circumstances, the user presses the button “Submit and Get the Suitable Color Range”. Then the program begins to do its hidden procedures.

4.2.2. Hidden procedure

It includes calling and executing rules related to every one of the inserted factors.

After getting the suitable color range for the inevitable circumstances (Table 6), LSCR begin to get the color preferences of the architect, the investor and the user (Table 7). Then he gets the crossed range between the two ranges (Table 8)

Figure 8 shows the results of reasoning and inference process due to the sequence of running.

TABLE 6. The suitable color range for the inevitable circumstances.

Circumstances	Color Properties depending on PCM palette					
	Hue (1:360)		Lightness (%)		Saturation (%)	
	from	to	from	to	from	to
The Building Function is Residential	1	360	33	100	0	100
The Local Climate is Hot Zone	180	360	66	100	0	100
The Sun Shine Level is Medial	1	360	0	100	0	100
The Facade Orientation is North	1	360	66	100	63	100
The Pollution Level is Low Level	1	360	0	100	0	100
The Surrounded Colors is Light	1	360	66	100	0	100
Properties of the crossed color range for inevitable circumstances	**180**	**360**	**66%**	**100%**	**63%**	**100%**

TABLE 7. The suitable color range for the commended circumstances.

Circumstances	Color Properties depending on PCM palette					
	Hue (1:360)		Lightness (%)		Saturation (%)	
	from	to	from	to	from	to
The Architect ‘s Preferences is Ignored	1	360	0	100	0	100
The Investor ‘s Preferences is Light colors	1	360	66	100	0	100
The User‘s Preferences is Specific (greens)	210	270	67	87	27	90
Properties of the crossed color range for commended circumstances	**210**	**270**	**67%**	**87%**	**27%**	**90%**

TABLE 8. The suitable color range for all circumstances.

Circumstances	Color Properties depending on PCM palette					
	Hue (1:360)		Lightness (%)		Saturation (%)	
	from	to	from	to	from	to
Properties of the crossed color range for inevitable circumstances	180	360	66%	100%	63%	100%
Properties of the crossed color range for commended circumstances	210	270	67%	87%	27%	90%
Properties of the crossed color range for all circumstances	**210**	**270**	**67%**	**87%**	**63%**	**90%**

4.2.3. Result

LSCR found that the color ranges of the inevitable and the commended circumstances are crossed. So, there is a common color range for all inserted circumstances. LSCR presented a report for limitation process as a text file (Figure 9) that shows all inputs, reasoning and outputs of the limitation process.

LSCR shows the suitable color range for all circumstances and its properties in the output section of the user interface and saves it as a bitmap file (Figure 10). Result corresponded to the circumstances of the facade (as it is shown in figure 10 and the report) depending on the PCM color palette is:

Suitable color Hues from 210 to 270
Suitable Lightness from 67 % to 87 %
Suitable Saturation from 63 % to 90 %

Now the architect obtained the common color range, suitable for all circumstances that influence the facade that he studies.

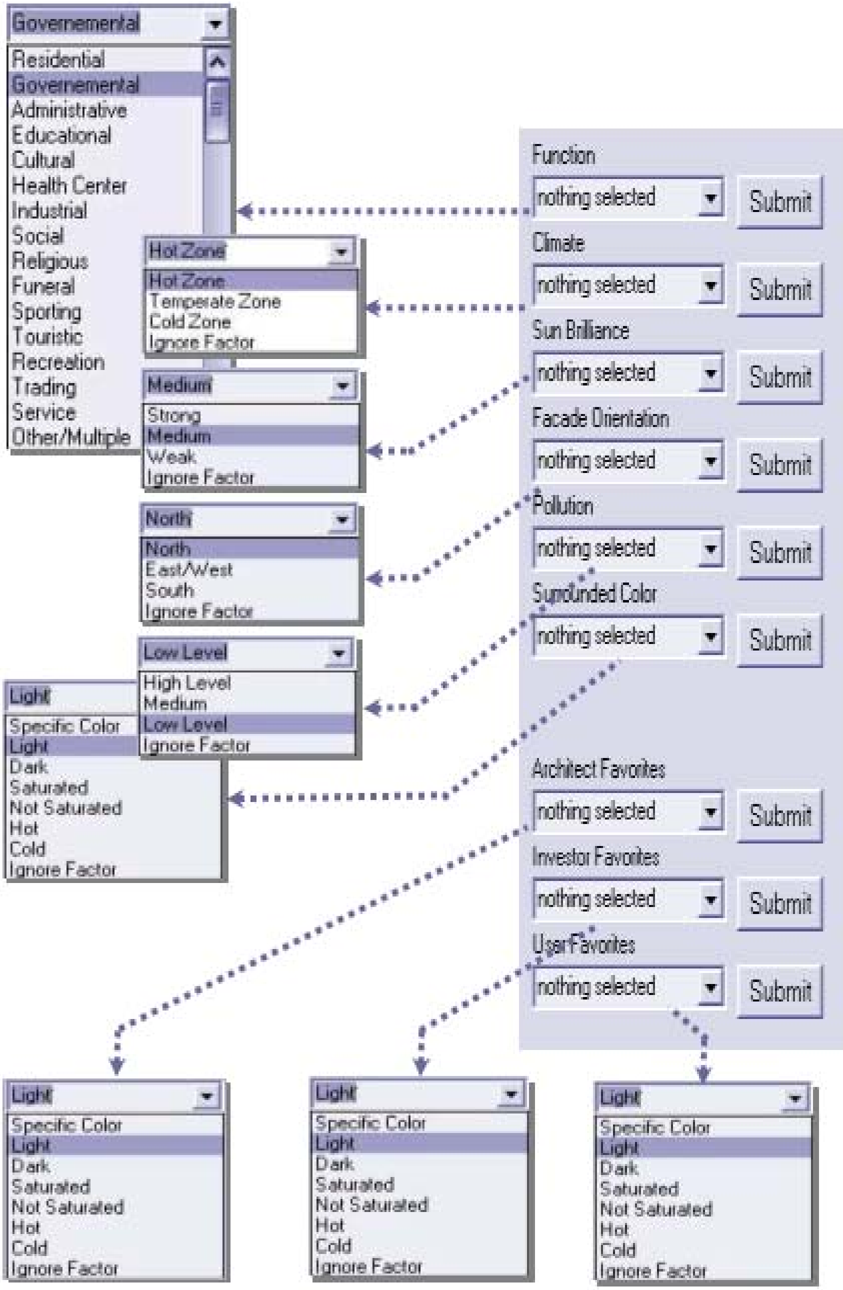


Figure 7. User inserts circumstances of the facade into LSCR through the Input part of the user interface.

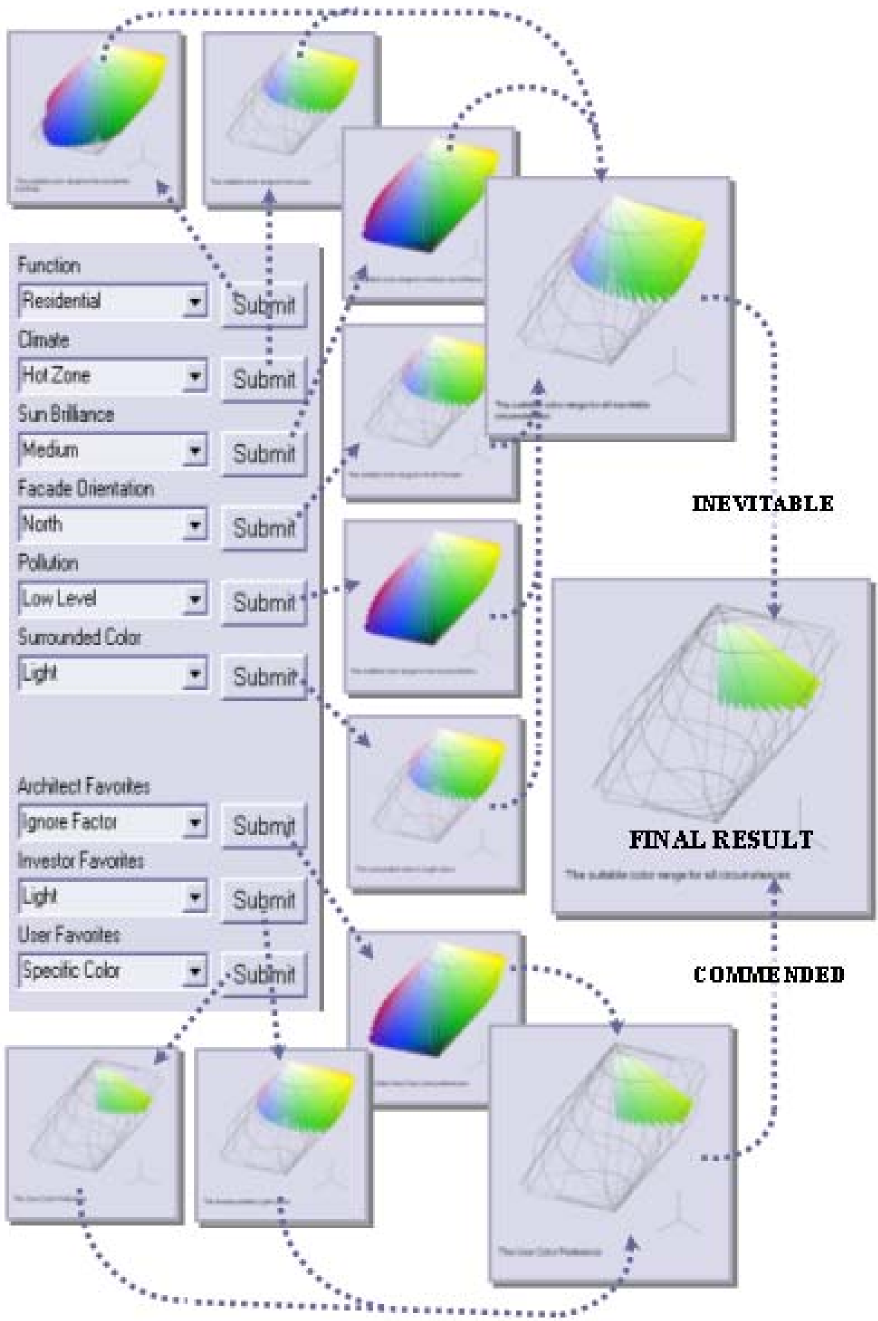


Figure 8. The hidden process to get the suitable color range for the inserted circumstances

LSCR RESULT REPORT

The suitable color range for Facade No. 95/59
for building: ABC

I. General Information

Date: 8/15/2004 7:17:52 PM

Building Name: ABC
Address: 50 M. A. Makarem St.
City: Assiut
Country: Egypt

Architect: DARCO
Investor: UNITED GROUP LTD.
User/s: Multiple

II. THE INSERTED CIRCUMSTANCES

The Inserted circumstances for the facade are:

1- The Inevitable circumstances:

The Function is Residential
The Climate is Hot Zone
The Sun Shine is Medium
The Orientation is North
The Pollution Level is Low Level
The Surround Color is Light

2- The Commended circumstances:

The Architect Preferences are Ignore Factor Colors
The Investor Preferences are Light Colors
The User Preferences are Specific Color Colors

III. REASONNING

LSCR found that properties of the correspondence color range for the inserted circumstances are:

1- For the inevitable circumstances:

	Color Properties depending on PCM palette					
Circumstances	HUE (1:360)		LIGHTNESS (%)		SATURATION (%)	
	FROM	TO	FROM	TO	FROM	to
The Building Function is Residential	1	360	33	100	0	100
The Local Climate is Hot Zone	180	360	66	100	0	100
The Sun Shine Level is Medium	1	360	0	100	0	100
The Facade Orientation is North	1	360	66	100	63	100
The Pollution Level is Low Level	1	360	0	100	0	100
The Surrounded Colors is Light	1	360	66	100	0	100
Properties of the crossed color range for inevitable circumstances	180	360	66 %	100 %	63 %	100 %

2- For the Commended circumstances:

	Color Properties depending on PCM palette					
Circumstances	HUE (1:360)		LIGHTNESS (%)		SATURATION (%)	
	FROM	TO	FROM	TO	FROM	to
The Architect Preferences is Ignore Factor	1	360	0	100	0	100
The Investor Preferences is Light	1	360	66	100	0	100
The User Preferences is Specific Color	210	270	67	87	27	90
Properties of the crossed color range for commended circumstances	210	270	67 %	87 %	27 %	90 %

LSCR found that the two color ranges weren't conflicted and they are crossed.
So, there is a common color range for all inserted circumstances.

IV. DECISION OF LSCR

Depending on PCM palette, Properties of the Suitable color range for the facade are:

Suitable color Hues are from 210 to 270
Suitable Lightness are from 67 % to 87 %
Suitable Saturation are from 63 % to 90 %

An illustration for the suitable color range for the inserted circumstances of the facade
is presented in image file at: c:\colorizer\results\SCRange_59_95.bmp

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LSCR, All Rights Reserved to
M.Sc. Arch. Khaled Salah Said AbdelMagid
The Architectural Dept., Assiut University
Assiut - Egypt
2004

Figure 9: A snapshot for LSCR report that shows limitation process and its results.

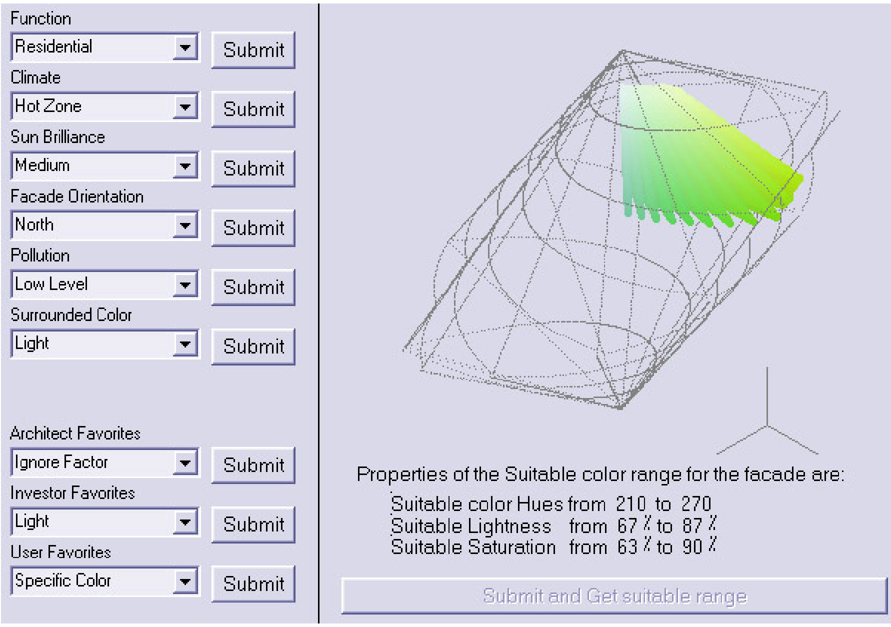

Figure 10. The suitable color range of the facade due to the inserted circumstances and its properties.

5. Conclusions and Future work

The paper presents a rule-based program LSCR that simulates the architect in limiting the suitable color range for a facade, due to the entered circumstances. Program developed by the author using Visual Basic as a programming language.

The future work is integrating LSCR with some other components (that presented by the author in previous studies) in order to construct an expert system that can present the correct color alternatives for building facades, that LSCR is its central program.

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A REVIEW OF OBJECT ORIENTED CAD POTENTIAL FOR BUILDING INFORMATION MODELLING AND LIFE CYCLE MANAGEMENT

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Abstract. In many countries, the Architecture/Engineering/Consulting (AEC) industry is characterised by poor performance reflected in project delays and cost overruns. A contributor to the problem is the traditional approach to handling building information and its communication in life cycle management (LCM). Recent developments in Object Oriented Computer Aided Architectural Design (OO CAD) have provided the opportunity for improving building information modelling and its communication for more effective LCM. The aim of the paper is to review the potentials of OO CAD for building information modelling (BIM) and LCM. The paper reviews building information in the life cycle process, identifying the various actors and activities and the need for communication and information flow to support life cycle management. The paper also reviews the concept of OO CAD, highlighting its potential to improve building information and its flow and communication in life cycle management. The paper then goes on to review the potentials and limitations of OO CAD implementation in the AEC industry. The paper concludes by pointing out that the widespread adoption of OO CAD and the anticipated associated improvement in life cycle management will only be encouraged when the building industry is able to agree on a widely acceptable, interoperable standard for encoding building objects.

1. Introduction

Building facilities go through a complex evolutionary life cycle process, which starts from conception to design, construction, use and demolition (Blockley and Godfrey, 2000). The process involves many actors engaged in different activities that add value to buildings. The life cycle process from design to construction and delivery is project bound and takes place within the context of the AEC industry. In many countries, the AEC industry is characterized by poor performance manifested in inappropriate design solutions, construction delays and late delivery, cost overruns, and the general lack of adequate support and consideration for Life Cycle Management (LCM) (Day, 1992; Blockley and Godfrey, 2000). The situation is leading to disaffection by the main clients of the industry, building owners and developers. Industry initiatives such as quality assurance, quality management, total quality management, business process re-engineering, lean and agile, construction partnering, supply chain management, value management, all acknowledge the prevailing performance problems of the industry and the need and desire to address them (Blockley and Godfrey, 2000). There are several problems that combine to account for poor performance by the AEC industry. Among the problems is the lack of relationship and integration of activities across the industry, particularly between design, construction, and operations and management. This results in poor or inadequate communication in the building life cycle process. There is also a general lack of the recognition of interdependence among the players. In some cases, clashes of culture among the various actors preclude coordination and results in inappropriate assumptions or unjustified expectations of other actors in the life cycle process (Blockley and Godfrey, 2000). There is a general and growing recognition of the need to address the problems of the AEC industry and improve performance and the LCM of building facilities (Blockley and Godfrey, 2000). There is recognition that substantial opportunities could be created through a better development process that result in better design development and improves construction delivery and the operation of building facilities (Blockley and Godfrey, 2000). Industry wide integration of processes for better management of information and communication (Blockley and Godfrey, 2000) is the core focus in the search for improvement.

Buildings are the core focus of the AEC industry and building information is the critical element that binds the AEC industry in building projects and LCM. The main activity in the life cycle process is the processing of building information in order to ensure that a design intention becomes physical reality (Day, 1997). Building Information and its communication are therefore critical requirements of the building life cycle process. Efficient coordination and communication is needed to facilitate the flow of building information and the management of the process of development. The traditional approach to handling building information and communication in LCM accounts for much of the problems of the AEC industry. Activities in LCM tend to be fragmented with poor communication and information flow usually built on manual methods and techniques (Blockley and Godfrey, 2000; Day, 1997; Hegazy et al., 2001; Betts, Clark and Ofori, 1999). This result in building information conflicts, inconsistencies and mismatches that translates into higher construction cost, late delivery of facilities, and inadequate information for operational management of facilities (Hegazy et al, 2001; Chaaya and Jaafari, 2001). There is a desire within the industry to address the issue reflected in the amount of research work on it, for example Elzarka and Bell (1995), Brown et al (1995), Karim and Adeli (1999), Chaaya and Jafaari (2001), Hegazy e al (2001) and Erdener (2003). Much of the research work is focused on creating additional frameworks to improve the coordination of activities in LCM. The suggestions of additional frameworks appear to complicate an already complicated life cycle process and many reported initiatives are not usually backed by adequate consideration of their practical implication. There is a general recognition, however, that computers and information technology provide unique strategic opportunities that could be tapped for improvement across the AEC industry (Betts, Clark and Ofori, 1999:11; Brown et al, 1995). Object Oriented computer aided design (OO CAD) is one of the evolving Information technology products with potential to facilitate building information modelling and its flow and coordination across the AEC industry in LCM. OO CAD by streamlining building product information into a single database provides the potential to unify the focus of life cycle activities thereby enabling improvements in the overall process of management. The aim of the paper is to review the potentials of OO CAD for improving building information modelling and general performance in LCM. The focus of the paper is on project level coordination. The paper is divided into four main sections. The first section reviews the building information requirement in the building life cycle process. The second section reviews the potential of OO CAD in Building Information Modelling (BIM) and LCM, pointing out the specific product, process and industry wide advantages that could accrue from implementation. The third section reviews available OO CAD tools for modelling Building information and the functionalities they offer. The last section reviews the prospects and limitations of OO CAD adoption of in the AEC industry.

2. Building Information and the Life Cycle Process

Even though delivery methods may differ, almost all buildings go through a predictable life cycle process (Day, 1997). This process can be divided into 5 stages; feasibility studies and programming, design and construction documentation, construction and delivery, operations and maintenance and decommissioning. The principal actors and activities differ according to the different stages of the life cycle process. Figure 1 illustrates the various processes, actors and activities in the different stages of LCM.

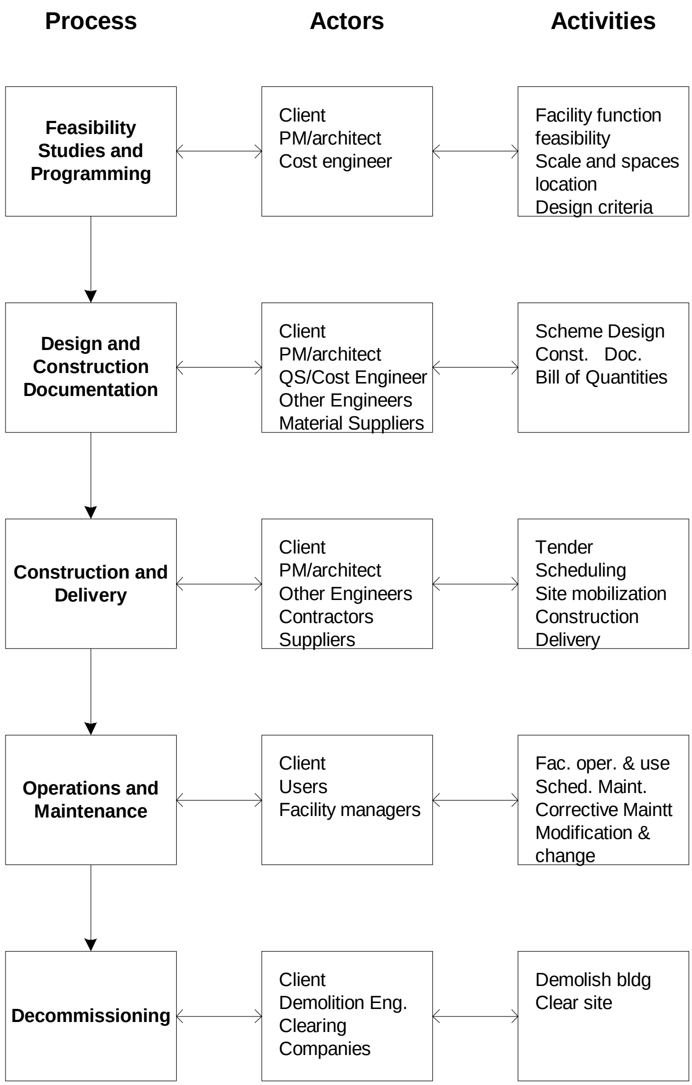

Figure1. The Building Life Cycle Process

Buildings information is the critical element that binds the AEC industry in building projects and LCM. The main activity in the life cycle process is the processing of building information in order to ensure that a design intention becomes physical reality that is deployed for use (Day, 1997). Building information generation, transmission and use varies according to the various stages of the life cycle process as is illustrated in Figure 2. In the feasibility stage, input is acquired from the analysis of existing facilities and previous experience to produce the facility program, cost estimates and facility location. Existing buildings along with their operations and maintenance history provide a database of information that can be mined to assess both design and systems performance. Unfortunately, as Bröchner (2003) observes, designers seldom return to assess the performance the buildings they are responsible for. There is also no established or poor framework for coordination in the industry between facilities operations and maintenance and the facilities planning and programming stage. Information from the feasibility and programming state is passed on to the design and documentation stage. It is at the design and documentation stage that fundamental decisions about the design of a building and the ways that project information is structured and presented are made (Day, 1997). The scheme design is first generated based on input from the feasibility stage. The scheme design is thereafter translated into detailed design and construction documents. The document, consisting of working drawings, specification, contract conditions and bill of quantities, provides information in sufficient detail to enable the pricing and construction of the work. The level of information varies depending on project and delivery method. There are several information and communications issues at this stage that affects the overall efficiency and effectiveness of LCM. The design process brings into play, many actors from different disciplines all with their working methods and ways of processing and presenting building information (Brown et al, 1995; Hegazy et al, 2001). The process generates new information, much of which is complex, fragmented, and has to be interpreted, mediated and acted upon by others (Brown et al, 1995; Chaaya and Jafaari, 2001). The evolutionary nature of the design process also means that changes and alterations are frequent, requiring effective communication and coordination among the various actors as well was with regulatory authorities and manufacturers to ensure the consistency and accuracy of building information (Hegazy et al, 2001; Day, 1997). Unfortunately manual methods of documentation and communication prevails in the process resulting in poorly coordinated documents with conflicts, inconsistencies and mismatches (Hegazy et al, 2001). There is also a need for active coordination in design with material manufacturers to facilitate design as well as the takeoff, procurement and the construction process (Elzarka and Bell, 1995). Such integration has been found to lead to significant cost reductions as well as reductions in document-processing cycle time.

Information from the design and documentation stage is packaged as a bid document to contractors who price and bid for a work. Once a contractor is selected, then “the information flow becomes increasingly intense as activity begins on site. Detailed matters have to be finalized, materials and fittings ordered and conflicts resolved while construction is proceeding. The flow of materials and operations has to be coordinated to ensure an efficient construction phase and the emerging building checked to ensure that quality standards are being achieved. The operative on site who finally has to fix a component in a particular place is just the final, but most visible, part of a complex information processing chain (Day, 1997). Efficiency in the construction stage is largely tied to the soundness of information from the design and documentation stage. Integration of design with activities of materials manufacturers and suppliers facilitates procurement activities in construction (Elzarka and Bell, 1995). The consequences of poor coordination in the design and documentation stage also becomes evident during construction, resulting in variation orders and contractual disputes that lead to cost overruns and to client dissatisfaction (Hegazy et al, 2001). This escalates with the complexity of a building project and the constraints on design time and cost.

Once the construction is finished, the facility is handed over to the client for deployment, and operations and maintenance. During the operations and maintenance stage, the focus of activity is getting people and processes deployed to a facility and ensuring that the facility remains in an operational state. The complexity of operations and maintenance depends on the size of the facility and the processes it is to hold (Erdener, 2003). To facilitate activities at this stage, a facility management information system is required. A building database is one of the critical components of the facility management information system. A building database shows the geometrical configuration of the building as well as systems, materials and technology of construction, and maintenance schedule. Where the facility information system also allows a facility database that includes space allocation, equipment inventory and other necessary facility management information to be tagged on, then building information systems can serve as the basis for developing a facility management database. The traditional approach to facilities operations and maintenance information generation as is illustrated by Osama Abudayyeh and Al-Battainneh (2003) in the example of bridge maintenance is through the preparation of as-built drawings that provide historical information relating to design and construction. There is however a lack of coordination in efforts to collect and store the necessary drawings creating room for improvement in the process. At the end of the lifespan of a building facility, it becomes scheduled for demolition and site clearance in preparation for the erection of a new facility in its place. At this stage, the principal building information requirements are of the materials and construction system. Knowledge of construction systems enables demolition experts to plan the demolition of the building while knowledge about materials helps in ensuring the removal of toxic and polluting materials before demolition.

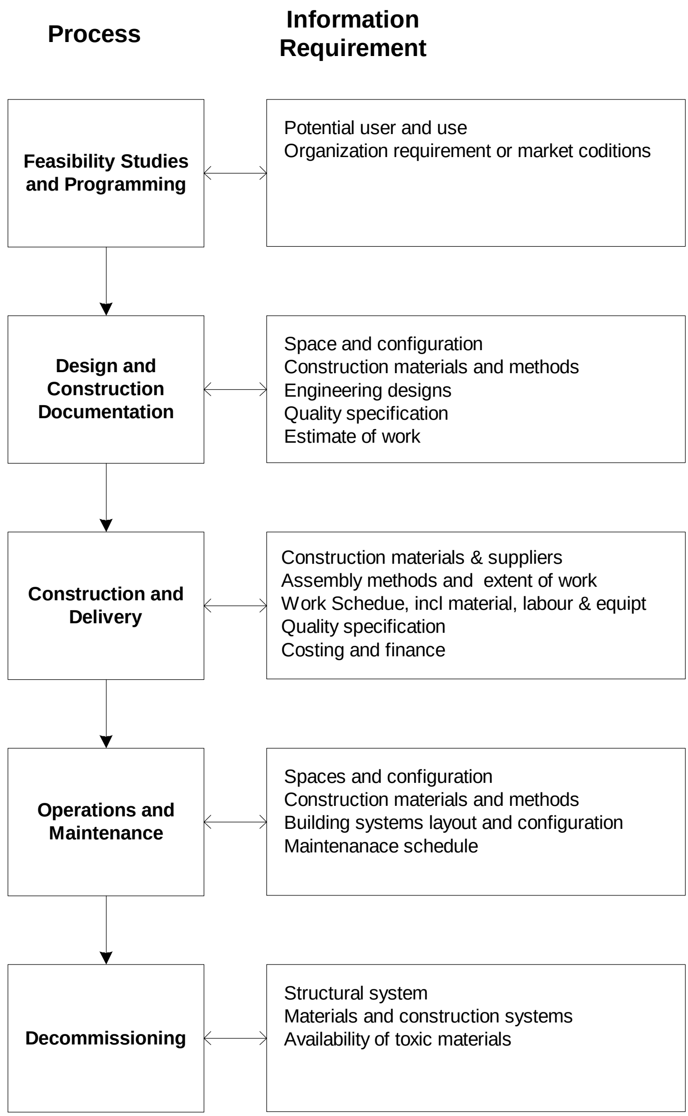

Figure 2. Building Information in Life Cycle Management

3. Potentials of OO CAD in BIM and LCM

Computers and information technology have played an increasing role in the AEC industry initially in design, but later in documentation and construction. Currently, computers and information technology are viewed as a way of addressing the communication problems of the industry and automating some parts of the design and construction process (Day, 1997). One of the technologies with the greatest potential is OO CAD. The concept of object oriented computing is based on the idea of electronic building objects. An electronic object represents a real world entity by encapsulating its characteristics, both data and function (Elzarka and Bell, 1995; Karim and Adeli, 1999; Brown et al, 1995). Data describes the state of the object while function describes the behaviour of the object under different conditions. The objects are smart and can communicate with each other. The benefit of the electronic object is proportional to the soundness of the data model of the objects (Elzarka, and Bell, 1995). In OO CAD building components are specified as electronic building objects. The Objects store 3D information - geometry, appearance, surface, material, quantity, construction and 2D information - such as plan representation, minimal space requirements, labels, etc, and property information - serial numbers, price, dealer information, cost and performance attributes, and other data base information. Objects describe real building component such as doors, windows, walls, roof, furniture, plumbing fixtures, HVAC system, structural elements, etc. The electronic building objects as representations of real life building components have parametric information that mirrors the behaviour and character of the components they represent. The objects behave smart and can easily be customized. The rich information about components embedded in electronic objects would be accessible by a wide variety of software applications and used throughout a building's life cycle without conversion or translation to other formats. Properties including shape, behaviour, performance data, and transport requirements, along with embedded links to relevant code requirement and test results, could all be included in an electronic object. An OO electronic door component, for example, will not only describe the physical attributes of the door needed for design by the CAD program, but also the cost, maintenance, supply and installation properties of the door for use in project costing and scheduling, and later for facilities management. Objects combine to form a complete model of the building which is much richer in information than 3-dimensional computer models. The adoption of OO CAD virtual modelling in the AEC industry has the potential to significantly impact the LCM process and the performance of the industry in three significant areas; the structuring and communication of building- i.e. product information, in facilitating processes in the AEC industry, and in improving the general performance of the AEC industry.

3.1. PRODUCT INFORMATION – THE VIRTUAL BUILDING MODEL

In OO CAD, the virtual building model is actually a database of information that tracks all the elements that make up the actual building (Figure 3). The virtual building model contains a great deal of information about the products that make the building as well as about the building itself. The Object-Oriented virtual model needs to be distinguished from generic 3D models. These are models based on a fundamental topology of lines, shapes and forms. Generic models are created using primitive and derivative geometric objects. The forms used in generic models have no relationship to the building elements they represent and modelling in this instance is of limited use, and is more or less a means for visualization. The OO CAD virtual building model as the electronic equivalent of the physical building provides comprehensive and consistent building information to support activities in LCM. The generation of all building information from an integrated model means that problems of poorly coordinated documents, conflicts and mismatches which characterise the traditional approach in the AEC industry is done away with. All information about the building is derived from the same source, is consistent and accurate. Also because building information is integrated in one database, it becomes easier to monitor and implement changes and alterations. This does away with the major source of the conflicts in building information documentation.

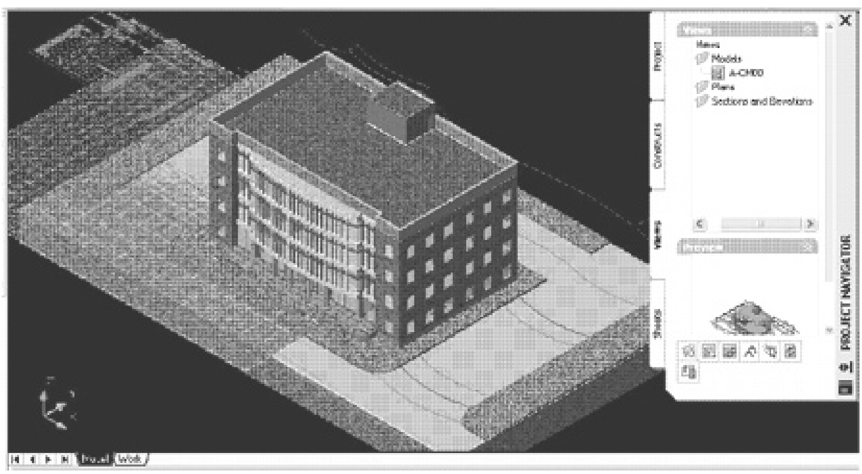

Figure 3. Example of an ADT Object Oriented Virtual Model

The virtual building model is also capable of supporting activities across the whole AEC industry and throughout the LCM process. Designers would all work on the same database, Objects used in the database would be supplied by industry or conform to established standards. Objects would embed information that supports all types of performance modelling and analysis for design purpose. Objects and the virtual model will embed information to support activities of all industry participants, from design to estimating, costing, scheduling, constructability analysis, and facilities management. Electronic objects in OO CAD, illustrated in Figure 5, would usually be supplied by building component manufacturers and suppliers. Electronic catalogues are easily integrated into design, as can be seen in Figure 6, enabling active coordination between building component supply and design and also improving the efficiency in procurement during construction. Design in OO CAD would usually be coordinated on a single virtual model.

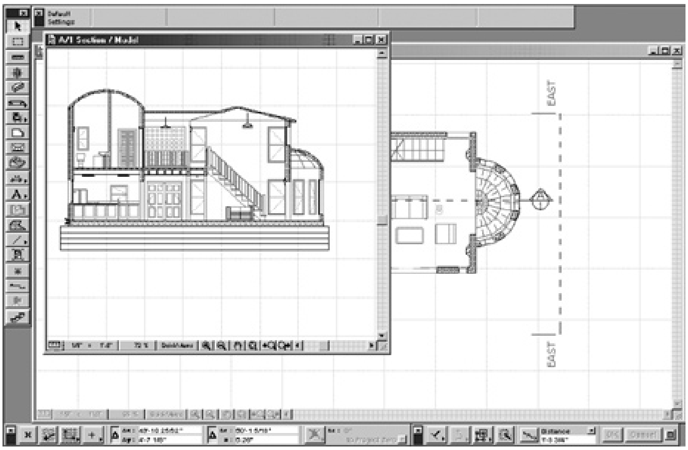

Figure 4. Conventional Drawings from an ArchiCAD Object Oriented Virtual Model

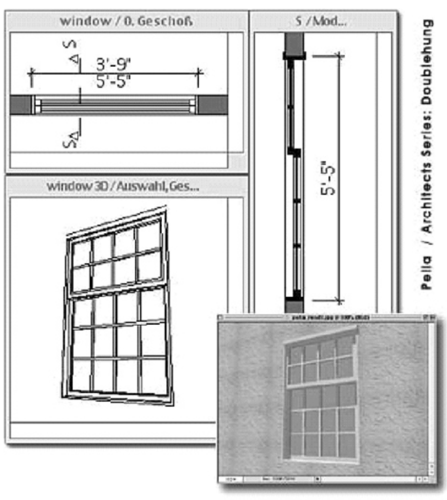

Figure 5. GDL building object supplied by Pella Corporation (www.pella.com)

The use of a single model reduces errors, improves coordination and the tracking of changes and the general accuracy of building information. This translates to a more efficient construction regime in later stages of the life cycle process and to time and cost savings. The OO CAD model also supports the generation of all kinds of report, including, doors and window schedules, illustrated in Figure 7, bill of materials and quantity, equipment and space inventory, etc. In supporting the generation of diverse information from the virtual model, the OO-Virtual model minimizes the time to prepare construction documents and therefore design and documentation cost in life cycle management.

At the construction stage, the potential for a more consistent and accurate building information coupled with coordination with building component manufacturers and suppliers means that pricing of contracts would be more accurate, change orders due to inconsistencies minimized and construction planing and scheduling much more efficient leading to better prospects of on-time and on-cost delivery. Construction can also be facilitated through improve project and construction planning. At the operation and management stage, the virtual building database provides a ready tool for use. With the addition of facility information it can be easily be transformed into a facility management information database to be used for long-term operational management. When the facility lifespan is over, it is also easier to plan for its demolition and removal because of the comprehensive building database available.

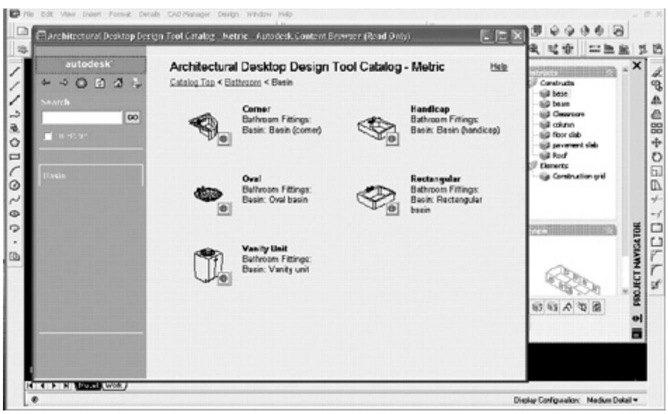

Figure 6. ADT Content Browser for Design objects

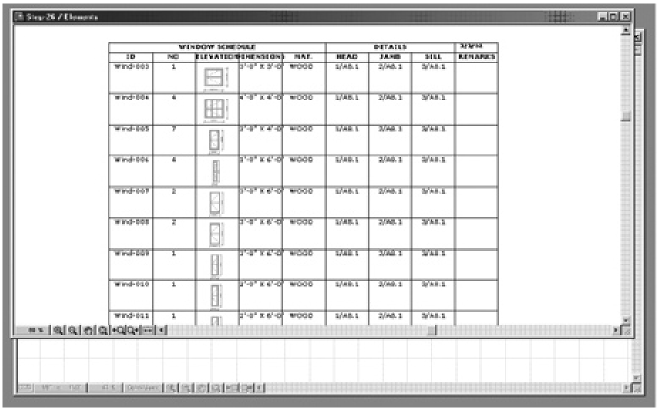

Figure 7. Door and Window Schedule from an ArchiCAD Object Oriented Model

3.2. FACILITATING PROCESSES ACROSS THE INDUSTRY

The implementation of OO CAD virtual modelling has the potential not only to impact on Building information and how it is handled in the AEC industry, but also on processes and operations of the industry. Virtual building modelling can become the basis for the integration of activities across the AEC industry. The development of a single project database that incorporates input from all design professionals, and provides the basis for quantifying and estimating building cost, project and construction planning may establish the framework for integration of activities and cultures and general coordination across the industry. Such integration would also be accompanied by improvements in communication and increased efficiency and effectiveness in handling conflicts all resulting in improved project performance.

3.3. IMPROVING GENERAL INDUSTRY PERFORMANCE

The widespread adoption of OO CAD virtual modelling across the AEC industry may in the long run lead to significant improvements in the performance of the industry. Virtual modelling will in general lead to more accurate building information in LCM, doing away with a major source of performance degradation in the industry. Accurate building information will mean a more streamlined and efficient delivery process. Cost overruns will be minimized and Scheduling and planning will be more accurate and information from construction will be used to support operations and management thereby enabling a global connection of the life cycle process and general improvement of LCM.

4. Available OO CAD Tools for Modeling Building Information

For OO CAD to gain widespread acceptance in the AEC industry, it is first necessary to have the necessary products in the market. It is therefore pertinent to ask whether there are OO CAD products to support the needs of the AEC industry. OO CAD systems have been in the AEC market for some time. Among the most prominent ones are Sonata, Reflex, ArchiCAD and Architectural Desktop (ADT) (Day, 1997). Some specific industries such as wood and metal fabrication also have OO programs designed to meet their specific needs. Among all the commercially available OO CAD programs, two appear to have taken a leadership position, ArchiCAD by Graphisoft and ADT by AutoDesk, and have been the driving force for the expansion of the implementation of OO Computing in LCM. They both provide parametric interfaces for virtual modeling supported by a library of generic and manufacturers building objects. ArchiCAD (www.graphisoft.com/products/archicad) is among the premier object oriented programs in the AEC market. It is built on a proprietary Geometric Description Language (GDL), though it is compatible with the International Alliance for Interoperability (IAI) Industry Foundation Classes (IFC) an industry wide standard for information interchange. Several Manufacturers support the GDL format and supply catalogues in GDL format. Several website are available supporting the GDL format. ArchiCAD as a building information authoring tool allows the creation of building databases that support design and documentation and provides for collaboration and coordination across disciplines and for easy alterations and modifications without comprising the integrity of the building database or the accuracy of project building information. To extend the functionality of ArchiCAD, Graphisoft is also marketing a 5-D Construction management solution that links 3-D modeling with scheduling and costing to support 5-D construction simulation (www.graphisoft.com/products/construction). The construction management system allows connectivity between accurate 3D construction models with Primavera Engineering and Construction and Primavera Contractor to enable the generation and analysis of scheduling alternatives. The system incorporates model based estimating functionality providing for the extraction of exact quantities and cost estimates. The systems is also supports procurement scheduling. The systems, in general, supports a vast range of activities integral to the AEC industry, including design, construction modeling, constructability analysis, and construction and procurement planning. To support the implementation of the construction management system, Graphisoft is promoting the emergence of a new AEC industry profession, “the construction modeler” who will be in charge of ensuring that every intended use of a model is considered when creating building elements.

ADT has developed through several release versions with the latest being ADT 2005. The program is built on AutoCAD and the proprietary dwg format, through it has more functionalities than AutoCAD. ADT uses ObjectARX technology to create intelligent architectural objects. These are kept in a content library of building objects and other modeling support tools. ADT supports design, documentation and schedule generation. The program has the capability of supporting all design professions and coordination can be undertaken using proprietary AutoDesk Building systems. Information could be shared through direct exports or through the use of proprietary DWF file sharing format. Data can also be exchanged with IFC-compatible applications using a plug-in. Developments in recent versions of the program have simplified the process of modeling.

5. Prospects and Limitations of OO CAD Implementation in LCM

What are the prospects for OO CAD adoption across the AEC industry and what forces may serve to limit such adoption? In terms of prospects for adoption, the two leading programs already have a wide installed base pointing to significant acceptance by the industry. Increase in future acceptance of OO CAD in the AEC industry will likely be propelled by three main factors. First is the general dissatisfaction in the industry and the search for initiatives to improve the performance (Betts and Clark, 1999:127-8). The need to improve integration of processes and activities throughout the industry will drive the adoption of information technology and OO computing will be one of the main beneficiaries. The second reason has to do with the need for industry wide initiatives that cuts across all segments. In this respects, OO CAD promises a means for bringing together members of the design team with suppliers to create better information flow to the construction process and to facility operation and management. In enabling such a broad connection across the industry, OO CAD fulfils the basic requirement for the adoption of any initiative. The third factor deals with developments in OO CAD. Improvements in the technology along with its growing adoption, and the increasing supply of electronic building objects by manufacturers point to a potential of wide adoption in the AEC industry in future. Already cases of coordination both in design and between design, materials suppliers and construction is being reported spurred by developments in computing technology (Bordenaro, 2003).

However just as there are forces which may encourage its adoption, there are also many forces that appear set to work against the adoption of OO CAD in LCM. One of these is the fragmented nature of the industry and the independent approach to addressing issues of project information. While construction engineers are busy looking for better ways to communicate through project schedule and information exchange, architects and design professionals are also approaching the same issue from a design perspective and facility managers from a facility management perspective. With such diverse perspectives and investment in different initiatives, it is going to be very difficult to accept and promote an industry wide initiative. Another problem has to do with the unique characteristics of buildings, the major focus in LCM. Each building is unique in its own instance, and construction technology has to cope with different types of special conditions. Building components and construction system also vary widely between localities. This means that for OO CAD program to be widely acceptable they have to be able to meet the needs of all anticipated conditions in building design. The ability to produce software that can respond to varying needs of users and design conditions will determine the willingness to adopt OO CAD.

Another limiting factor is technological. In an ideal environment, one would construct a three-dimensional computer model of a building which contained an accurate representation of every important component and material, including attribute data on physical properties and cost. This model could then be used to simulate the construction process and thus many of the problems which currently have to be dealt with on site could be resolved during design. As all the drawings would be views of this single model they would be automatically coordinated and if a component such as a window were moved there would not be the traditional problem of ensuring that every drawing which contained the window was changed accordingly (Day, 1997). Such a model will however raise a number of problems. The first is that it would contain a huge amount of data even for a small building and would create problems of data management. The second issue relates to the ownership and security of the information in the building database. Traditionally, the architect maintains the copyright to his drawing. Conflicts over ownership of data and fear over data security would all limit the adoption of OO CAD (Betts and Clark, 1999). There is also the issue of familiarity with the technology. While architects are currently rapidly embracing OO CAD, the other disciplines in the industry are not eager to adopt it. Adopting it for them might mean investment in training and in equipment changeover, which would limit enthusiasm. Finally, there is also the issue of data standards and interoperability. Due to the complex nature of the networks that contribute to a construction project, standards remain a key issue. The lack of a critical mass to impose standards has resulted in parties being unwilling to make technological advances, especially with respect to communication technologies (Betts and Clark, 1999; Laiserin, 2002).

6. Conclusion

The paper examines the potential of object oriented CAD for building information modelling and life cycle management of building facilities. The emphasis of the paper is on project level coordination. The paper reviewed building information in the life cycle process, the potentials of OO CAD in LCM, available OO CAD tools and adoption prospects. From the paper, it is evident that traditional LCM is characterised by coordination and integration problems which translate to higher project cost and late delivery. The fundamental problem of the life cycle process lies in the lack of effective frameworks for communication and the flow of information. Any initiative aimed at improving the performance of the AEC industry must therefore embody the sharing of building information.

Computers and information technology offer unique opportunities for addressing the problems of the AEC industry in building LCM, and OO CAD is one of the technologies with significant potentials. Examination of the potentials of OO CAD shows that it can unify building information and provide a framework for the integration of activities, and coordination and communication across the AEC industry. There are, however, several significant factors that may work to limit the adoption and implementation of OO CAD. In general though, it appears that there is a single issue that may propel adoption irrespective of limiting factors and that is the availability of electronic objects. The widespread availability of building objects by component manufacturers may be the tipping balance in favour OO CAD implementation in the AEC industry. This would only happen, however, when the industry is able to agree on an acceptable interoperable standard for the encoding of building objects that meets the information and process requirements of all actors in the life cycle process.

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TOWARDS COMPUTER AIDED LIFE-CYCLE COSTING

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Abstract. Sustainability is recognised as a necessary public good. Building sustainable buildings requires architectural methods, specifically CAD systems, that include suitable predictions of long term performance. Unfortunately the predominant view in the Building Industries of the Developed world is essentially short term; this is because building developers – not being the end users - are essentially interested in short term profit. Until they can see the 'value-added' by sustainability impacting on the selling price of their buildings, they will not be motivated to build 'sustainably'.

This paper describes the issues that have led to this situation. It discussed how the advent of computers has allowed life-cycle data to be gathered over time, and may be included intro CAD system databases to enable sustainability performance predictions to be made. Once made we are now able to reap the benefits by performance benchmarking. The availability of this building performance information on-line is making life-cycle costing more readily available, and more accurate, allowing building developers, owners and users to make rapid and timely feasibility studies well in advance of design. This also allows owners to test various capital to operating cost options in order to get the best economic performance over time, as well as map future capital replacement cycles.

These emerging possibilities are discussed in this paper.

1. Introduction

Life-Cycle Costing is an integral feature of the assessment of sustainability, because sustainability takes the long-term view and demands that developments – particularly buildings – have the least impact on the future. That is, the least impact in terms of the non-renewable resources used, the minimum of wastage, and the minimum degradation of the planet for future generations.

The design process is a means of postulating a physical solution to solve a complex problem. It stems from a description of the problem and proceeds by testing possible solutions to ensure that they solve the problem. A design solution progresses by incremental modification directed by the outcome of constant testing of whether it leads towards a better solution to the problem (Maver, 1970). Successful amendments to the design are incorporated into the project database until such time it is sufficient to uniquely describe the proposed building (Leifer, 1984).

Computer Aided Design has developed not only by including computer aided means of conceptualising solutions, (that is the mechanics of evolving solutions and constructing their depictions), but also the means of testing hypothetical solutions to the problem. Computer programs that deal with cost modelling, resource scheduling, structural sufficiency, energy performance etc. in many instances preceded the development of CAD modelling programs (Lawson, 1982). The common theme has been using the Cartesian dimensions of the design solution as an index to related information: that is, elements in space when linked to related data can be used to automatically generate performance information. For example, cost data of materials when associated with the areas and volumes of components produce a materials cost estimate and schedule of quantities.

A sophisticated extension of this would be the inclusion of data gathered from what we know of the performance of generically similar solutions to comparable problems. For example, the knowledge of the performance of one thousand existing government schools should be made available as performance benchmarks for new ones. Such tests of life-time practicality are every bit as relevant as tests for structural integrity or energy performance.

This can be considered as a Design – Construct – Feedback loop where experience of other solutions in practice is fed back into the design process. This is becoming increasingly emphasised as ‘life-cycle costing’ supersedes simple short term capital cost considerations in importance. Such an inclusion into CAD is essential if the managerial techniques of ‘benchmarking’ and ‘continuous improvement’ are to be introduced into portfolio management.

‘Benchmarking’ is a managerial technique that establishes the average performance across a portfolio of similar buildings. For example, the average cost of operating a Sydney CBD office building is $85 per square meter per annum (PCA, 2003). When managing a property portfolio we can use such knowledge to identify under-performing buildings. ‘Continuous improvement’ is the management technique of taking remedial action to improve the performance of the under-achieving examples. By doing so the average performance of the portfolio improves, and ultimately the benchmark changes – exposing the next round of under-achieving buildings.

This becomes significant in the management of extensive property portfolios the capital value of which can be ‘guesstimated’ at hundreds of billions of dollars in the case of the Australian Government (Jacka, 1992; Pahlow, 2004). Modest savings made through management techniques will have a very significant payback.

The organisation of experience of buildings-in-use is another area for computer application, as there are many thousands of individual transactions involved in the operation of building. This complexity can lead to a large array of Key Performance Indicators (KPI’s) such as those for University buildings (TEFMA, 2004). Hence information from buildings-in-use needs to be structured into coherent input into Computer Aided Design programmes.

The reality is at present that buildings are **constructed** with short-term economics in mind. This is particularly so in the government sector where the endowment of buildings is a high-profile government act, but there is little political kudos in merely operating buildings. Non-residential buildings are generally too expensive for individuals to afford – around $2,000/m^2 in Australia (Rawlinson’s, 2003). Even private companies and corporations have to seek finance from other lending institutions (Mann, 1992). Increasingly governments want to stretch their capital development programme over the widest area possible; there are many worthy projects vying for funding, so that governments are forced to seek the maximum amount of building for the minimum capital cost – again a short term expedient.

2. What do we Mean by ‘Whole of Life’ of a Building?

The life-cycle of a building encompasses its conception through design and construction. This includes the initial feasibility study where economic considerations tend to hold sway. It includes the buildings life in operation, during whose course the building might undergo many make-overs and transformations as the needs of the users change. Ultimately the life cycle includes the buildings disposal and demolition, hopefully with the materials being used as stock for other building projects. However, if the building contains asbestos, or the site has become contaminated disposal could be a significant part of the life-cycle cost.

Generally, organisations are concerned with the current year, and next years budget. If they have a forward plan – how far ahead can one predict. Few organisations think in terms of more than five years ahead (Avis et al, 1989).

It is society that asks building developers to build sustainably, and at present developers do not have the tools to forecast how the costs of doing so will reflect on their future earnings

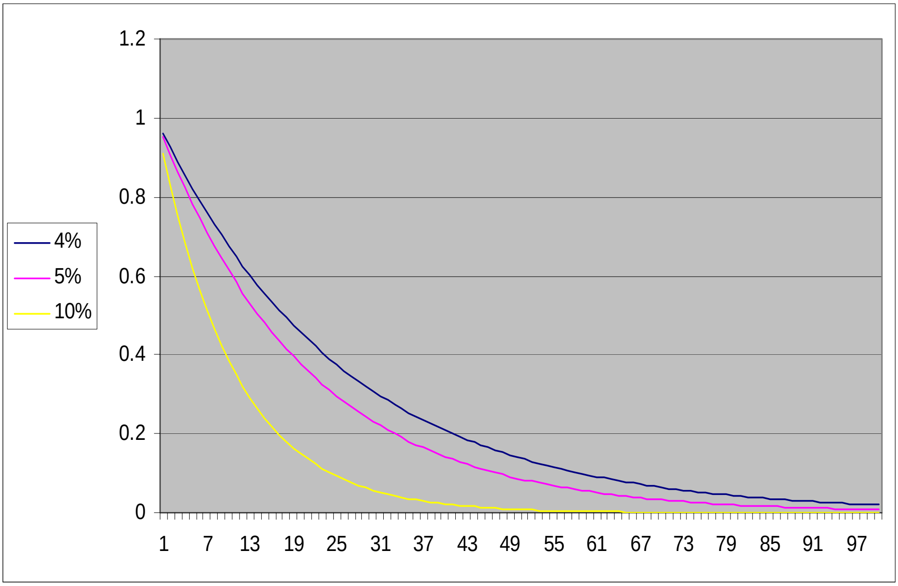

Figure.1. Graph Showing the Future Value of $1 over time at 4%, 5%, and 10%.

2.1 LIFE-CYCLE COST ELEMENTS

These elements become significant when one looks at the relative ratio of lifetime cost. If the construction cost = 1, then the lifetime operating costs are in the order of 10, and the disposal costs in the order of 0.1. Looked at this way it is clear that it is more cost effective to perhaps spend more initially on the construction of the building if it leads to a lower cost-in-use. Unfortunately this perception is altered when one looks through the practice of costing future expenditures by their Net Present Values. The above graph (Figure 1) shows the value today of a cost of $1 in the future assuming that one could put money aside today at assumed rates of interest. For example 39c invested today at @ 4% compound interest, 31c @ 5%, or 10c @ 10% would produce $1 in 24 years time. You can see that from this perception future costs after 60 years appear negligible, therefore the long-term, sustainability considerations are reduced to irrelevance.

2.2 THE BUILDING DEVELOPER

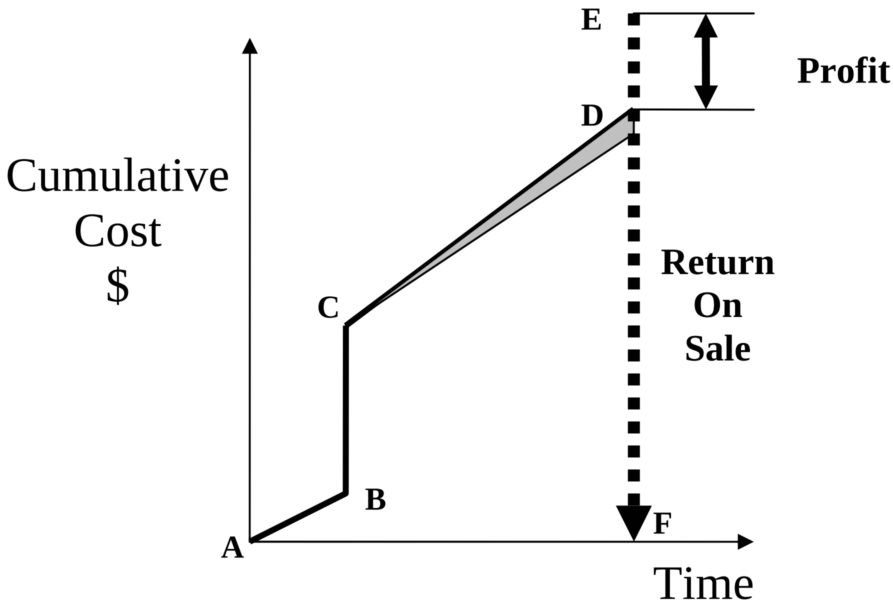

Figure.2 Showing the Developers Cumulative Costs over Time.

Let us consider the Developers role and perceptions. In the graph above (Figure 2) A to B represents the cumulative expenditures involved during the Feasibility and Design phase of the project.

BC represents the site purchase commitment once development approval has been secured. It is likely that the developer has 'hedged' by offering the site vendor a purchase option pending building approval. That is, the developer offers a modest non-returnable deposit if the vendor agrees to sell at a negotiated price if and only if planning permission is obtained within a predetermined period. C to D represents the construction period with phased payments and the imposition of interest on development finance.

The developers major and over-riding concern is to maximise profit on the sale of the project (EF). This is done by building at low cost, and selling high. The lower the construction cost, the less money is borrowed and less interest payable. Provided the quality of the project attracts the selling price sought, cheap construction is an advantage.

2.3 THE BUILDING OWNER

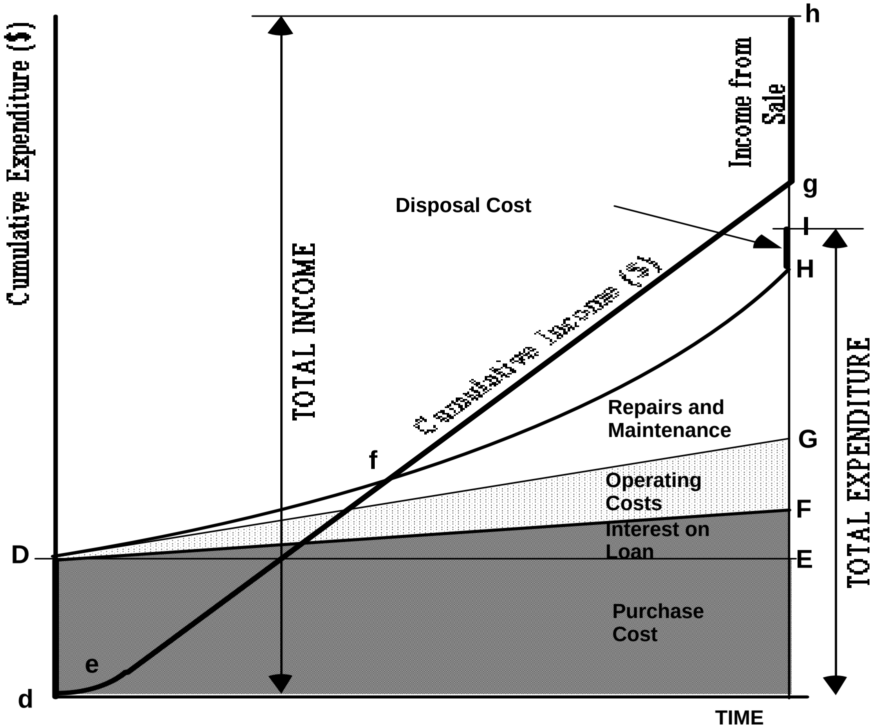

Figure.3. The Building Owners Concerns – cumulative costs over time.

The situation of the Building Owner's perspective differs. In Figure 3 above which graphs the cumulative costs of a building development over time, dD represents the capital cost of purchase of the building from the developer (including the developer's profit). From the time of purchase there is interest to be paid on the purchase cost, as well as recurrent operating costs, such as rates, power, insurances etc. The costs of Repairs and maintenance are assumed to increase as the building ages due to the ravages of wear and tear. All of these costs are offset by the income stream from rental.

TABLE 1. Sydney CBD Office Operating Costs (PCA, 2003).

INCOME	**Average**	**%age**	**Upper**	**Lower**
Total Rental Income	232.13	309.22	142.94	
Gross Income	261.02	355.22	159.18	
EXPENSES	**Cost Item**			
Statutory Charges	34.99	43.6	44.91	23.95
Energy	9.07	11.3	5.01	3.71
Air Conditioning	6.71	8.4	11.88	2.45
Lifts and Escalators	5.10	6.3	8.43	2.57
Cleaning	4.99	6.2	7.70	2.46
Insurance	4.54	5.6	6.28	2.86
General Fees	4.20	5.2	9.01	0.98
Repairs and Maintenance	3.20	4.0	6.60	0.95
Caretaking & Overhead Wages	2.13	2.6	3.66	0.57
Other Operating Expenses	1.67	2.1	3.61	0.22
Sundries	1.57	2.0	2.81	0.25
Security	1.47	1.8	2.82	0.33
Fire Protection	0.65	0.9	1.11	0.23
TOTAL	**$ 80.29**	**$ 123.83**	**$ 41.53**	

Table 1 indicates the incomes and operating costs of buildings in the Sydney central business district in order of magnitude. Some, like taxes are fixed by others; others like energy are amenable to some control but are necessarily incurred.

As the repairs and maintenance increase the total rate of expenditure approaches the rate of income, meaning that the profit margin is decreasing. The property owner has to decide whether the building has reached the end of its economic life, or whether to invest further capital to refurbish it in order to bring the operating costs back to manageable levels.

2.3 THE BUILDING USER

The user is possibly faced with fit-out cost ($500/m^2 Davenport 91) – unless they lease it - before the space can be productively used. Users are then faced with rent, communications, power, consumables etc. Some of these, like local taxes and Insurance premiums are set by other parties, whereas some like cleaning, and power, are amenable to management – although they cannot be dispensed with.

These costs are likely dwarfed by the salaries and wages bill of the people employed and housed in the premises. User's priorities are to maintain their income stream and ensure a positive cash-flow. Again, the controlling information is contained within their business Management Information Systems.

3. Information

In view of the mismatch between the various stakeholder's perceptions it is easy to see how shared information can reduce the boundaries between them. Figure 4 below indicates an information environment encompassing the design/build and operation environments. An information environment that would link the design/construction phase with the longer term operational phase would have the following characteristics.

3.1 AT THE DESIGN STAGE

The design process involves the designers proposing a hypothetical structure made up of many thousands of individual components. These components are considered individually or in sub-assemblies and systems. Frequently systems are considered in separation from the design as a whole by consultants: such as the structure and air conditioning. The consultants work on the shared generalities, and feed back specifics to those in charge of design project integration.

Computer tools such as AutoCad, ArchiCaad etc. are these days reasonably flexible in that different consultants can use specific add-ons or can otherwise interface with the CAD data files. In undertaking their systems designs the consultants not only specify particular components and products, but undertake simulations and models whose data is useful in establishing basic criteria that can be used in setting up the computerised building management system. For example, output volumes for variable air volume registers, and temperature set-points etc. Anticipated energy usage profiles and costs can be estimated given the predicted annual climate and building usage patterns.

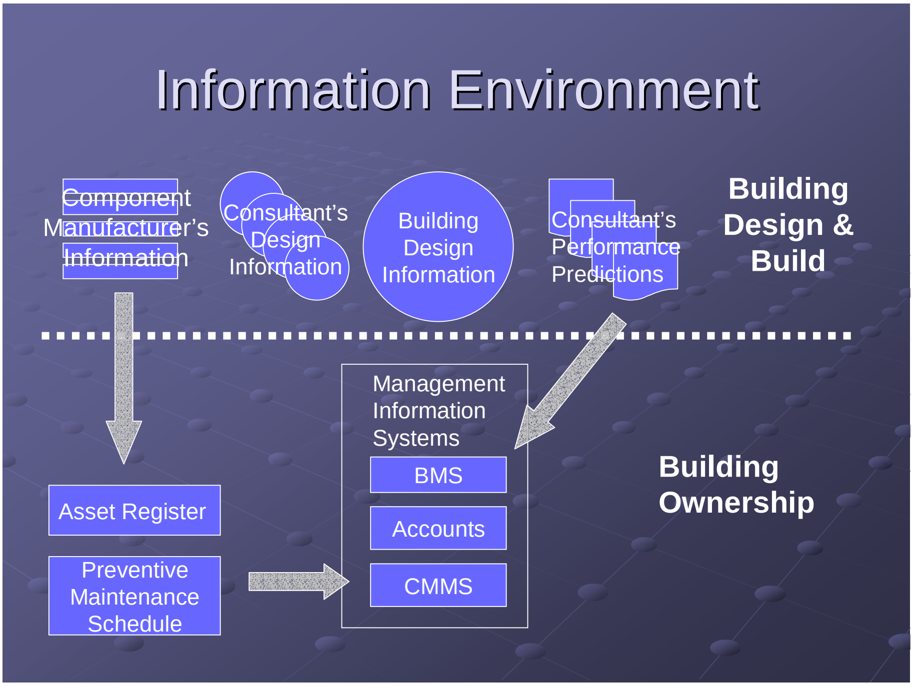

Figure.4 *The* Design/Built and Operating Information Environment (after Leifer, 1984)

As the components and systems are specified, an asset register emerges. Not only does this assist in informing the building owner, but one can foresee that relevant maintenance manuals and schedules will be available form the manufacturers via the internet. There is little reason why maintenance schedules for the entire building cannot be easily generated along with cost estimates for capital replacement cycles over time.

The existence of these features in the hand-over data base to the potential building purchaser means that the purchaser can compare the future costs between different buildings. With this, the purchaser can take a longer term life-cycle cost view.

3.2 AT THE OPERATIONAL STAGE

The owner, as we have seen, is most interested in the difference between rental income and the costs of ownership as this determines her/his profit margin. The major manageable components of on-going costs are repairs and maintenance (18.7% if we aggregate R&M with the operation of the lifts and air conditioning systems), and energy costs (11.3%) These two areas consume over half of the non-tax costs of operation.

As we have seen, the asset register and preventive maintenance schedule should be transferred to the building owners Management Information System which will include a maintenance management program module depending on the size and complexity of the building portfolio. This is discussed more fully elsewhere, eg. Thomas (2001).

Between 1995 and 1998, Symonds Group spent about 18 months working with a computerised maintenance management system called **Maximo**® during which they developed the operating procedures for a government organisation. A Symonds Group team also worked on a Rolls Royce Aerospace Group project for seven months evaluating all the leading computer based maintenance management systems available at that time. After exhaustive research and demonstrations, Maximo was determined to be the best.

Maximo is an asset based system. Every asset, from the whole estate down to every item likely to require maintenance, was given an asset number that uniquely identified what it was, where it was and what hierarchy it belonged to. Whenever a maintenance task was carried out it was recorded against the asset number. It was therefore possible to interrogate the system for costs related to any horizontal or vertical asset grouping. This provided easy means to identify any asset with greater maintenance demands than comparable assets, allowing the building managers to make informed decisions as to whether it would be cheaper, in the long run, to replace the asset completely or just keep fixing it when it went wrong.

The system was set up on a network where each party to the process had a workstation and varying degrees of authority. Apart from the initial data input, which was carried out by the Symonds Group team, the procedures required the setting up of a "Help Desk" where reactive maintenance requests could be made. The Help Desk operator would key in the request that would be forwarded to the maintenance department. The latter would identify what the requirement was and the asset number(s) to which it related and feed this back into the system together with an approximate costing based on a pre-agreed "Schedule of Rates". There was a financial threshold that, if exceeded, required the "task" to be electronically forwarded to the workstation of the member of staff with the relevant approval authority. He/she would electronically authorise the work (there were procedures to deal with work request authorisation rejections) and email it back to the maintenance department to action. Once the work was completed details of the labour, plant and materials would be logged back on to the system.

Maximo allowed all planned preventative maintenance jobs to be set up and automatically generated the work dockets at the appropriate time whilst capturing all the details of reactive maintenance. It must be appreciated that the setting up of the system and defining the operating procedures was a mammoth task. Just creating the asset code was a major exercise let alone gathering all the asset data which included manufacturers names, addressed, points of contact, model numbers, dates of manufacture, warranty details and expiry dates, part numbers and consumables together with maintenance procedures and intervals.

The Symonds team were asked for input to a potential Saudi project that included a computerised maintenance management system being offered by a Saudi software source. We are also aware that the US Corps of Engineers Research Laboratory (USACERL) collected and collated maintenance information from all their buildings and developed a computer based methodology for predicting routine maintenance costs over a 25 year building life. This information was intended for use in calculating life-cycle costs. The maintenance prediction system was entitled MRPM (Maintenance Resource Prediction by Model) and covers everything from replacing a tap washer to replacing complete systems. One of the drawbacks was that it appeared to assume that the profile started at the end of the defects liability period of a new building and therefore wouldn't necessarily be relevant for other segments of a building's life. It also assumed that all maintenance tasks required were actually carried out when they were due and had no provision for deferring tasks within the profile.

We do not know if USACERL developed a life-cycle costing program and, if so, whether it is available to the public but MRPM is in the public domain. Symonds acquired a copy of MRPM back in 1991 but found the reporting procedure in the supplied software only suited a military organization. Since the hard copy provided a detailed breakdown of labour plant and materials for each maintenance task, it would be a relatively easy task to write a database program to provide reports, using the data, in a more useful format.

One point of note is that MRPM does not appear to be in current use by the US Military. We may speculate that perhaps they now have something better. Initially design settings for equipment, and anticipated performance of environmental systems can be used as initial Key Performance Indicators (KPI's) that can be modified at the in-use data set aggregates. Also, on-line comparisons with performance data from other similar portfolios allows a cross-check to be carried out. In Australia the Tertiary Educators Facility

Managers Association (TEFMA) collect and publish over one hundred and twelve KPI's that cover twelve areas subscribed to by fifty six educational establishments. This allows each institution to compare its performance with similar institution and put into practice Continuous Improvement.

3.3 COMPLETING THE LOOP

Long term performance data is usefully fed back into the preparation of design briefs for future projects by identifying which combinations of equipment and design features work well, and which do not. Through these means the entire building stock can be improved.

4. Summary

Currently building developers do not adopt a life-cycle attitude to the buildings they sponsor. This is because they do not see evidence of a competitive advantage in building sustainably. This is in large part due to the lack of information systems that allow both they, and their prospective building purchasers to life-cycle cost options.

The discussion above suggests that with today's technology it should be possible to create an information environment that could provide the means of 'short-circuiting' this mismatch. The writers note that this is as applicable in Saudi Arabia as it is in Australia.

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- محمد عبد الوهاب، محمود عبد اللطيف، مجدى رضوان، عبد المنطاب محمد علـى – ٢٠٠٤ – استخدام خرائط الضوضاء لتحديد استعمالات الأراضى وتخفيض الضوضاء فى المناطق الحضرية بمدينة أسيوط – المؤتمر الدولى الثـانى للتنميـة فـى الـوطن العربى.
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- أضيف نظام الـ ANC لجهاز الاستريو ببعض السيارات اليابانية حيث يقوم بإنتاج أصوات عكسية للضوضاء الداخلية لمقصورة السيارة.
- تجرى أبحاث عن استخدام هذه النظم الفعالة للتحكم فى ضوضاء السفن والغواصات وأبراج التبريد وفى عمل أغلفة واقية من الضوضاء يمكنها إحاطة أى مصدر للضوضاء.

٦- الخلاصـــة :

اعتمدت الصوتيات المعمارية لفترة طويلة على أسلوب التجربـة والخطـاء والخبرة المكتسبة, ثم دخلت عصر النظريات الفيزيقية والمعادلات التى تفسر سلوك الصوت وموجاته وما تبع ذلك من حلول رياضية شديدة التعقيد ممـا جعلها غير عملية فى العديد من الحالات ومما استوجب اللجوء إلى التبسـيط المخل فى كثير من الأحيان.

ومع ظهور الكمبيوتر وما فتحه من آفاق ونشوء برامج المحاكاة وفكـرة الواقع الافتراضى وتمثيل الرسومات فقد بداء عصر جديد لعلـم الصـوتيات آخذا فى التقدم بسرعة والتطور المستمر، مما أتاح الفرصة لمزيد من الفهـم والدراسة والتقييم والوصول إلى افضل النتائج للمشاكل الصوتية المعماريـة، وظهر ذلك واضحا فى مجالات مختلفة والتى تناولها البحث وشملت الأجهزة والدراسات والأبحاث الصوتية والتحكم فى الأداء الصوتى للقاعات وتيسـير دراسة علم الصوتيات وخاصة للدارسين الجدد واخيرا فى مجالات التحكم فى الضوضاء.

لقد اصبح الكمبيوتر عنصرا أساسيا فى علم الصوتيات المعمارية الـذى ما زال ينتظر المزيد من إسهامات الكمبيوتر فيه.

٥-٢ تطبيقات التحكم الإيجابى للضوضاء ANC :

تتضح أهمية الـ ANC فى التحكم فى ضوضاء الميزات المغلقة .. وظهر ذلك جلياً فى تطبيقات أهمها دكتات التكييف – مقصورات السيارات – شكمانات السيارات – سماعات الحماية للأذن حيث يقوم الـ ANC بالتخلص من الضوضاء ذات الترددات المنخفضة والتى تشكل عبئاً كبيراً على منتجى هذه الصناعات حيث تتطلب استخدام أوزان وأحجام كبيرة من المواد العازلة صوتياً أكثر من تطلبها الترددات المتوسطة والعالية .. ولذلك فإننا نجد أن معظم تطبيقات الـ ANC تشمل تداخل بين فكرة التحكم الشامل للضوضاء للترددات المتوسطة والعالية بجانب استعمال الـ Passive Noise Control ـ ANC فيما يخص الترددات المنخفضة.

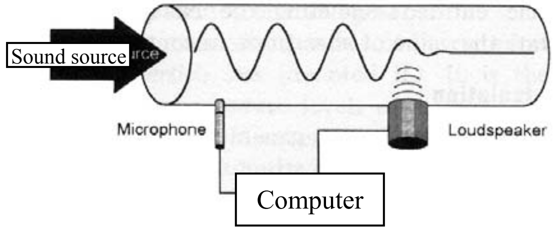
٥-٣ أمثلة لتطبيقات التحكم الإيجابى فى الضوضاء(FAQ 2003):

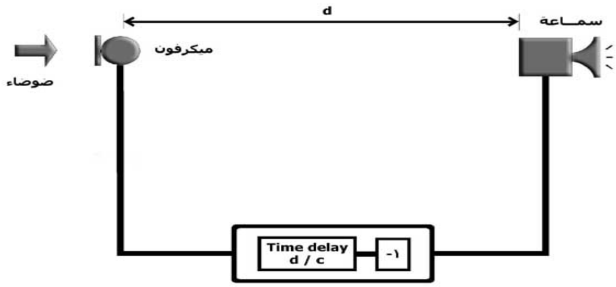
- ظهر فى الأسواق سماعات الأذن التى تمنع سماع الترددات المنخفضة المسببة للإزعاج بينما تسمح بسماع الأصوات الأخرى ذات الترددات المتوسطة والعالية مثل أصوات المتحدثين أو أجهزة الإنذار الصوتية. وقد استخدمت على نطاق واسع لقائدى الطائرات الهيليكوبتر والطائرات المروحية الصغيرة.
- استخدمت العديد من شركات السيارات فكرة الـ ANC فى الشكمانات وذلك للتحكم فى الضوضاء ذات الترددات المنخفضة .. مما أتاح عمل شكمانات بسيطة تسهل عملية خروج العادم.. مما مكن هذه الشركات من زيادة قدرة المحركات وكفاءتها وتقليل الفاقد بسبب دفع الغاز خلال الشكمانات التقليدية.
- استخدمت بعض الشركات الفكرة فى تخفيض ضوضاء الترددات المنخفضة داخل مقصورات الطائرات المروحية أو السيارات حيث تم وضع سماعات على أسطح الكابينة الداخلية تمنع سماع صوت المراوح داخل الكابينة .. ساعد هذا الأمر فى تخفيض وزن الطائرة أو السيارة لحد كبير.

فالمجال الصوتى مثل الذى يحيط بمنزل ما حيث يحتوى الصوت على ترددات عالية ذات موجات قصيرة بالإضافة إلى التركيب الهندسى لكتل المبنى وما يجاوره ويجعل المجال الصوتى حول المنزل مركب (معقد) ليس من السهل التحكم فيه إيجابياً ذلك فى حين يسهل التحكم الإيجابى فى ضوضاء الفراغات المحددة والمغلقة مثل كابينة سيارة خصوصاً عند الترددات المنخفضة، وكذلك فى دكتات التكييف حيث يكون المجال الصوتى ذو اتجاهين فقط (Two Dimensional) .

وعادة فإن تخفيض الضوضاء فى مكان ما محدد يصاحبه تأثيرات جانبية غير مرغوبة تتشكل من حدوث تضخيم للصوت فى أماكن أخرى .. حيث أن نظام الـ ANC يستطيع التحكم فى الضوضاء (محلياً) Locally وليس شاملاً Globally، وعموماً فإن يمكنه الحصول على التأثير الشامل للمجالات الصوتية البسيطة، وتعقد المجال الصوتى فإنه يكون هناك ضرورة إلى استعمال عدد أكبر من السماعات لبث الصوت المعاكس للحصول على تأثير أشمل .. ولهذا بزيادة التردد فإن المجال الصوتى يصبح أكثر تعقيداً أو تركيباً ويصبح استعمال عشرات أو مئات من السماعات وما يصاحب ذلك من الحاجة إلى أجهزة كمبيوتر أكثر سرعة لإمكانية تشغيل هذا العدد من السماعات .. أمراً ضرورياً لتحقيق إمكانية التحكم الشامل فى الضوضاء.

ومن ناحية أخرى فأن تطبيقات الـ ANC تعمل بصورة جيدة عندما تكون الضوضاء المراد التحكم فيها ثابتة مع الزمن .. وبذلك فإنه يمكن قياسها ومعرفة خصائصها قبل وصولها إلى المكان المراد تخفيض الضوضاء فيه .. مما يعطى فرصة كافية لإعداد الأصوات العكسية لمجابهتها مثل ما يحدث فى دكتات التكييف .. فإن لم يمكن قياس الضوضاء مبكراً ومعرفة خصائصها فأن الأصوات العكسية لابد أن تخضع للتصحيح المستمر عن طريق التغذية المرتدة الأمر الذى يتطلب مرة أخرى كمبيوتر فائق السرعة حتى يستجيب لهذه التغيرات السريعة والمستمرة.





شكل (١٣) مكونات نظام التحكم الإ ا الضوضاء
ا صدر: Cowan 2000

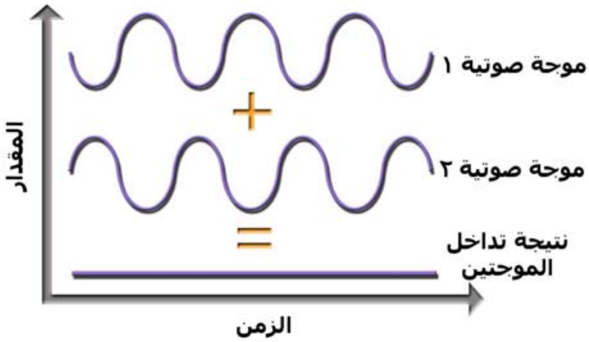
١-٥ أنواع التحكم الإيجابى فى الضوضاء :

هناك مدخلان لفكرة التحكم الإيجابى للضوضاء هما : Active Noise Control والآخر هو Active Structural Control Acoustic .

فى النوع الأول يتم إنتاج صورة مرآوية مختلفة فى "الطور" Out of Phase عن الأصوات المسببة للإزعاج .. بينما يتعامل النوع الثانى مع الضوضاء الناتجة من اهتزاز الأسطح حيث تقوم مولدات اهتزازات Vibration Generators بالعمل على منع هذه الأسطح من الاهتزازات.

وتعمل فكرة الـ ANC بصورة جيدة عند الترددات المنخفضة (الموجات الطويلة) عندما تكون أطوال الموجات أكبر من أبعاد الفراغ الذى توجد فيه .. وكذلك عندما يكون المجال الصوتى بسيطاً (غير مركب) فإن استخدام ANC للمجالات الصوتية المركبة هو أمر ما زال حتى الآن أبعد من إمكانيات التكنولوجية المتوفرة حالياً.

الأدراج حتى منتصف الثمانينات نظراً لاعتمادها على وجود كمبيوتر سريع ضمن الأجهزة المستخدمة يتحكم فى سماعه لإنتاج صوت هو صورة مرآوية تماماً للضوضاء التـى تسبب الإزعاج.



شكل(١٢) فكرة التحكم الإيجابي فى الضوضاء

عند تداخل الصوت يلغى كل منهما الآخر. (شكل ١٢)، وقد بدأت تطبيقـات الـ ـ ANC تظهـ ـ ـر منـ ـ ـذ الثمانينـ ـ ـات (FAQ 2003).

ويتكون النظام الفعال للتحكم فى الضوضاء من أربعـة مكونـات أساسـية (شكل ١٣) (Cowan 2000) هى:

- المكان المصدر للضوضاء : ومن أمثلته الهواء المتحرك داخـل دكت التهوية – سماعات هواء بداخلها.
- ميكروفونات : أو أى نوع أخر من الحساسات Sensors .
- كمبيـوتر أو(Digital Signal Processor): وهـو يقـوم بقـراءة المدخلات القادمة من الميكروفونات ثم القيـام بإنتـاج الصـوت العكسى لها.
- سماعات : تقوم بإخراج الصورة العكسية للضوضاء.

يمكن وضع أكثر من مصدر صوتى فى المشهد الواحـد .. وتكـون هـذه الأصوات مسجلة فى ملفات وهى أصوات أصيلة (جافة – مباشرة) .. وعنـد تحرك مستعمل (VR) من مكان لآخر داخل مشهد الـ (A3D) فأن محـرك الصوت Sound Engine يقوم بحساب البعد عن كل من المصـادر وكـذلك الانعكاسات المحتملة من الأسطح القريبة وكذلك أى حجـب أو انكسـار أو حيود لأشعة الصوت قد تواجهه فى مسارها وذلك تبعاً لأبعاد ونـوع مـادة الحوائط المحيطة وكذلك المفروشات داخل الفراغ. ويتم من خـلال متابعـة الموجات الصوتية Wave Tracing الموجودة على كـارت الـ A3D ممـا يجعل عملية المتابعة اللحظية للصوت ممكنة.

إن إدخال الخصائص الصوتية للمواد الداخلة فى تكوين المناظر قد أمكـن تحقيقه من خلال قاعدة معلومات ضخمة تضم الأشـكال المختلفـة للمـواد وملمسها وكذلك خواصها الصوتية مثل معامل الامتصاص عند كـل تـردد والنفاذية .. وذلك بإعطاء كل مادة كود معين.

وحتى الآن فإن كروت الصوت المتاحة تأخذ فـى حسـابها الانعكاسـات الأولى فقط من كل سطح ثم يقوم بتقدير قيمة الانعكاسات التالية .. كمـا أن معاملات الامتصاص والنفاذية ما زالت تقتصر علـى تـردد عـال وأخـر منخفض فقط، ومن المتوقع التغلب على هذا القصور النسبى فـى المسـتقبل القريب.

٥- استخدام الكمبيوتر فى تطبيقات التحكم الإيجابى فى الضوضاء Active Noise Control (ANC):

ظهرت فكرة التحكم الإيجابى فى الضوضاء ANC منذ الثلاثينـات مـن القرن الماضى ثم أخذ فى التطور نظريـاً حتـى الخمسـينات حيـث أدرك العاملون عليها أنه لا يمكن تحقيقها عملياً .. وظلـت هـذه الفكـرة حبيسـة

ومن ثم تم تطويرها واستعمالها فى مجالات التصميم والعمـارة والمجـالات الطبية وأيضاً فى مجال الألعاب الإليكترونية حيث يـتم إدخـال المعلومـات الصوتية عادة إلى الكمبيوتر بطريقة تتبـع الأشـعة أو بالحسـاب المباشـر للانعكاسات المحتملة من المصدر وصوره المخلقة على أسطح الفراغ.. كـل هذه الطرق يمكنها حساب تأثير الأشعة المباشرة والمنعكسة التى تصل إلـى مستمع ما وعلاقة ذلك بالوقت ومن ثم حساب زمن الترديد وبعض المحددات الأخرى ولكن المشكلة الأكبر التى واجهت هذه التطبيقات هى كم الحسـابات الضخمة المطلوبة والتـى تحتـاج إلـى زمـن طويـل لاجراؤهـا علـى الكمبيوتر(Drumm 2003) .

استخدمت فكرة الحقيقة الافتراضـية Virtual Reality لتبسـيط ورسـم الصوت وسماعه داخل الفراغات المعمارية وهو يتحرك داخلها .. وقـد تـم تطوير هذه التطبيقات باستخدام لغات الكمبيوتر مثـل C^{++} وتطبيقـات مثـل Open Gl , Aural A3D , API (Applications Programming Interfaces).

من هذه التطبيقات ما تم تطويره بجامعة سالفورد بإنجلترا .. حيث يسـتطع مستعمل هذه التطبيقات التحرك داخل الفراغات المعمارية المختلفة ورؤية ما بداخلها من زوايا مختلفة وكذلك سماع الأصوات متعـددة المصـادر مثـل التليفزيون وماكينة التصوير ومتحدثين تبعاً لمكان تواجده النسبى لهم .. يمكن وضع عناصر الفرش المختلفة وتحريكها فى الفراغات ومعرفة تأثيرها على خواص الصوت داخل الفراغ ..وبذلك يمكن للمستعمل تقييم المناخ الصـوتى للفراغات الداخلية قبل بناؤها وكذلك قياس بعض المحددات الصوتية كـزمن الترديد RT ،زمن اضمحلال الأصوات المبكرة ودرجة وضوح الصوت.

استوجب الطلب المتزايد على الألعاب الإليكترونية تطوير كروت صوتية توضع داخل الكمبيوتر لتوفير تلك الإمكانية بسهولة وسرعة عالية ومن أمثلة هذه الكروت Aureal وهى تعتبر مثالاً جيداً لمنتجات الـ API، Aureal API

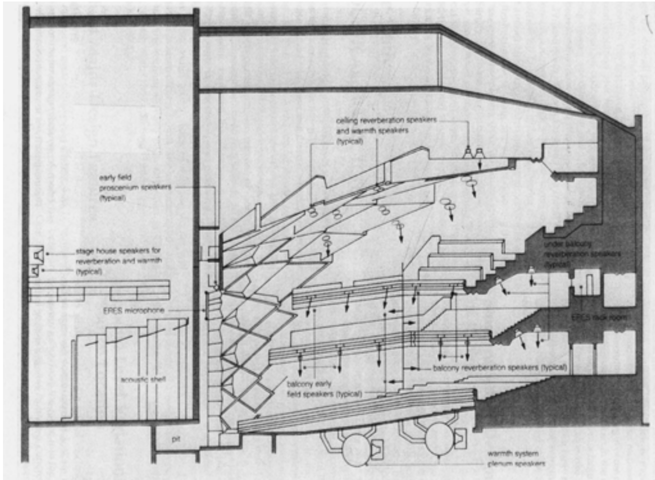
للقاعات.. هذه الأنظمة تصمم لكى تنتج رسومات ثلاثية الأبعاد للقاعات بعـد تغذيتها بالخصائص الصوتية المطلوبة والسعة والشكل العام للقاعة اعتمـاداً على ما لديها من قاعدة بيانات ضخمة عن علاقـة الخصـائص الصـوتية بالمظاهر والسمات المعمارية لمبانى سابقة، وإن كانت مثل هذه الأنظمة مـا زالت تحت التطوير إلا أن المتوافر منها الآن يمكن من أداء بعض هذه المهام التصميمية (Radwan 2003)

٤- دور الكمبيوتر فى تعلم وممارسة الصوتيات المعمارية :

ساهم ظهور أجهزة الكمبيوتر فـى تسـهيل مهمـة تعلـم الصـوتيات المعمارية .. حيث أمكن عمل برامج Animation يستطيع الطالب من خلالها رؤية الظواهر الصوتية المعقدة على شكل موجات تتحرك وتتداخل وتنعكس وتنكسر على شاشة الكمبيوتر (Visualisation)، كما أنه يستطيع سماع نتـاج هذه الظواهر (Auralisation)، وجدت مكتبات تعليم للصوتيات تحوى أمثلـة لهذه الظواهر المرئية والمسموعة يمكن للطالب استعمالها لتسـهيل إدراكـه للظواهر الصوتية المختلفة وتنمية فهمه لهذه الظواهر.

ومن أمثلة هذه المكتبات الصوتية المرئية تلك المكتبة التى يقـوم فريـق عمل من جامعة Chalmers للتكنولوجيا بالسويد فى إعدادها وتجربتها علـى الطلاب .. حيث بدأ هذا المشروع عام ١٩٩٦ وقسم لمرحلتين ويـتم تقيـيم التجربة بعد كل مرحلة. وأثبتت التجربة نجاحها لحد معقول فى تسهيل عملية فهم الظواهر الصوتية وأيضاً فى تحفيز الطلاب غير المهتمين على استعمال الكمبيوتر فى دراسة هذه الظواهر ومواصلة الدراسة والفهم(Internet 2004).

أن استخدام الكمبيوتر فى مجال التمثيل ثلاثى الأبعاد (3D) قـد تطـور بصورة كبيرة وبقفزات واسعة خلال الأعوام القليلة الماضية .. وكان قد بـدأ استعمال (3D) أساساً فى المجالات العسكرية وفى مجال الملاحة الجويـة ..



شكل (١١) قطاع توضيحى لقاعة Evangeline Atwood

ا صدر : Cavanaugh 1999

٣-٨ المحاكاة المسموعة: Aural Simulation

تستعمل النتائج التى تم الحصول عليها من النمـاذج المصـغرة Scale Models أو نماذج الكمبيوترomputer Models التـى تشـمل زمـن الترديـد والانعكاسات المبكرة وغيرها من المحددات، تستعمل كمؤثرات تضاف إلـى أصوات موسيقية مسجلة فى غرف عديمة الارتداد ويعاد الاسـتماع عليهـا ومعرفة مدى تأثير القاعة عليها وهو الأسلوب الذى يطلـق عليـه الحقيقـة الافتراضية للمجال الصوتى Virtual Reality of Sound Fields وبذلك يمكن سماع موسيقى تعزف فى قاعة غير موجودة فى الواقع وإنما فى الكمبيوتر أو كنموذج مصغر(Radwan 2003)

٣-٩ الأنظمـة الذكيـة للتصـميم بـالكمبيوتر Intelligent and Expert Systems :

بدأ التفكير فى السنوات القليلة الماضية فى عمل أنظمة ذكية تعتمد علـى البيانات المتوافرة عن الخصائص الصوتية وعلاقتهـا بالسـمات المعماريـة

والممرات، كما تم وضعها أيضاً أسفل خشبة المسرح وفى دكتـات الهـواء الصاعد أسفل أرضية القاعة .. تم التقاط الصوت بميكروفون ويتم مضاعفته ثمانية مرات ثم يمر عبر دوائر تأخير قبل بثها للمستمعين.

٣- **النظام الثالث** وهو خاص بزمن الترديد Reverberation on Demand System (RODS) وهو يختص بزيادة زمن الترديد للقاعة بمقدار يمتد حتـى ٠,٥ ثانية، فى حالة استخدام القاعة للعرض الاوبرالى أو السـيمفونى فـإن حجم الغرفة وما ينتج عنه مـن زمـن ترديـد يعتبـر غيـر كـاف لهـذه الاستعمالات .. لذلك فإنه من الضرورى إطالة هذا الزمن، أحد أجزاء هـذا النظام يضيف ٤٨ تكـراراً لصـوت المصـدر الأصـلى عنـد التـرددات المتوسطة .. الجزء الثانى من النظام يضيف ٧٢ تكراراً لصـوت المصـدر الأصلى عند الترددات المنخفضة يتم بعد ذلك تقوية الصوت ثم يتم بثه إلـى المستمعين من خلال السماعات المركبة على السقف العلوى للصالة والبلكون وكذلك فى خلفية القاعة .. تعطى السـماعات المتعـددة الإحسـاس بترديـد الصوت وإحاطته بالمستمعين، ويذكر استشاريو الصوت لهذه القاعة أن هـذه الأجهزة الإلكترونية لا تغير من شخصية الصوت الصادرة مـن المصـدر ولكنها تعطى الفرصة لتغيير نوعية الصوت بالضغط علـى بعـض الأزرار فقط دون الحاجة إلى تحريك حوائط أو قواطيع.

ويوضح شكل (١١) قطاعا مبسطا لهـذه القاعـة موضـحاً عليـه الأنظمـة الإلكترونية الثلاثة.

ولعل أكثر القاعات استخداماً لهذه الأنظمة هى قاعـة Evangeline Atwood Concert بمركز ألاسكا للفنون بأمريكا.

استخدمت فى هذه القاعة ثلاثـة أنظمـة إلكترونية مستقلة يمكن أن تعمل منفردة أو مجتمعة (Cavanaugh 1999) كما يلى :

١- **النظـام الأول** وهو يتحكم فى المجال الصوتى المبكـر Early Field System .. وهو يعطى تأثير الانعكاسات الصـوتية المبكـرة مـن خـلال مجموعة من مكبرات الصوت موضوعة حول فتحة المسرح وفى واجهـات البلكونات، يتم التقاط الصوت بميكروفون موضوع على خشبة المسرح حيث يمر الصوت الملتقط عبر دوائر تأخير رقميـة Digital Signal Processing Units ويتم تكبير الصوت إذا لزم الأمر.. يتم بث الصوت عبر السـماعات المخصصة لذلك بحيث يصل متأخراً عن الصوت المباشر بزمن يتراوح من ٢٠ إلى ٣٠ ملى ثانية مما يضمن تحقيـق الإحسـاس بالوضـوح والآلفـة واتجاهية المصدر الصوتى مع زيادة علو الصوت.

٢- **النظام الثانى** وهو يتحكم فى الأصوات المتأخرة Late Field System أو ما يطلق عليه نظام الدفء الصوتى Warmth System .. وهو مخصـص لتوفير الانعكاسات عند الترددات أقل من ٢٥٠ هيرتز والتـى تصـل إلـى المستمعين فى أماكنهم متأخرة عن الصوت المباشر بزمن يتراوح مـن ٧٥ إلى ٣٠٠ ملى ثانية .. هذه الانعكاسات توفر عادة بعمل قاعات ذات أحجـام كبيرة وذات أسطح صادة عاكسة للصوت .. كما فـى قاعـة ميكـدورميت السيمفونية بدالاس- تكساس شكل (٤)، ولكن فى قاعة مركز الاسكا هذة فقد تم توفير هذه الانعكاسات بطريقة إلكترونية، وضـعت مكبـرات الصـوت الخاصة بالانعكاسات المتأخرة فى السقف وعلى أسطح البلكونات والميزانين

وظهرت أفكار أخرى للتحكم فى صـوتيات القاعـات بتغييـر خـواص المساحة المخصصة للمستمعين أو بإضافة مواد ماصـة بكميـة كبيـرة أو استخدام الشواية أعلى خشبة المسرح فى إضافة حجم للقاعة .. إلا أن كل من الأفكار لاقت الإعراض عنها من بعض الخبراء.

٣-٧-١ الوسائل الإلكترونية للتحكم فى صوتيات القاعات :

ظلت فكرة إحداث تغيير فى صوتيات القاعات بمجرد ضغط " مفتاح على لوحة الكمبيوتر " أمراً له جاذبية خاصة باستخدام الطرق الإلكترونيـة فـى التحكم فى خواص الصوت .. وبالرغم من هذه الأنظمة تكون عـادة معقـدة ومكلفة إلا أنها تظل أقل من تكلفة الوسائل الطبيعية السابقة بفارق كبير.

أن استخدام الوسائل الإلكترونية عموماً فى القاعات هو أمر شائع الحدوث ويبدأ باستخدام نظم تقوية الصوت Public Adress Systems، والذى يتكـون من ميكروفون يوضع قريب من المتحدث وسماعات موجهة إلى المسـتمعين وحتى لا يتسبب هذا النظام فى فقدان الإحساس باتجاه المصدر الصوتى فقـد تم تطويره بإضافة دوائـر تـأخير للصـوت فيمـا يسـمى بنظـام Delta Stereophony System .

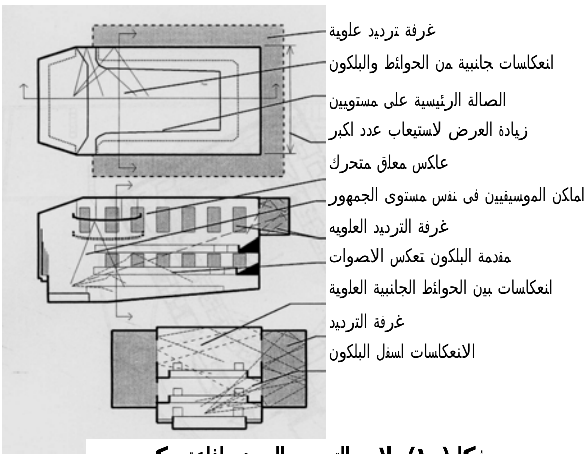
أما بالنسبة للتحكم فى زمن الترديد فقد ظهرت عدة تقنيات منها :

- Assisted Resonance System (ARS)
- Multiple Channed Reverberation . (MCR)
- Acoustical Control System (ACS)

وجميعها تعتمد على وجود كمبيـوتر أو Processor يسـتطيع الـتحكم فـى الإشارات الصوتية وتوجيهها.

زمن الترديد من ٢ ثانية إلى ١/٢ ثانية فقط تبعاً لحاجة الاسـتعمال (Barron 1993). ويذكر أن سعة هذه القاعة ٤٥٠ مستمع ومؤدى فقط، كما أن تكلفة إنشاؤها كانت مرتفعةً جداً.

وتعددت الوسائل المعمارية لتحقيق تغيير الخواص الصوتية للقاعـات .. فظهرت فكرة عمل فراغ يحيط بالصالة Reverberant Chamber يمكن فتحه عليها أو إغلاقه ممـا يمكن من تغيير الحجم، وقد أتبعت هذه الفكـرة فى العديد من قاعـات أمريكا الشمالية مثـل مركز انترايو بكنـدا، وفى قاعة ميكيديرموت بتكساس والتى يمكـن تغيير زمن الترديد بها من ١,٥ إلى ٣,٥ ثانية حيث تركت فراغـات كبيرة الحجم فى الجزء العلوى من القاعة ذات زمن ترديد مرتفع، بحيث يمكن فتح هـذه الفراغـات على القاعة أو إغلاقها لتغيير زمن الترديد تبعا للاستعمال, ويوضح شـكل (١٠) ملامح التصميم الصوتى لهذه القاعة(Cavanaugh 1999). وبالرغم من تبنى هذه الفكرة فى العديد من القاعات إلا أنها لم تكن مقبولة لدى العديـد مـن خبراء الصوت حيث يعتقدون أن الأذن تسـتطيع إدراك أن مصـدر الأصـوات المترددة يقع خارج نطاق القاعة.

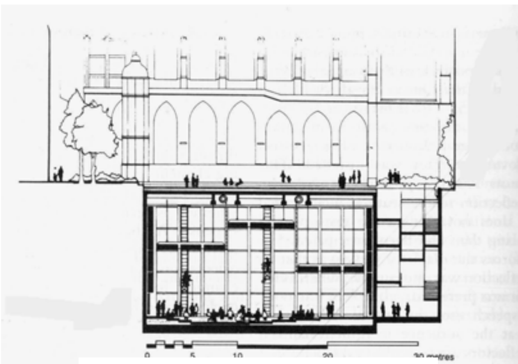


شكل(١٠) ملامح التصميم الصوتى لقاعة ميكديرموت Mcdermott ا وسيقية بتكساس

ا صدر : Cavanaugh 1999

المرور الآلى كمصدر رئيسى للضوضاء .. حيث يأخذ ضمن مدخلاته محددات المرور والشكل العام للموقع السكنى ثم يقوم بإخراج النتائج على شكل خرائط للضوضاء يمكن الاستفادة منها فى توزيع استعمالات الأراضى وتحديد أنسب الأماكن للاستعمالات المختلفة للمبانى ويوضح شكل (٨) مثال لمخرجات البرنامج.

٧-٣ استخدام الكمبيوتر فى التحكم الالكترونى فى الخواص الصوتية للقاعات القائمة :

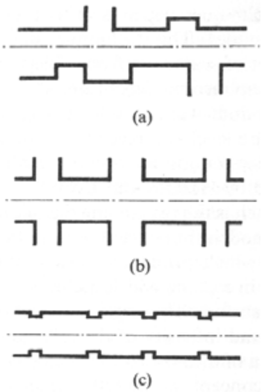


شكل (٩) قاعة ا عهد ا وسيقى الفرنسى

ا صدر : Cavanaugh 1999

أدى ارتفاع تكاليف إنشاء القاعات الصوتية إلى ضرورة الاستفادة القصوى منها وذلك بإتاحتها لاستعمالات عديدة تشمل الدراما – الموسيقى .. حيث يمثل هذين الاستعمالين أقصى درجات التباعد بين الاستعمالات، ففى حين تحتاج الدراما إلى زمن ترديد لا يتجاوز ١ث حتى يمكن الحصول على أعلى درجة من فهم الكلمات فأن استعمال القاعات للغرف الموسيقية يتطلب زمن ترديد يتجاوز ٢ث فى حين أن الاستعمالات الأخرى مثل الأوبرا وغيرها من الأنشطة تقع داخل هذا النطاق,يتحكم فى زمن الترديد عاملان أساسيان هما حجم القاعة ومساحة المواد الماصة داخلها، وقد أنشأت عدة قاعات تتيح لمستخدميها التحكم فى أحد هذين العاملين أو كلاهما، ومن أبرز هذه القاعات قاعة المعهد الموسيقى الفرنسى، شكل (٩) التى يمكن أن يتحرك سقفها ارتفاعاً أو انخفاضاً مما يتيح تغيير الحجم بنسبة ٤ : ١ ، كما أن جميع أجزاء السقف والحوائط يمكن تغيير خواصها الصوتية بتحريك أجزاء منها عن طريق التحكم من بعد بحيث يتغير

كما أنه يوجد بعض البرامج التجارية المتاحة والتى يمكن اسـتخدامها فـى العديد من الحالات .. ومن أمثلة هذه البرامج :



شكل (٧) أنواع الشوارع ا ضرية
ا صدر : Radwan 1989

٣-٦-١ Noise Propagation in Urban Areas (NPUA) : حيث يقوم هـذا البرنـامج بدراسة تأثير توزيع المبانى المحددة للشـوارع الحضرية ونسبة الفراغات بينهـا وعـروض الشوارع على مستوى انتشار الضوضـاء فـى هذه الشوارع والشـوارع المتعامـدة عليهـا. ويوضح شكل (٧) بعـض أنـواع الشـوارع الحضرية التى يمكن اختبارها بهـذا البرنـامج (Radwan 1989).

٣-٦-٢ برنامج Beasy : ويدخل فى تطبيقاتـه التحكم فى الضوضاء المبينة والتصميمات المعمارية والهندسية.

٣-٦-٣ برنامج Immi: وهو معد فى المانيا للتقيـيم الصـوتى للمبـانى والمناطق الحضرية

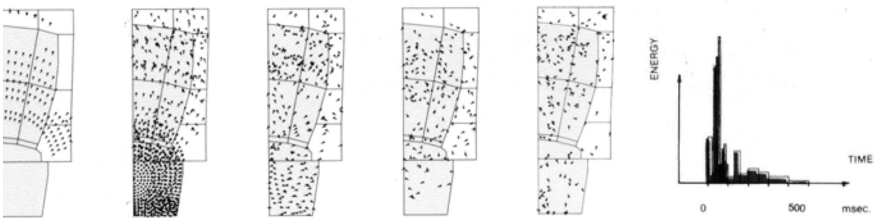
٣-٦-٤ برنامج sound plan : لحساب مستويات الضوضـــاء للمواقع السكنية : يأخذ هذا البرنامج الذى اعـد فـى المانيا ضوضـاء

شكل (٨) مثال خرجات برنامج sound plan
ا صدر : مد عبد الوهاب ٢٠٠٤

رقم (٥) مثال ثلاثى الأبعاد لبعض الانعكاسات فـى قاعـه صـوتية تبعـا للبرنامج .

٣-٥-٤ برنامج تم إعداده بمعهد التكنولوجيا بالنرويج :

و هو يعتمد على فكرة الـ Ray Tracing ويستطيع مراجعة سلوك الصـوت فـى اشكال القاعات المختلفة، ويوضح شكل (٦) بعض مخرجات هذا البرنامج (ELEB)



شكل (٦) توزيع الطاقة الصوتية عند الترددات ا امه

ا صدر : ELAB

٣-٦ استخدام برامج المحاكاة فى التنبـؤ بالسـلوك الصـوتى للمنـاطق والشوارع الحضرية :

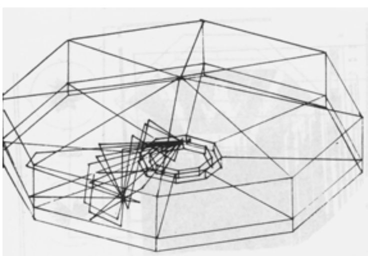
تمثل الضوضاء مشكلة كبرى لجزء كبير جداً من سكان المدن .. وتتعدد مصادر الضوضاء المسببة لهذه المشكلة وقد تلعب البيئة المبينة دوراً كبيـراً فى زيادة هذه الضوضاء وانتشارها .. ولكـن بالتصـميم الجيـد للأسـطح والفراغات المشكلة لهذه البيئة المبينة فإنه يمكن تفادى مشكلة الزيادة هذه بل وجعل البيئة المبينة تعمل على خفض هذه الأصوات غير المرغوبـة، ويـتم ذلك بإتاحة الفرص أمام المصممين الحضريين لاختبـار جميـع الخيـارات التصميمية واختيار الأفضل من بينها باعتبار تأثيرها على المسـتوى العـام للضوضاء, وقد تم تصميم العديد من البرامج لتحقيق هذه الأهداف.

المحددات الصوتية.. تحليل الانعكاسات الرئيسية .. وتظهر مخرجـات هـذا البرنامج على شكل خرائط صوتية.

٣-٥-٢ برنامج أودوين Odeon Program .. وهو من البرامج التجاريـة المعروفة ويعتمد على طريقة المخروطات ويستخدم فى التصـميم الصـوتى للقاعات الكبيرة .. ويتميز بسهولة وسرعة كافية إدخـال البيانـات وتمثيـل الأشكال المختلفة من القاعات.

٣-٥-٣ برنامج راى نويز Ray noise Program .. صمم هـذا البرنـامج لتمثيل سلوك الموجات الصوتية داخل الفراغات المغلقـة مثـل المسـارح – قاعات المؤتمرات – المعامل – عنابر المصانع .. وهو مثل سـابقيه يعتمـد على طريقة المخروطات والمثلثات الهرمية.

يقبل البرنامج إدخال البيانات الهندسية للقاعة بواسطة نظام الإحداثيات أو بقراءة ملفات الأتوكاد مباشرة يـتم إدخال معاملات الامتصاص فى الثمانى ترددات عند الأوكتافات الكاملـة مـن (٦٣ هرتز إلى ٨ ك هرتـز) يسـتقبل البرنامج بيانات المصدر أو المصـادر الصوتية الموجودة داخل المكان ونوعها وصفاتها وتوجيهها. ويحـدد المسـتقبل على شكل مكعبات شفافة تسمح للأشعة الصوتية باختراقها ويتم تحديد صـفات الأشعة الصوتية التى تخترقها وتظهر نتائج هذا البرنامج على شكل خـرائط كنتورية أو على شكل انعكاسات مرسومة Reflectograms توضح مسـتوى الطاقة كمتغير مع الزمن – المكان – الزوايا الرأسية والأفقية للأشعة الصوتية – عدد الأسطح التى اصطدم بها الشعاع الصوتى قبل وصوله، ويوضح شكل



شكل (٥) بعض الانعكاسات ثلاثية الأبعاد كما يوضحها برنامج Raynoise
ا صدر : Abdel_latif 1997

.. Directional Distribution وكذلك التوزيع الاتجاهى Time Distribution ومن ثم فإن هناك العديد من المحددات التى يمكن الحصول عليها مثل : زمن التردید Reverberation Time - درجة علو الصوت فى أماكن مختلفة مـن القاعة Loudness – الانطبـاع الفراغـى Spatial Impression – الاتسـاع الفراغى Spaciousness – الوضوح Clarity – إدراك مكان المصدر الصوتى Localizations

ومن القاعات التى استخدم فى تصميمها برامج المحاكاة قاعة ميكديرموت الموسيقية بمركز ميرسون السمفونى – دلاس – تكساس والتى تم بناؤها سنة ١٩٨٩ وكان استشارى الصوتيات بها شركة آرتك – روسيل جونسون وهى تسع ٢٠٦٢ شخص .. وهى على شكل حدوة حصان واعتمدت على وجـود أسطح عاكسة معلقة تعكس الأصـوات المبكـرة للمسـتمعين مـع تـوفير الانعكاسات الجانبية بالحوائط وواجهة البلكون، شكل (٤)(Barron 1993).

٣-٥ البرامج المتاحة تجارياً لتصميم القاعات الصوتية :

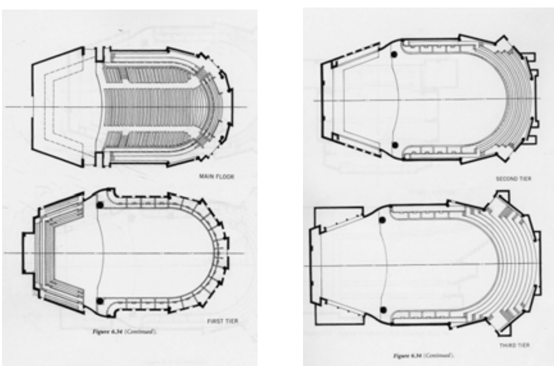
توجد بالأسواق برامج جاهزة يمكن استخدامها للمسـاعدة فـى تصـميم القاعات الصوتية المختلفة ومن أمثلة هذه البرامج (Abdel_latif 1997) :

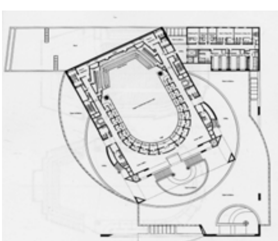
٣-٥-١ برنامج ايبيدور Epidaure Program .. وهو برنـامج تجـارى تطور من خلال أعمال Vian & Van Maerds ويعتمد على فكرة المخروطات والمثلثات الهرمية المختلفة عن الطرق التقليدية فى تمثل الموجات الصـوتية مثل طريقة تتبع الأشعة أو طريقة الصور التخيلية .. يتيح البرنامج فـرص التعرف على الخصائص الهندسية للقاعة والخواص الصوتية للمواد المستعملة فى تشطيبها، اتجاهين المصدر الصـوتى – أمـاكن السـماعات، الأسـطح العاكسة، مدى تركيز الطاقة الصوتية – يسمح هذا البرنـامج بتقـدير زمـن الترديد والاستجابة للنبضـات Impulse Response وحسـاب العديـد مـن

٣-٤ استخدام برامج المحاكاة فى التنبـؤ بالسـلوك الصـوتى لصـالات الاستماع خلال تصميمها :

استخدمت برامج المحاكاة Simulation فى تصميم العديـد مـن قاعـات الخطابة وقاعات الموسيقى وغيرها .. حيث تعطى هذه البرامج مؤشراً حقيقياً عن مدى كفاءة الشكل المختار للقاعة من الناحية الصوتية مما يتيح للمصـمم اختيار الفكرة الرئيسية لتصميماته وعمل التعديلات اللازمة قبل البـدء فـى دراسة التفاصيل الدقيقة .. وذلك نظراً لسهولة وسرعة وقلة تكلفة عمل هـذه التعديلات والتغييرات بهذه البرامج مقارنة بغيرها من الوسائل مثل النمـاذج المصغرة Scale Models بأحجامها المختلفة.

وبالرغم من الدقة التى يجب مراعاتها فى إنشاء نماذج المحاكاة .. إلا أنها يجب أن تخضع لاختبار صلاحيتها حيث تتم هذه الاختبارات بمقارنة نتـائج النماذج النظرية بنتائج مأخوذة من تجارب النماذج المصغرة أو من قياسـات مأخوذة من الطبيعة، فإذا ما ثبت صحة البرامج فى الوصول إلى نتائج قريبة من تلك النتائج الحقيقيـة فإنه يمكن استخدامها بثقة فـى دراسـة القاعـات الجـارى تصـميمها واختبـار مظاهرهـا الصوتية المختلفة.



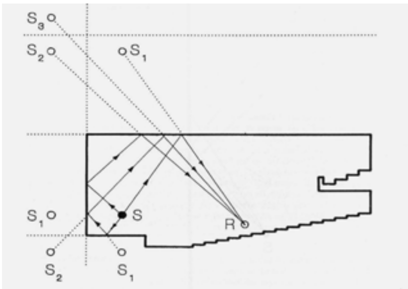


شكل(٤) ا سافط الأفقية لقاعة ميكديرموت Mcdermott ا وسيقية بتكساس

ا صدر : Duncan 1997

تتيح هـذه البـرامج دراسة التوزيع المكـانى للطاقـة الصـوتية، والتوزيـع الزمنـى لوصول الطاقة الصوتية

يساهم فى تركيب المجال الصوتى عند أى مكان محدد بالقاعة ومدى مساهمة كل منهم، ويمكـن للكمبيـوتر بـذلك دراسة جميـع محـددات الاسـتجابة للنبضـات الصـوتية Impulse Response عند الترددات المسموعة جميعها، ويؤخذ على هـذه الطريقـة صعوبة اعتبـار كـل مـن التشـتت والحيود نظراً لاعتبار الأسطح كلهـا ملساء ومستوية.



شكل (٣) طريقة الصور التخيلية للمصدر الصوتى
المصدر: Beranek 1994

٣-٣ طريقة الجزيئات الصوتية Method of Sound Particles

ظهرت هذه الطريقة مؤخراً فى الدراسات الصوتية بعد ظهـور أجهـزة الكمبيوتر ذات السرعات الفائقة والسعة التخزينية الكبيرة، وفيها يعبـر عـن الصوت بجزيئات تنبعث من المصدر فى جميع الاتجاهات وسرعة تسـاوى سرعة الصوت حتى تصل إلى حائط فى القاعة ثم منه إلى حائط آخر وهكذا، وفى كل انعكاس يفقد الجزئ المتحرك جزء من الطاقـة الصـوتية نتيجـة للامتصاص .. ويمكن لهذه الطريقة أخذ التشتت فى الاعتبار عنـد حـدوث انعكاس ما بخلاف الطرق السابقة، ويستمر الجزئ فى التحرك حتـى تقـل الطاقة به عن حد معين مع أخذ امتصاص الهواء فى الاعتبار أيضاً، ويتـابع الكمبيوتر تحديث حالة الجزئ من حيث طاقته الصـوتية، اتجاهـه وزمـن تحركه، فى النهاية وعندما يمر الجزئ بكرة ذات حجم ومكان محدد مسـبقاً تعمل كعداد (Counter) فإنه يتم تسجيل بيانات الجزئ فى ذاكرة الكمبيـوتر، ويتوالى متابعة أعداد كبيرة من هذه الجزيئات يمكن التعرف على خصـائص المجال الصوتى فى القاعات عند الترددات المختلفـة ودراسـة خصـائص الاستجابة للنبضات الصوتية.

يرجع تـاريخ نمـاذج الكمبيـوتر لعـام ١٩٦٠ (Cavanaugh 1999) وتطورت خلال هذه الأعوام الأربعين الأخيرة تطوراً كبيراً .. وتأخذ نمـاذج الكمبيوتر فى اعتبارها اتجاهات الأبعاد الثلاثة بالإضافة إلى البعد الرابع وهو الزمن .. وقد استحدثت برامج جديدة تسـتطيع التعامـل مـع الرسـومات المعمارية المجهزة بالكمبيوتر (CAD)، تمكن هـذه النمـاذج مـن دراسـة الاستجابة للنبضات الصوتية للقاعة "Impulse Response" بيسر وسـهولة، تعتمد نماذج الكمبيوتر على طريقة تتبع الأشعة الصـوتية Ray Tracing أو طريقة الصور التخيلية Image Source Models أو طريقة الجزيئات الصوتية Sound Particles Method

٣-١ طريقة تتبع الأشعة الصوتية Ray Tracing

وفى هذه الطريقة يصدر عدد من الأشعة الصوتية من المصـدر خـلال القاعة، هذه الأشعة تتعرض للانعكاسات المختلفة على سطح القاعـة التـى تقابلها ويقوم الكمبيوتر بتسجيل مقدار وزمن وصول واتجاه الأشعة عنـد أى سطح أو مكان معين بالقاعة، تعطى أسطح القاعة معاملات امتصاص لكـل تردد، وتأخذ النمـاذج الحديثـة فى اعتبارها المظاهر الصوتية مثل التشتت والحيود، ويوجد العديد من نماذج المحاكاة التى تقوم بتبسيط خطوات التقدير للأشعة ذات الترتيب العالى باعتبار أن المجال الصوتى هو مجـال تـرددى Reverberant Field.

٣-٢ طريقة الصور التخيلية Image Source Models

تعتمد هذه الطريقة على إنشاء صور تخيلية للمصـدر الصـوتى علـى سطح القاعة كما هو موضح بشكل (٣) ثم صور فى المستوى الثـانى لهـذه الصور الأولى وهكذا بعدد الانعكاسات المتوقع مساهمتها فى تركيب المجال الصوتى داخل القاعة، وللحصول على نموذج متكامـل للصـور التخيليـة يستخدم الكمبيوتر مع برامج فعالة لتحديد أماكن الصور التخيلية واختيار أيهم

٢-٣ يوجد العديد من معامل الصوتيات التى لا تزال مجهزة بـأجهزة مـن النوع القديم Analogue والتى ما زالت تعمل بحالة جيدة ويصعب اسـتبدالها فى الوقت الحاضر .. وحتى يمكن الاستفادة من إمكانيات الكمبيوتر وتقليـل الوقت والجهد فإن اللجوء إلى تقنية وسيطة تعتمد على دمج هذه الأجهزة مع الكمبيوتر أصبح أمراً لا غنى عنه فى العديد من الحالات فى ظل الظـروف الاقتصادية السائدة (Heap ,1981).

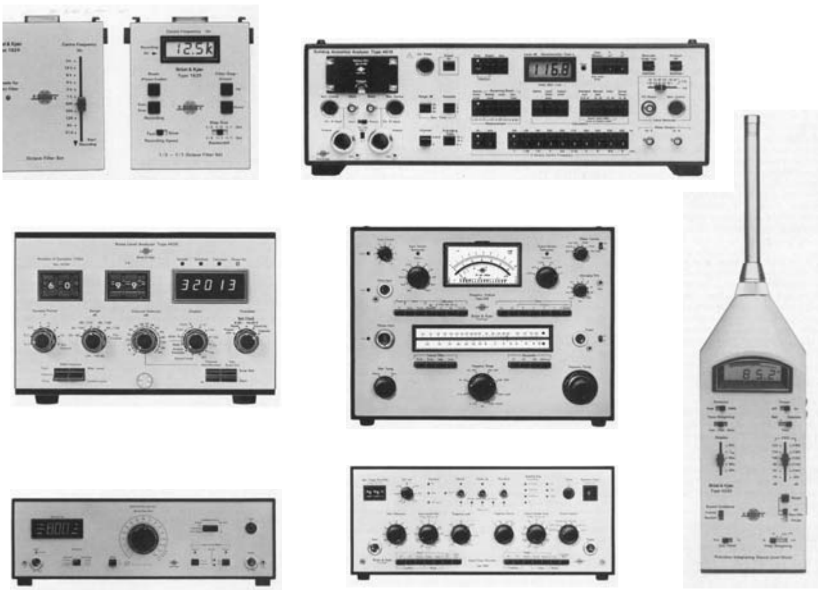
٢-٣-١ فى هذه التقنية الوسيطة يبرمج الكمبيوتر بأى من لغـات البرمجـة المتاحة High Level Language ثم يتم عمل تداخل Interface بينـه وبـين الجهاز المراد التحكم فيه بحيث يتم نقل المعلومات الواردة للجهاز الصـوتى إلى الكمبيوتر الذى يتولى تحويل البيانات غالبـاً عـن طريـق IEEE Port المرسلة إليه من الأرقام الثنائية Binary Codes أو الأرقـام Hexadecimal Codes إلى الأرقام العشرية المتداولة ثم القيام بعمـل التحلـيلات المطلوبـة وطباعة النتائج (Heap 1981) .

٣- استخدام الكمبيوتر فى مجال الدراسات الصوتية :

تنقسم الدراسات الصوتية إلى فرعين رئيسين، أولهما يخـتص بدراسـة صوتيات الحجرات Room Acoustics ويهتم الفرع الأخر بدراسة الضوضاء ووسائل التحكم فيها Noise Control .

وقد تطورت العديد من برامج المحاكاة فى كل من الفرعين حيث تهـدف هذه البرامج إلى تمثيل المكان المراد دراسته ومن ثم إمكانية معرفة السـلوك الصوتى للبيئة المبينة (الداخلية أو الخارجية) قبل بناؤها .. تعتمد هذه البرامج على وجود أجهزة كمبيوتر سريعة وذات سعة تخزينية كبيرة تستطيع تشغيل برامج المحاكاة كبيرة الحجم.

ويوضح الشكل رقم (١) مثال لأحد هذه الأجهزة والتى يمكن باستعمال برامج تشغيل Soft wear أن تؤدى وظائف متعددة، كما يمكـن توصـيل الجهـاز بطابعة للحصول على نتائج مطبوعة، ويوضح شـكل رقـم (٢) مجموعـة الأجهزة البديلة التى كانت تستخدم لأداء هذه المهام، ويشار إلـى ضـرورة استخدام العديد من كابلات التوصيل من وإلى هذه الأجهزة وما قد يتسبب عن ذلك من مشاكل.



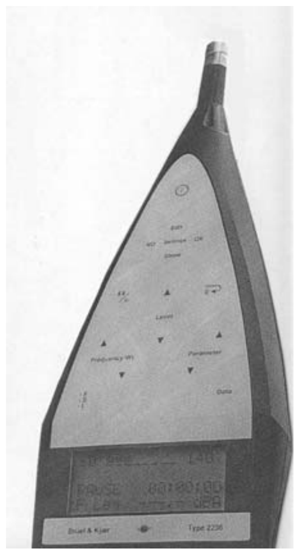
شكل (٢) موعة الاجهزة التقليدية ا كافئة للجهاز ا وضح بشكل (١)

ا صدر: B&K ,master catalogue 1988

٢-٢ ظهر أخيرا فى هذا المجال لوحات اكتساب للبيانات Data acquisition boards وكروت خاصة Plug-in cards و تعمل من خلال بـرامج معينـة أعدت لها مما أدى إلى وجود معامل صوتية متكاملة Virtual acoustics labs تؤدى العديد من الوظائف.

Analogue والتى يقوم كل منها بدور محدد، وبالرغم مـن ارتفـاع أسـعار الأجهزة الرقمية مقارنة بغيرها من الأجهزة إلا أن المهـام المتعـددة التـى يمكنها القيام بها تغنى عن تعدد الأجهزة الصوتية المطلوبـة لعمـل معمـل صوتيات متكامل.

٢-١ ومن أمثلة هذه الأجهزة والتى وجدت فى الأسواق حالياً أجهزة قيـاس مستوى الصوت Digital Sound Level Metres تستطيع القيام بالعديد من مهام القياس والتحليل والتسجيل فى نفس الوقت، مثل :



شكل (١) جهاز رقمى حديث لقياس مستوى الصوت

المصدر:B&k monitor 2002

- قياس مستويات الصوت (الضغط الصـوتى والشدة الصوتية).
- إظهـار النتـائج الإحصـائية Statistical Values .
- عمل تحليل تـرددى Frequency Analysis عنـد الأوكتافـات الكاملـة أو الـ ـ ١/٣ أوكتافات.
- قياس زمن الترديد Reverberation Time
- تحتوى على مولد للصوت Built-in Noise Generator.
- قياس العزل الصـوتى باسـتخدام خاصـية Two Channel Building Acoustics.
- عمل تحليل الـ F.F.T.
- بالإضافة إلى ما يحتويه الجهاز من فلتر أوكتافات كاملة أو ١/٣ أوكتافات .

الصوت واستخراج البيانات الإحصائية وغيرها وما يستلزم هذه الأجهزة من توصيلات معقدة.

٢-١ وأيضاً فى مجال الدراسات الصوتية سواء صوتيات الحجرات أو التحكم فى الضوضاء فقد ظهرت العديد من برامج المحاكاة Simulation Models والتى تطورت تطوراً كبيراً بفضل وجود أجهزة كمبيوتر متقدمة وسريعة يمكنها أداء العديد من العمليات فى وقت قليل .. وقد ساعدت هذه البرامج العديد من المصممين فى اختيار أفضل الأشكال المناسبة للقاعات التى يقومون بتصميمها أو اختيار أنسب المواد الملائمة للتشطيبات الداخلية بما يكفل أفضل جودة صوتية داخلها.

٣-١ وقد ساهمت أجهزة الكمبيوتر فى تحسين الأداء الصوتى للعديد من الصالات القائمة بالفعل وذلك بتداخلها فى أجهزة تكبير الصوت وإطالة زمن الترديد أو عمل بعض التأخير Delay فى الصوت المرسل عبر السماعات الموزعة فى الصالات المختلفة.

٤-١ وإذا نظرنا إلى مجال تدريس الصوتيات فقد أتاحت أجهزة الكمبيوتر وسيلة سهلة وميسرة لتبسيط الظواهر الصوتية المعقدة والمركبة حيث يمكن للطلاب مشاهدتها وفهمها فهماً دقيقاً.

٥-١ وكان لأجهزة الكمبيوتر دوراً جوهرياً فى مجال التحكم الفعال فى الضوضاء Active Noise Control تلك الفكرة التى ظلت حبيسة الأدراج حتى ظهرت أجهزة الكمبيوتر فائقة السرعة حيث أمكن لتطبيقات الـ A N C الظهور إلى عالم الواقع.

ويتناول البحث بالتفصيل هذه المحاور الخمسة.

٢- استخدام الكمبيوتر فى مجال الأجهزة الصوتية :

تطورت الأجهزة الصوتية تطوراً واضحاً بما أتيح لها من استخدام الـ Microprocessor لإدارتها وأصبحت الأجهزة الصوتية أقل حجماً وأكثر قدرة على أداء وظائف متعددة فى نفس الوقت بيسر وسهولة .. هذه الوظائف التى كانت تستلزم عدداً أكبر من الأجهزة التى كانت تعتمد على تقنية المشابهة

عرض للاستخدامات المتقدمة للكمبيوتر فى الصوتيات المعمارية

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المستخلص :

يتناول البحث عرض للاستخدامات المتقدمة للكمبيوتر فى مجال الصوتيات المعمارية، ومنها مجال أجهزة القياسات الصوتية الحديثة حيث تم عمل مقارنة بينها وبين الأجهزة التقليدية، وركز البحث على مجال الدراسات الصوتية والتحكم فـى الأداء الصوتى لبعض الصالات القائمة وأوضح كيفية مساهمة الكمبيوتر فى تطور الدراسات الصوتية مما جعل منها وسيلة فعالة للتنبؤ بالسلوك الصوتى للقاعات فى مرحلة التصميم، واستعرض البحث أهم البرامج التجارية المتاحة بالأسـواق، ثـم تناول البحث برامج المحاكاة فى التنبؤ بالسلوك الصـوتى للمنـاطق والشـوارع الحضرية وأهم البرامج التجارية المتاحة، واستعرض البحث وسائل الـتحكم فـى صوتيات الصالات القائمة والتى استخدمت فى أماكن مختلفة من العالم ثم تنـاول الأنظمة والوسائل الإلكترونية للتحكم فى صوتيات القاعات – أوضح البحث أهمية دور الكمبيوتر فى تعلم وممارسة الصوتيات المعمارية وفى فتح مجـال تطبيقـات التحكم الإيجابى فى الضوضاء.

١ - تقديم :

كان لاختراع الكمبيوتر أثراً كبيراً فى تطوير علم الصوتيات فى العمارة .. وقد ظهرت هذه الحقيقة بوضوح فى العديد من المجالات .. وهى :

١-١ مجـال الأجهـزة الصـوتية والتـى تطـورت مـن اسـتخدام تقنيـة المشـابهة (Analogue) إلى الأجهزة الرقمية وأصبح من الممكن أن نجد جهازاً صغير الحجم لقياس المستوى الصوتى Sound Level Metre يمكنه فى نفس الوقت أداء أعمالاً إضافية كانت تستلزم أجهزة أخرى كثيرة ومركبة مثـل أجهـزة تسـجيل وتحليـل

A REVIEW OF ADVANCED COMPUTER APPLICATIONS IN ARCHITECTURAL ACOUSTICS

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Abstract: The paper is a review of the advanced computer applications in Architectural Acoustics in its different fields, one of these fields is the new measuring apparatus and how it has moved from basic measurement using transducers and analyzers to final documentation based an advanced software. Computers have been proved to be a very useful tool in acoustic studies and prediction of acoustics performance of halls in the design stage. Recent commercial models have been reviewed in both fields; room acoustics and noise control in the built – up areas. Controlling the acoustic performance of some halls by different means and recently by computer has been discussed. The role of computers in the field of learning acoustics by means of auralisation and visualization and in the active noise control has been studied.

التصميم الإلكتروني في العمارة

لقد تشعبت إستخدامات الحاسب الآلى فى معظم مناحى الحياة وصار الحاسب الآلى يشكل جزءاً هاماً من أنشطتنا اليومية ومجتمعنا المعلوماتى يؤثر فيها ولكن نادراً ما يتأثر بها. ولا عجب أن نستشرف دوراً للحاسب الآلى يؤثر ويتأثر من أجل آداء تكاملى أفضل مع مستعمليه. فكذلك الإنسان والعمارة رديفان متلازمان فمع تطور حياة الإنسان تتطور العمارة والعمران. ومع تطور إستخدامات الحاسب سوف يغدو التصميم الإلكترونى فى العمارة هو السبيل المعتمد للتصميم فى المجتمع المعلوماتى ولن يكون فقط ميزة المتخصصين بل صبغة للمعماريين حيث يرتقى التصميم الإلكترونى بالمهنة المعمارية فينقلها من الإسلوب التقليدى التى تمارس به إلى مستوى أفضل يتم الإرتقاء فيه بمستوى الإبداع التصميمى والتنفيذى ومن ثم الذوق المعمارى العام للسكان ومشاركتهم فى تصميم مبانيهم.

و تهدف عملية التصميم المعمارى الى إبتكار تشكيلات معمارية يتحقق من خلالها أهداف وظائفية وسلوكية فى بيئة وسياق خاص. ويحمل توظيف الحاسب الآلى فى عملية التصميم المعمارى بمراحلها المختلفة مضامين لسبل وكيفية إنجاز التصميم. لذا لا يمكن حصر توظيف إستخدامات الحاسب الآلى فى العمارة فى الحيز الضيق للرسم والإخراج الإلكترونى على الرغم من أهميته. بل يجب أن يتعداه الى توظيف مفهوم الحوسبة فى: عملية ماقبل التصميم لتعظيم الفائدة ودراسة الجدوى ، عملية التصميم المعمارى من أجل إثراء الفكر المعمارى بتنوع الأفكار وتعمقها وشموليتها للنواحى الجمالية والتراثية والثقافية والبيئية والإنشائية والمناخية ، التعليم المعمارى للإرتقاء بمستوى الإبداع وجعل عملية التعلم أكثر إستمتاعاً وأعمق أثراً ، تنفيذ المشروعات المعمارية لتحسين مستوى الآداء ورفع الجودة وترشيد الإنفاق ، ما بعد عملية التصميم لرفع مستوى الصيانة وتوفير الراحة للمستعملين ، التغذية المرتجعة والتعلم من تجارب الماضى لتطوير المستقبل. ويبشر المجال البحثى فى التصميم الإلكترونى فى العمارة بإسهامات كبيرة فى تطوير وتحسين عملية التصميم المعمارى وما ينتج عنها وكذلك عملية التعليم المعمارى.

ويأتى دور مؤتمر التصميم الإلكترونى فى العمارة كمنتدى متنوع حول طرق الحاسب الآلى المطبقة على نطاق واسع فى العمارة حيث يتضمن سجل أبحاث المؤتمر ٢٣ بحث علمى محكم من باحثين ومهنيين متخصصين فى مجال العمارة والتصميم بالحاسب الآلى من ثلاثة عشر دول عربية وأجنبية. وتتمثل إسهامات المشاركين فى عدة محاور هى: النماذج الحاسوبية فى عملية التصميم وإتخاذ القرار ، إستخدام الحاسب الآلى فى التصميم البيئى والمستدام ، التعليم المعمارى الإلكترونى وعمران القرن الحادى والعشرون ، توظيف تقنيات الواقع الإفتراضى فى التصميم ، نمذجة المبانى وإدارة المعلومات.

د. ربيع محمد رفعت

رئيس اللجنة العلمية

التصميم الإلكترونى فى العمارة

سجل أبحاث

المؤتمر الدولى الأول

للجمعية العربية للتصميم بالحاسب الآلى

ASCAAD
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بالتضامن مع

قسم العمارة

كلية تصاميم البيئة

جامعة الملك فهد للبترول والمعادن

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سجل الأبحاث

المؤتمر العالمي الأول
لاستخدام الحاسب الآلي
في التصميم المعماري
١٣-١٥ محرم ١٤٢٦هـ

الراعي الرسمي

الأولى
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