Using Computers in Exploring Architectural Shapes

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Abstract

This paper introduces a computational tool (SLiDe) to support one of the primary designing activities at the conceptu al stage; that is exploring various design compositions of architectural shapes. Integrating SLiDe with conventional CAD systems helps in providing a medium for designers to explore the design space and to enhance the perceptual interaction with design elements.

1 Introduction

Designing is taken to be a complex process that includes activities and tasks. During the process of designing, design solutions are generated by dynamic and situated designing activities. Although designers have always managed with pencil, paper and imagination, computers could help them in conceptual designing. Through shapes designers express ideas, present elements of design and abstract concepts. Hence, the role of constructing shapes in designing is significant and the formation and discovery of relationships among parts of a design composition are fundamental tasks in designing. The ability to provide useful computational designing support at the conceptual stages is important to accommodate the situated and fluid nature of early schematic designing and to allow new design solutions to emerge.

This paper introduces a computational tool (SLiDe) that could be used to support one of the primary designing activities at the conceptual stages, that is exploring various design compositions of architectural shapes. The aims of using SLiDe integrated with conventional CAD systems are to provide a medium for designers to explore the design space and to enhance the perceptual interaction with design elements. SLiDe can help in providing designers with useful and applicable design knowledge during the generation of design concepts and maintains the integrity of these concepts during different stages of designing. The usefulness of such knowledge is based on its applicability to a situation rather than determined a priori.

I this paper, it is not meant to fully automate the design process but rather to help designers in designing. SLiDe can help in offering designers with means to explore different design alternatives from which they may select a new design move to develop it further. SLiDe can provide the capability to recognise shape semantics (e.g. reflective symmetry, cyclic rotation, dominance, etc.), in design compositions that have been developed and bring these shape semantics to designers' attention. Designers may select one of the recognised shape semantics based on their interest to re-explore the design space. This could help in enhancing the perceptual interaction with design elements in developing architectural compositions while designing.

2 The role of architectural shape in designing

Shape composition is an important design activity in architectural designing, as in many other design disciplines. Designers use shapes to express ideas and represent elements of design, abstract concepts and construct situations. Shapes have significant role in designing. The formation and discovery of relationships among parts of a design composition are fundamental tasks in designing (Mitchell and McCullough, 1995; Kolarevic, 1997).

2.1 Shape semantics

Shape semantics have many characteristics, one of which is they encapsulate design knowledge that can be ascribed to design artefacts and are among design knowledge that tend to be fundamental to aesthetic design. Shape semantics are the interpretation of visual patterns or visual forms of groups of shapes in the drawing (Jun, 1997). An architectural shape semantic is a collection of high-level information defining a set of characteristics with a semantic meaning based on a particular view of a shape. Various types of shape semantics can be explained in a variety of ways by grouping structures using the laws of figure perception (Arnheim, 1977; Meiss, 1991). Grouping structures is supported by such factors as: repetition, similarity, proximity and orientation. Gestalt theory deals with the grouping phenomenon in a comprehensive way. The central concept of the theory is the concept of Gestalt-form or configuration of any segregated whole or unit (Köhler, 1970). Examples of shape semantics representing congruence among parts of design compositions are shown in Figure 1.

2.2 Multiple representations of architectural shapes

Designers interpret and perceive their designs differently and discover various shape semantics related to their interest from their design compositions. Multiple representations provide the opportunity for a wide range of interpretations where each interpretation reveals certain shape semantics. Hence, multiple representations may allow for implicit shape semantics in one representation to become explicit in another representation. There is a vast range of possible architectural shape semantics, which could be emerged. Shape semantics are recognised in terms of similarity of spatial relationships as well as physical properties. A group of shape semantics recognised in each representation forms an observation. A set of observations can be constructed from a set of multiple representations.

There is a vast range of possible architectural shape semantics which could be emerged. For instance, different representations as shown in Figure 2 allow for some shape semantics to be readily recognised such as reflective symmetry, cyclic rotations, dominance, multiple reflective symmetry, simple rotation and centrality as shown in Figures 2(a) to 2(f) respectively. Each representation helps in the recognition of certain shape semantics whereas it could not be readily recognised at other representations. For instance, dominance cannot be easily recognised in the representations shown in Figure 2 except in the representation shown in Figure 2(c) wherein it can be readily recognised

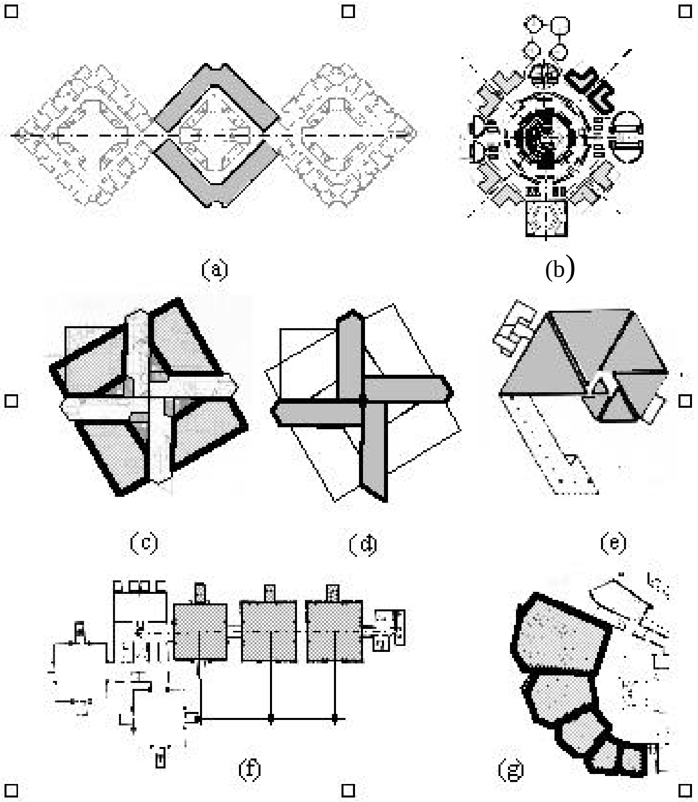

Figure 1. (a) reflective symmetry around an axis, Erdman Hall Dormitory, Bryn Mawr by Louis I. Kahn; (b) reflective symmetry around multiple axes, National Assembly Hall in Dacca by Louis I. Kahn; (c) and (d) closed cyclic rotation, Price Tower, Bartlesville by Frank Lloyd Wright; (e) scaling, Holy Trinity Ukrainian Church by Radoslav Zuk; (f) translational repetition, Richards Medical Research Building, Philadelphia by Louis I. Khan; and (g) scaling, Wolfsburg Cultural Centre by Alvar Aalto.

2.3 Situated learning of architectural shape semantics

Situated learning of architectural shape semantics is mainly concerned with locating shape semantics in relation to their situations within which they were recognised in the design environment. This situatedness of any of the shape semantics is not determined a priori but constructed based upon what is there in the design environment. What make one situation different from or similar to others are the relationships they express in which relevant distinctions could be made among situations within the design environment. The constructed set of observations can be viewed as an internal design environment a learning system might construct to learn the situatedness of knowledge within that environment. The regularities of relationships among shape semantics across the observations are the triggers to learn the situatedness of these semantics. The importance of these regularities lies in the development of coherent distinctions among situations.

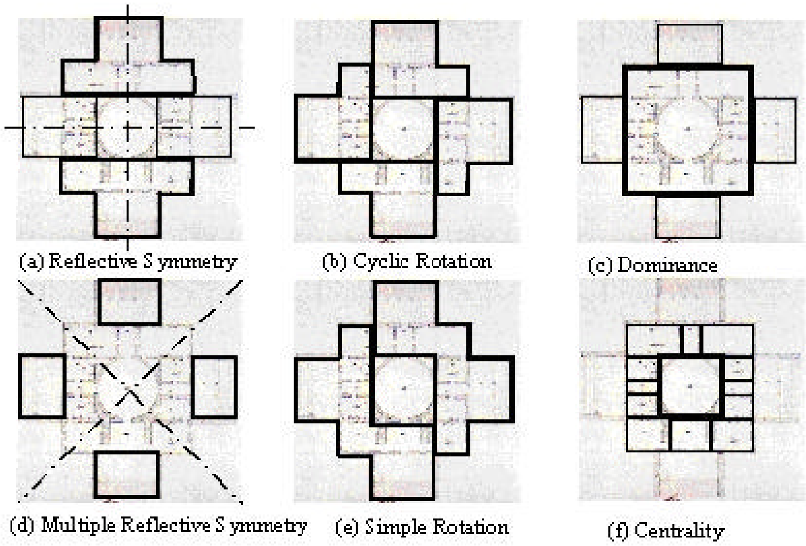

Figure 2. Recognition of different shape semantics from multiple representations of the same design composition.

3 SLiDe: A Computational Situated Learning System in Designing

A computational system for situated learning in designing (SLiDe) is implemented and exemplified within the domain of architectural shape semantics (Reffat and Gero, 2000). Its underlying concepts could be used in other domains. SLiDe consists of three primary modules: Generator, Recogniser and Incremental Situator. The Generator is used by the designer to develop a set of multiple representations of a design composition. This set of representations forms the initial design environment of SLiDe. The Recogniser detects the design environment and produces a set of observations, each of which consists of a group of shape semantics recognised in each representation. The Incremental Situator consists of two sub-modules: Situator and Restructuring Situator. The Situator module locates the recognised shape semantics in relation to their situations by constructing the regularities of relationships among shape semantics across the observations and clustering them in situational categories organised in a hierarchal structure. Such relationships change over time due the nature and fluidity of designing in which changes in the design environment. The Restructuring Situator updates previously learned situational categories and restructures the hierarchy accordingly.

4 Exploring various alternatives in the design space

The use of multiple representations (provided by the Generator module in SLiDe), can be useful for designers to conceptualising, exploring and perceiving their designs differently. This helps in exploring the shapes in a design composition and allows designers to have a variety of representations of what has been designed, which may lead them to different discoveries to those they may otherwise have pursued. It also helps to focus a designer's attention to potentially hidden visual features in such designs. This is achieved through the use of the Generator module in SLiDe as shown in Part I in Figure 3. The Generator constructs the design space by developing an infinite maximal lines representation of the initial design composition. The designer selects a shape of interest from among the intersections of these infinite maximal lines. The Generator searches the design space for shapes congruent with the selected shape. The congruent shapes are highlighted as shaded areas and the generator module develops a representation of these. Designers may continue exploring the design space for other alternative shape compositions by selecting other shapes from among the intersections of the infinite maximal lines representation. Consequently, the Generator module develops a corresponding representation. For instance, an initial representation of the design composition shown in Figure 4(a) is drawn by the designer (user) as shown in Figure 4(b). The infinite maximal lines of the initial representation is generated using the Generator module in SLiDe as shown in Figure 4(c). Examples of some of the representations developed using the Generator module are shown in Figures 5(a) to (f) showing the representations N_1 to N_6 from the initial representation of the design composition shown in Figure 4(b).

5 Conclusion

This paper outlined one of the features that SLiDe can provide to conventional CAD systems that help both interactivity and designing support in the preliminary stages of designing. SLiDe can help in exploring the design space for various shape compositions. The purpose of this computational system is not to replace the designer, but to assist through a form of collaboration with the designer in designing and producing a solution. This provides the potential to change the nature of currently passive conventional CAD systems to be more active and responsive CAAD support system at the very early stages of designing.

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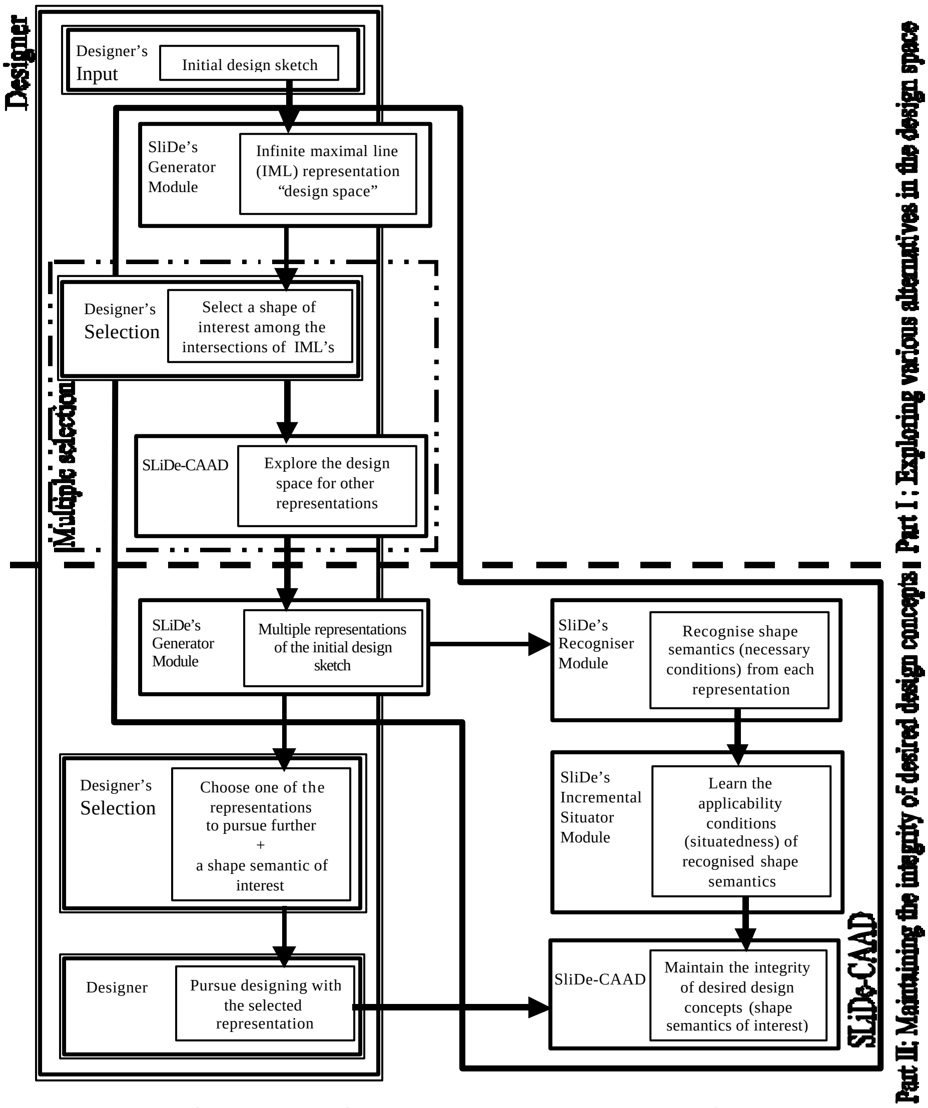
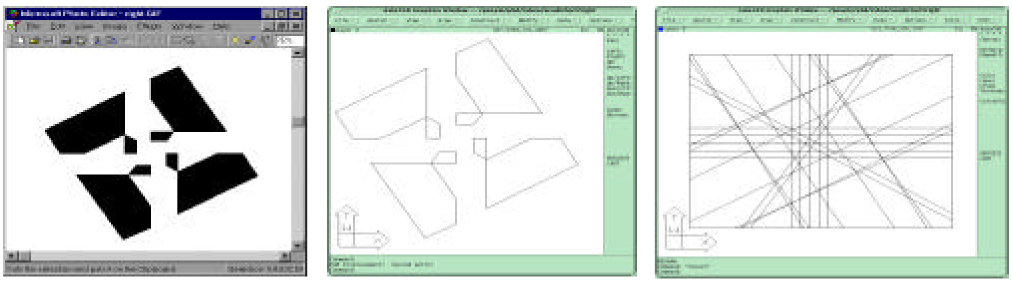
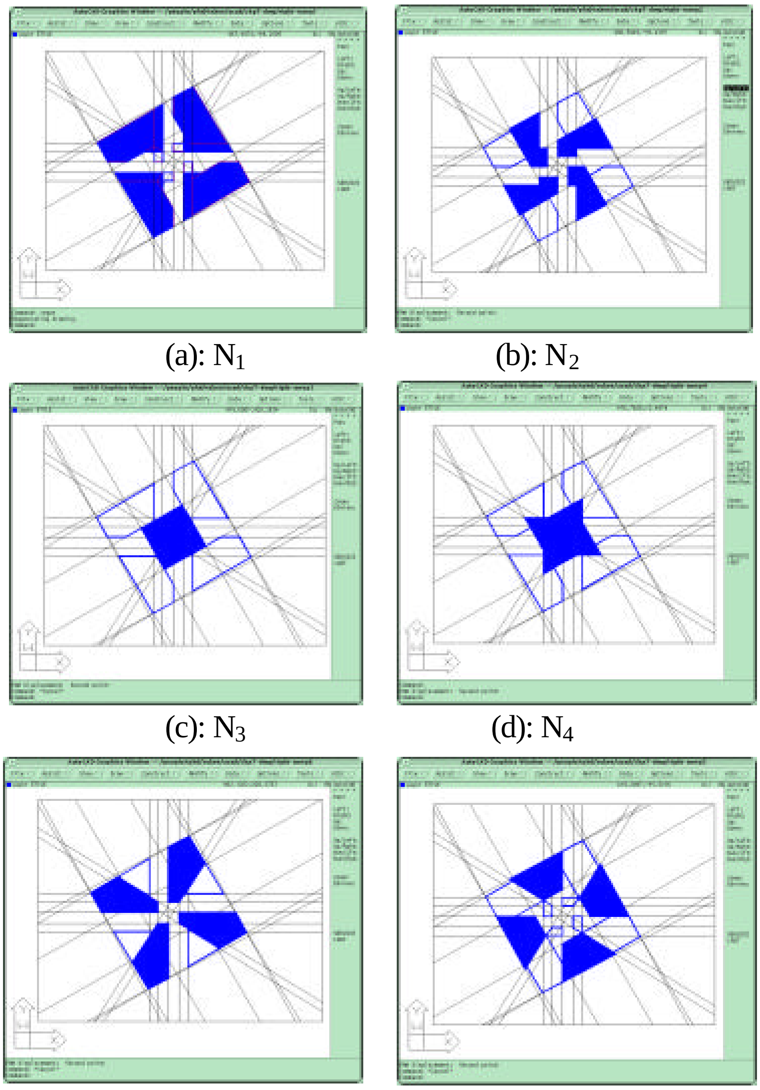


Figure 3. Part I: A framework of exploring various alternative of shape compositions and Part II: A framework of maintaining the integrity of a shape semantic of interest.



(a) (b) (c)

Figure 4. (a) An example of a design composition; (b) an initial representation of the design composition; and (c) an infinite maximal lines of the initial representation produced using the Generator module.



(a): N_1 (b): N_2

(c): N_3 (d): N_4

(e): N_5 (f): N_6

Figure 5. Various alternatives of shape compositions produced while exploring the design space of the initial design composition using the Generator module, from (a) to (f) show the developed representations N_1 to N_6 from the original shape in Figure 2(a).