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MULTIPLE REPRESENTATIONS FOR SITUATED AGENT-BASED LEARNING

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Abstract. Designers interact with the world not as actors following preconceived plans but related to the situations encountered. Learning the situatedness of design knowledge is as important as learning design knowledge. Knowledge can be represented in many ways. Multiple representations combine the advantages of different representational forms within one system. Situated agent-based learning discovers and acquires useful knowledge and recognises the situation from multiple representations of the knowledge. A model of this situated agent-based learning is described and the use of multiple representations in learning knowledge is presented.

1. Introduction

What computer-aided drafting tools, computer-aided analysis tools and passive computer-based design aids have in common is that each tool is unchanged by its use. While, there are clear and obvious benefits in having the tools unchanged by their use there are also significant disadvantages in this. Each design that a designer works on adds to the experience of the designer, in this sense the designer learns from each design. When he next tackles a similar design it would be useful if the tools he uses had knowledge which included some form of experience. The effect of this would be tools which are increasingly useful to the designer. In order for this to occur the tools would have to learn which are the beneficial aspects of the designs being produced (Gero, 1996).

An agent receives percepts from the environment through its sensors and performs actions using its effectors. Each agent is implemented by a function that maps percepts to actions. Intelligent agents are systems that can decide what to do and do it by taking the best possible action in a situation (Russell and Norvig, 1995). These features direct the agent to be an active agent in the situation: it would be a situated agent.

This paper introduces a situated agent-based learning approach that discovers and acquires useful knowledge and recognises the situation through multiple representations of design knowledge. The situation is not predefined to the agent but has to be recognised by it each time depending on the characteristics (features) of learned knowledge. The role of multiple representations in learning is viewed from a situated perspective.

The remainder of this paper introduces the notion of situatedness in learning design knowledge, describes situatedness and situated actions and learning, and presents the role of multiple representations in learning with an example.

2. Learning situatedness in design

One way to look at design is that design involves taking the best possible action in a situation. Evans (Evans et al, 1982) view designers as change agents. Designers may be seen as behaving within the world not as actors following preconceived plans but according to the situation encountered (Suchman, 1987). They interact with their environment to bring their prior experience to the particular situation. Their actions rely upon the context, type of design domain, and upon the changes in the given context, and coherent differences in the conditions of the design domain. If design is to be based on this perspective it must be viewed as situated. Situatedness states that agents are involved in a continuous interaction with a changing environment, make sense of this environment, and take actions related to it. Actions are based on previous interactions and on the current situation (Hofman et al, 1993).

Learning in one sense is the ability to acquire new information during the exploration of alternative actions. It enables the learning agents to improve their own performance at given tasks over time without reprogramming (Fisher et al, 1991; Forsyth and Rada, 1986). Learning in design takes place within a given situation where the learned knowledge is useful and applicable. This implies that learning design knowledge is associated with learning the situatedness of this knowledge as well as the knowledge itself. It would be beneficial to have agents that learn useful design knowledge in conjunction with the situatedness of this knowledge. These agent will change after use and perform better with similar situations. They will be able to recognise when it is appropriate for them to apply their learned knowledge because they will also know the situatedness of that knowledge.

3. Situations

The term *situation* is defined by Sowa (Dick, 1994) as a state of affairs that occurs at a single place and time. The concept of situation is important for the understanding of context. Situation is used to represent a family of states or specialisation of a state. In the former case there are several states to a situation; in the latter case several situations correspond to the same state (Sandewall, 1994). Situation can also be represented by a set of facts at any given instant of time. A situation is not an objective entity but is conceptualised by an agent. This conceptualisation comprises the agent, the actions it is currently performing as well as its interactions (Hofman et al, 1993).

A central tenet of situated action is that the structuring of activity is not something that precedes the situation but only grows directly out of the immediacy of the situation. In situated actions every activity is by definition uniquely constituted by the confluence of the particular factors that come together to form the situation (Nardi, 1996). Situated learning was first described as an emerging model of instruction and its use as an approach to the design of learning environments has significant implications for the instructional design of learning agents.

4. Model of Situated Agent-Based Learning

Our approach is to utilise and integrate the notion of situated learning with the notions of unsupervised and incremental learning using the agent approach to bring about learning agents that learn about and within the situation. In other words, a learning agent that learns in a situated action manner and not in a plan-based manner.

The model we propose in this paper is constituted by the environment and the agent. The environment represents the external situation and the agent builds its view about the environment through its sensors. The agent has containers for information, called pools, and functions that process information and transfer it among pools. The external situation (EXT) contains a representation of the domain in front of the agent. The pools contain representations of the agent's model. The sensors detect the environment, perceive its representation and place their output in the perceived information (PERC) pool. The perception function (P) processes the information in the EXT and expands this information by inferences using its knowledge. The information in the EXT is converted into a structured representation and accommodated in different perceptual categories. The PERC pool contains information about the objects, relations and assemblies of objects. The cognition function (C) provides a means of additional cognitive inferences based on the information in the PERC and discovers the situatedness parameters and places its output in the situation pool (SIT). The handling function (H), given the situatedness of the acquired information, prepares actions and places them in the actions pool (ACT). The action function (A) executes the actions prepared by the H function. Its results draw the interaction between the agent and the environment. The learning in this model takes place at PERC, SIT and ACT pools where the agent learns from the perceived features and the situatedness of these features which leads to new learned features (features in conjunctive with their situatedness) and from the actions taken while acting with similar situations. This model is illustrated in Figure 1.

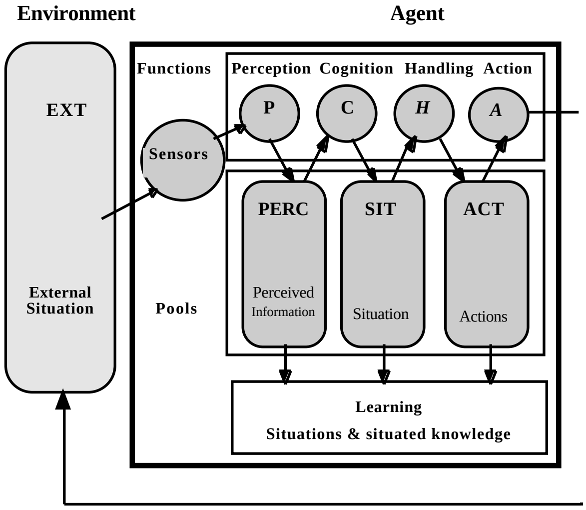

Figure 1. A model of situated agent-based learning.

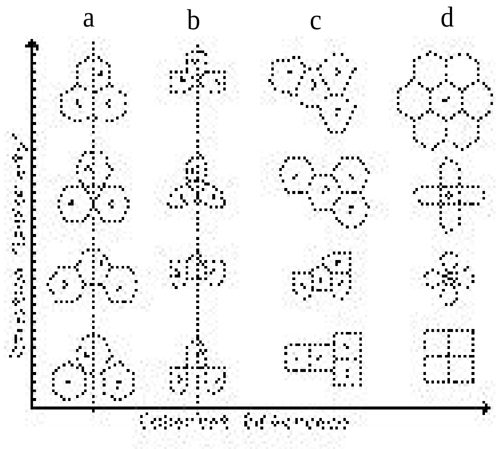

Figure 2. Representing situatedness from multiple representations of spatial knowledge.

5. Multiple Representations

Representations may include objects, relationships, which establish meaningful links from one object to another, and process, which govern the creation, destruction, transformation and other behaviour of objects. In design the representation used can strongly influence the result obtained. There is no one representation that allows detailed consideration of such diverse concerns. The only means possible to represent such diversity is the use of multiple representations. So it is often convenient and sometimes necessary to use many different representations to combine the advantages of different representational forms within one system. Equally significantly in support of multiple representations, since some specific representations favour specific outcomes and it is not known in advance which outcomes may be required it is not known a priori which representation to use.

5.1. REPRESENTING SITUATEDNESS USING MULTIPLE REPRESENTATIONS

In this research we postulate that the two items which make the world for the agent are: knowledge and its situatedness. The situatedness is the structured parts that the agent discriminates or possibly individuates. The agent classifies the world, either by cognitive individuation or by behavioural discrimination. The situation would be represented by the uniformity or by the common features of the represented knowledge in one or more of the multiple representations forms. The distinctive knowledge or the coherent differences of the situation represent the situated knowledge to be learned by the agent. Figure 2 illustrates this concept of representing the situation. The uniformity through the multiple representations of spatial knowledge distinguishes the situation which is the symmetry shown in Figure 2 labelled a and b. In Figure 2 the situation of adjacency is labelled c and cyclic rotation of objects is labelled d. The coherent differences represent the situated knowledge to be learned at each given situation.

5.2. THE ROLE OF MULTIPLE REPRESENTATIONS IN LEARNING

Having different kind of representations provides different views where each type of representation captures certain aspects and neglects others. The interesting and intriguing point of using the multiple representations is that we never know in advance what information we will get out of a representation because of the infinite richness of the world and the relationships between the representations and their meanings.

From such multiple knowledge representations, such as spatial knowledge which could be used to represent shape and space in several ways, a diverse range of relations and interpretations about the shape will be able to be represented. The agent discovers and acquires from the uniformity of these representations the useful features that distinguish the situation. From this uniformity the agent would be able to learn about the situation and to learn within the situation from the coherent differences of the context within that given situation. The agent benefits from the divergences among the multiple representations which provide an important view for the situated knowledge. Implicit features of the structural description can be made explicit through these multiple representations.

5.3. MULTIPLE REPRESENTATIONS FOR LEARNING SITUATED KNOWLEDGE

A representation may be conceived as a set of feature detectors which can be used to locate the features which the can be represented. Using the feature detectors as an agent's sensors to detect the environment provides a perceptual level about the shape. The agent traces the object schemata for the represented shape. From these schemata the agent discover the uniformity which represents the situation and the coherent difference represents the situated knowledge to be learned by the agent. These new learned features will be a added to the agent's sensors as new features detectors. The situatedness for the learned features is useful when the agent faces similar situations. The effect of this process is an agent that learns. Figure 3 illustrates the process for learning situated knowledge. An example of multiple representations of shape is illustrated in Figure 4. Figure 4(a) represents the floor plan of an office building designed by Mies Van Der Rohe and Philip Johnson (Manasseh and Cunliffe, 1962). Figure 4(b) illustrates some of the possible representations of the shape of that building. Representations 1 to 12 include those using features based on nodes and orientations, relative line units and orientation, angles and lengths, figure and ground, transformations, subshapes among boundary lines, decomposition, reflection, reflection and stretch, arrays of rectangle units, arrays of square units, stretched units, and addition and subtraction respectively. Many other representations are possible using other feature detectors.

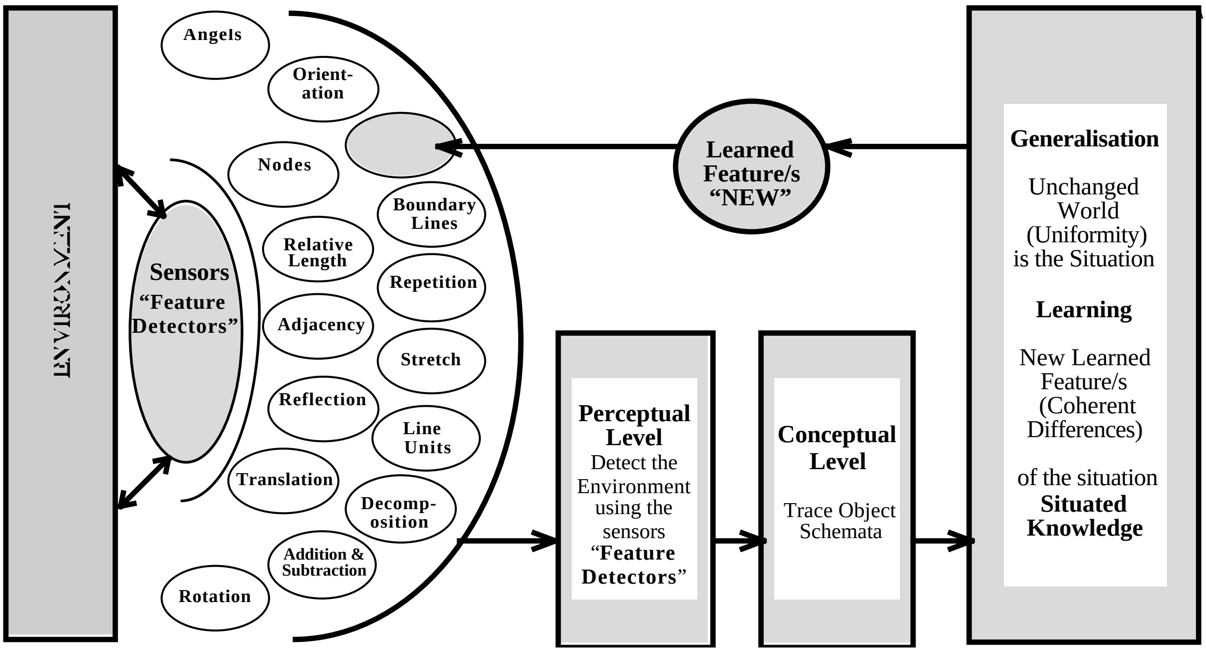

Figure 3. Learning situated knowledge from multiple representations.

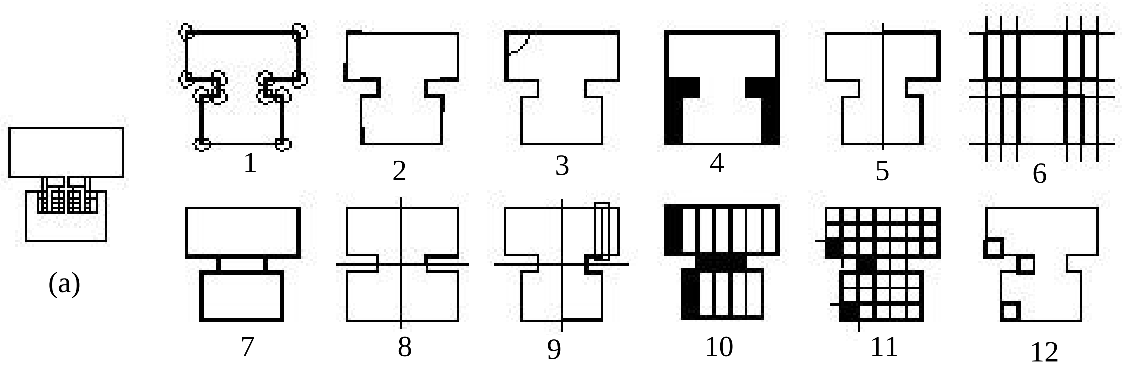

Figure 4. Multiple representations of shape:(a) floor plan; (b) multiple representations.

6. Discussion

The importance of learning the situatedness of the design knowledge, development of a situated agent based model and the role of multiple representations in learning situated knowledge has been described. An example of multiple representations of shape has been shown. For agents to learn over time in order to improve their performance they need to be able to recognise the difference between the situation (which is largely static knowledge) and the active knowledge which needs to be learned related to that situation. For this to occur multiple representations based on multiple feature detectors appears to provide a useful starting point.

Acknowledgments

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References

Dick, J. (1994). Using contexts to represent text, in Tepfenhart, W., Dick, J. and Sowa, J. (eds), *Conceptual Structures: Current Practices*, Springer-Verlag, Berlin, pp. 196-213.

Evans, B., Powell, J. and Talbot, R. (1982). *Changing Design*, John Wiley & Sons, Chichester.

Fisher, D. Pazzani, M. and Langley, P. (eds) (1991). *Concept Formation: Knowledge and Experience in Unsupervised Learning*, Morgan Kaufman, San Mateo.

Forsyth, R. and Rada, R. (1986). *Machine Learning Applications in Expert Systems and Information Retrieval*, Ellis Horwood, Chichester.

Gero, J. S. (1996). Design tools that learn: a possible CAD future, *in* Kumar, B. (ed.), *Information Processing in Civil and Structural Design*, Civil Comp Press, Edinburgh, pp. 17-22.

Hofman, H, Pfeiefer, R. and Vinkhuyzen, E. (1993), *Situated Software Design*, AI Lab Report, University of Zurich, Winterthurestr.

Manasseh, L. and Cunliffe, R. (1962). *Office Buildings*, B. T. Batsford, London.

Nardi, B. A. (1996). Studying context: a comparison of activity theory, situated action models, and distributed cognition, *in* Nardi, B. (ed.), *Context and Consciousness, Activity Theory and Human-Computer Interaction*, MIT Press, Cambridge, pp. 69-102.

Russell, S. and Norvig, P. (1995). *Artificial Intelligence a Modern Approach*, Prentice Hall, Upper Saddle River.

Sandewall, E. (1994). *Features and Fluents: The Representation of Knowledge About Dynamical Systems*, Clarendon Press, Oxford.

Suchman, L. (1987). *Plans and Situated Actions*, Cambridge University Press, Cambridge.

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