

## SITUATEDNESS: A NEW DIMENSION FOR LEARNING SYSTEMS IN DESIGN

RABEE M. REFFAT AND JOHN S. GERO  
*Key Centre of Design Computing and Cognition*  
*The University of Sydney*  
Email {rabee, [john@arch.usyd.edu.au](mailto:john@arch.usyd.edu.au)}

**Abstract:** In this paper we adopt the approach that designing is a series of situated acts, ie designing cannot be pre-planned to completion. This is based on ideas from situated cognition theory that claims that what people perceive, how they conceive and what they do develop together and are adapted to the environment. For a system to be useful for human designers it must have the ability to associate what is learned to its environment. In order for a system to do that such a system must be able to acquire knowledge of the environment that a design constructs. Therefore, acknowledging the notion of situatedness is of importance to provide a system with such capability and add on a new dimension to existing learning systems in design. We will call such a learning system within the design domain a Situated Learning Design System (SLDS). A SLDS should be able to create its own situational categories from its perceptual experiences and modify them if encountered again to link the learned knowledge to its corresponding situation. We have chosen architectural shapes as the vehicle to demonstrate our ideas and used multiple representations to build a platform for a SLDS to learn from. In this paper the notion of situatedness and its role in both designing and learning is discussed. The overall architecture of a SLDS is introduced and how the potential outcome of such a system will support human designers while designing is discussed.

Key words: Designing, Situated Knowledge, Multiple Representations, Situated Learning

### 1. Introduction

The first generation of design theories and methods in the early 1960s was heavily influenced by the theories of technical systems. Designing is perceived in these theories as a rational problem solving process and has been the dominant influence shaping prescriptive and descriptive design methodology ever since. Describing designing as a rational problem solving may be appropriate when the designing process is routine. The rational paradigm focuses on the process components of design decisions and does not provide a complete basis for the study of design problems and their structures (Dorst and Dijkhuis, 1996). A fundamentally different paradigm has been proposed (Schön, 1983) describing designing as a process of “reflection in action”. Design knowledge is seen in the former as knowledge of design procedures and scientific laws, however in the latter it is seen as the experience of the designer: when to apply which procedures or piece of knowledge. The essence of Schön’s approach is that designers are active in structuring the problem, and they do not evaluate concepts, but they evaluate their own actions in structuring and solving the problem. Designers work by framing (representing) a problem in a certain way, making moves towards a solution and evaluating those moves. The reflection in action paradigm is focused on the process links in design decisions and the perception of the design problem. This paradigm works well in the conceptual stage of the design process, when the designer does not follow a predefined strategy.

In designing there are things to know, ways of knowing them and finding out about them. The designerly way of knowing has been identified in the attempt to understand how designers work. It is suggested (Baker, 1993) that designers share a solution focused strategy, which allows them to learn about a particular problem by generating a set of possible solutions to it. This is different from the more scientific definition of a solution as the result of a process of optimisation or formal analysis. Each possible solution is a different perspective (representation) of how the designers are looking at the problem.

We view designing as a situated activity (Reffat and Gero, 1998) in which designers interact with their design environment and bring their prior experience to the particular situation. The way in which designers interact with objects in the design environment and find out about these objects is based on what is available in front them at that moment of time in the environment. Their interactions with the design environment cannot be completely planned a priori, simply because designers do not know in advance what will be available in the design environment in order to pre-plan their actions. Designers' actions take place in situations. The effect of this, is that designing is an activity that does not exist except in relation to situations and design knowledge cannot be fully understood or explained in isolation from its situation. The situated view of design knowledge will be elaborated further in this paper.

In this paper, based on the notion of situatedness of design knowledge, we introduce a situated learning system that will be able to associate design knowledge that is learned to the environment in which it is learned, making it situated knowledge. Section 2 elaborates the notion of situatedness in designing and learning. Section 3 explains situatedness in the context of learning about architectural shape semantics. Section 4 introduces the overall architecture of the Situated Learning Design System (SLDS) and shows how SLDS is interactive, capable of learning and goal directed to link the learned knowledge to its corresponding situation. **The application of SLDS in the domain of architectural shape semantics is presented in Section 5.** Section 6 discusses how the potential outcome of SLDS can support human designers while designing.

## 2. Situatedness in designing and learning

We take the view that designing is a dynamic process in which one of its major concerns is to change the world within which it operates. In designing, the goal state is often hard or impossible to completely define. Often, it is the result of the design process that identifies candidate goal states. The implications of various design actions are not always predictable. For instance, if a new object is added to a design, it is not possible to fully predict that object's impact on the design. This new object might combine with other objects, or might not interact with other objects at all (Brown and Birmingham, 1997). This clearly indicates that it is not possible for designers to know beforehand what particular set of states they would be at and in consequence what kinds of actions they might take and similarly what kind of results they might achieve. This is simply because they travel among different surroundings in the environment in relation to the goal state in which these relations might change and their effect might lead to different situations.

Thus, it is claimed that designing is a process experienced within the situation which designers encounter. Most recently, tools from cognitive science have started to provide some insight in human activities where cognition and knowledge are emergent properties of the interaction of an individual with its environment, ie. its current situation (Clancey, 1997). Accounting for the situation entails that learning methodology cannot be limited to the task at hand but has to take the whole environment in which the task has to be performed into account. Situatedness implies that where you are when you do what you do matters.

Situatedness has antecedents in the work of Heidegger (1962) and Bartlett (1932). Bartlett gave a very broad definition of what constitutes a situation. He claimed that a situation cannot be adequately described merely as a series of reactions, or merely as an arrangement of sensations, images, ideas or train of reasoning. A situation always involves the arrangement of cognitive materials by some more or less specific active tendency, or groups of tendencies. To define a situation in any given case we have to refer not only to the arrangement of material, but also to the particular activities in operation. On the same line Heidegger (Heidegger, 1962; Stahli, 1993) defines the situation as the person's sensitive context including the physical surroundings, the available tools, and the circumstances surrounding the task at hand within the person's aim. A richer conception about situatedness has been recently proposed by Loren et al (Loren et al., 1998): to say that something is situated is to say it is interactive, capable of learning, goal directed and that a dialectical relation obtains among the first three criteria in which the first three are not a logical sum, but rather they work together. Hence, something that is situated is interactive with respect to its learning and goal directness. It learns about its own interactions and its goal directed behaviour. It is goal directed in its interaction and learning.

## 2.1 SITUATED VERSUS PROCEDURAL AND DECLARATIVE KNOWLEDGE

Declarative knowledge describes how things are. This is accomplished through objects (office, building, and entrance), their attributes (functional, open and attractive) and the relations between them (functional building, open entrance and attractive office). Procedural knowledge describes and predicts actions or plan of actions. All knowledge of "how-to" (How to make stairs? How to construct a building?) are examples of procedural knowledge. Before the declarative knowledge can be of use, an understanding of how the goal state is linked to the initial problem state must be present and a set of transformations to accomplish this must be developed, ie procedural knowledge.

Situated knowledge is captured and associated with the specific situation. Situated knowledge about an object would be understood as a relation between this object and a social or physical situation rather than simply a property of the object. A relativised concept of situated knowledge would be analogous to the concept of motion in physics. The velocity and acceleration of an object in motion are not properties of the object itself, but are properties of a relation between the object and a frame of reference (Greeno, 1989). Situated knowledge could be seen by this view as a reflection of a situated activity.

The role of situation, in situated knowledge, is to provide the applicability conditions of what has been learned. So, the situation is different from preconditions, which define the necessary conditions that must be met before any learned knowledge can be applied.

## 2.2 LEARNING AND SITUATEDNESS

Learning implies the acquisition or restructuring of knowledge rather than the simple acquisition of facts. Some of computer-based design systems developed in recent years incorporate some machine learning. The rationalist perspective assumes that the world can be described objectively, ie dealing with independently existing facts or conditions and from these objective descriptions optimal (rational) solutions to problems can be deduced. The methodological implications of the rationalist perspective have been concisely summarised as a sequence of three steps (Winograd and Flores, 1987):

1. characterise the state in terms of identifiable object with well-defined properties;
2. find general rules that apply to state/s in terms of objects and properties; and
3. apply the rules logically to the state of concern, drawing conclusions about what should be done.

The assumption that the real world can be objectively described suggests that the interpretation of knowledge is context independent and observer independent. The rationalist perspective views cognition as data processing and behaviour as being predetermined by plans. As a consequence of the rationalist perspective on the learning paradigms generally and in design specifically is that learning is context independent and what is been learned is applicable in a universal environment.

Recently, it has been argued that cognition cannot be reduced to internal data processing – it cannot be de-contextualised, ie made situation-independent, into a set of abstract descriptions (Suchman, 1987; Brown et al, 1989 and Lave and Wenger 1990).

Situated learning is a general theory of knowledge acquisition that has been applied in the context of technology-based learning activities for schools that focus on problem-solving skills. Situated learning can be traced back to the work of Vygotsky (1962), social learning, and Gibson (1977), theory of affordances. Other researchers have further developed the theory of situated learning. Suchman (1987) explores the situated learning framework in the context of artificial intelligence. Brown et al (1989) emphasise the idea of cognitive apprenticeship. Lave and Wenger (1990) argue that learning as it normally occurs is a function of the activity, context and culture in which it occurs, ie. it is situated.

### **3. Situatedness in the context of learning about architectural shape semantics**

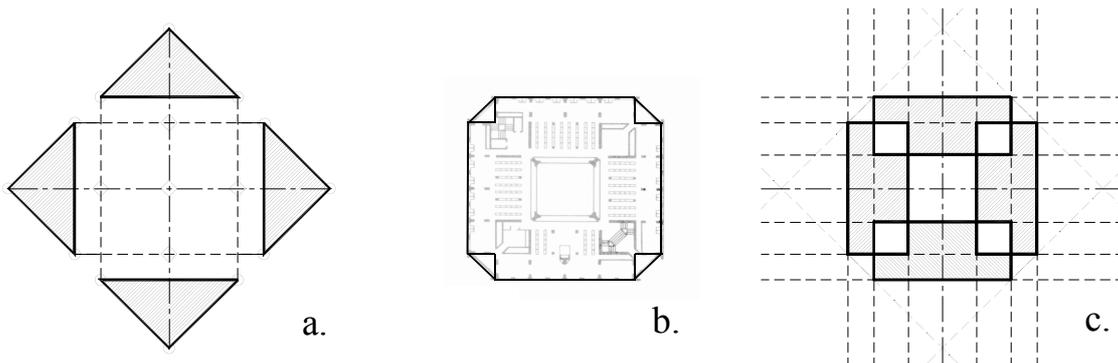
In designing, drawings are the most common way to represent real and imagined objects. Drawing and sketching play an important role in design reasoning. Drawings provide a mechanism for externalising the designer's ideas and subsequently for analysis and reconsideration of these ideas. In this work a drawing or part of it represents the design space. Within this design space various design qualities can be recognised or found. Since our interest here is in shapes, the design qualities within the design space are reflected as shape semantics. Shape semantics are visual patterns of relations among parts of the represented shape.

Shape semantics appear in many architectural works. Some examples of shape semantics are reflective symmetry, repetition, adjacency, cyclic rotation and simple rotation. For instance, reflective symmetry has preconditions without which it will not be found in a design space. At the same time, reflective symmetry has an environment in which it operates and functions. It has some relationships that determine its applicability within the environment. The applicability conditions of reflective symmetry are the situated knowledge to be learned through the interrelationship between the reflective symmetry and its environment. This what is called situated knowledge. Figure 1 is used to illustrate visually the difference between the preconditions and situatedness for the reflective symmetry of the shaded objects in Figure 1(a). Reflective symmetry is found when all of its preconditions are met but this tells nothing about in which situation reflective symmetry functions and operates. The preconditions of reflective symmetry between two shapes are that they are congruent and that certain geometric conditions are met by the midpoints of the lines joining corresponding vertices. Figure 1(b) is a graphical representation of a public library (Clark and Pause, 1996). Figure 1(c) is a representation of this representation of the public library. This representation is one of a number of possible views of how the design might be looked at by designers. Within this representation all the preconditions of reflective symmetry are met; as a consequence reflective symmetry is found. Reflective symmetry in this representation operates within other shape semantics such as repetition, adjacency and cyclic rotation. So, what is learned here is where and within which situation does the reflective symmetry operate; ie the situatedness of this knowledge. In this context we consider each shape semantic as the “focus” and the regularities around this focus in the

environment become the “situation”. The system we are developing learns from multiple representations of the design description.

Within the domain of shapes all the preconditions of shape semantics must be met before learning about them. Thus, situatedness is concerned with locating shape semantics within its environment or “active context” so that the decisions that are taken are a function of the situation and the way the situation is constructed or interpreted.

Figure 1. The preconditions and situatedness of reflective symmetry.



## 4. An overall architecture of the Situated Learning Design System (SLDS)

The situative perspective of knowledge focuses on the way knowledge is distributed in the world among individuals. This view suggests that a fundamental change in the way a learning system interacts with the environment. The change is in the way to relate and link knowledge to its environment where it operates in which neither the goal state nor the design space is fixed. Based on the situated view of knowledge exemplified within the domain architectural shapes we are developing a Situated Learning Design System (SLDS) that will be interactive, goal directed in its interaction and learning.

One interesting hypothesis based on conjectures about human cognitive behaviour is that what is learned is not learned at the time when the state description, which forms the experience on which the learning is based, exists but rather later when there is a need for the knowledge. This hypothesis allows the current situation to disambiguate what makes the earlier situation and what makes the knowledge to be learned. Such a hypothesis may be difficult to implement directly here, but it can be partially simulated using the concepts associated with situatedness (Gero, 1998). All regularities in a state description of a particular state of designing are candidates for both knowledge and situation. Thus, each regularity could be knowledge and all the remaining regularities become candidates for that knowledge's situation either singly or conjunctively. We have explored this approach by using multiple representations of the design description (Gero and Reffat, in preparation). Multiple representations allow for dynamic representation of the design world we see around ourselves. Each representation provides the opportunity for alternate interpretations of what can be seen. Therefore, each representation provides the opportunity to construct the situation for any piece of learned knowledge. The regularities among various representations help to draw conclusions about situations in which the learned situations might be reinforced or decayed. Since it is not known at the time of learning which is useful design knowledge to learn about, therefore all regularities are treated as potentially useful knowledge. In the SLDS system we restrict such learning of knowledge to regularities between structure and behaviour only in the design.

SLDS consists of four modules: Generator, Recogniser, Situator and Situation Analyser. The Generator module as shown in Figure 2 handles the generation of multiple representations. The Recogniser finds shape semantics from the state description at different design states (representations). The regularity surrounding certain shape semantics at different states is the trigger for the Situator module to learn when that regularity occurs. The Situation Analyser is triggered to learn when the relationship learned by the Situator for a certain shape semantic in “focus” occurs at different representations across different examples. The result of SLDS is a set of situational categories in relation to a set of shape semantics “focuses”.

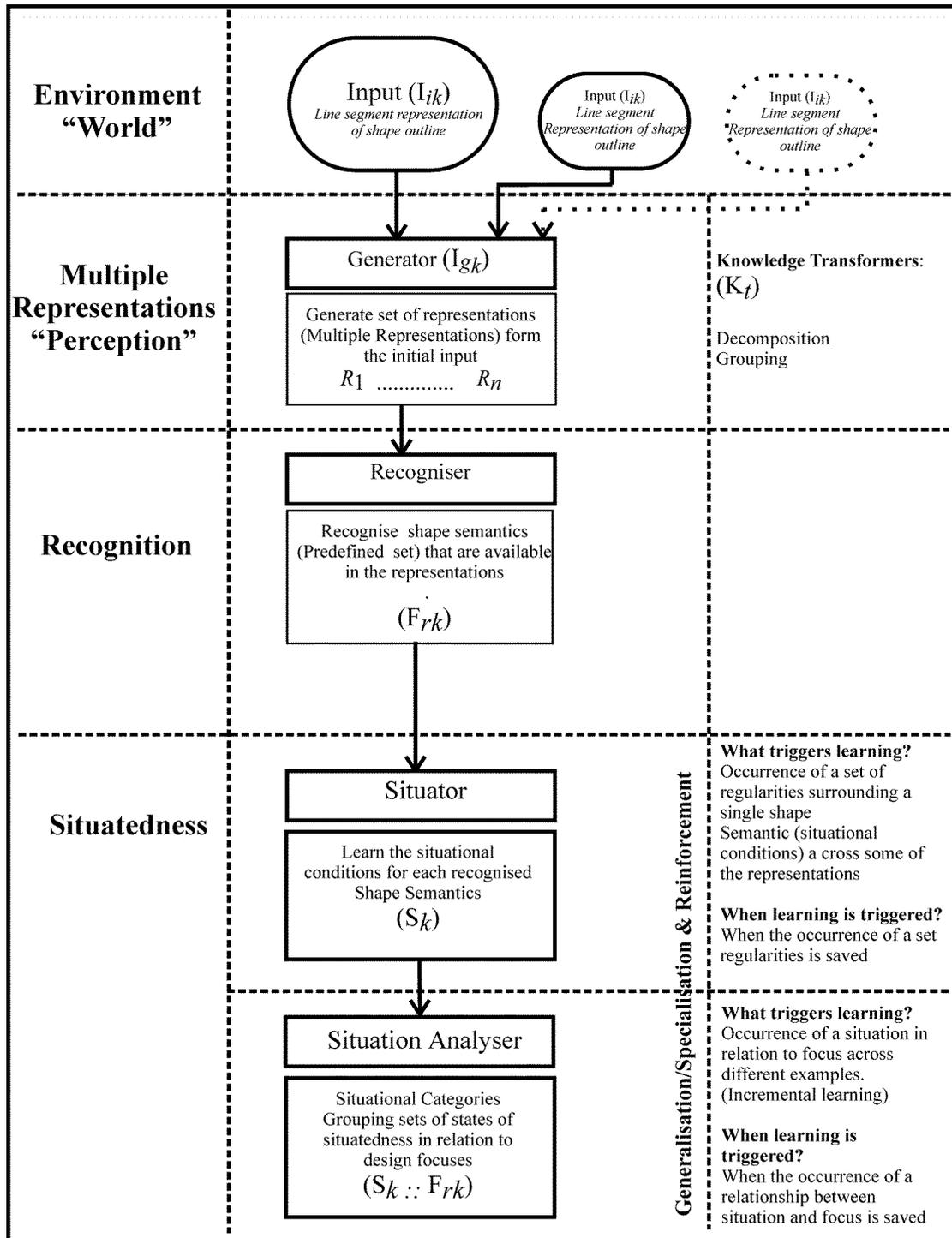
## 5. A SLDS in the domain of architectural shapes

Shape semantics have specific situations in which they function and operate in the environment. In order to learn about the situatedness of these shape semantics we are developing the SLDS to function in that domain. However, the notion of situatedness and its role in learning and design is applicable in other domains. The purpose of this SLDS is to learn the applicability conditions, the situatedness, of shape semantics. The primary input to the SLDS system is an initial representation of the design description. The system commences by generating multiple representations from the design description. The generation process is carried out by the Generator module through the interaction between the designer and the system. Frame and objects of interest in the initial representation are selected and that leads the system to generate different representations. Each representation is an interpretation and in consequence different shape semantics appear in different representations. The Recogniser module detects these representations and recognises shape semantics that are available in the representations. These representations constitute the environment for the recognised shape semantics. The SLDS interacts with that environment and learns based on what is available in the environment within a specific goal. For instance, if the system’s goal is to situate the reflective symmetry then the system looks for the regularity surrounding reflective symmetry in the environment. This regularity is the trigger for the system to learn the situatedness of reflective symmetry. This is carried out through the Situator and Situation Analyser modules. An example of applying the SLDS structure in the domain of shape semantics is presented in Figure 3 where  $S_m$ ,  $P_r$ ,  $A_d$ ,  $R_c$ ,  $S_r$  and  $R_t$  refer to reflective symmetry around multiple axes, repetition, adjacency, cyclic rotation, reflective symmetry and rotation respectively. For instance, if the SLDS’s current knowledge goal is  $S_m$ , it will find a regularity across the representations with other shape semantics that  $S_m$  is associated with, such as  $P_r$ ,  $A_d$  and  $R_c$  in the representations  $r_b$ ,  $r_c$ ,  $r_d$ ,  $r_f$  and  $r_g$  in Figure 3 which together construct the situation of  $S_m$ . So,  $S_m$  is situated within these shape semantics

## 6. Discussion

Situatedness in design learning opens a different perspective of designing and learning that has not been adequately explored. Considering the relationships between a set situational categories and a set of focuses makes a learning system interacting with the environment dependent on what is happening. On the other hand, most current learning systems in design deal with the environment independently from the situational conditions. Assuming that knowledge that has been learned

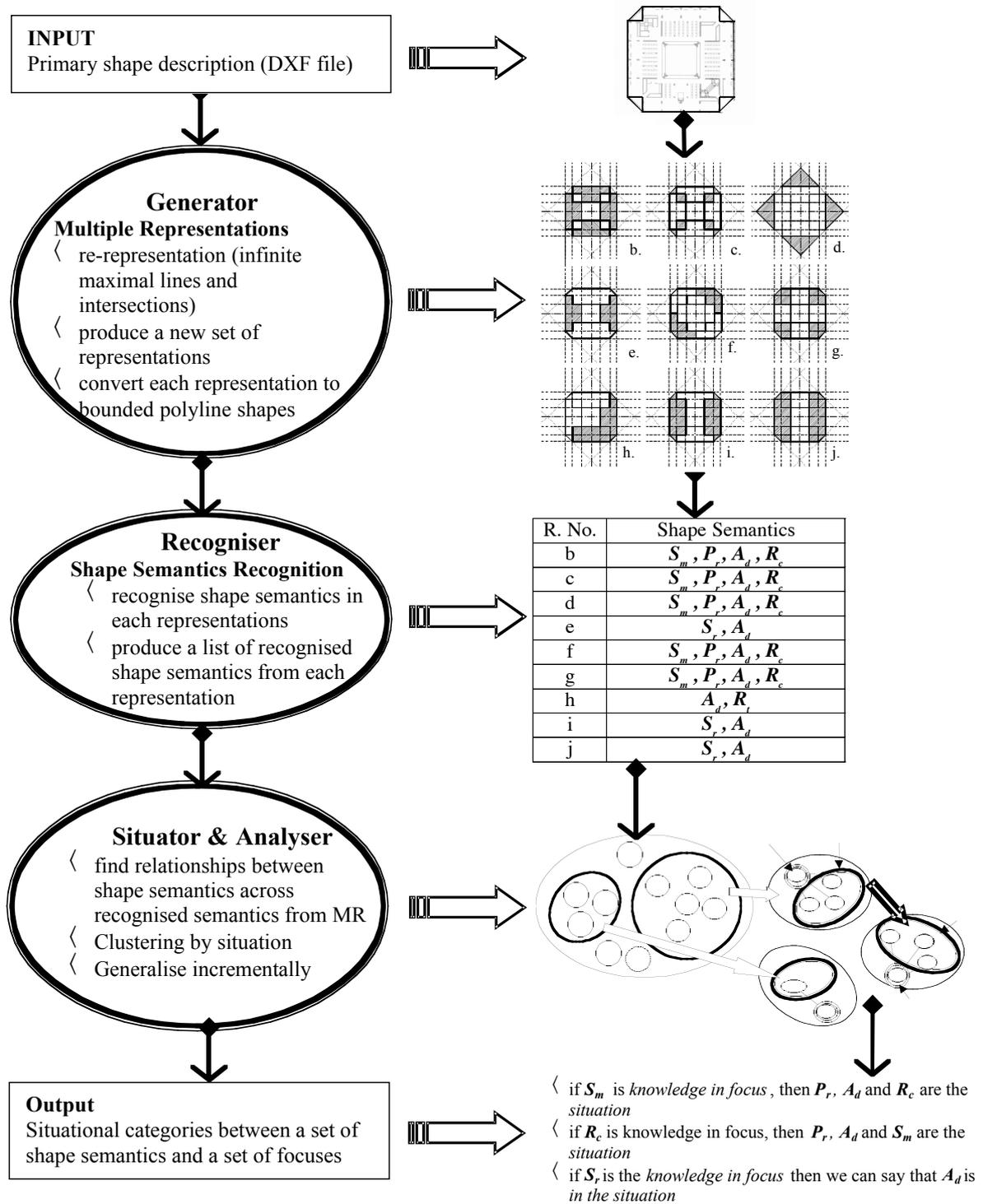
Figure 2. An overall architecture of the SLDS, Situated Learning Design System.



exists in multiple contexts (representations), how does the system distinguish between them? It is by moving through these representations or states of situatedness where this knowledge is elicited that provides the opportunity to situate that knowledge within its environment by learning about its situatedness. The situatedness of knowledge carries with it aspects of the situation within which it was

acquired. The role of situatedness in designing can be seen as a means by which the designer changes the trajectory of the developing design. Different situations provide different opportunities to move in different directions. It is because what is being focussed on with the situation as a background is not given but is a function of the interpretation of the designer based on how the representation is constructed or interpreted. This might explain why designing is not a predictable act but rather a situated activity. As a consequence, design needs to be understood not as an end point but rather as a starting place, or platform, for ongoing processes that are situated within the settings of when designers are designing. Supporting situatedness within a learning system is an initial and important step towards building designing support systems. In this sense the process of situated learning in design is adding another dimension to the current applications of machine learning in design.

Figure 3. An example of the application of SLDS in architectural shape semantics



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## References

- D. Brown and W. Birmingham, Understanding the nature of design, *IEEE Expert* 12: 2 (1997) 14-16
- D. Schön, *The Reflective Practitioner* (Harper Collins, New York, 1983).
- F. Bartlett, *Remembering: A Study in Experimental and Social Psychology* (Cambridge University Press, Cambridge, 1932 reprinted 1967).
- G. Stahl, Supporting situated interpretation, in: *Proc. of the Cognitive Science Society: A Multidisciplinary Conference on Cognition* (Boulder, 1993) 965-970.
- J. Brown, A. Collins and S. Duguid, Situated cognition and the culture of learning, *Educational Researcher*, 18:1 (1989) 32-42.
- J. Gero and R. Reffat, Multiple representations as a platform for situated learning in design, Working Paper, Key Centre of Design Computing and Cognition, University of Sydney, Sydney ( in preparation).
- J. Gero, Situated learning in design, in: A. Duffy, (ed.), *AID'98 Workshop on Machine Learning in Design*, (AID'98, Lisbon, 1998) 1-5.
- J. Gibson, *The theory of affordances*, in: R. Shaw and J. Bransford (eds), *Perceiving, Acting and Knowing*. (Erlbaum, Hillsdale, NJ, 1977).
- J. Greeno, Situations, mental models and generative knowledge, in: D. Klahr and K. Kotovsky (eds), *Complex Information Process: The Impact of Herbert A. Simon* (Lawrence Erlbaum, Hillsdale, New Jersey, 1989).
- J. Lave and E. Wenger, *Situated Learning: Legitimate Peripheral Participation* (Cambridge University Press Cambridge, UK, 1990).
- K. Dorst and J. Dijkhuis, Comparing paradigms for describing design activity, in: N. Cross, H. Christiaans and K. Dorst (eds), *Analysing Design Activity* (John Wiley & Sons, Chichester, 1996) 253-270.
- L. Loren, E. Dietrich, C. Morrison and J. Beskin, What it means to be "situated", Working Paper, Department of Psychology, Binghamton University, Binghamton, NY, 1998.
- L. Suchman, *Plans and Situated Actions: The Problem of Human/Machine Communication* (Cambridge University Press Cambridge, UK, 1987)
- L. Vygotsky, *Thought and Language* (MIT Press, Cambridge, MA, 1962).
- M. Heidegger, *Being and Time* (Blackwell, Oxford, 1962).
- R. Baker, *Designing the Future: The Computer Transformation of Reality* (Thames and Hudson, Hong Kong, 1993).
- R. Clark and M. Pause, *Precedents in Architecture* (Van Nostrand Reinhold, New York, 1996).
- R. Reffat and J. S. Gero, Learning about shape semantics: a situated learning approach, in: T. Sasada, S. Yamaguchi, M. Morozumi, A. Kaga and R. Homma (eds), *Proc. CAADRIA '98* (CAADRIA, Kumamoto, Japan, 1998) 375-384.
- T. Winograd and F. Flores, *Understanding Computers and Cognition* (Addison-Wesley, Reading, Massachusetts, 1987).
- W. Clancey, *Situated Cognition: On Human Knowledge and Computer* (Cambridge University Press, Cambridge, UK, 1997).

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