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SITUATED CASE-BASED REASONING AS A CONSTRUCTIVE MEMORY MODEL FOR DESIGN REASONING

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Abstract. This paper describes an extended case-based reasoning model that addresses the notion of situatedness in designing through constructive memory. The model is illustrated through an application for predicting the corrosion rate for a specific material on a specific building.

1. Introduction

Previous research by Liew and Gero on constructive memory (Liew and Gero 2002a; Liew and Gero 2002b; Liew and Gero 2004) emphasize the mechanisms for memory construction in which fundamental memory construction processes are described and implemented via a neural network. In this paper, constructive memory processes are mapped onto a case-based reasoning model to provide a situated view of using past experiences and knowledge. This results in a model for *situated* case-based reasoning in which memories are constructed through an interpretation of the context of the problem, previous experiences and knowledge. The model for situated case-based reasoning is illustrated with an application in the domain of corrosion prediction of building materials.

2. Situated Case-Based Reasoning

Case-based reasoning (CBR) provides a model for design reasoning based on the use of a set of previous design experiences represented as design cases (Maher et al. 1995). These cases are indexed and retrieved using information about a current design problem, and then through analogical reasoning, a selected case (or set of cases) is adapted until it satisfies the current design specifications and constraints. One aspect of design reasoning that is not addressed by traditional models for case-based reasoning is that designing is situated (Gero 1998). To accommodate the notion of situatedness in designing, the basic idea of case-based reasoning is extended to create a model of *situated case-based reasoning* (situated CBR), Figure 1, based on a model of constructive memory that operates within a framework of situatedness.

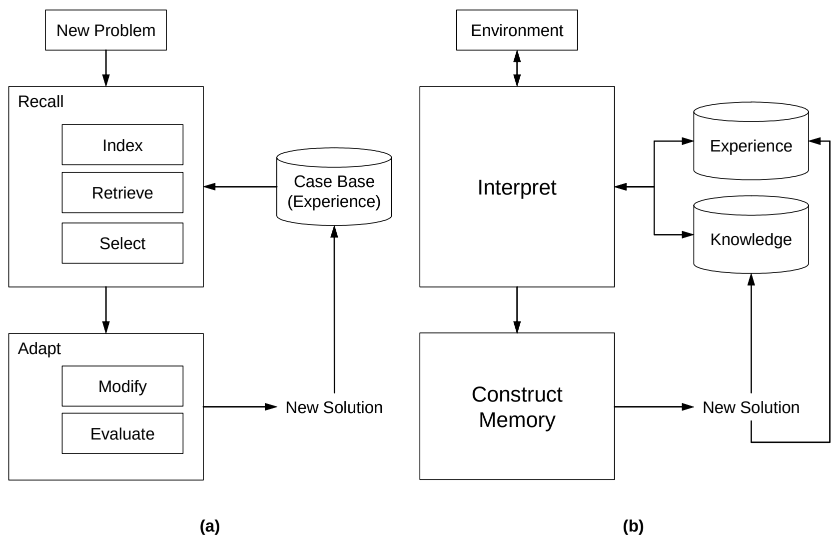

Figure 1. A conventional case-based reasoning model (a) and a situation case-based reasoning model (b)

In the situated CBR model, instead of focusing on just the design problem and finding a solution to it, emphasis is also given to the environment within which the problem is framed. The model *interprets* the environment according to the *current situation* and the problem is framed accordingly. This interpretation is dependent on the current environment, the internal state of the situated CBR system and the interactions between the system and the environment.

The internal state of a situated CBR system is defined by its content. This content is made up of individual *entities* that are classified either as experience or knowledge. Interactions between the system and the environment define different interpretations of the environment according to different interpretations of the selected entities used for memory construction.

A distinctive characteristic of situated CBR is the way its knowledge and experience are understood and used. In CBR, retrieved cases provide a solution or a starting point for case adaptation. In situated CBR, the memory of an experience and/or knowledge (entities) is constructed according to an interpretation of the environment and an interpretation of the selected entities relevant to the problem at hand. Rather than adapt a selected case to new design specifications, the selected entities are interpreted according to the interactions between the system and the environment. These interactions provide a specific view (interpretation) of the relationship between the design specifications and the environment. This view dictates another interpretation of the environment that can introduce new specifications. This "feedback" loop causes the interpretations of the environment and the selection of experiences and knowledge to occur recursively until a common interpretation is reached.

The recursive interpretations of the environment and the selected entities result in new memories as well as new indices to the selected experiences and knowledge to be created. Memories are constructed by:

- instantiating the parameter values of the selected entities according to the current situation;
- mapping existing parameters in the selected entities to new ones through an analogical process; and
- restructuring the selected entities according to the current situation.

This is similar to creation of new functional or behavioural indices to an old design prototype within the domain of situated analogy (Gero and Kulinski 2000).

3. Constructive Memory Model

Figure 2 illustrates a conceptual model of memory construction. Memories are constructed according the environment, the *knowledge* and *experience* of a situated computational system and the interactions and between the system and the environment.

Knowledge can be considered as general facts that can refer to a generalized or compiled construct (Rosenman et al. 1991), such as a design prototype (Gero 1990) that collects function, behaviour and structure information related to designing within a single representation. Other than design prototypes, knowledge can also include: design principles, guidelines, procedural knowledge that dictates the steps to be taken to compute a parameter, formulas that calculate a parametric value or a series of rules that proposes what are to be done when certain conditions are met. Methods to acquire knowledge include:

- abstraction over classes of objects, as in the case of design prototypes;
- generalization over facts as in the case of design guidelines (Boothroyd 1994), rules (Witten and Frank 2000) or formulas; or

- direct learning from external sources such as books, domain experts, etc., as in the case of design principles (Suh 1990), rules (Giarratano and Riley 1989) or procedural knowledge.

The generic nature of knowledge implies that it does not carry with it any particular solution. A particular situation has to be fitted to the knowledge and a solution has to be inferred from it.

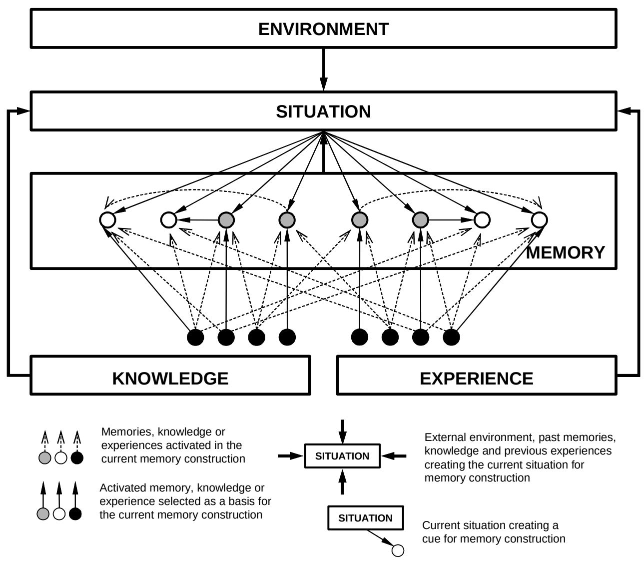

Figure 2. *Conceptual model of memory construction (from (Gero 1999))*

Experience refers to previous episodes recorded in or encountered by the system. It entails the system's involvement as the "first person" in dealing with the substance of that episode. This form of experience can refer to experimental data collected under controlled conditions or to information obtained by data logs.

Memory is a construct created "here and now" for the purpose of operating within the current environment according to a design goal. Knowledge and experience provide the base for constructing a memory according to the current situation.

Memory construction commences with the current situation providing the cue to start off the process. Related knowledge and experience are activated according to this cue and the relevant knowledge and experience are selected as a basis for memory construction. After this selection, the environment and the selected experience are recursively interpreted to construct a memory. This memory contains the required actions to be effected to the environment according to the current design goal. Each memory, after it has been constructed, is added to the system as a new experience by augmenting its representation experience. This new experience is available for subsequent memory constructions.

4. Framework of Situatedness

The model of constructive memory resides within the framework of situatedness in designing (Liew and Gero 2004). This notion of situatedness encompasses the fundamental ideas of *interaction*, *memory construction* and *interpretation*.

Interaction implies that the content of a situated CBR system are not encoded a priori and indexed for use later, but rather the content of the system is developed through interactions with the environment. The development of this content entails the construction of a memory about related entities, influenced by any knowledge and experience gained since the entities, and interpreted by the prevailing situation.

Memory construction provides the basis for the recursive interpretation of the current situation. This process of constructing new memory is similar to the notion of "re-representation" described in (Gero and Kulinski 2000). A constructed memory defines both the interpretation of the relevant content and the interpretation of the environment in light of the current interactions between the system and the environment. The content of the situated CBR system is interpreted through a "filter" defined by the present situation. An experience and/or knowledge is not "copied" into the present but rather it is interpreted according to the current situation. This interpretation situates the relevant content of the system through the current environment so that it is not necessary to encode all possible forms of know-how a priori. New interpretations of past knowledge and experience is produced by every constructed memory of these entities. This new interpretation is added to the memory system as a new experience and is interpreted later as if it were part of the original content of the system.

A constructed memory also interprets the environment according to the current expectation of the system. This expectation is derived from the goal of the system captured within the relevant entities selected for memory construction. The expectation dictates what is to be focused upon, and the way the environment is to be interpreted in order for the system to perform its task according to its goal.

4.1 RECURSIVE INTERPRETATIONS

Figure 3 illustrates the recursive interpretations between the environment and the selected experience and/or knowledge used for memory construction. Both the environment and the selected entities are interpreted through the lens of the current interaction in this recursive fashion. The recursion behaviour is resolved when the interpretations of the environment or selected entities remain the same after a complete cycle of interpretations: interpretation of the environment or selected entities followed by an interpretation of the selected entities or environment. The final constructed memory provides a coherent interpretation of the environment and of relevant knowledge and experience within a single cohesive structure.

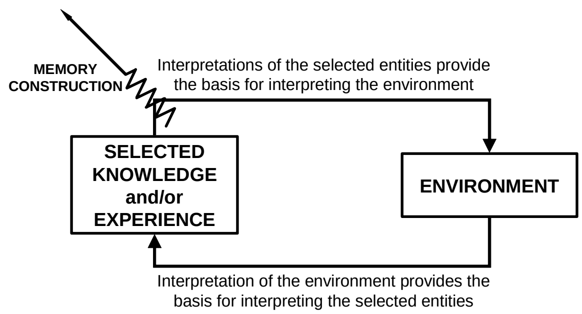

Figure 3. Recursive interpretations of a selected memory, experience or knowledge and the environment

After the successful interpretation of the environment and selected entity, the actions that were performed previously are transformed into a suitable form for the current situation and effected into the environment, as external actions, or to the system, as internal actions, to perform the necessary task according to the current goal of the system.

5. Situated CBR for Predicting Corrosion Rates

The situated CBR model is illustrated by the design of a situated case-based reasoning system that predicts the atmospheric corrosion of building materials, as shown in Figure 4. Predicting corrosion rates is a complex process which includes reasoning about examples in which corrosion rates are known, knowledge of the material properties and the impact of the environment on those materials, and an interpretation of the site in which the material is located. A standard CBR approach does not apply well due to the lack of complete models or extensive cases.

The local conditions of the site in which the material is located are used to determine the environmental component of the situated CBR system. Parameters within this environment are used to select previous experiences and/or knowledge from the system for memory construction. A memory is constructed based on a combination and interpretation of previous experiences that can be used to predict the atmospheric corrosion rate of a specific material on a specific site.

A selected experience may be relevant if a corrosion rate has already been calculated in a similar situation. The differences in conditions are examined to see if they are significant to warrant additional interpretation and computation. If a selected previous experience is based on experimental data, additional knowledge may be needed to interpret the implications of the differences between the experimental situation and the current situation or site conditions. A corrosivity map of the region in which the corrosion rate is to be predicted may exist through data collected from the actual site. If the current situation matched those presented during the collection, the corrosion rate can be read off from such a map.

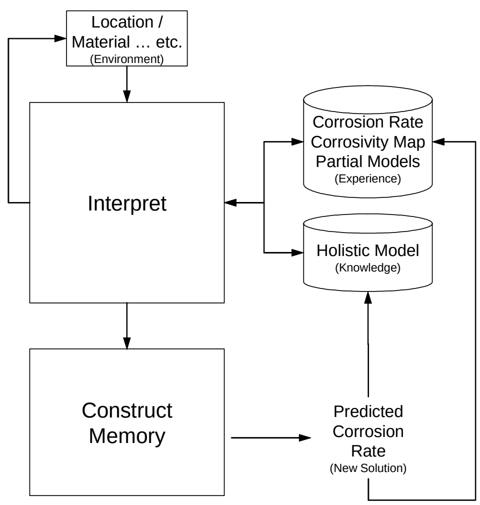

Figure 4. Model of situated CBR applied to the prediction of atmospheric corrosion rate

If a relevant experience is not close enough to the current site conditions, the relevant knowledge may be used in the form of a holistic model that computes a corrosion rate through first principles. When used as a basis for memory construction, the corrosion rate is computed through a series of process models (partial models) or database look ups of collected field data, as shown in Figure 5. Each parameter required for calculation can either be calculated through a process model or selected from a database of collected data, as shown in Figure 6.

During the course of memory construction, the environmental conditions are reevaluated according to the relevant experience used for memory construction. The relevant experience can shift the focus to different aspects of the environment according to the critical features of the selected experience and thus introducing new specifications. New indices to the selected experience are created when the experience is found to be applicable in similar situations and when the experience is restructured according to the interactions with the environment.

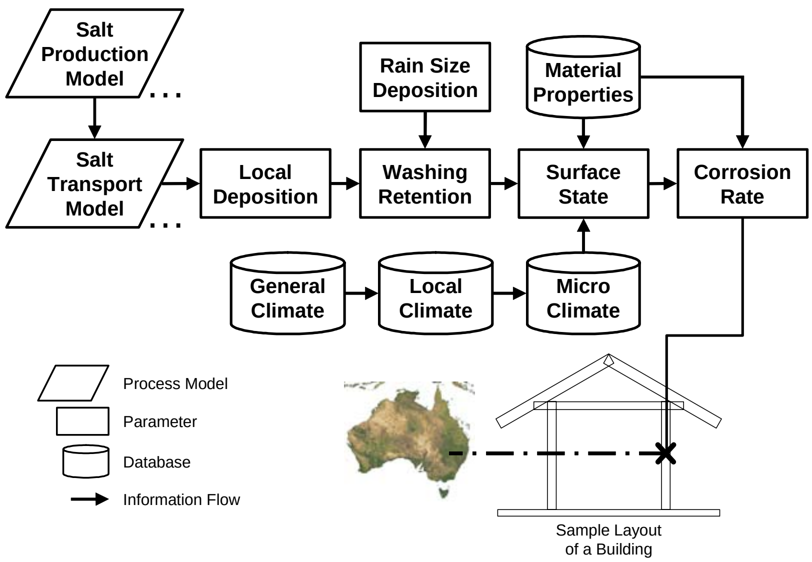

Figure 5. *Computation of corrosion rate through a series of process models and parameters obtained from database lookups*

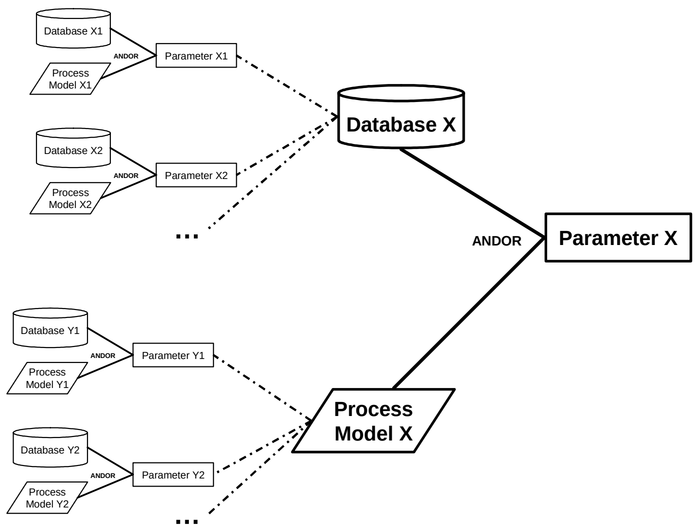

Figure 6. Computation of a required parameter through a process model or database lookup

6. Conclusions

A new model of case-based reasoning that recognizes the importance of situated reasoning is proposed. Fundamental processes related to situatedness, such as the recursive interpretations and interactions with the environment that cause reframing the original problem and the relevant experience and/or knowledge, are introduced to the CBR model. A case-based system incorporating the notion of situatedness changes CBR from selection, retrieval, and adaptation to one in which memory construction plays a major role. This model is suitable for domains in which the previous, stored solutions are just a starting point for reasoning about the new problem and generalized knowledge is insufficient, as in design problems and complex predictions such as the corrosion rate example.

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