Go to contents 13

A Case with a View

Towards an Integration of Visual and Case-Based Reasoning in Design

OXMAN, Rivka Oxman; HEYLIGHEN, Ann
Faculty of Architecture, Technion, Haifa, Israel
Dept. of Architecture, Urban Design and Planning, K.U.Leuven, Belgium
http://www.technion.ac.il/shell/Academic/Architecture.html
http://www.asro.kuleuven.ac.be/asro/english/home/HA/
arrro01@techunix.technion.ac.il ann.heylighen@asro.kuleuven.ac.be

Despite the long-term effort to establish the theoretical foundations for Case-Based Reasoning (CBR) in design, it appears that additional theoretical efforts are needed in order to achieve the promise of this affinity. In this paper we argue that visual reasoning, is a fundamental attribute of architectural design, and therefore combining it with CBR may provide significant results both for the field of design thinking as well as for the field of CAAD. This paper focuses on reformulating theoretical foundations for CBR in design by incorporating insights from studies in fields like visual imagery and creativity, where visual reasoning is recognized to play a key role. Within classical CBR research, however, visual reasoning has not received much attention until now. Instead, researchers have concentrated on traditional issues and topics in CBR such as indexing, retrieval and adaptation. The second part of the paper therefore switches attention to how these traditional issues may benefit from integrating Case-Based with visual reasoning.
Keywords: *Case-based reasoning, Visual reasoning, Visual imagery, Visual cognition*

Introduction

Design experience has been recognized as a significant source of knowledge in the creative process of design. Among the different approaches in Artificial Intelligence (AI), Case-Based Reasoning (CBR) is regarded as a promising paradigm for modelling design thinking. However, despite the general consensus as to the cognitive significance of CBR for design we have yet to realize this potential. In order to strengthen the field of Case-Based Design (CBD), it appears that additional theoretical efforts are needed.

One possible direction for future exploration is to view CBR as part of a complex, hybrid “designerly” (Cross, 1982), reasoning process. In architecture, as in other design domains the centrality of cases as a source of experiential knowledge is based upon the confluence of visual representations and semantic content in a consistent representational medium. Essentially, a design comes into being through manipulation of non-verbal information: the visual is the way in which the designer knows, thinks and works. The centrality and power of visual reasoning as a cognitive mechanism makes design a unique field of research for AI, cognitive psychology and CBR in particular. Furthermore, it suggests interesting possibilities with respect to the incorporation of visual material in computerized case libraries, and the potential to interact with and exploit visual case data in the process of computationally supported design.

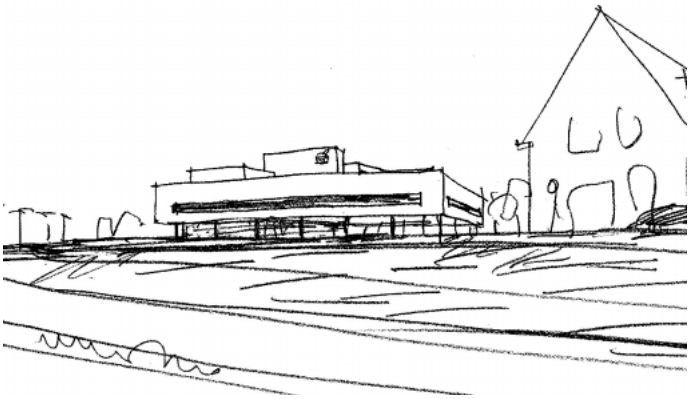

Figure 1. A villa Savoye for Apple (project) by Paul Vermeulen & Henk Desmet (Heylighen, 2000).

This paper reports and embroiders upon the results of a workshop on Visual Reasoning in Case-Based Design, which was organized as part of AID Conference 2000 in Worcester (Oxman, 2000).

The first part of the paper argues that visual reasoning, i.e. thinking in shapes, forms and images, is a fundamental attribute of architectural design. It focuses on reformulating theoretical foundations for CBR in design by incorporating insights from studies in fields like imagery and creativity, where visual reasoning is recognized to play a key role.

The second part of the paper switches attention to how traditional issues within classical CBR research, such as indexing, retrieval and adaptation, and their relevance to CAAD might benefit from integrating Case-Based with visual reasoning.

The role of mental representations in CBR

The process of selecting relevant ideas from prior design in current design situations has been termed "precedent-based design" (Oxman, 1994). In order to illustrate the role of visual reasoning in precedent-based design, consider the following example. Once two Belgian architects designed an office building for a computer firm. The design was explicitly 'based' on a 'precedent' that seemed to have little in common at first sight, namely Le Corbusier's Villa Savoye (see Figure 1). How did they come to basing their design on this precedent? As one of the architects contends, "In fact, we were making that design, and at a given moment there are a sort of general ideas of how it should become more or less, conceptual ideas, and you try to sketch it a bit, and you start noticing – because you never sketch that very well, of course – this looks like the Villa Savoye…" Although it was somewhat funny, initially the architects offered resistance, "because you think: 'we simply can't do that'. Yet, when thinking it over more deeply, they finally started realizing that the resemblance was more than coincidental. "On a conceptual level, we were actual making a great big Villa Savoye: a ground floor tailored to the car, then a spacious residential platform – a sort of show-box towards outside and apart from that very strongly introverted – and further free volumes on the roof for other parts of the program that were not repetitive." At the moment they recognized their design as being the Villa Savoye, the reference became in fact productive (Heylighen, 2000; Heylighen and Verstijnen, 2000) (fig 1).

Starting from this concrete anecdote of how architects (re-)use precedents, several complex reasoning processes that relate to human case-based design in architecture can be identified.

The anecdote illustrates the importance of visual reasoning in design case retrieval. Given only the view of a façade, the architect was able to derive the corresponding floor plan. In general, designers are apt at constructing a whole from a partial view, thereby switching smoothly from one visual representation to another.

This anecdote also highlights the importance of mental association in human case-based design. The architect did not only associate the façade with the corresponding floor plan, but also with more abstract, high-level concepts – in this case the architectural concept known as 'piano nobile'.

According to Kosslyn, when visual mental images are formed these processes access the stored representation of the structure of an object in associative memory (Kosslyn and Osheron, 1995). The ability to access the underlying structure, a concept, or schema, of an image is significant to our ability to reformulate an image in drawing. The reformulation, or re-representation, of visual images in drawing is one of the cognitive foundations of emergence in design (Oxman, 2001).

Taken together, these different kinds of associations seem to imply that a single design precedent may have multiple meanings, which suggest designers to have a layered case representation. Rather than chunking each case into separate components, as several CBD systems tend to do, this representation allows designers to view a case from several perspectives, interpret it in various ways, and switch smoothly between different interpretations.

A theoretical model that may account for this layered case representation with reasonable accuracy is the Issue-Concept-Form (ICF) formalism (Oxman, 1994). In this formalism, issues stand for high-level statements or starting points (orientation, for instance), concepts refer to domain-specific ways of achieving certain issues (centrality is a possible concept to achieve orientation), whereas forms represent the physical realizations of these concepts. A single issue may be addressed by different concepts, just like a single concept may address different issues. Consequently, the relationship between issues, concepts and forms should not be thought of as a strict hierarchy, but rather as a semantic net.

This sophisticated net may help to explain what happened in the anecdote mentioned above and, more in general, in human case-based design. A stimulus (a vague sketch, in this case) triggers the retrieval of a concrete form (c.q. the Villa Savoye), which is – on the conceptual level – associated with/ interpreted as a domain-specific concept (c.q. the concept of 'piano nobile'), which in turn is translated into a new, concrete form (c.q. an office building).

Implications for CBR technology

Visual reasoning, we have argued, plays a key-role in human case-based design. Within classical CBR research, however, visual reasoning has not received much attention until now. In the following section we suggest how traditional issues such as retrieval, storage and indexing may benefit from integrating Case-Based with visual reasoning.

Case retrieval

A central issue in CBR research is the retrieval of a relevant case. Underlying most CBR research is the assumption that the most relevant case is the one having the most features in common with the situation at hand. Accordingly, CBD systems tend to index and retrieve their cases by a set of keywords that describe design features and attributes. In reality, however, designers often remember cases from characteristics that are more easily expressed in a visual way.

This suggests that precedents/cases should be labelled and retrieved by using visual in addition to verbal indices (Heylighen e.a., 2001).

To this end, several possible approaches have been proposed. One approach uses a method for accessing a visual database of designs by canonical diagrams (Gross, 1995). Another approach suggests the use of graphic units in architectural drawings (e.g. grid, contour, circulation system) (Achten, 2000). The

underlying assumption is that architects' drawing conventions are so strong, that the knowledge content of these conventions can be called in to determine the similarity between cases. An important issue that still needs to be addressed, however, is the definition of partial matching: What partial matches provide the most relevant case? And how do these partial matches translate into weights for graphic units? Another issue has to do with the relationship between graphic units. When looking for cases containing say a modular field, it should be possible to recognise a grid as a specialisation of a modular field or, more in general, to identify related graphic units.

Whether implemented as canonical diagrams, graphic units or other kinds of images, visual indices should be integrated in a network. As illustrated by the anecdote above, an important phenomenon in human design case retrieval is mental association. Consequently, association should be supported by CBD systems, both across visual representations as well as between visual and semantic nets.

At this point, the ICF-formalism pops up again, for this formalism is more than a theoretical model. It underlies the case representation and indexing system of WEB-PAD, a web-based tool for the construction of architectural case bases (Oxman and Shabo, 2000). WEB-PAD uses the formalism both for the input of new cases, and as a basis for indexing, retrieval and search. In addition to 'traditional' database search – searching for perfect matches – ICF allows to search the case base for partial matches, which is more in tune with the CBR paradigm and human design case retrieval. If at a given level – say the form level – a perfect match cannot be found, WEB-PAD shifts to a higher level and starts looking for cases with a similar concept. Once a matching case has been found, the user can easily browse to other cases that share the same issue and/or concept.

Promising as these steps towards visual case indexing may be, a major obstacle remains the human effort needed for encoding. Indeed, both WEB-PAD and the graphic unit approach heavily rely on people who encode and index cases manually. Moreover, since WEB-PAD is to be used primarily by design students, it would be interesting to provide an explanation of why/how a specific form realizes a certain concept, or why/how a specific concept addresses a certain issue – especially when the system comes up with a partially matching case. Currently, this knowledge is implicitly embedded in the links between the different nodes and levels of the ICF-formalism. Yet, to make this knowledge explicit would make the process of acquiring (new) cases even more time-consuming.

Case representation

Many CBR systems treat cases as collections of attribute-value pairs, which is obviously a very poor representation for architectural design. Given the importance of visual reasoning in design, visual representations (such as shape drawings, photo's, sketches, plans, diagrams, etc.) must be considered. Yet, the need for visual case content has serious consequences for the process of case acquisition, as there exists a strong tension between the richness of a case presentation and the facility to acquire (new) cases (Heylighen, 2000). It is obvious that a CBD system cannot acquire new cases easily when its case representation and indexing system are too complex.

In fact, it was precisely this tension that inspired the development of EsQUIsE, a software prototype for (semi-)automating the interpretation of design sketches (Leclercq, 2000). Given nothing more than a rough sketch and a few captions specified by the designer, the system is able to derive the main functional, geometrical and technological features of the design. The main objective was to facilitate the creation of a semantic case representation. Thus, in addition to facilitating the encoding of new cases, EsQUIsE might support the retrieval of relevant cases and, based on their technological features, help to predict the performance of the design at hand. Given the ambition to encode cases in an objective way, questions may arise as to the objectivity of the input, especially when being used in practice. Different designers have different ways of sketching, drawing

and organizing information, and EsQUIsE bases its representation on these 'personal' sketches. Nevertheless, the system clearly represents a promising step towards an integration of visual reasoning and CBR technology.

Case adaptation

A final classical issue in CBR is the reuse or adaptation of selected cases. Enriching this process with visual reasoning may be a powerful way to stimulate creative design, yet requires new modes of interaction with cases.

In a recent paper we have presented an experiment that illustrates how a mental image of a sunflower is transformed in the architectural domain and is employed as a configurative pattern of a shape, consisting of a set of spiral arcs radiating about a center core (Figure 2). This configurative schema evolves the elaboration of the form of a configurative structure and its structural generation (the "know-how") as an adaptive strategy in the design of the school in Berlin by the Israeli architect Zvi Heker.

Afterthough

This paper has reported and embroidered upon the results of a workshop on Visual Reasoning in Case-Based Design, which was organized as part of the Artificial Intelligence in Design Conference 2000 in Worcester. The major objective of this workshop was to explore the potential of integrating visual reasoning with CBR, and to identify what issues on the CBD agenda still need to be addressed.

The issues raised transcend the scope of the CBR recipe as such, opening up the discussion to cognitive, technological and even practical aspects of design at large. Indeed, if we are to develop reliable CBR tools for design, we should not escape in the realm of the CBR paradigm, and forget about what is involved in designing something as complex as say meaningful architecture. On the contrary, the success or failure of these tools might well depend on their ability to incorporate insights, knowledge and expertise from other fields, other than CBR as such. In our opinion, such incorporation and cross-fertilization would not only be rewarding. If we are to realize CBR's potential for design, it might very well be a must.

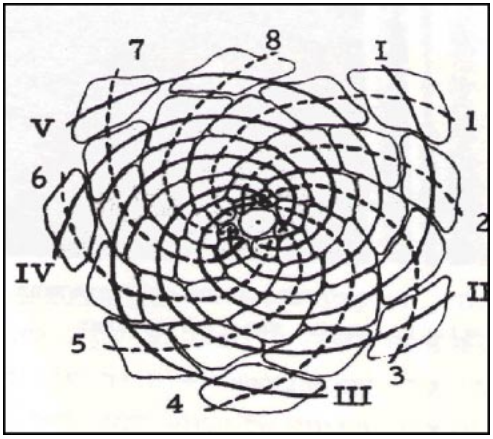

Figure 2: Visual image as a configurative basis for a geometrical structure (Oxman, 2001).

Acknowledgements

This research is sponsored by the Technion Fund for Research, and by the Fund for Scientific Research (FWO) Flanders, of which Ann Heylighen is a Postdoctoral Research Fellow. The authors would like to thank all participants of the AID'00 Workshop on "Visual Reasoning in Case-Based Design" for their ideas, suggestions and collaboration: Henri Achten, Pierre Leclercq, Maciek Orzechowski and Nicole Segers, Kamal Mubarak and Ömer Akin.

References

Achten, H. H.: 2000, Design case retrieval by generic representations, in J. Gero (ed.), Artificial Intelligence in Design '00, Kluwer Academic, Dordrecht, pp. 373–392.

Cross, N.: 1982, Designerly ways of knowing, Design Studies, 4(3), pp. 221–227.

Gross, M. D.: 1995, Indexing visual databases of design with diagrams, in A. Koutamanis (ed.), Visual Databases in Architecture, Aldershot, Avebury, pp. 1–14.

Heylighen, A.: 2000, In case of architectural design. Critique and praise of Case-Based Design in architecture, PhD Dissertation, K.U.Leuven, Leuven.

Heylighen, A. and Verstijnen, I. M.: 2000, What triggers a designer's memory?, AID'00 Workshop on Visual Reasoning in Case-Based Design, Worcester (Mass).

Heylighen, A., Morisse P. and Neuckermans, H.: 2001, What you see is what you get, working paper.

Kosslyn, S. M. and Osheron D.N: 1995. Visual cognition – an invitation to cognitive science, MIT Press, Cambridge, Mass.

Leclercq, P.: 2000, The contingency of using the sketch interface to support deep analogies in a case base design work, AID'00 Workshop on Visual Reasoning in Case-Based Design, Worcester (Mass).

Oxman R. E.: 1994, Precedents in design: a computational model for the organization of precedent knowledge, Design Studies, Vol. 15 No. 2

Oxman, R. E. and Shabo, A.: 2000, WEB-PAD – a Web-based Tool for Storage and Retrieval of Visual Cases, AID'00 Workshop on Visual Reasoning in Case-Based Design, Worcester (Mass).

Oxman, R. E.: 2000, Visual Reasoning in Case-Based Design, AID'00 Workshop, Worcester (Mass).

Oxman R. E.: 2001, The Thinking Eye: Visual Re-Cognition in Design Emergence, working paper, submitted to Design Studies.