(Learning from experience)2: Promises, problems and side-effects of CBD in architecture

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Learning from design experience is the essence of Case-Based Design (CBD). Because architects are said to learn design by experience, CBD seems to hold great promises for architectural design, which have inspired various CBD tools. Learning from the experience of developing and using these tools is the objective of this paper. On the one hand, the original expectations seem far from being accomplished today. Reasons for this limited success can be found at three different levels. Level one is the cognitive model underlying CBD, which raises some specific difficulties within the field of architecture. At the level of implementation, few tools manage to draw the full consequences of this view, thus leading to an oversimplification of CBD and/or architectural design. Level three has to do with introducing CBD tools in design education and assessing the effects of this introduction. On the other hand, CBD seems to have caused some interesting side effects, such as an increased interest in creativity and copyright, and the recent re-discovery of the key-role cases play inside and outside the field of CAAD. Thus, although its promises may not be fulfilled, CBD definitely can contribute to design education, be it sometimes without the support of computer technology.

Keywords: *Case-Based Design, design education*

Introduction

Computer-Aided Architectural Design (CAAD) has gone through many generations and philosophical perspectives. One of them, the focus of this paper - is the application of Case-Based Reasoning (CBR) to design, in short Case-Based Design (CBD). CBR is a relatively young theory and technology within the field of Artificial Intelligence (AI) based on an alternative view of human reasoning. Rather than linking abstract pieces of knowledge (e.g. rules or models), reasoning is seen as remembering one or a small set of concrete instances and basing decisions on comparisons between the new situation and the old instance (Kolodner 1993). This cognitive model was inspired by Roger Schank's Dynamic Memory Theory (Schank 1982) and in turn inspired AI researchers to model people's raw memory. With someone's raw memory we mean the huge collection of individual experiences that one has had or has heard about. Unlike the generalised knowledge that can be distilled out of it, the raw memory contains these experiences in their original form, including all details that make the experience individual. The main part of a CBR system, then, consists of a case base: a relevant set of specific cases stored as complete patterns of experiences. Given a new problem, the case-based reasoner retrieves the most relevant case in memory and subsequently adapts the corresponding solution to the current situation.

Promises

Because architects - and designers in general - are said to learn design by experience, the blend of CBR and CAAD seemed to hold great promises for the field of architecture.

First of all, CBD would bypass the knowledge acquisition bottleneck of Rule- and Model-Based approaches to enrich CAAD tools with design knowledge. Whereas architects may have trouble citing the rules they apply or developing models of the objects they work with, they usually have no problems telling stories (which can be represented as cases) about previous design experiences.

Secondly, since generalising always implies the danger of losing some important information, general rules, models or types are necessarily impoverished versions of the original experience from which they have been derived. Analyses are not guaranteed to be correct and the resulting generalisations never perfect. Once knowledge is compiled into general principles, it remains compiled forever. In contrast, concrete cases, which contain experiences in their original, detailed form, can always be re-analysed, re-interpreted and re-understood.

Given the fact that design problems are difficult to decompose, a third advantage is that "cases can provide the glue that hold a solution together" (Kolodner 1993). Buildings have to fulfil a whole series of different, sometimes even contradictory, requirements. It is quite impossible, though, to design a building by decomposing it into parts according to these different constraints, solving each part separately and recomposing them into a solution. For every decision an architect takes is likely to have implications that cut across multiple aspects. Enlarging a window, for instance, may result in more light and a better view, but at the same time cause more heat loss and greater problems of privacy (Lawson 1990). The architect's task is to integrate these different aspects into one coherent and meaningful design. Achieving integration in a Rule- or Model-Based approach is extremely difficult because there are few general principles that hold over all aspects. Cases, on the other hand, provide a natural solution to this integration problem: they themselves are integrated design solutions to particular contexts, including trade-offs among the several requirements a building needs to fulfil.

Fourthly, CBD has the potential to improve the efficiency in architectural design. Many architects design every building as if it were the first in kind, coolly ignoring the design experiences of their learned predecessors. Making use of previous cases during the design process could help architectural design out of its current inefficiency. The underlying assumption here is that adapting a previous design solution to a new situation takes less effort than generating a design from scratch.

A final promise is that CBD tools extend an architect's memory by storing design experiences he may not have had by himself. The current problem may lie somewhat outside his proper area of specialisation, or perhaps he is a student and thus relatively novice in the field. Whereas novices approach a design by trial and error, experienced architects rapidly reduce the abundance of design solutions to a manageable handful. The difference lies in a repertory of heuristics that is accumulated through many years of design experience (Rechtin 1991). Awaiting these years, CBD tools can provide students with a substitute for the experience they are lacking so far.

Inspired by these and other prospects, a whole range of CBD tools have been - and are being - developed in the field of architecture, e.g. CADRE (Hua e.a. 1996) and SEED (Flemming e.a. 1997) for building design, FABEL for technical buildings with complex installations (Schmidt-Belz & Hovestadt 1996), ACHIE and ARCHIE-II for courthouse design (Domeshek & Kolodner 1993), and IDIOM for apartment floor layouts (Smith e.a. 1996). Several of them, like for example PRECEDENTS (Oxman & Oxman 1994), EDAT (Akin e.a. 1997) and DY*N*AMO (Heylighen e.a. 1998), are explicitly education-oriented. To learn from the experience of developing

and using these tools is the objective of this paper.

Problems

At first sight, the expectations of the CBD pioneers seem far from being accomplished today. Despite numerous attempts by researchers to develop reliable CBD tools, a convincing breakthrough of CBD in architectural practice and education has yet to emerge. Reasons for this rather limited success can be found at three different levels.

The cognitive model underlying CBD

The first level concerns the model of cognition in which CBD is historically rooted. Although this model may provide a plausible explanation of how designers acquire and apply design knowledge, within the field of architecture it raises some specific difficulties.

First of all, there is some confusion about the leading actor in this cognitive model: *design experience*. In general, design experience can be interpreted in multiple ways (Heylighen 1998). Strictly speaking, having experience in design means having designed yourself. In a wider sense, observing an architect's design process can be seen as a source of experience too. Finally, architects acquire experience by exposure to designs made by others, either in real life or, more often these days, through pictures in journals, books, lectures or exhibitions. CBD researchers, however, tend to focus exclusively on this latter interpretation of design experience, the Galathea team being the proverbial exception to the rule (Arlati e.a. 1996). Design cases, i.e. patterns of design experience, are usually interpreted as (fragments of) design products, generally, but not necessarily, at the final stage of the design process. Although design products definitely contribute to the acquisition of design experience, they cannot reveal the constantly changing conditions that actually structure the process of designing (Brown & Duguid 1996). Indeed, "conflicting demands from within the client organisation, the remoteness of the user, difficulties with the bearing capacity of the soil, an unsympathetic planning authority, changing circumstances during the design period, restricted or inflexible methods of financing scheme… and many more difficulties remain inscrutable to all but the most perceptible and insightful of architectural critics" (Lawson 1990). Dealing with such changing and conflicting conditions requires a form of knowledge that is embedded within the very act of designing (Schön 1985) and thus escapes the static form of a design product. It is obvious then that if architects learn design by experience, this learning does not only involve exposure to designs, but also active engagement in designing.

It would be misleading, however, to depict CBD researchers as completely unaware of the difference between product and process. Evidence of such awareness can be found in the idea of "deep cases" (Hua e.a. 1996), design products augmented with traces of the design and building process, such as options, decisions, justifications, assessments, revisions etc. In PRECEDENTS, for instance, cases contain descriptions of conceptual points, highlighting those aspects which were particularly decisive in the early stage of the design (Oxman & Oxman 1994). ARCHIE-II supplements cases with stories from different stakeholders - people who carried out, use or maintain the building - telling how the design turned out (Domeshek & Kolodner 1993). Nevertheless, many projects share CADRE's preference for cases that are as shallow as possible for the obvious reason that deep cases are not there for the taking (Hua e.a. 1996). Similarly, the FABEL team seems rather pessimistic about getting richer cases and advises to identify cases one might get in a realistic setting (Voss 1997).

Another element of confusion in CBD's cognitive model is the retrieval of a relevant case. What makes a previous design experience relevant to a new design situation in architecture, is far from clear. Underlying most CBD research is the assumption that relevance equals similarity, in other words that the most relevant case is the one having the most features in common with the new design. In FABEL, these features range

from functional components and visual appearance over occurrence of certain layout patterns to structure or topology (Voss 1997). Although this interpretation of relevance might apply to other design disciplines, its applicability to architectural design is highly questionable. In a series of interviews with architects we conducted last year, few interviewees did recognise the model of CBD, neither did they manage to formulate exactly why they call on a particular case during design. Probably the most honest answer we got was: "often simply because I *feel like* designing something like it." This feeling is not necessarily prompted by striking similarities between previous and current design situation. On the contrary, the more significant the difference, the greater the challenge.

The implementation of CBD tools

A second level which poses serious problems is that of implementation. Even if CBD's model of cognition would perfectly match an architect's designerly way of thinking (Cross 1982), few tools manage to draw the full consequences of this model, often leading to an oversimplification of CBD and/or architectural design.

The problem already starts with the representation of cases, i.e. records of design experience in a computer memory. A major advantage of using cases (as opposed to abstract rules or models) in design is that cases are concrete, full of detail, vivid and open to interpretation. However, the price of having to represent cases may be that this very richness is lost, simply because it refuses to be encoded in a digital form. Indeed, "representing design cases requires an *abstraction* of the experience into a symbolic form that the reasoner (either computer or human) can manipulate" (Maher & de Silva Garza 1997; our italics). No wonder CBD researchers prefer interpreting cases as products rather than processes. A major implementation question Galathea faces is finding an appropriate format to describe and compare different states during design (Arlati e.a. 1996). Yet, even in case of design products, i.e. building designs, digital representation can be characterised as a movement toward abstraction (Matthews & Temple 1999). As long as this representation is used by human designers, there may be little cause for alarm. Indeed, what an architect derives from what is shown on the screen is much richer than what the computer only knows as 0s and 1s (Maher 1998). During the years he has learnt to develop a mapping between a design's representation and reality, allowing him to form an idea of what the real building looks like. Yet, when cases are manipulated by the computer, as happens in CADRE, FABEL, IDIOM and SEED, the problem becomes more serious. Computers are not aware of a reality other than a design's digital representation. For them, this representation *is* the design. Thus, the representation of design cases reduces architecture to an abstract, geometric shape, instead of a meaningful form.

Another major advantage of cases that is seriously challenged by implementation, is the coherence between the different aspects architects must take into account. Just like a case's richness, this integration is often lost in CBD systems. Some of them focus entirely on one single aspect of architectural design. CADRE and IDIOM, for instance, have specialised in geometry, more precisely in the geometrical constraints on floor layouts. In these systems, integration is not a question, as other issues are simply not taken into consideration. A totally different approach, adopted in FABEL and SEED, is to develop different modules according to different aspects in architectural design (e.g. construction, topology, functional subsystem). Precisely because integration of such diverse aspects proved to be a non-trivial task, FABEL's modules - significantly called 'specialists' - are rather independent and each equipped with a separate case base and adaptation method (i). As long as this independence exists, perhaps the tool should rather be called a collection of Rule- or Model-Based systems than a Case-Based one.

CBD in design education

Unlike the previous levels, where CBD's (in-)

effectiveness has been discussed in relative isolation from the wider context in which it is used, level three tries to adopt a broader perspective. This perspective includes how CBD is integrated into design education, and how its use is presented by teachers, viewed by students and supported by the school. All these factors can influence the effectiveness of learning outcomes, even although they may not relate directly to CBD itself (Gunn 1998).

In general, design teachers are rarely burning with enthusiasm to introduce CAAD tools in design education (Neuckermans & Geebelen 1999). In case of CBD tools, this enthusiasm is even harder to find, as these tools would increase the danger of students blindly copying previous projects considerably - a phenomenon known as 'design fixation' (Christiaans & van Andel 1993). Judging from our experience with DY*N*AMO, student opinions are more divided. Some find cases an interesting source of inspiration, others share their teachers' concern that being original becomes more difficult. As one student testifies, "I know that everything has already been done. There are just some things that I'm not yet aware of." In our opinion, the present emphasis on originality and uniqueness wrongfully excludes cases as treasures of knowledge from informing design in the studio (Press 1998). Moreover, "originality consists more in thinking for yourself than in thinking differently from others, and continuation of a living tradition, or an intelligent deployment of acquired knowledge are not the same as blind mimicry" (Tzonis & White 1994).

Finally, the physical environment in which design education takes place should not be underestimated. Students do not always have easy access to computers, and this often prevents CBD tools from functioning the way they were originally supposed to. As long as students must leave their drawing board - or even the design studio - in order to access a CBD system, the majority of the students simply will not use it.

In our opinion, merely providing each student with his personal computer will not do. If CBD is to really support designers, cases should be accessible from within an integrated CAAD environment that supports sketching, modeling and testing, in short designing, from the very beginning of the design process. This scenario still lies largely in the future, yet significant steps have already been taken in this direction (Hendricx et.al. 1998).

Side effects

Although CBD may not have lived up to the early expectations, research in this field seems to have caused some interesting side effects. First of all, it has (re-)drawn attention on issues like creativity and copyright, often giving rise to interesting and lively debate.

As already mentioned, CBD is often criticised and dismissed as not being creative. Such criticism reveals as much about the critic's (mis-)conception of creativity as about CBD itself. Creativity here is viewed as 'creatio ex nihilo', i.e. creating something out of nothing, a view researchers in creative behaviour apparently do not share. According to Arthur Koestler, "the creative act is not an action of creation in the sense of the Old Testament. It does not create something out of nothing; it uncovers, selects, reshuffles, combines, synthesizes already existing facts, ideas, faculties, skills" (Koestler 1989). Others describe creativity as "the easy recombination of ideas in the preconscious" (Barron 1969) or "putting the elements of one's experiences into new combinations" (MacKinnon 1970). What these attempts to define creative behaviour demonstrate, is that the fact of starting from an existing design is no reason to accuse CBD of inhibiting creativity.

A second issue raised by CBD research is that of authorship in architecture. In principle, architectural designs are protected by the law of copyright. When complete designs become available in CBD systems, the danger of architects copying their colleague's masterpieces would increase considerably. Back in 1834, Gottfried Semper said exactly the same about transparent tracing paper: "it would certainly hamper contemporary architectural design practice, and

contribute to the then prevailing lack of ideas by facilitating copying of architectural elements of all times" (Semper 1979). More than one and a half century later, transparent tracing paper is still widely available, yet relatively few cases of plagiary in architecture have been reported. On the one hand, the jurisdiction is not very inclined to give protection to architectural designs, presumably because of the important role technical means and their constraints play in these creations, and because they also have a utilitarian character (Ballon 1995). On the other hand, most architects seem to feel to what extent pre-existing designs can be 'copied' (Maher 1998). Moreover, Tzonis and White remark that copyright is far from being intended to prevent further use or development of a design. "The point of intellectual property is to encourage invention by rewarding the inventor, not by restraining those who learn from him (Tzonis & White 1994).

Interesting to mention in this respect, is Phase(x), a design strategy that leaves behind the single-authorship design process (Kolarevic e.a. 1998). Students are introduced into the principles of CAAD by means of a design assignment divided in five phases. After each phase, students are not simply encouraged to look at each other's work, they must select the project of another student and further develop it in the next phase. Because the final results are design projects with shared authorship, there is much less "negative" competition between designers. Students are able and willing to develop the best solutions, instead of continuing on their own, sometimes weaker, solutions. Although the applicability of Phase(x) seems limited to architectural education, its developers could imagine working in practice under similar conditions, thus realising a breakthrough of productivity and quality in architectural design.

Apart from raising issues and stimulating discussion, another side-effect of CBD may be the recent re-discovery of the key-role concrete cases play both inside and outside the field of CAAD. One example is the development of design support for daylighting in architecture. Although a growing number of testing tools to evaluate a building's daylighting performance have been developed, architects often continue to design in the "traditional way", i.e. with reference to previous cases. Therefore, some researchers have decided to change track and provide architects with updated case studies of buildings embodying effective daylighting concepts, rather than with sophisticated testing methods (Baker e.a. 1993).

Finally, we end with a project that lies outside the field of CAAD, yet successfully adopts a Case-Based approach to architectural education. The project, significantly called 'Little brother', is a 1st year design assignment at the architecture school of Newcastle upon Tyne (Leitch 1995). First, each student is introduced to an architect and his architecture. After an analytical phase in which students try to uncover and understand the architect's design philosophy, they are asked to design a small, single cell, studio, to be built within the garden of a house from his repertoire. Students have access to the building itself and to copies of the original working drawings. According to Diana Leitch, the choice of local architects for this project holds the double attraction of a direct link between student and architect, and of course, a wealth of extra tutorial expertise. In fact, 'Little brother' combines different sources of design experience in a unique way: a 'living' architect, who can be inquired about his intentions during design and 'Big brother', a concrete product devised by this process. The surprisingly high quality of the student designs, which inspired the organisation of an exhibition, clearly indicates the value of this unique combination. Strictly speaking, 'Little brother' has nothing to do with CBD. However, it clearly demonstrates that a Case-Based approach definitely can contribute to architectural design education, be it without the support of computer technology.

The future

Having discussed the problems and side-effects of almost two decades of CBD research, what about the

future? Is CBD a valuable path to follow, or should CAAD turn down another road? Although current CBD tools do not fulfil the early expectations, we should be careful not to throw out the baby with the bath-water. Projects like 'Little brother' encourage us not to brush the whole Case-Based paradigm aside. Of course, it is tempting to conclude that to develop more successful CBD tools, further research is needed. Yet, perhaps, something else is needed this time. A major reason for the so far limited success turns out to be confusion - confusion at the side of CBD researchers, over the meaning of design experience in architecture; at the side of architects, teachers and students, over what CBD is, and is not. As long as CBD researchers keep gathering at conferences to discuss new implementation methods, (student-) architects will probably quietly ignore their work. If CBD tools are to really support architectural design, what may be needed is a better communication and co-operation between on the one hand the practice and education of architectural design and on the other hand the world of research. For who better to tell researchers how cases can help during design than architects?

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