Ondersteuning door informatiesystemen in het architectuurontwerp

Reconsidering Information System Support
for Architectural Design Thinking

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English summary

Over the past years, numerous information systems have been realized which support various aspects in architectural design. These systems help the designer in various ways: they provide drafting support, they allow a variety of photorealistic visualizations, they provide very diverse calculation and simulation aids for structural, thermal, acoustic and other aspects of the design. Yet, despite the richness of the design tools currently available, various deficiencies remain in the way in which they can be used to effectively support design activities. Several aspects of design, in particular there where the designer's knowledge, expertise and past experiences are involved, remain essentially without proper information system support. This thesis addresses the question embodied in this statement: why is it that computer-based design aids still lack in providing full design support?

In addressing this question, this thesis starts by looking into some of the central issues in existing information system support for architectural design thinking. Four types of information system support are outlined: modeling applications, archive applications, calculation applications and visualization applications. Applications in these categories are very diverse in their design and implementation, yet they often show very similar shortcomings when they are evaluated in a real-world context. The information that can be described within modeling applications is either 'not enough and too simple', or 'too much and too complex'; the functionality provided by simulation applications is 'not correct' or 'irrelevant'; and so forth. Additionally, none of the applications effectively reuses information from any of the other applications.

So it turns out that various effects are in play, all in some way related to deficiencies in the information exchange (1) among information systems, as well as (2) between information systems and the designer. The first deficiency relates to the issue of interoperability between information systems that has been distinguished in various domains, not only architectural design. The second deficiency relates to the mismatch that is typically encountered between the functionality provided by information systems and the functionality supposedly desired by the end user. Also this deficiency is not only encountered in architectural design, but can be distinguished in other domains. These two main lines of investigation are fol-

lowed throughout this thesis. As such, it is investigated in what ways and to what extent design activity –commonly called design thinking– could be supported by information systems.

The first research line in this thesis focuses on the outlined interoperability issue in information system support. Diverse approaches are documented to address this issue: sharing information in the wild, the remodeling effort, kernel-level interoperability, the centralized information structure, the software suite strategy, and the linked data approach. When relying on semantic web technologies, the last approach appears to be the most promising, because these technologies allow to explicitly and unambiguously connect information deployed in diverse application domains and applications. Additionally, semantic web technologies use a generic description language, namely the Resource Description Framework (RDF), and they appear to be deployed on a global scale. Information thus has a notably higher chance of being available and related to information in other knowledge domains of possible use to the architectural designer.

The experimental investigation of a linked data approach with semantic web technologies suggests two methods for combining information in different application domains, namely a method relying on explicit links between concepts residing in different application domains, and a rule-based method which enables an active conversion between diverse information structures that represent nearly the same information.

Apart from the interoperability issue, the linked data approach might also address the functionality mismatch issue. This is tested for the four application types outlined earlier. From this tests, it is concluded that improvements are possible in the sense that the web of information used by applications can include an unambiguous RDF graph that to some extent represents aspects of design information of a designer. By relying on this information, information systems might thus be customized so that they provide the functionality requested and needed by the designer. This leads naturally to the two following connected research questions.

1. To what extent can aspects of design information be represented in an unambiguous model or web of information?

2. What is the role and effect of this representation in the design process of a designer?

The second line of research, which focuses on the functionality mismatch issue, addresses these two research questions. It does so by going through existing theories of design thinking. An outline is given of the most significant theories of how designers deal with the design situations they encounter, with or without information system support, and how they construct and use information. This research points towards four key elements in the design thinking process:

- the importance of *analogical reasoning* in producing creative ideas,
- the concept of *co-evolution* of (sub)problems and (sub)solutions,
- the world with which the designer interacts (*experiences*), and
- *guiding principles* or background knowledge built up by experiences.

Central in the way in which designers think is the 'guiding principles' element, which is the knowledge by experience of the designer. This design knowledge is formed by a set of personally collected and thus familiar design patterns. These guiding principles help architectural designers to recognize and categorize a new experience through an analogical reasoning process, whether this be the interface of an information system, the feedback given by a colleague designer, a sketch, a thought experiment, or a CAD model. Furthermore, guiding principles help designers to devise design tryouts that can be used to confirm or refute their mental model of a design situation. And finally, these guiding principles also allow learning from experiences resulting from design tryouts. Design situations are continuously framed and reframed (co-evolution) by endlessly iterating through a process of (1) analogical reasoning, (2) devising design tryouts, and (3) performing design tryouts and learning from experiences (Fig. 1).

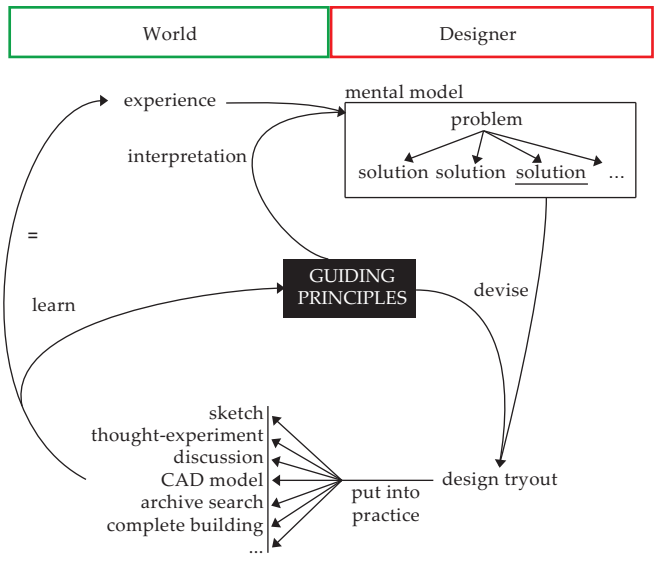

Figure 1: Design situations are continuously framed or reframed (co-evolution) by endlessly iterating through a process of (1) analogical reasoning, (2) devising design tryouts, and (3) performing design tryouts and learning from experiences.

From this overview of theories in design thinking, it is finally concluded that information systems essentially provide additional environments to architectural designers for externalizing their design knowledge and, as such, make design tryouts. However, external representations of design knowledge, such as the kind of representations that would result from using semantic web technologies, differ substantially from the design knowledge in the human mind. The former typically represents a static snap-shot of a particular mental model, whereas the latter consists of a dynamic set of experiences and corresponding mental models. In other words, architectural designers primarily rely on their own design knowledge and primarily use external representations, such as a graph in the semantic web, a sketch or a physical model, as external mediators for their design tryouts. This indicates the bounded impact that current information systems have on the complete design process: information systems that provide support to designers should primarily be considered as additional parts of the world, with which architectural designers can engage for making design tryouts. Similar to a paper and pencil environment, a CAD system or a simulation environment allows a designer to make design tryouts. This is how information systems are generally used nowadays, knowingly or not. Also the suggested linked data approach results in such an information system support.

Nevertheless, information management and exchange among information systems for design tryouts can be notably improved with semantic web technologies. Links can be made between different representations of information residing in different information systems. This can be done both in a static and direct way, using explicit links, or in a dynamic and indirect way, using complex rule sets. Additionally, designers have improved facilities to model aspects of a design situation in their terms and concepts, and link these to concepts residing in information systems. This can bring improvements to standard applications (modeling, archive, calculation, and visualization applications) which are then able to customize their functionality based on the designer's information.

Also far more complex functionality can be provided from within a design tryout environment. Based on the information provided by the designer, complex heuristic methods can be used, taking into account more parameters than human designers can in a time period that is shorter. As such, they provide extra environments for making elaborate design space explorations in a very short time. When coupled to generative techniques, such systems might provide specific suggestions based on findings that result from the considered design space exploration. In this context, a linked data approach with semantic web technologies enables designers to construct their proper representations of the design situation, so that far more customized design space explorations or generative designs are feasible. As such, they could bring designers another step closer to expert agents that take only a part of the design situation into account, but that are at

least more easily tailored to the designer's needs in this specific design situation.

This leads to the final conclusion of this thesis. The suggested linked data approach based on semantic web technologies can to some extent improve the two main issues currently encountered in information system support for architectural design. In this case, information systems are to be considered as tools for design tryouts, in which information is presented for a designer to interpret, and the way in which the designer makes this interpretation cannot be 'managed' or 'determined' in any way. This approach will most probably not be able to completely address the interoperability issue and the functionality issue. Nevertheless, the linked data approach can bring significant improvements to both issues, because of the improved possibilities for information management.