

Shared Design-Web-Space in Internet-Based Design

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1. Introduction

1.1 Web-based computational studies in architectural design education

The introduction of the computer into architectural studies has resulted in innovative pedagogical approaches to design education. In recent years we have employed a teaching approach in which the student models the formalization of design knowledge in a computerized environment and experiments with the formal processing of this knowledge in the generation of designs (Oxman 1990). Interacting with the computer in the generation of designs requires making design knowledge explicit and formalized. *Knowledge modeling* is an approach to design and education in which the designer models the design thinking involved in the making of the object. In this process appropriate computational technology is essential to support and enhance certain phenomena of reasoning. From the pedagogical point of view such computational design environment appear also to enhance design learning and performance through the capability gained in computer modelling. In this respect, there is an analogous impact on the potential of design knowledge environments which can support design performance in practice.

In this paper we consider the Internet as a potential design knowledge environment. The nature of the Net as a medium for the representation, storage and accessing of *design knowledge* is presented and various research issues are introduced. The potential of this new medium as a resource for design learning, design practice and design collaboration derives from the attributes of the technology. We elaborate on the appropriateness of certain attributes of the medium as a potential design environment. Future possibilities of the Net as a *shared design resource* are proposed. Considerations of the Net as a collaboratively constructed design resource as well as a medium for collaborative design are introduced.

1.2 Shared Design-Web-Space

We present certain of the theoretical and research issues related to the concept of Shared Design-Web-Space environment for the representation and activation of design knowledge.

An experimental program is described in which the representation of various classes of design knowledge within Web documents has been developed by a group of architectural students. The formalization of this knowledge on the Internet has proved to be extremely challenging as an educational medium. Its utilization in the formal processing of designs provides a transparent learning environment. Furthermore, this pilot research and design program has helped to identify issues for further research and development such as shared knowledge structures in collaboratively constructed Web-based design resources. We have referred to this program as *Shared Design-Web-Space*. This work introduces the potential for the future collaborative development of shared design sites. We look at certain of the theoretical and research issues related to this powerful concept.

1.3 The Internet Design Triangle: designs-models-computation

Designs are what we are attempting to represent. *Models* are most important in the development of shared facilities. Shared representations require shared models. Models are underlying the representations of designs. By shared models I refer to the underlying conceptual structures constitute such fundamental aspects of the representation of designs as the underlying formal content and logical structure of the representation. The development of shared models is an important component of the research agenda upon which we are currently working.

Computational technology provides a particular environment which technically supports the modelling of design. These rapidly developing capabilities of the Internetmedium suggest important future possibilities for design facilities such as collaboratively shared constructed sites of designs.

We refer to these three components: designs, models and computation as the *Internet Design Triangle*. They include the designs to be represented, the shared models underlying these representations and the Internetmedia and technologies which can be employed.

The pilot program described in this paper has dealt with experimentation within the Web as an appropriate medium for the modelling of various classes of design knowledge. In our approach, currently emphasis has been placed upon the exploration of cognitive models such as typological and design precedent knowledge.

1.4 Shared Design-Web-Space: an experimental program and proposal for future agenda.

In the following sections we first characterize current attributes of the Net. These attributes are reviewed with respect to their potential contribution to the exploitation of the Net as a design resource. In the consideration of the implications of the characteristics of the Net, we also review certain of the problems associated with the current form and operation of the Net. On the basis of this review of characteristics, we propose a set of theoretical and research issues which must be addressed in order to achieve *shared design-Web-space*.

Following this theoretical introduction we present the results of an experimental program of design representation in the Internet. This program has emphasized a case study on the representation of design precedent knowledge within the Net. This particular modelling approach is based on the paradigm of case-based design. Theoretical issues related to the Net as a shared case-based design resource are presented and analyzed. Finally, future agenda for research and development are proposed.

2. Internet-based Design

2.1 The Internet and its potential for exploitation as a design resource

The rapid development of the Web as an electronic community (Negroponte, 1995; Mitchell, 1995) has resulted in an information-rich medium which has become a reservoir for, among other subjects, design information and design collaborative activities (M. Tan and Robert Teh, 1995). In the current situation the Web encourages the individual development of sites. The lack of coordination and resultant fragmentation of information creates a set of problems for accessing and navigating this huge body of data. Search engines tend to be domain independent further complicate problems of navigation. Norms for site development and the presentation of information are rare.

As a community - the design community, or the design educational community- it would be of great potential benefit to us, if we could focus collaborative efforts on structures, norms and procedures for the development of shared environments and domain-specific search engines.

We consider below certain of the endemic problems of the Net as a large and continuously extendible information system. Finally we draw conclusions with respect to the requirements of future *shared design-Web-space*.

2.2 Problems and issues

The current unstructured nature of the medium limits the potential for joint projects and shared activities which require a higher level of structuring in the representation of information. The following characteristics of the Net are problems which must be addressed in the development of future shared design resources:

- *Structure and organization*

Structuring is a subject which has implications for the functionality of the Net. Information structure, the way information is displayed and organized, has implications for navigation, browsing and search. Navigation is dependent upon the linkages which are specified by site developers. Linkages and references are currently hand-crafted and are dependent on the individual views of the developer. If we are interested as a professional community to collaboratively develop a shared source of knowledge, we require accepted structures and models behind the organization and presentation of design information.

Among the issues for development which are raised by the problem of structure are how associations can be related, or linked; how knowledge can be organized and presented, etc. in ways which can enhance their functionality as design resources. This proposition of accepted common structures also underlies the possibility of the collaborative development of design knowledge resources within the Net.

- *Domain dependent Vs domain independent information bases*

Given the quantity of information now available in the Net and the open introduction of information without guidelines or restrictions, finding and exploiting material becomes extremely inefficient. One potential solution appears to be the employment of domain specific organizational media such as indices based upon domain specific vocabularies. This would appear to provide improvements with respect to search and linkage.

- *Textual Vs graphical representation*

Today it is possible to make references, or to access information, primarily through textual means. Current Net tools such as Map-Edit support graphical indexing in a limited way. This possibility of graphical indexing is obviously of great significance to design resources in the Net. This would relate to possibilities such as the search for similar examples based upon their graphic content. In the case of the provision of such facilities research problems relate both to models for graphical coding of design solutions as well as to the development of computational tools which might support such search.

- *Passive Vs active presentation*

The Web has so far operated as a computational media for disseminating information to distributed locations. However, interaction with the information is still static, or passive. The Internet supports the presentation of information, either in 2d or 3d, in animation, video, etc., but does not adapt and respond to specific requirements of users. With the development of new programming languages such as JAVA, there are new possibilities for the inclusion of programs and algorithms within sites which enable operative characteristics.

This raises the issue of how to support in a more effective way the activation of information and knowledge rather than presenting static documents on the Web.

We have reviewed four broad categories of Net characteristics which appear to have significant implications for Net-based design resources:

- structure and organization for shared sites;
- domain specific indices enabling more efficient search and utility;
- graphical indexing for more intuitive search
- interactive knowledge-bases.

In the following sections we will consider these problems with respect to our current research.

2.3 Towards a Model for Shared Design-Web-Space

We propose one model for a Shared Design-Web-Space. This model proposes a general approach to the representation and structuring of design information. Furthermore, this approach also provides a basis for the establishment of domain-specific indices for design solutions. It also provides a foundation for the identification of elements of designs which may function as a graphical indexing for designs. This approach will be exemplified within the field of architectural design.

The general model which underlies this approach to *Shared Design-Web-Space* is based upon cognitive models and schemas of design representations. That is, beyond the graphical presentation of the design itself as characteristic of current Web presentation, the proposed approach would provide underlying knowledge as well as information such as views, plans, etc. That is, beyond the provision of general information, a Shared Design-Web-Space should provide knowledge which would support the understanding, reasoning about, and re-use of a precedent.

Such an approach can be developed through the application of computational concepts and models. In recent years we have attempted to develop formalisms for the representation of cognitive-based representations of design knowledge which can be exploited in design and design reasoning processes (Oxman 90a; 90b; 94, 96). Among the forms of design

knowledge representation which we propose as relevant candidates for exploitation in *Shared Design-Web-Space* are the following:

- *precedents* (related to the computational paradigm of case-based design): This approach provides a representation of the solution as well as potential decomposition of the solution description as a set of separate design ideas (chunks). It suggests a potential inclusion of rationale for the re-use of the solution (in CBR terminology: case-adaptation).
- *typologies* (related to the computational paradigm of prototype-based design): Within the representation of designs it is possible to provide a representation of the schema, or prototype, which underlies the specific solution. In addition, the representation would include the steps of the process of refinement, or the development of final solutions from the source schema. The representation of the schema and refinement procedure would enhance the possibilities for active rather than passive representation of knowledge.
- *indexing schemas*, including analogical and graphical indexing for references of similar designs (related to the computational paradigm of case-based design) : finally in addition to the two forms of representation proposed, we propose the need for development of domain specific indices and search schemas.

3 The Internet as a case-based phenomenon

CBD (Case-based Design), developed as a domain-based application of CBR (Case-based Reasoning). This is a cognitive-related computational theory which has now been applied to the modelling of design. A foundational research priority in CBR is to model human reasoning in the re-use of past solutions. Since the re-use of the experience of prior solutions in all of its complex phenomena is characteristic of design, CBR is a highly relevant technology for design fields. In order to differentiate CBD, we refer to it as Precedent-based Design, since prior design solutions which have something to contribute to current design problems function as design precedents.

In the behavior of Net users as well as in the construction of sites, we can observe case-based phenomena. For example, indexing, browsing, down-loading and re-use of material are all phenomena which have an analogous relationship with CBR (Oxman, 1996). This affinity of the Net as a resource-base and its relationship with Case-based Reasoning suggests possibilities for a new form of development of design resources within the Net. CBR has developed a rich experimental and applicative technology which has recently resulted in CBD systems in different applicative fields and tasks in design. In constructing design resources within the Net, we can derive much experience from approaches in CBR including search and adaptation paradigms.

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With the development of Network technology CBD appears to be entering a phase of new developmental potential. The Net already functions as a large case-based system. What is required in order to enhance the performance of the Net as a world-wide CBD system? What foundational work is necessary in order to enable collaborative activities towards this end. Should we entertain the idea of an international research program to develop a global Shared Web-Design-Space? If this is a desirable objective for our community, should this effort be conceived of as a collaboratively developed Case-Based global site?

Certain issues related to this potential are relevant to advancing this possibility :

- the Web as a global design case-base: large scale case bases, their function and performance requirements;
- collaborative development and usage of design cases: the possibility of a jointly constructed and collaboratively maintained design resource site;
- standardization of the representation of information in a format which, beyond the visual information: this requires the acceptance of a model and structures for design representations which can function as the basis for shared design-Web-space.
- design search engines based on semantic taxonomies for design: how to develop semantic, or conceptual, taxonomies to support linkages and browsing; can semantic Nets of design issues and design concepts furnish convenient category sets for a global indexing schema?
- design search engines based on graphical design ontologies: is it possible to enable graphical indexing and browsing, to index designs according to a graphic design ontology without use of the textual index ?
- automation of indexing and linkage: can the process of index creation be automated;
- interactive design: what degree of interactivity within the site is possible and how can it be achieved? How can the record of interactive activities and results be preserved and communicated further?
- case acquisition in the Net: how are new cases are acquired and introduced;
- adaptation engines: to assist in re-use.
- general vs specific adaptation engines: should the adaptation procedures be general or specific to the case itself;
- legal issues: legal problems related to the re-use of intellectual property in the form of designs, design representations, etc.;
- refinement and adaptation of design cases: how can we in future generations of Web sites achieve the dynamic and interactive activation of information and knowledge rather than merely presenting static documents on the Web.

4. CBR as a Cognitive Model for Shared Web-Design-Space

4.1 The ICF formalism as an indexing Network schema

Our current work deals with the representation and interactive use of designs in a future archives of shared, interactive representations of designs. In order to support collaborative activities, we explore a structuring ontology for the representation of design information. The order of knowledge in the representation refers to three coordinated levels of design knowledge employing the ICF (issue, concept, form) formalism (Oxman, 1994) for the representation of chunks of design knowledge in solutions:

- issue: domain specific semantic information related to goals and design issues of the problem;
- concept: domain specific semantic information of the particular design task in the form of a Network of solution concepts;
- form: physical design information, particular to the detailed formal structure of the design object.

In the example described, the ICF formalism was employed to establish a common structured representation for design information in the development of a shared site of design projects in the Web. Beyond the simple objective of representing design objects, the formalism provides a structure of representation which emphasizes the encoding of design rationale and method as well as the causal relationship between the formal and functional elements of the design. Given the structured nature of the representational set, and the significantly developed relationship between textual and graphic content (semantic and geometric modeling) in ICF, this ontology preserves a high level of specific representational flexibility within sites while providing the essential structure to support queries, search and linkage of sites.

Potential for browsing is significantly enhanced by the independent searchability of the three levels in the ontology: design issues and design concepts as domain specific semantic Nets; and interactive formal representations of solution principles as represented by a formal aspect of the design.

Our current work is attempting to explore the issues outlined above is a series of research related studies in the program of Graduate Studies in Faculty of Architecture and Town Planning, Technion. Over the next semesters we plan to build upon the findings of this pilot program in order to systematically address the issues related to the construction of shared design-Web-space. This is a brief report on the first results of this long-range objective.

4.2 Case study in representing design case knowledge on the Web: Regionalism in Architecture (http://arrivka@technion.ac.il/~rivka/inter_caad.html)

A set of domain-specific semantic information related to goals and design issues of the design problem is explicated and can be employed as part of the indexing system for cases in the Web. Among such issues are: topography, controlling the view, content of elements, content of vernacular architecture, regional attention to natural physical forces such as light, spatial institutions, materials and technology, etc.

Design concepts employed in a collection of design precedents exemplify conceptual approaches to the design solution of these issues in selected examples of regional architecture (Done by Anat Sarid, Ruth Rotenshtriech, Shoshi Bar-Eli). In the current case-base precedents have been drawn from case studies of the Mediterranean House, a sub-class of regionalism for which the case-base provides a collection of important precedents. Within the case-base specific formal elements are identified which provide formal solutions for the significant issues.

The collection of examples which constitute a case-base for the Mediterranean House provide, through the acceptance of a given model, a means to address certain of the theoretical issues in constructing structured shared design-Web-space sites. This model also addresses many of the other issues such as domain-specific indexing, etc. which were outlined above.

4.3 Case study in representing typological knowledge on the Web: Historical Religious Buildings (http://arrivka@technion.ac.il/~rivka/inter_caad.html)

This collection of examples of historical religious buildings employs a typological model for the construction and organization of the site (Done by Zili Gur). There is emphasis placed upon a syntactic definition of the components of these buildings as a basis for the definition of types. Thus typological schema are developed out of a set of component elements of syntactical content. Both levels, the syntax and the typologies can be employed as indexing devices. A schema of refinement is typologically specific and is illustrated within the representation of the case studies. The case studies in this pilot program are a library of church types from various historical periods.

5. Computational tools

What are the possibilities and limitations from current computational tools to the achievement of our objective of *Shared design-Web-Space*. As we have attempted to indicate relative to the "Internet - Triangle", the great need for accepted models appears to be one of the most important prerequisites for such a collaborative effort. In the following section we provide a preliminary review of the tools which we have employed in the pilot program as well as some comments on current technological developments.

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In our current work we have employed the following Net tools:

An HTML language for textual descriptions, and the construction of HTTP references. We have employed Map-Edit for the edition of forms and image maps in order to achieve graphical indexing and interactivity. This tool, employs geometrical entities such as squares, rectangles, polygons etc. for the editing of specific objects and image maps. The disadvantage of Map-Edit is that it requires a re-identification of objects. What we expect from a referencing tool is the ability to identify a certain object or grouping of objects interactively. This probably requires a link with a VRML tool which is employed for visual presentations and graphical descriptions. We are currently considering the use of JAVA for achieving dynamic icons and animation processes. The installation of algorithms for refinement and adaptation are still in a research stage.

6 Conclusions

The Web has opened up opportunities for the collaborative development of Shared Design-Web-Space in Internet-based Design.

Already, new systems for browsing, searching and sharing textural and graphical information are beginning to play a major role in the Net computing. The paper has identified problems and issues in the way available Net technology is employed in the development of design sites. We have proposed the use of cognitive models in order to overcome limitation such as lack of structuring and for addressing indexing problems. A particular approach was presented which utilizes case-based reasoning as a possible general model. We have examined the inter-relationships between theoretical issues in case-based design and their potential application in the Internet. Finally, a report was given on a pilot program demonstrating how the employment of this model assists in building shared design sites exploiting current Net technology and tools.

The concept of Shared Design-Web-Space is an idea whose time has come. The rapid development of the Web as, among other things, a resource of design information is already a fact. It shows promise of great potential for the design professions. The great challenge is to exploit this potential intelligently. Whether we can act collectively to create global design resources is part of this challenge. A corollary is the ability to transcend the temptation to simply use the Net as a convenient filing system for conventional presentations of design information. The Net challenges our understanding of design knowledge and our ability to exploit leading edge technology to represent it in a manner which will ultimately improve the performance of the design professions. This is perhaps the greatest challenge of our generation.

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