20 TYPES AND DOCUMENTS: STRUCTURING BUILDING PROJECT INFORMATION

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Abstract

We describe a methodology for integrating a number of design documents of different formats within a single information structure. When this integrated structure is highly related, it provides support for effective searching and browsing of this information. To achieve such relatedness, we consider a notion of types from architecture as a semantic structure for project document management in the AEC industry. We discuss specific techniques to support this use of types with respect to EDMS's and Web-based project management systems. We describe a prototype application, a presentation tool for architectural analyses that combines these techniques.

Keywords: *types, EDMS, document classification, information structure, recognition*

INTRODUCTION

Building projects are expressed in a variety of documents presenting different aspects of the building. Web-based project management systems are gaining ground as environments for organizing and managing these documents. However, a common problem of such systems is that they either offer only a loose organization of the design documents or, on the contrary, impose a rigid structure. We propose a methodology for increasing the effectiveness of such a system that does not impose a fixed frame of reference. This methodology integrates a number of design documents of different formats within a single information structure. When this integrated structure is highly related, it provides support for effective searching and browsing of this information.

The first part of the paper introduces a notion of types from architecture and explores how this notion can be beneficially applied in the area of information management for the AEC industry. The second part of the paper discusses specific techniques to support this use of types with respect to Electronic Document Management Systems (EDMS's) and Web-based project management systems. The third part describes a prototype application, a presentation tool for architectural analyses that combines these techniques.

TYPES: A CONCEPT FROM ARCHITECTURE

Within a discipline, members commonly share a definition and classification of common concepts. This structuring of shared knowledge through common concepts gives insight into that particular discipline (Leupen *et al.*, 1997). Architects generally classify building designs based on spatial and formal features. This classification features the concepts of type and typology.

The concept of building types plays a central role in architecture, although there is no single definition of type and various approaches to the subject exist (Madrazo, 1995). Building types generally define classes of buildings that have common, often functional, characteristics. For example, we can define museums, offices, or libraries as building types. However, the functional classification is not the only aspect of building types. Generally a type can be described as the encoding of prominent features of a design object. Such features include function, form, and context. According to Moneo (1978), a type can be "defined as a concept which describes a group of objects characterized by some formal structure. It is fundamentally based on the possibility of grouping objects by certain inherent structural similarities." Type as a formal structure embraces a vast hierarchy of concerns from social activity to building construction. The relationships between all these aspects and the elements that make up the whole define the formal structure.

Types in architecture assist, besides the communication of shared knowledge, analysis of existing buildings, and design of new buildings (Leupen *et al.*, 1997). In analysis, one gives names to aspects of buildings and describes how these fit into a composition, resulting in an "analytical typology" (e.g., Madrazo, 2000; Flemming, 1990; Mitchell, 1990). In design, a reproducible system of design choices is stored in a "generative typology" (e.g., Achten, 1997; van Leusen, 1994; Gero, 1990). Within a generative typology, a type can be considered as bearing a specific design experience for a specific situation (e.g., a design aid).

Studies that make use of typological classification have established a rich body of architectural knowledge. Exporting the notion of classification using types to other domains, such as project document management in the AEC industry, may also deliver important results. We discuss three points where the concept of types is of interest in such a context.

Separation of Syntax and Semantics

Types in architecture are highly conceptual. Types define classes of design objects that share common characteristics. The designs themselves are represented through design documents, e.g., texts, drawings, models. A design document is associated with a conventional image of the respective type or class of objects. This association is understood both by the creators and by the users of this object, be it a building, a window, or a chair (Lawrence, 1994). Type as a concept has no notion of representation. Instead, relationships between types play an important role. This results in a semantic structure of types and relationships. However, it does not impose any particular structure on the design document depicting an instance of a type. The explicit linking between documents and types may be achieved simply through assignment.

An EDMS offers a framework for a flexible organization of documents, treating the individual documents as entities or objects that are organized and related according to different categories and attributes. However, simply specifying one or more keywords for each document does not provide the powerful organization that successfully assists users in retrieving documents of interest. A semantic network describing the document's composition, as in a product model, is too rigid (Tunçer and Stouffs, 2000). Taking a middle way between a collection of categorized documents and a full product model is desirable. Separating syntax and semantics allows the semantic structure to augment the document structure without imposing a specific compositional structure. This separation provides extensibility and flexibility within a system without imposing a fixed frame of reference, as the semantics can easily be altered without an adaptation of the syntactic structure. Types can be imported as a network of concepts, organized according to their relationships and dependencies, then associated with documents.

Semantic Structure

We can consider types in their most simplistic form as keywords. Keywords are commonly used as a means for the categorization of documents in EDMS's. An analogy with types adds a notion of relatedness to keywords: a type is related to and dependent on other types. According to Johnson (1994), a relationship has first to do with identifying characteristics of elements. These make the elements recognizable as belonging to some family of elements. Second, a relationship relates to the distance between the elements, be it abstract, conceptual, mathematical, semantic, or physical distance. Relationships between types result in formal and spatial organizations and ordering principles (Ching, 1979). For example, relationships can be expressed in the form of a hierarchy. As types are associated to documents, in the form of keywords, relationships between types induce additional relationships between document entities that otherwise do not exist. These additional relationships tighten the information structure, already defined by the document entities and their relationships. Such a tight information structure provides support for effective searching and browsing of an information space (Tunçer and Stouffs, 2000).

The semantic structure may also facilitate the assignment of types to document entities. When types or keywords are organized in a structure, these are more easily visualized and conceptualized. Effective visualizations allow efficient and fast access to data, and provide a better overview of data entities (Papanikolaou, 2001). Effective visualizations that facilitate visual exploration and manipulation support the process of relating appropriate types or keywords to document entities.

Various Formalizations

Types in architecture usually have various formalizations related to them. Formalizations of types make it possible to search for instances of types within documents of different formats. Since types are conceptual entities, with images of these associated to design documents, the format of a document defines the respective type's formalization: as a keyword, an image, a sketch, etc. Formalizations of types in different formats can assist in automating the classification of documents by automatically recognizing instances of types within documents. This automation facilitates the process of relating and categorizing documents within an EDMS. It also supports the creation of a component view of a document. Recognizing instances of types in documents provides both qualitative and quantitative information about the importance of a type for a document. Furthermore, it enables a specification of exactly which part of a document a type applies to.

The recognition of document components corresponding to types further increases the relatedness of documents in an EDMS. Going back to the concept of a tight information structure, an enumeration of the different types of relationships that exist between documents assists in establishing how the organizational structure supports effective searching and browsing of documents. In this organization, keywords or types, which define the semantic structure, are related within a network. These keywords are associated with documents. Documents that share a keyword are implicitly related. Furthermore, since keywords are organized in a network, their relationships add to the relationships between documents. The level to which this relatedness is considered is flexible. Finally, document decompositions create additional relationships in the form of document component hierarchies.

The result of these various relationships between documents is a tight information structure defined by the relatedness between documents offering new possibilities for accessing, viewing, and interpreting this information. First, it allows one to access specific information directly instead of requiring a traversal of the document hierarchy. Individual components can be reached and retrieved more quickly when provided with more relationships. Second, components can be considered from a different point of view. The location of a component in the structure is no longer only defined by its place in the document hierarchy. Instead, components provide direct access to other related components, forming a part of the first component's view. Third, one can access the information structure from alternative views to those that are expressed by the individual design documents. New compositions of components and relationships offer new interpretations of the structure and generate views not inherent in the structure as created by the original design documents. (Tunçer and Stouffs, 2000).

The conceptual nature of types in architecture allows various depictions of types in different formats. When types are represented graphically and textually, one can browse or search a

document-based system using any of the available representations of keywords. Such flexible representations are especially interesting for browsing information, when users do not have any specific query in mind (Gross, 1995). In an architectural analysis, such uses are plentiful, as users are not only interested in individual design documents but in an interpretation of the entire structure seeking information related to a concept of interest. Graphical representations of keywords, or types, are of great use in such a context.

TECHNIQUES FOR RELATING TYPES AND DOCUMENTS

We consider three techniques for achieving a tight information structure. These are the modeling of the type structure, the decomposition of the documents with respect to these types, and the use of recognition algorithms to assist in this decomposition.

Modeling and Visualizing the Type structure

The relationships between types constitute the semantic structure defined by these types. The form of this structure, however, is not predefined. It may be a linear structure, such as a chronological list of project phases. It may also be a hierarchical structure of types offering various levels of detailing. Furthermore, parts of the hierarchy may be reused as leaf nodes at various locations, resulting in a network structure, where elements can have more than one 'parent'. Elements within such a network may be further individually related, creating an even more complex structure. The structure's complexity can be extended or reduced according to individual cases. The overall structure may also constitute a combination of hierarchies and linear dependencies, describing different aspects or parts of a typology. In this case, the individual structures may be considered as different dimensions within the semantic model.

Elements of such a structure do not necessarily need to be considered conceptually as types in the architectural sense. Types in this context are used to denote the dependency between elements. When these elements are related according to a semantic structure, they are more than simple attributes.

The kinds and dimensions of a type structure results from the modeling of the semantics. The chosen model, however, also has an impact on how the resulting structure is visualized in order to facilitate an effective use of this structure in the process of augmenting the relatedness of project documents. Simple attributes can be presented in a 2D list view. When types have relationships and dependencies, this complexity initiates other ways of visualizing. These visualizations may be 2D or 3D, depending on which best fits the particular purpose (Tunçer *et al.*, 2000). A disc view in which the user can navigate, zoom, and pan seems to be very appropriate in the visualization of hierarchical structures (Papanikolaou, 2001). A dynamic visualization for visualizing relationships in a network is very appropriate (Plumb Design, 1998).

Decomposition View of Documents

The use of XML (eXtensible Markup Language) (W3C, 2000) for the purpose of describing a decomposition of documents related with types has many advantages. One of the strengths of XML for this purpose is its ability to represent information structures: how various pieces of information relate to one another. Once a structure is agreed upon, decompositions of existing

documents can easily be expressed in XML. XML also serves to integrate such a decomposition of documents into an existing Web-based EDM environment. When decomposing documents in XML, the effect of this decomposition on the structure and representation of the EDMS can be kept to a minimum. Rather than having to replace a document entity by its composition hierarchy of document components, the XML decomposition can be linked to the document as an attribute, simply as text. By interpreting this document attribute, the decomposed document structure can be retrieved and presented. In this way, both the flexibility and the effectiveness of the EDMS is improved without altering the structure of the EDMS, nor imposing any fixed frame of reference. Visualization approaches, as mentioned above, can also be integrated into an EDMS in order to improve on its expression. These can be plugged into the EDMS and can work on different levels, by interpreting the component hierarchy and displaying the relatedness of components from different perspectives.

Recognition of Components and Relationships

The process of document decomposition can be (semi-)automated using pattern recognition mechanisms and AI techniques. Within this paper, we are only concerned with text documents, images, and simple line drawings. Other formats will require similar, though different, recognition techniques. Image recognition mechanisms for images, shape recognition mechanisms for simple line drawings, and keyword or concept recognition mechanisms for texts can assist in presenting the user with suggestions about document components corresponding to given types.

When dealing with texts, neural networks and pattern recognition algorithms can pinpoint keywords in and extract key concepts from documents (Greenberg, 1999). Determining which sets of text are related is achieved by identifying content patterns in one set and recognizing the same or similar patterns in other sets. For simple line drawings, shape recognition algorithms can be based on the matching of distinguishable elements in the drawing and the type descriptions (Krishnamurti and Stouffs, 1997; Krishnamurti and Earl, 1992). In order to automate the process of decomposing images, we propose a four step approach. Starting with a collection of types whose instances may appear in these images, we proceed from the assumption that each type has an associated set of shapes and forms dependent on the current context that makes it possible to recognize this type within the images.

The first step is to determine the intrinsic structure (Barrow and Tenenbaum, 1981) of the scene, reflecting on the spatial properties of this scene. Using image processing and manipulation techniques, the appearance of objects is enhanced and objects' edges accentuated, thereby, providing preliminary object description data such as edges, surfaces, surface orientations and distances. This is done to reduce the large amount of information available in an image and to extract the useful information necessary for the next step. We intend to use neural networks for the manipulation of image data.

The second step is to determine boundaries and regions of the geometry by segmenting and grouping the features in the intrinsic images. The resulting segmented images are formed by gathering the feature elements into sets likely to be associated with meaningful objects in the scene, i.e., edge segments corresponding to polyhedral edges. Some domain-dependent information may be used in this stage in order to determine the type of a boundary curve and to

reduce noise. The form and shape information encoded within types plays an important role in providing this domain information.

The third step is the recovery of the geometry or shape of objects that make up the scene, from the line drawings resulting from the previous step. Information about regions and their adjacency, the relationships between boundary lines and vertices, and surface orientation information, enable the building of a geometric representation of the scene.

The last step is to interpret the geometry, matching it with a representation of instances of types that may be in the scene. These matches must subsequently be controlled and validated. The overlaps between the geometries of matches can be optimized. The neighborhood relationships of these geometries can be validated by relying on the relationships of types within the type hierarchy. Shape recognition and artificial intelligence techniques can further be used for the matching itself (Çiftçioglu *et al.*, 1999), and for the control and validation of matches. As an example, neural networks are widely used for pattern recognition (Inoue and Urahama, 2000; Bishop, 1995).

PROTOTYPE APPLICATION

We are developing an application that will combine the described techniques in the form of a Web-based tool for the presentation of architectural analyses in an educational setting. Analysis plays an important role in design and education. From a representational point of view, an analysis is composed of various abstractions describing different aspects of the building such as geometry, structure, context, and functional organization (Schmitt, 1993). These abstractions exist in a variety of formats. An information structure that integrates the different aspects of the analysis, such that the analysis can be interpreted and used in ways other than the original abstractions present, would be particularly useful in education. Examples of environments to build up, store, and present architectural analyses exist on the Web (e.g., Madrazo, 2000; Madrazo and Weder, 1998). These use keywords to organize and classify abstractions. This organization can be augmented by applying the methodology presented in this paper. Ottoman Mosques serve as a case study for this work.

The analysis presentation tool allows for a decomposition of documents by content using a hierarchical type structure. The input to the application is a set of design documents in the form of images, texts, and simple line drawings, and a type hierarchy. The output is an integrated structure of components and relationships. In between, a number of steps are traversed: documents are broken up into their components, and these components within and between documents are related through types. We are using XML for the purpose of decomposing documents and integrating these into a single structure.

Structure

The prototype application specifies two information hierarchies: types and documents (Tunçer and Stouffs, 2000) (figure 1). The type hierarchy specifies the semantic structure. The document hierarchy is defined by the collection of design documents and their decompositions. Both hierarchies are recursively defined.

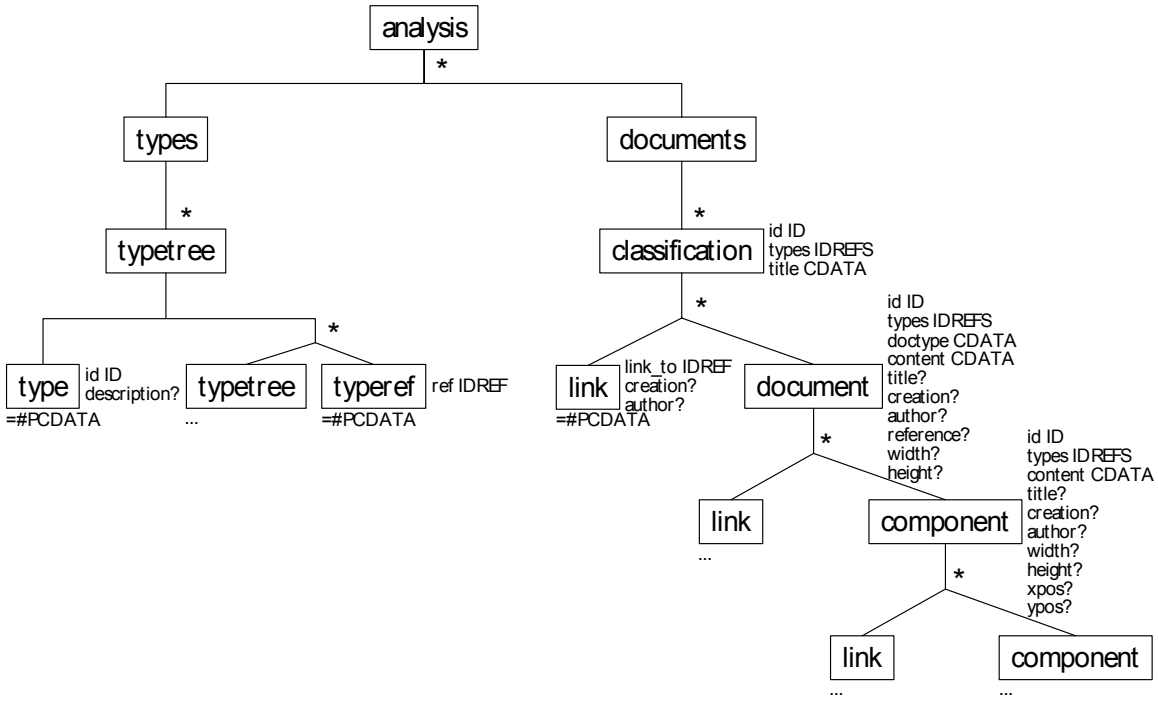

Figure 1. The recursively defined types and documents hierarchies. The grammar of XML, i.e., the DTD, specifies the structure of both hierarchies in the system: their elements, their nesting and additional properties, and their attributes.

The type hierarchy (figure 2) can be incorporated from an external framework or specifically defined corresponding to the subject of the analysis. The latter may require the hierarchy to be constructed across the viewpoints of different groups or users. As a result of the separation of syntax and semantics, this construction can easily be achieved, and altered even after documents have been decomposed. The structure is defined in XML by using the type name as the tag, and by nesting the elements according to the hierarchy. Each type is additionally identified by an ID, which is used for linking types to components. Below is a snippet of XML code for the definition of the type hierarchy:

```
<types>
<typetree>
<type id="t166">types</type>
<typetree>
<type id="t70">physical</type>
…
</typetree>
</typetree>
</types>
```

Decompositions of abstractions are expressed in XML. Each component is identified by an ID, and the component hierarchy is defined by using the ID as the index, and by nesting the elements. Types are assigned to components by their ID's. Below is a snippet of XML code for the decomposition of an image abstraction:

```
<document id="d6" types="t68 t66 t31" doctype="img" content="sehzade17" title="plan and longitudinal section" creation="2000-05-03 15:35:03" reference="3" width="769" height="1075">
<component id="d36" types="t68t t31t t66t" content="sehzade17-b" title="plan highlighting different zones" creation="2000-05-04 12:49:06" width="769" height="489" xpos="0" ypos="494">
<component id="d54" types="t48t" content="sehzade17-b-2" title="courtyard" creation="2000-05-08 10:00:42" width="423" height="489" xpos="15" ypos="494">
</component>
</component>
</document>
```

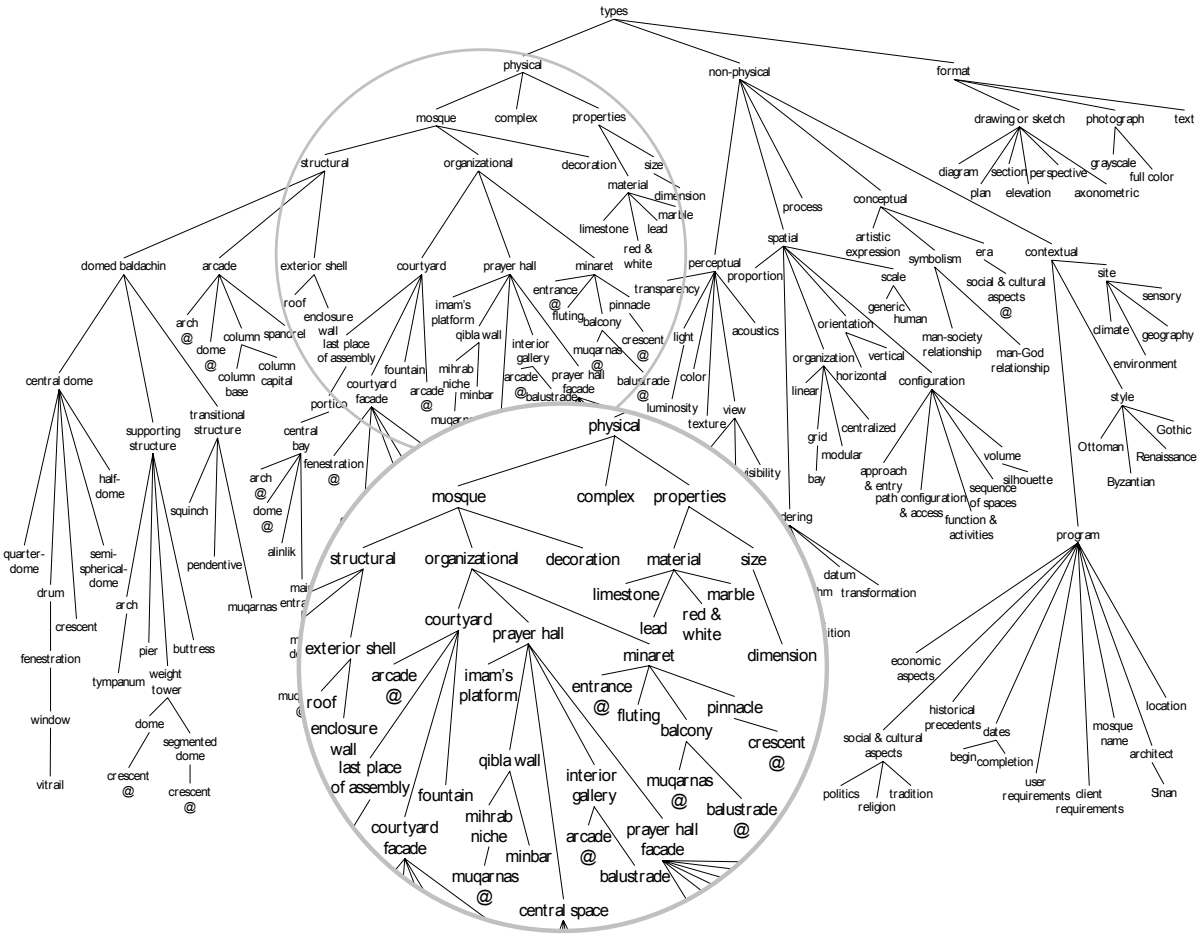

Figure 2. An exemplar type hierarchy, defined for the categorization abstractions of three Ottoman mosques. The keywords that are defined elsewhere in the hierarchy are marked by '@'.

In this organization, the abstraction hierarchy initially relates components. Additionally, components that share the same type are implicitly related. The type hierarchy further relates components, these relationships are derived from the nesting in the type hierarchy. Finally, explicit relationships between components can be specified as references to the component ID's. These are transferred to the XML structure as IDREFS tags.

The resulting XML structure offers a flexible source for further manipulation and traversal. Components can be selected according to their relationships and attributes, offering various views of the information structure. Views can be traversed and linked using both explicit and implicit

relationships. The XML documents are visualized through related developments such as XSL and XSLT, also using XPointer and XLink.

Interface

The interface allows the user to view both the type and document hierarchies and their relationships in an intuitive way. These views include both in-world and out-world views (Papanikolaou and Tunçer, 1999). An in-world view presents a component (or type) together with its immediate neighbors within the hierarchy, and displays all other components that share a type with it (figure 3). The in-world view allows one to browse the structure and interpret relationships, and as such lets the user be guided to interesting out-world views. Types mainly serve as binding elements in the structure providing semantic relationships between components. When traversing the information structure, the content as available in these components is of most importance to the user. As such, while the component's types, and their locations in the type hierarchy, may be presented as properties of the component, its relationships are given primarily as component-to-component relationships. This not only ensures that the links are presented as shortly as possible, tightening the information structure, but it also shifts the focus onto the content, rather than on the structure surrounding it. Types further serve a role as index to the information structure. Access to the analysis is provided through the collection of abstractions and from the type hierarchy.

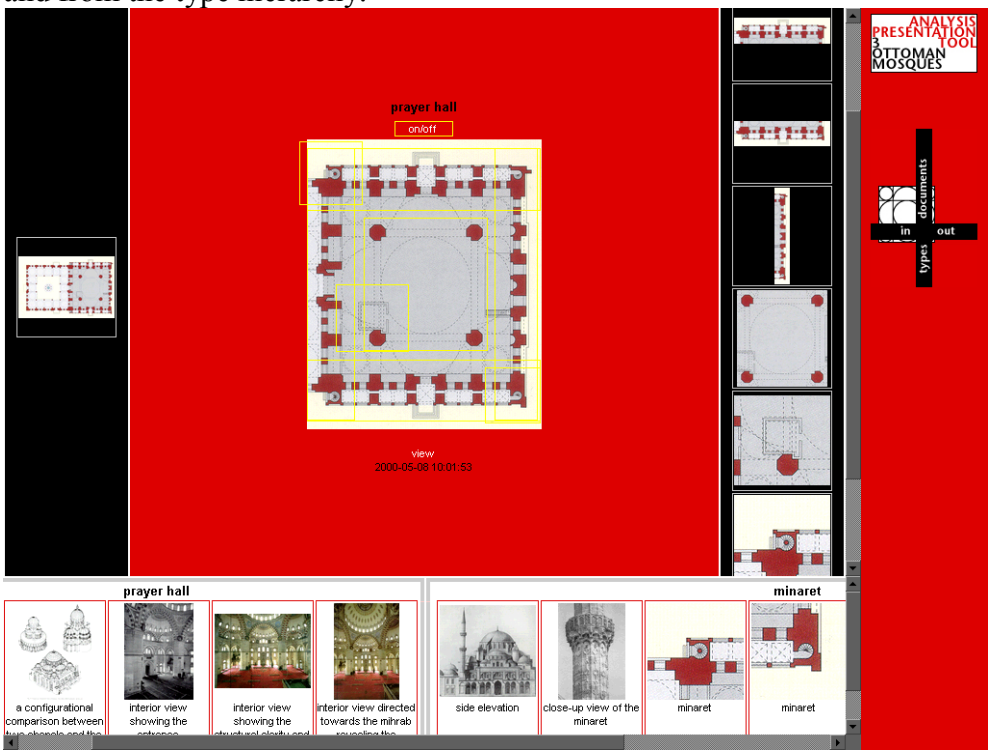

Figure 3. A snapshot of an in-world view from the prototype implementation.

In addition to the different in-world views, structural maps can provide visual feedback to the users on their traversals and offer selected views by presenting the location of the currently viewed node within the hierarchy. Such maps can be developed using SVG, X3D, and Java in relation to XML.

The presented approach provides the users with a simple interface and easy mechanisms for the presentation of an analysis of design precedents, and possibly their own designs. The system is designed in a way that the project grows as users add abstractions from different buildings, even from their own designs. Since all the information is integrated within a single environment, users will benefit from the different studies collected in the analysis, and can draw new conclusions across studies and presentations.

BRIEF DISCUSSION

We have described a methodology and its implementation as a tool for the presentation of architectural analyses in an educational setting. Our next step is to undertake an exemplar integration of this methodology into an EDMS in order to augment its capabilities to confirm the applicability of this methodology in this context. Though we have not attempted this yet, we are confident this will be successful mainly because of the advantages of using XML for document decomposition.

There has been a lot of research into the field of image recognition, especially in engineering. Remarkably, there are very few practical applications of this research in the field of architecture. With the advances in Web technologies, many institutions are placing their slide and image archives on the web (de Jong and van der Voordt, 2000; Gross, 1995). One can expect to have (semi-)automatic recognition mechanisms to be in place for the indexing of these images for effective and efficient retrieval. The functionality of such mechanisms in these environments should be pretty straightforward. We are hoping to have a practical contribution that would be of immediate use in this respect.

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