Abstract

Information systems increasingly appear as core elements of computer-aided architectural design environments. They provide the input and accommodate the output of automated and interactive procedures. The paper proposes the development of architectural information systems as an unobtrusive multimedia infrastructure in the background of specialized programs used for performing specific design tasks. Background multimedia systems facilitate communication between specialized programs by means of their compound representations. These combine different types of information and provide an overview of the overall system and of the processes implemented in it.

Introduction: modularization, representation and communication

The proliferation of computers in almost every aspect of professional, public and private life is a well known and widely publicized fact. The acceptance of the computer is also growing rapidly with the number of users and applications of computer technology. Nevertheless, computerization remains a recent phenomenon with consequences and prerequisites that are not always understood readily. Often there is significant hysteresis between the introduction of computer techniques and the development of useful, powerful and comprehensive tools based on these techniques.

One important consequence of its proliferation and acceptance is that the computer has become a truly general purpose instrument, applicable to a wide variety of information processing tasks. These range from small private matters, such as maintaining a list of telephone numbers, to significant contributions to the solution of professional problems, such as the calculation of a budget in a spreadsheet. As a result, the computer...
user works with a rather large number of programs with a limited scope each. Their number is moreover growing under the influence of a vision of modular software structure. This vision suggests that current programs should be segmented into smaller modules. Each program module performs a specific task like spelling checking in a variety of contexts with efficiency and supports connectivity with other, equally highly specialized modules which receive output and provide input to the module.

Such distributed, modular structures have significant conceptual appeal. They can decrease redundancy and lead to more elegant and better coordinated computer systems that can be augmented and customized at will. However, developers of software have the tendency to disregard problems arising from the application of their prototypical products. Expert systems based on just a few production rules and case-based reasoning relying on a tiny, arbitrary collection of cases are unfortunately not uncommon. Such shortcomings in academic research can be easily justified by its bias towards fundamental results and its structural limitations. Less acceptable are similar situations in professional software development. There interaction and utility are sometimes reduced to simplistic concepts that have little in common with the complexity of our current problems. For example, it was only after database management systems had reached a relatively high level of sophistication and large amounts of information had been stored in the computer that weaknesses in retrieval approaches and facilities were finally acknowledged and addressed (Locke, 1991), even though solutions to such problems had been available for several decades. It seems that the purpose of storing information in the computer, i.e., fast and precise retrieval, was and still remains less developed than storage structures and indexing. A foray in Internet in search of a specific item can be frustrating, time consuming and unproductive if the precise location and its accessibility are not known exactly.

Similarly the coordination and integration of specialized modules into a customized, comprehensive and coherent system poses several questions concerning interaction, communication and storage. Answers to these are often reduced to the technologies that can be used in the implementation of the solutions. The picture currently propagated is one of a knowledgeable, well equipped user who connects programs using little but common sense and devices such as OpenDoc or STEP on the basis of required input or requested output. While it is true that a number of such connections is indeed ad hoc, we are all acquainted with the problems of the resulting unstructured, unruly and unmanageable networks. Moreover, repeatedly inputting the same values and setting up the same connections is a tiresome affair that leads to reduced accuracy and reliability.

Links between different information processing procedures can be seen differently from links between the programs that perform the procedures. Instead of using the programs as the starting point, we should consider first the structure of information being processed. This structure forms an underlying pattern that constrains the applicability, scope and results of the programs. The information structure therefore forms the connecting tissue between the different tasks in a process, the container of input and output of the programs used for performing each task. An information system that contains such input and output is moreover largely responsible for generating the representations used by the computer or the human operator and for linkage between the different representations. In other words, the information system establishes and maintains communication between computer programs and between the computer and the user (the latter especially when the user does not wish do be confined to the scope of a single program).

**Multimedia information systems as background to design processes**

Following the above reasoning we are currently developing information systems that operate in the background and coordinate unobtrusively the
processing of design information by specialized computer programs. The goals of these systems include:

*The formation of adequate design representations.* These should not be limited by the requirements and capabilities of the computer programs that use the information conveyed in the representations. The representations should instead transcend the scope of specific programs or even categories of programs. This does not mean that we are working towards some unattainable holistic representation. We are simply aiming at richer representations which test the strengths and limitations of current design supporting systems and can therefore be used to determine their future development. A corollary of the use of several interconnected representations is that multimedia systems with their inherent ability to handle compound representations are an obvious implementation environment for our background information systems (Hodges and Sasnett, 1993).

*The provision of reliable communication between programs used for different stages and aspects of the design process.* A multimedia system is in principle capable of such communication. The compound multimedia representations can be seen as supersets of the representations used in the contributing programs: drafting and modelling programs, spreadsheets, text processors, etc. The primary obstacle is the storage structure of different types of information. Some information storage structures are amenable to subdivision into atomic components such as fields which can be grouped into records and files. For example, biographic, bibliographic and other textual information on buildings and their designers can be analysed into a logical structure of (mostly) alphanumeric fields with straightforward interrelationships. Other types of information appear in structures which are practically unusable. Digital images (scanned or rendered) are arrays of pixels that are usually manipulated as a whole by means of computationally expensive, time consuming image processing procedures. Yet other types of information have a loose, low level structure with little affinity to the symbolic level of the database logical structure. A CAD drawing, for example, is a collection of simple geometric objects. Groups of such objects form symbols of design entities such as spaces and building elements but the grouping relationships are mostly implicit: as with analog drawings it is human perception that determines the fusion of a straight line segment and a ninety degrees arc into a door symbol in floor plan. The permissible forms of grouping in CAD (such as standardized symbols and layers) are too arbitrary and loose to be seriously considered as a de facto structure in all cases.

The diversity and disparity of information storage structures poses a major challenge to the integrity of multimedia information systems. The symbolic representations of the conventional database logical structure and of most retrieval mechanisms presuppose an analytical organization of information. This is possible for textual and other information that consists of readily identifiable chunks but for images it requires extensive preprocessing. In most cases this preprocessing amounts to either a subdivision of the original documents in smaller documents comprising a single information chunk or interactive indexing of parts. Annotations in CAD files and hotspots in digital images are effective techniques for identifying and indexing parts of an image (Michon, 1992). However, being interactive and deterministic they are expensive, slow and possibly unreliable (especially when many indexers are involved or when the indexing assumptions are not comprehensive enough).

Our approach is based on automated recognition of relevant design entities in an image, namely building elements and spaces. Our working hypothesis is that the dual network of building elements and spaces – as in the dual graph representation (Steadman, 1983) – is sufficient for representing most aspects of built form. Techniques such as vectorization, skeletonization, template matching and constraint propagation are employed in order to recognize these entities in digitized architectural drawings (Koutamanis and Mitossi, 1993b; Koutamanis, 1995) and in CAD files (Koutamanis and Mitossi, 1993a). Recognition of building elements and spaces constitutes a form of document analysis aimed not at data exchange but at making explicit (and hence usable) the structure and symbolic content of the representation (Baird et al., 1992). While data
exchange schemes are preoccupied with retaining as much information possible at the highest level of precision without any pretence as to recovering the meaning of the image (Helpenstein, 1993), we aim at transforming the digital array and the geometric data into a symbolic network of architectural entities that retains just topologic and basic geometric information (Figure I). This information is sufficient for retrieving such entities in an image without human interpretation or indexing of the image as a whole or in part.

The coherent and comprehensive presentation of compound representations. In the introduction we stressed the strengths and limitations of the use of specialized programs for performing specific design tasks. An overview of the whole design process and of complete design aspects requires representations that transcend the confines of such specialization. One could assume that as long a user is concerned with a single task the corresponding program provides an adequate representation. However, this is not always true. For example, rendering a perspective of a new design is closely related to other forms of digital information, such as digitized photographs of the site for making a composite image; photographs of colour and texture precedents for the extraction of colour / texture palettes (Lenclos, 1989); and documents such as the building programme for checking requirements on the appearance of the building or climatic data of the site for fine tuning the rendering process.
In multimedia systems related documents can be connected by means of several mechanisms which result into dynamic, fixed or reconfigurable networks. The richness and versatility of such networks suffices for effecting the required compound representations. One evident danger is that we might mistake a simplistic juxtaposition / accumulation of relevant documents or information as the compound representation. This poses significant problems to the user who is bombarded with uncontrolled, unfiltered and incoherent information. For example, opening all documents retrieved by an Internet gopher search (i.e., all documents indexed under the query term) returns a highly redundant stack of windows without any usable overview or summary. The recent explosive growth of Web servers on Internet is an attempt to mould unruly information supply into a compound representation. But even if we set aside issues such as adaptability, extensibility and revisability, such integrated interfaces are a solution only for browsing. If a query is meant to support the execution of a specific task, then the results of the query should not obscure the task and its context. Even sophisticated multimedia retrieval systems tend to clutter up and dominate the computer ergonomically and computationally.
results of the information processing programs. The information system forms the connecting tissue between the different tasks in a process, input and output of the programs used for performing each task. An info that contains such input and output is moreover largely responsible for representations used by the computer or the human operator and for later representations. In other words, the information system maintains communication between computer programs and between the user (the latter especially when the user does not wish to be confused single program).

Multimedia information systems as background to design processes

Following the above reasoning we are currently working on the development of information systems that operate in the background and coordinate un the processing of design information by several specialized computer programs. The role of these systems includes:

- The formation of adequate design representations. These should not be limited to certain requirements and capabilities of the computer programs that use them.

- The conversions of the representations. The representations should instead be used as a database for the other representations.
Our intention is to make the underlying information systems less conspicuous, a supportive background to the programs used for performing each task. For this reason we are investigating minimal retrieval interfaces and interfaces that operate from within the specialized programs. The reason is that retrieved information should be made directly available at the location where it is wanted with a minimal effort on the part of the user. Figure 3 depicts an instance of seamless, unobtrusive retrieval and integration of background information. In a Web program showing night and day regions (used among others for radio wave propagation estimation), the current cloud spread is added to form a composite image. The cloud spread is automatically derived from another Web site with a minimal intervention by the user (choice of cloud representation). An architectural equivalent would be the addition of similar climatic information to a daylighting simulation. This information should be added directly to the rendering parameters on the basis of a user request within the rendering program. Having to leave the renderer, open another program, retrieve the climatic information, return to the renderer and finally adjust the lighting and background would discourage all but the more fluent computer users. And even then quite a few would find the sequence of actions rather tedious and might fall back on rule-of-thumb estimation of the relevant factors.
Extensive support of retrieval approaches. A multimedia information system as a background to specialized computer programs offers significant advantages for information management. Connections between programs with devices such as dynamic data exchange ensure that the system is always up-to-date, as changes in one representation are taken into account in other, related representations. The combination of several types of documentation, including dynamic images and aural records, into compound representations provides a semantically rich context for every information item. Yet retrieval remains a thorny issue. Mode and technological opportunity determine the majority of current retrieval approaches, with little consideration for the starting points of a query, the semantic content of the information system or the particular interests and capabilities of the user. As a result of our approach and because we are working in an educational context we are especially sensitive to such problems. By placing information systems in the background we have turned them into global support systems rather than self-sufficient
applications running next to specialized programs. In a sense these programs form special-purpose information processing modules of the background information systems. Consequently we have to ensure that the information systems offer a variety of connections (entry points) to the specialized programs. Moreover, the majority of the users of our systems are students with variable knowledge of architecture and computing. The entries to the information systems must therefore be adjustable and supportive to poorly formulated queries.

The above considerations suggest that the information system should provide a number of entries which serve as starting point for a query. Figure 4 shows entry points in a multimedia information system developed for the Dutch Government Building Organization. The system offers a geographic entry, a typologic entry, a natural language query interface and several overview lists automatically compiled on the basis of the current content of the system. Initial tests show that users make intensive use of all entry points. Some have a strong preference for a specific entry but most use several entry points depending the context of the search. In developing the system almost forty percent of the project duration (twelve months) was spent on developing the retrieval system – a percentage equalled only by the time spent on the development of the representation of spatial data.

Providing sufficient entry points is only part of the retrieval process. Different search modes, such as fixed customized hypermedia interfaces with full text capabilities for browsing, natural and controlled language retrieval and graphic query systems, should also be available. Their combination with the entries and the representations used in the database ensure a large number of alternative routes in the system. Choice of a particular route is almost always a matter of experience and circumstance. Of particular importance is controlled language retrieval, even though it is not common in multimedia information systems. Controlled languages have the advantages of high precision and recall, increased relevance feedback and multilinguality and the disadvantage of regular maintenance (Koutamanis and Mitossi, 1992). They can also be combined with the products of automated recognition for the retrieval of graphic information (Koutamanis, 1995) and facilitate the operation of a background information system: while the user is busy within a program, the system can anticipate forthcoming queries by forming expectations and subsequently selections of data on the basis of broader or related terms of previously used query terms.
Applications: reference information and monographs

Teaching at the Faculty of Architecture, Delft University of Technology, is organized on a thematic basis. For a period of six weeks students study a specific cluster of architectural subjects. CAAD teaching is accordingly organized around specific problems and the computational methods and techniques that can be used for their resolution (Koutamanis et al., 1994). The connecting tissue of the different CAAD courses is a
potentially extensive multimedia information system that supports student activities within each course and correlates the courses with each other by reference to a general background of architectural information. We concentrate on two main issues: the inclusion and integration of reference information and the design and utilization of electronic monographs.

Every CAAD course at Delft requires study of precedent and reference information, such as relevant design solutions, component catalogues and building and professional rules and regulations. Such information is currently being computerized by a variety of external information providers. Already available are an online database of the current Dutch building regulations and databases of building components on CD-ROM. Integration of such information in our exercises is of paramount importance for the training of the future architects. However, the information providers are not concerned with integration problems but with the integrity of their own products. Letting the students merely use these products next to the drafting, modelling and analysis programs of each CAAD course has mostly negative effects. In particular the variety of interfaces and the linkage of information available in the databases to the programs in the framework of specific design tasks pose conceptual and technical difficulties for a novice user of CAAD.

Information available in the databases often plays an important role in the CAAD courses. For example, legal requirements on fire safety, daylighting or staircases form parameters for the analysis of designs by the students. Browsing the relevant building regulations in the database provides useful background information to the analysis and the parameters of the analysis. However, browsing is a slow, arbitrary retrieval mode. We are working on customized hypermedia interfaces which guide the students through the analysis and also permit retrieval of relevant
information from the building regulations database. The interfaces link the analysis with the search mechanisms of the database, as well as with the drafting and modelling programs which provide geometric information on the designs. The advantage of this approach is that the interface integrates all relevant information in a single structured package. Moreover, the interface is customizable and adaptable and hence appropriate for students with different knowledge levels. The disadvantage is that even the most flexible interface is necessarily confined to the theme of the CAAD course. Students interested in the subject of the analysis who are not following the course preferably use the database of building regulations directly.

The recent interest in case-based design testifies to the potential of precedent information. In architectural education precedents provide relevant information in a uniquely compact and direct way. A problem that remains to be solved is how to select, organize and present architectural precedents. We have opted for a rather safe approach, electronic monographs on specific architects. In these monographs the significant buildings and designs of the architect are documented and analysed with respect to both the usual abstract theoretical / historical criteria and practical, everyday aspects of the built environment such as fire safety, daylighting or stair ergonomics. Such aspects form focal points for CAAD courses at Delft and consequently serve as entry points for the study of the monographs and of the architects described.

The monographs are based on available analog information on an architect and his work. This information is digitized and structured into a multimedia database. The database consists of several interconnected modules (Figure 5). The most interesting are:

- **Biographic information.** This module has a flexible timeline structure loosely based on the principles of the *ChronoScope* project (Hodges and Sasnett, 1993). It presents textual and visual information (including digitized films and audio files) on the life and work of the architect. This module also forms the core of the hypermedia interface.

- **Visual information on buildings.** Archive and published visual material on the buildings by the architect is currently simply digitized, stored and indexed under a few basic terms such as the use type of the building, abstract typologic categories and morphological characteristics. In the future we intend to use automated recognition in order to transform the images into symbolic representations.

- **Simulations.** On the basis of the analog documentation we make CAD models of selected buildings. These serve as basis of interactive simulations such as walkthroughs and analyses of aspects which have to do with our CAAD courses. The reason for developing simulations is to link information with some form of experience with the buildings. Such linkage is seen as an essential component of an educational environment.

- **Games.** Games based on digitized information and computer simulations form an integral part of a monograph. They range from multiple choice question games on the buildings in the database to jigsaw puzzles on the basis of digitized images to configurational games which use shape grammar techniques to allow the user to design in the idiom of the architect. Such games are important as a creative outlet for students who have the opportunity to employ their knowledge and understanding of the subject in a relaxed environment.

- **Controlled language retrieval.** This module forms the most ambitious part of the interface. Based on existing controlled vocabularies such as *The Art and Architecture Thesaurus* and *Architectural Keywords* we are developing a short bilingual (Dutch and English) thesaurus for aiding and guiding retrieval. In a future version the thesaurus is also to include graphic symbols of building elements and spatial arrangements.

**Conclusions**

In the process of identifying problems and means for resolving them, and then trying to achieve reasonable solutions, researchers and educators sometimes get the illusion that they have reached some kind of final state from where it is possible to proceed to straightforward applications,
fully defined by the research results. Information systems have the tendency to shatter this illusion. Every new type of information, every new item, every new use of an information system poses new problems and gives rise to new ideas on the enrichment and improvement of the system structure and its facilities. This organic growth, coupled with the necessity to continually augment and update the content of the system, makes clear the dynamic character of information systems. Multimedia systems, in particular, are especially amenable to change following new technological developments in the digitization and storage of existing analog media. The systems we are currently developing will probably look terribly na’ive and outdated sooner than we expect. Nevertheless, the existence of rich, comprehensive information systems is a prerequisite for the improvement of computer-aided architectural design. Such systems cannot exist in isolation. Their connections to the specialized programs used for performing specific tasks are of obvious importance. Equally important is the overall structure of information systems and specialized programs which use and provide the information contained in the systems. Our approach is to attenuate the conspicuousness of information systems by placing them in the background of specific design tasks. There information is gathered and supplied to the programs performing the tasks in an unobtrusive manner. The application areas of this approach currently include reference information and monographs. These areas cover a wide spectrum of information types and present a variety of cognitive, ergonomic and computational problems that test the scope and applicability of the approach and determine the development of the logical structures, interfaces and other implementation mechanisms required by the approach.

References


