Multivalent Architectural Case Information for Creative Reasoning

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The theoretical underpinnings, practical and technical implementation of a multimedia database to support creative designing is presented through a prototype system which would go on-line in the near future. At the heart. of the system is the notion that architectural knowledge is multivalent - requiring the means for recombination in new and different ways to support design thinking. The system also attempts to deal with the practical issues of case building, 3D modelling, interface design and technical clarity.

Keywords: creativity, multimedia, case-based reasoning, computer-aided architectural design, architectural database, visual database, virtual reality.

1 Introduction

Those who insist that creativity comes from sudden flashes of inspiration in monastic seclusion and unique works created *ex nihilo,* reject an important propellant of innovation - precedence.

"To view past works -whether of art, or science, or architecture, or music, or literature, or mathematics, or history, or religion, or philosophy - as given or unique objects rather than as incarnations of *process is to close off the traditions of effort from which they emerged. It is to bring these traditions to a full stop. Viewing such works as embodiments of purpose, style, and form revivifies and extends the force of these traditions in the present, giving hope to creative impulses active now and in the future."* [Scheffler 1991; p41]

Those who appreciate the power of precedence would seek to understand the "purpose, style, and form" of a design problem by either visiting or reading up similar cases. A crucial purpose of studying architectural history, executing measured drawings or making field trips is to perceive how a particular work of architecture was made. A more expedient way (common among younger designers and those in a hurry) is to look up parallel works in current architectural journals and books with the intention of abstracting or adapting some aspects of the design.

We are concerned with improving the methods of collecting, storing and retrieving of all forms of architectural knowledge for use with creative designing.

It is clear that the actual works of architecture historically and technologically significant and inspiring as many of them are - cannot function as an effective design support information system. They need to be encoded in a form that can be suitably recalled at the place arid time when design decisions are made.

It is also clear that a 'product-catalogue' approach cannot, in principle, meet this requirement. This is because the aggregation of isolated elements or general components of design does not record design relations which articulates the themes and overall concepts of specific works or types of work.

We believe that a means towards a solution to the first problem of accessibility and the second problem of holistic representation of design knowledge lie both in 'interactive digital multimedia database'. Before describing a project that implements this idea, a review of the limits of conventional media vis-a-vis creative thinking is necessary.

2 Creative thinking and the limits of conventional media

We maintain the position that creativity is contextual, i.e., creative thinking stems from a knowledge of precedents and has to be accepted as an extension of the established boundaries of the field of knowledge and not an isolated innovation per se [Bruner 1973] [Csikszentmihalyi 1987] [Gardner 1987]. This implies that creativity must spring from competence within established disciplines.

The knowledge within a discipline can be represented in a wide range of forms. In architecture, there are some persistent difficulties due to the multidisciplinary and discursive nature of design knowledge:

(a) Non-sequential order
(b) Multivalent connections
(c) Unbounded collections

2.1 Non-sequential order

An individual item in a multidisciplinary knowledge base is often associated with more than one other item (figure 1). Anyone with a sizable slides collection will be familiar with this problem. Short of duplicating a slide for every possible group of related slides, there has to be a practical indexing system to regroup and ungroup sets of slides. This is of course the basis of hypertext applications such as Hypercard or the World Wide Web. By selecting one of the 'active' components of a page of information, the user is taken to a new location in the knowledge base specified by the destination address linked to that active component. An increasing number of information stations (in airports, shopping centres, exhibitions, major buildings, banks, etc.) and 'multimedia publications' (often on CD-ROM) capitalise on this technology.

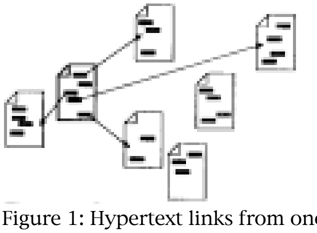


Figure 1: Hypertext links from one point in a knowledge base to many.

2.2 Multivalent Connections

Like chemical elements, discrete for of architectural information can be combined in many different and useful ways for case-based reasoning; cf [Alexander 1965]. For example, an article on aluminum cladding can be grouped simultaneously under "office buildings', "curtain wall technology", "metal building material", etc. (Figure 2)

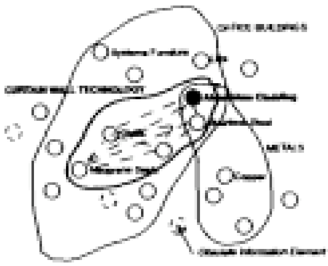


Figure 2: a diagram to illustrate the positions of information elements and their multivalent compounds.

Figure 2 also shows that 'valency links' (dashed lines) determined by a classification system can be used to form 'compound' information, e.g. "Curtain Wall Technology" would retrieve the five 'elements' bonded by connections determined not by knowledge within themselves (as in conventional multimedia publications) but by an independent classification system. The resulting 'compound' - as in Chemistry - is a unique, stable and coherent entity.

A multi-level classification scheme is necessary to provide sets of 'valency links' for meaningful and logical groups of information. In addition, it is imperative that there are multiple classification schemes which map into each other - a reflection of the many ways in which the world may be carved out; to borrow Nelson Goodman's term, "ways of worldmaking" [Goodman 1978].

2.3 Unbounded collections

Any knowledge base must be open to additional information because new knowledge is both necessary and inevitable. Moreover, some information can be superseded, revised or made obsolete. When knowledge is added or removed, the order and connections of the collection should remain functional [Tan 1994]. A classification system relieves the dependence on knowledge elements to maintain links, and gives greater flexibility for adjusting the contents of the collection.

3 IMFAGE and a means to support design thinking

The three issues reviewed above each give rise to a critical problem for a multimedia database to support design thinking, respectively:

(a) cross indexing of non-sequential order

(b) regrouping of multivalent connections

(c) adding to and subtracting from unbounded collections

These will now discussed with implementation strategies adopted in a research project called IMPAGE - Interactive Multimedia Presentation of Architectural Geometries by Example - funded by the National University of Singapore. Technical details are discussed in the next section.

3.1 Cross indexing of non-sequential order

Hypermedia is a step in the right direction but does not address all the problems raised so far. What it does provide is a common framework of representation to unify a broad range of information types. Architectural information in the equivalent form of drawings, maps, sketches, photographs, models, texts, calculations, audio and video recordings, can now be encoded and stored digitally. The well-known advantages are portability and integration.

The 'hot-wired' links from a point in the knowledge base to many other points appear to provide unstructured movement through the collection. However, these routes are predetermined. Choices, even though numerous, are limited by the routes prescribed by the author. In this sense it is like having a book with many cleverly interconnected bookmarks; and the ubiquitous 'home button' for those who get lost in hyperspace.

IMPAGE aims to take advantage of multimedia as a common media to integrate a full range of architectural representation. However, it recognises that new and revised orders are possible and necessary to refine and enhance the use of the repository. Contrary to Object Oriented Programming, the onus should not be placed on the discrete information themselves to establish links with other related information whether currently or in the future; not unless one is prepared each time to perform major surgery to transplant new links and redirect old ones to all relevant points within the repository. The task gets exponentially tougher and risks of errors increase as the collection grows.

The strategy adopted by IMPAGE is to free information from any direct links to each other. Instead, each discrete information is provided with a tag (not unlike a luggage tag). This way, the information can be freely associated with others as determined by a classification scheme which manages the relationships of different kinds of tags and the information they carry. The advantage of this approach continues into the other two critical problems.

3.2 Regrouping of multivalent connections

Information on a tag establishes its position (or positions) in the classification system. At the most fundamental level, this allows all media with the same tag to be gathered for viewing; e.g. all 'chairs'. Whilst this basic recall utility is useful, it lacks the sophistication and knowledge of relations in a classification system to regroup media based on a 'higher' level concept. For example, "furniture" would also recall chairs", plus other types of furniture, of course. For this reason, IMPAGE uses a classification system rather than a simple indexing system.

3.3 Adding to and subtracting from unbounded collections

The separation of media from its classification scheme enables new material to be easily added to the collection or obsolete ones removed without incurring tedious system maintenance. For example, as the World Wide Web grows, so too it seems, the frequency of 'media loss'- any change to addresses at destinations invalidates all the pointer links at sources. In IMPAGE, once a new media is tagged, it can immediately be recalled by a keyword match or by conceptual grouping within the classification system, along with similarly tagged media. In the same manner, removal of a media (and its tag) would not litter the interface with "media not found" messages.

3.4 Making cases

The strategy for developing cases was first to assemble distinct presentations with a self-contained storey-line. But because the links between the discrete media files are maintained separately, new cases either within existing ones or across cases can be assembled. Three test cases were selected for the IMPAGE prototype implementation:

(a) 7 South East Asian traditional houses.
(b) the Hong Kong and Shanghai Bank Headquarters, Hong Kong.
(c) the Yishun Stadium, Singapore.

The selection was made for the following reasons:

(a) they represented the interest and expertise of members of the research team.
(b) the cases have important lessons for architectural education and practice.
(c) sufficient amounts of information are available to cover the cases, as well as providing cross comparisons.
(d) they represented a range of building types and scales.

Another two cases - both historic sites in China - have since been added to the original collection through separate research projects:

(a) Reconstruction of Chang'An
(b) Conservation of Historic Suzhou

It is envisaged that many other cases would be added to the collection in the near future.

3.4.1 Background of test cases

The South East Asian vernacular collection comprise six houses from Indonesia - *Riau, Karo-Batak, Toba-Batak, North Nias, South Nias and Minangkabau* - and one from Thailand. In the current collection are primarily wood frame buildings sometimes with minimal use of stone as foundation; roofing materials are thatch, sheet metal or corrugated sheets, or clay tiles.

The Hong Kong and Shanghai Bank Headquarters in Hong Kong, designed by Sir Norman Foster, was completed in 1986. It is considered a suitable test case because of its innovative use of high technology and its important contribution to late modernist architecture, urban design and construction.

The Yishun Stadium in Singapore is a contemporary building by the Housing & Development Board. The project consists of an indoor stadium and a sports complex which uses a cable-stay structure.

3.4.2 Forms of media

The following forms of media are used in the test cases:

(a) Text
(b) 2D Vector Drawing
(c) 3D Model
(d) Images (Raster)
(e) Video

Out of the above, 2D Vector Drawing and Video have not yet been integrated into the system although separate viewing modules are now available.

Considerable emphasis is placed on the interactive 3D model as the most important form of representation. It is expected to provide the basis for links to other relevant or related information in other forms which are inherently better for cultural and other supporting information.

Originally, a fully interactive and rendered 3D computer model, of the cases constructed to a level of detail equivalent to conventional 1:200 drawings, was planned. However, due to the unexpectedly large files needed to represent the model - over 100,000 polygons -the scope of work had to be cut back.

It is imperative that a design be viewed in a range of scales. On one hand, there needs to be abstract massing models to represent overall order, whilst on the other, largescale close-ups are necessary to represent intricate construction details. For the 3D model and drawing forms of representation, there are currently no means of automatically determining the appropriate level of detail for viewing from the same model. Therefore, several models at different levels of detail have to be created in each case.

3.4.3 Types of information

The types of information used to represent the test cases are summarised in Table 1.

3.4.4 Classification

The IMPAGE project incorporates a customised classification coding system to enable the case-builder to attach multiple 'tags' on each discrete piece of information. In addition, sets of information can be grouped as ordered lists or 'nodes for convenient retrieval of strongly related material. The system allows for easy editing and attachment of additional tags at future points in time.

Plans have been made to cross-index to more established classification systems such as the CI/SfB allowing both case-writers and users to transparently use a different classification system to access the host classification system.

3.4.5 Timescale and expertise

The most critical skill for case building is 3D modelling.

The minimum time needed to build a basic 3D model and to organise related data and classification information in each of the test case is two man-months. This does not include basic research in the library and field work to gather data and measurements.

Manpower requirements for case-building are non-trivial, particularly for digital construction of the 3D model. Even if the full set of working drawings of the case is available, it would take at least six man-months to build the case to a reasonable level of detail and acceptable level of accuracy. The digital equivalent of conventional 1:200 drawings is the recommended standard for case-building. It is essential to work off information at a higher level for digital construction of the 3D model, access to working drawings at 1:100 scale should be a pre-requisite for future cases.

To minimise the need for supervision, research assistants with a first degree in architecture and CAAD competence would provide the recommended level of knowledge, skills and design appreciation for case-building.

Media/Case	SEA Houses	HKSB	Yishun Stadium
Text	49 files from student dissertations and publications by Dr Indorf.	20 files from relevant sections of the AJ comparative study of HKSB.	77 files, including lecture and interview by the design engineer.
2D Drawings	none in vector format	none in vector format	none in vector format
3D Model	Models of 7 houses: - Riau House - Thai House - Karo-Batak House - Toba-Batak House - North Nias House - South Nias House - Minangkabau House	Model of the whole building and several detailed model of significant architectural and structural components	3 models in 65 files, covering site, stadium complex, indoor stadium.
Images	101 colour and black & white images documenting the architectural traditions of SE Asia.	50 colour and black & white photographs and drawings (300dpi) of the building exterior and interior, site construction in progress, freehand concept sketches, and presentation perspectives and drawings.	226 colour images covering all aspects of design and construction.
Video	none	1 minute excerpts from the HKSB commemorative colour video.	none

4 Technical implementation

This section deals with the technical issues of retrieval, viewing and filing.
(a) Retrieval with the Navigator
(b) Display with the Viewers
(c) Filing with the Repository

4.1 General implementation technology

The conceptual framework outlined in the previous sections is prototyped as hybrid implementation using a multi-media authoring system 'Galaxia" (developed at the ISS) with a built-in scripting language, 'ActionScript', customised to allow Standard Query Language (SQL) access to a commercial relational database, 'Informix Online (Figure 3). The implementation hardware are Silicon Graphics International (SGI) Indy, Indigo-2 and Onyx. (A Windows version of Galaxia runs on 486s and Pentiums.)

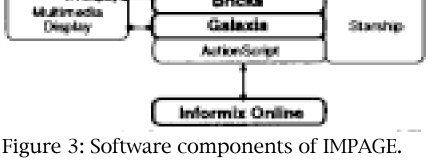


Figure 3: Software components of IMPAGE.

For interactive viewing of architectural models, a specialised Virtual Reality (VR) viewer written with the "Bricks" toolkit [Serra et. al. 1993] is utilised. The viewer is spawned via Unix shell calls, accessible from the scripting language.

Both Galaxia and Bricks are written in "Starship" (developed at the ISS) - an interpreted object-oriented language for multimedia applications [Loo 1991].

IMPAGE is structured in 3 levels (Figure 4):

(a) at the lowest level there is the repository within the Unix file system. Media files introduced into the repository are tagged using codes from the Classification System and meta-data about the file contents are catalogued into the inventory.

(b) the intermediate level is the creation of "nodes'. Each node has a caption and is a grouping of files existing in the inventory. e.g., a node could be "cable-roof forms" or "traditional structures" or "yishun-mast" and so on. It allows for generality as well as specificity.

(c) the highest level organises the nodes into linked hierarchies and lattices. Accessing any node enables the user to enter a hypermedia environment, of linked multimedia. Browsing can be via standard links, following the node structure, hypertext, or hotspots. Alternatively, the browser can return to the navigation system for direct query of the database.

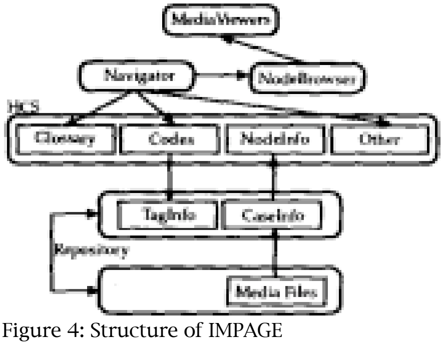


Figure 4: Structure of IMPAGE

4.2 Retrieval with the Navigator

4.2.1 Navigator

The Navigator is a Galaxia module that enables users to interactively query the Repository, by an interactive point-and-click interface. It allows the user to traverse the IHAA Classification lattice, [Indorf,1990], search the IHAA glossary and select the media collections associated with the keywords. (Figure 5)The advantage with this system of querying is the flexibility it affords the user in terms of relaxing or constraining the specifications. The Navigator passes the user request as an SQL select query to the underlying database. The returned list is then sent to the retrieved media window and the Viewer spawned. This set of retrieved media is organised at three levels, specified prior to executing the query:

(a) individual media files, displayed by their captions as specified by authors

(b) nodes, displayed by their icons.

(c) cases.

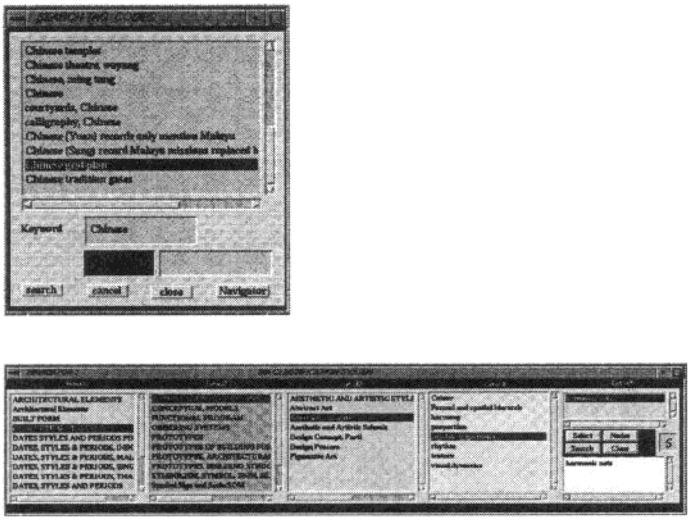


Figure 5: The IMPAGE Navigator

4.3 Display with the Viewers

4.3.1 Node Browser

The Node Browser consists of a node-hierarchy display window and a labeled retrieved media matrix (Figure 6). Any item in the matrix may be selected to be sent to the display. If the item is a media file, an appropriate generic viewer is spawned. If a node is selected, the node-hierarchy window displays a generated "map of the nodes that are themselves pointers to either other maps or nodes. The node pointers retrieve their collections from the database and send it to the appropriate interface, whereas the map pointers refresh the window and display the nested node-hierarchy.

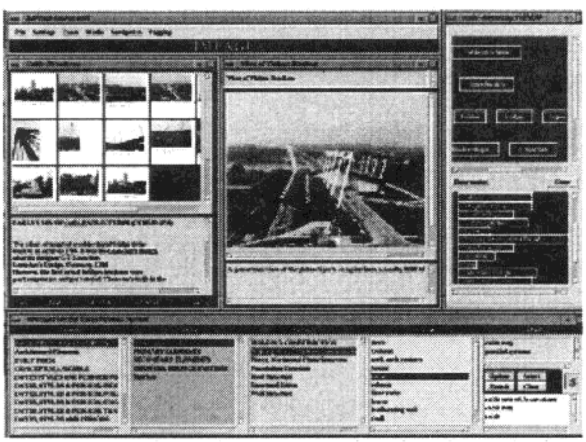
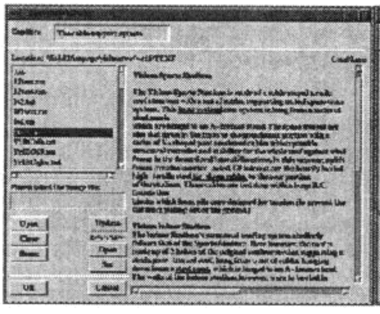


Figure 6: IMPAGE Node Browser with Yishun Sports Stadium Case

If a node is selected, a specialised node viewer, is triggered. The nodehierarchy to which the node belongs is displayed in the browser and the media contents of the node sent to the node viewer interface. In this interface, the images associated with the node are scaled and tiled in a graphics window. Text is sent to another window. The remaining media can be sent to 'media drawers" as they require a separate process to be spawned. Images, graphics and text contain "hot-spots' that allow the user to jump across nodes or terminate in dead-ends. At this stage, the user can also choose to follow a story-line using the hypermedia environment of the node viewers.

4.3.2 Media viewers

Galaxia provides a range of generic viewers to support the display of text and hypertext, (Figure 7) images in targa format (figure 8)and graphics.



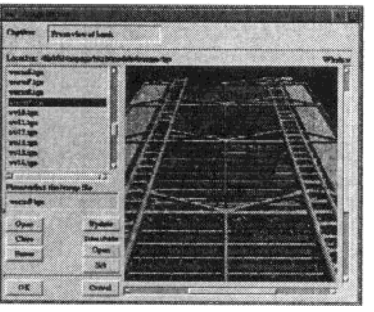


Figure 7: Hypertext viewer Figure 8: Image Viewer

3-D models are viewed using a customised Bricks viewer (Figure 9). Movies, animations and sound use the standard utilities provided in the SGI Indy.

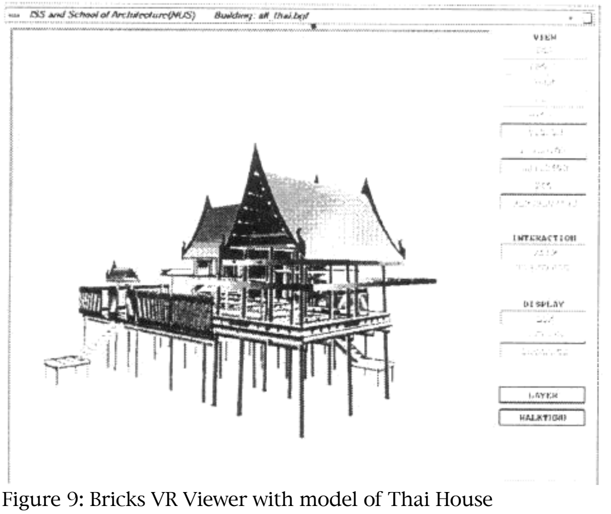


Figure 9: Bricks VR Viewer with model of Thai House

4.4 Filing with the Repository

4.4.1 Repository

The lowest level of the implementation is the repository. It comprises two distinct parts a relational database 'inventory'. and a collection of multimedia files. Architectural case information are digitised into multimedia files and organised into a standard SGI Irix filesystem and stored in an external disk.

The relational database provides a simple but powerful schema to store data, in this case meta-data about multimedia files. The meta-data' about these files are organised in a relational database table within inventory.

The initial approach was to utilise the generic datatype 'BLOB" available in Informix to store multimedia data in a Binary Large OBject" format but this was found unsuitable for development work as frequent editing of blob-type fields was cumbersome.

This separation of media storage and inventory enables us to use the relational engine to construct queries about the media by using their inventory details, rather than following their conventional locations.

The advantage of this is fast and efficient access to media files using information about the media themselves, easy editing and maintenance of large media collections. The main disadvantage of separation is the need for constantly updating the database about changes in the location of media, but this can be automated.

4.4.2 Classification and tagging

In order to achieve easier access and increase control over the archive, a preexisting information structure is mapped onto the media-file. Separate relational tables were created to model the "IHAA" classification system [Indorf 1990] (Figure 10). This system envisages information as being multivalent in nature, hence multiple codes may be attached to the same discrete item. The codes themselves are clustered into a lattice-like domain, consisting of nine "aspects", each aspect further branching into several "subaspects" up to five 'levels. The extensibility of the classification scheme is addressed in two ways:

(a) the core set of IHAA codes became the "host classification system" (HCS) and allows other classification systems to map onto its core. This supports customisation of the classification without sacrificing on the need to have a limited core set.

(b) although the first four levels of IHAA lattice are fixed in the present implementation, the possibility of extension in the fifth level to accommodate growing sophistication, and newer areas of study is proposed. If a case author finds the present core *set* insufficient, additional codes could be introduced.

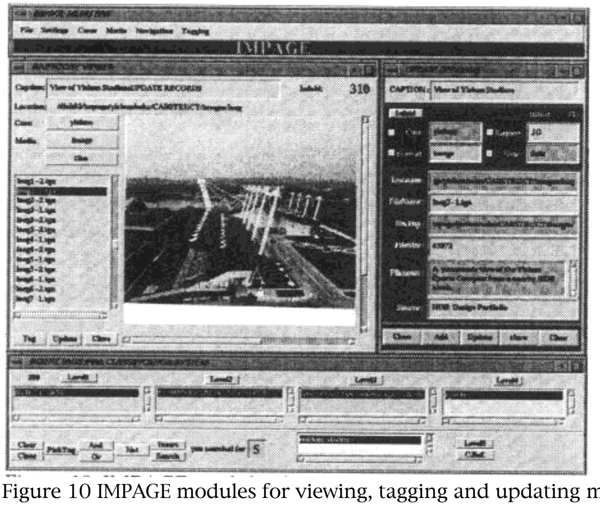


Figure 10 IMPAGE modules for viewing, tagging and updating media files..

4.4.3 Author tools

Case authors utilise a *suite* of IMPAGE modules (Figure 10) to perform tagging, dating and viewing tasks for individual media files:

(a) select files from the media archive by case and media for viewing,

(b) tagging the media file using the IHAA classification codes,

(c) delete, modify and update the fields of the meta data table 'caseinfo'.

The "caseInfo" table stores data about the media file, using the following fields: mediaformat, filelocation, filename, backuplocation, filesize, filenotes, filesource and caption.SQL queries are used on this "meta-data" to retrieve files corresponding to the appropriate qualifier(s).

The tagging module, enables the author to

(a) associate classification codes with media files.

(b) browse, delete and update existing tags

Once a media file is selected, it can be tagged using the tagging interface (Figure 10). The file is displayed using a generic viewer, depending on the file format. The media serial is passed onto the tagging module for association with codes. The author can selectively choose the set of codes that best fit the media and assign them interactively. Any number of codes from the IHAA lattice can be assigned to the media file. This data is maintained in the tagInfo table (Figure 4) of the inventory.

4.4.4 Case Building

A specific module, the Node Manager, helps in building multi-media case hierarchies. The relational table "nodeInfo" is modelled to implement this idea. NodeInfo enables the creation of semantic blocks to which atoms can be attached. The NodeManager has two functions

(a) create new nodes

(b) establish the node links

The node-hierarchy is used for conveniently browsing the structure of a case as envisioned by the author, once a node has been selected using the navigator.

The relationships established between the information atoms' and the classification lattice via taging are further expanded to accommodate the idea that these atoms can be organised into 'nodes" or related atoms.

These nodes serve a dual purpose: In the first instance, a node browser is provided for the user to visualise the structure of the node hierarchy. In the second case all atoms and nodes corresponding to the tag specified in the query are returned. The user then has the option of viewing these returned items or jumping to the node browser for a structured presentation of case information.

5 Conclusion

The IMPAGE project is a demonstration design information support system which allows the recombination of information through an open classification system for architectural knowledge. It also demonstrates the potential of mixed media in presenting architectural cases and many of its practical challenges.

The technical implementation issues revolving around the three aspects of retrieval, viewing and filing suggest that such a system is feasible and sustainable. Because of this the team has plans to advance the stand alone prototype to a networked version on the internet.

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