SPACE-CENTRED INFORMATION MANAGEMENT APPROACH TO IMPROVE CAD-BASED HEALTHCARE BUILDING DESIGN

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SUMMARY: *This study focuses on developing a space-centred CAD tool to enable designers to effectively manage and implement the information of design guidance information and user requirements during design processes, especially for the stages of design briefing and conceptual design. It aims to structure and store design guidance and user requirements for healthcare building design into a relational database, and link them to relevant space entities in design plans. The tool is developed on the platform of Autodesk Architecture Desktop (ADT). It also enables users to store and retrieve pictures associated with textual information, because pictures have been always used by designers as an effective medium to represent and deliver design information and knowledge. This can give users directly visual and more understandable perceptions of the design guidance. The tool is fully embedded with Autodesk AutoCAD systems to ensure the application of this tool being fully merged with CAD-based design process. A set of design guidance about Alzheimer clinic built environments are adopted as a sample to demonstrate and validate the tool. Moreover, the scenario of expanding this application to more broad areas has also been foreseen.*

KEYWORDS: *space, CAD, design guidance, requirement.*

1. INTRODUCTION & BACKGROUND

Space is one of the most important elements in building design to define the users' requirements and functions of a building. Any activities of an individual or an organization in a building must be carried out in a certain space. Thus, building spatial properties are determined on the basis of user organization requirements (Ekholm & Fridqvist, 2000). The most important design action of architecture design is to decide sizes, shapes and layout of spaces in a building to meet the users' requirements, design standard and so on. Today, as most outcomes of contemporary architecture design are produced in CAD systems, space has become an even more important concept in computer-based information systems applied in the process of building design, construction and management (Bjork 1992, Arvin & House, 2002). In CAD-based designs, space plays a role of a central entity to inject and deliver information of design requirements, guidance and standard into detailed design, which is represented in the diagram below (Fig. 1).

FIG.1: Space plays a central role of building design

The study presented here is a part of the Healthcare Initiative project, which was funded by the Salford Centre for Research and Innovation at Salford University, sponsored by the British Engineering and Physical Sciences Research Council. It specifically focuses on the issues regarding healthcare building design. It is commonsense that a healthcare building is far more complicated than other types of buildings (Marberry 1997, Kendall, 2005). This is because of large quantity of individual spaces and great diversity of these spaces with various restrictive requirements in a healthcare building (Tzortzopoulos et al, 2004). For instance, a hospital building consists of various medical departments; each department includes different rooms for various clinical functions and facilities. Eventually, the properties of each individual room have to be relevant to its occupants, visitors and equipments. In the consultancy of special design guidance and users' requirements for a healthcare building design, the specialists of clinic built environments usually marks their ideas on the floor plan (Fig. 2) or use pictures to archive their design expertise (Fig. 3). Meanwhile, the specialists of healthcare built environment have addressed an amount of design guidance on how to deal with various situations in healthcare built environments. Moreover, the actual design requirements capturing is an iterative process throughout the design phase. This also increases the complexity of users' requirements. As a result, for a single healthcare building design, the information of design guidance and user requirements involved can be addressed as an hundred-page paper-based document.

Accordingly, this implies a demand for standardizing design guidance and user requirements and implementing IT supports to facilitate designers to implement this large quantity of guidance and requirements information conveniently and promptly (Kiviniemi, 2005). So far, several methods have been developed to structure and formalise requirements capturing and documentation, including Quality Function Deployment (QFD), Client Requirements Processing Modelling (CRPM), Total Quality Management (TQM) and Failure Mode and Effects Analysis (FMEA) (Kamara et al, 2003). Also a breakdown list of software requirements developed by SWEBOK (2004) presents the demands for various IT applications of handling and managing requirements. In most recent research in CIFE, Stanford University, a requirement model specification has been developed to formalise and structure requirement capturing and documentation for architectural design and linked to the IFC specification. This enables users to handle detailed requirements associated with the relevant entities in an IFC model (Kiviniemi, 2005). It shows a fundamental solution toward IT-based requirement capturing and managing for building design.

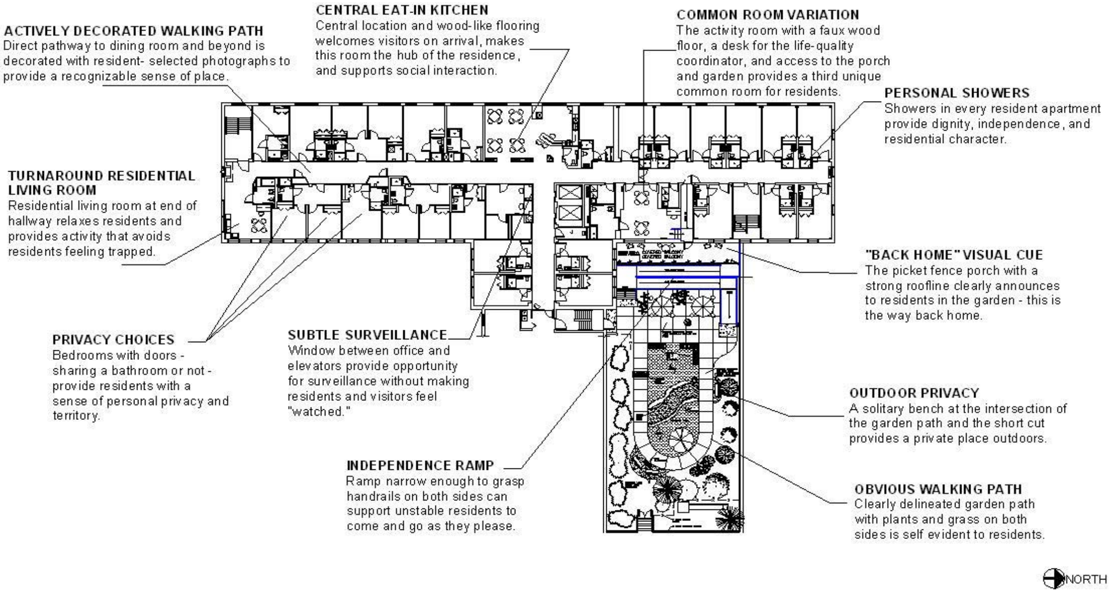

FIG. 2: design guidelines marked by the consultants on the plan drawing

In order to develop any IT applications for promoting the implementation of this large information, a proper approach to structure and digitise the textural-based information in design guidance and requirements has to be explored in this study at first. Typically, as stated earlier, most items in design guidance and users requirements are textual descriptions, which consist of both "hard" data, such as constraints on dimensions of spaces and building components, and "soft" information on how the spaces should be organized to incorporate with users' requirements. An example of this kind of "soft" issues, which is taken from the Healthcare Building Note specified by the NHS Estate (2002), is given as follow:

"The reception area at the main entrance should be immediately visible and provide an open and friend facility that does not give any sense of a barrier or generate a feeling for the patient of them and us."

FIG. 3: the picture is used in the design guidance for Alzheimer clinic environment

Today, although many information technologies, such as database technology can easily handle most of the "hard" data, it seems to be difficult to automatically work with this kind of "soft" information in design guidance, such as automatically planning the spatial layout. Architect's intelligence and skills are still the main mechanism to manage and implement this kind of "soft" information in building design. Nevertheless, information technology can offer architects an effective way to manage and apply this large quantity of information resources, which is needed in decision-making process. One of the focuses of this study is to structure and digitise this type of "soft" design information into a relational database.

Moreover, in a large healthcare building design, some special consultants who are the experts in certain healthcare built environments may involve in to represent hospital clients to consult the design with architects. Traditionally, the consultants may mark their suggestions on the plan drawings, such as Fig. 2. However, as a large number of design guidance may be involved, usually there is not enough space for the consultants to mark all of the guidance on the plan drawings. Additionally, very much of this expertise is also expressed in photo images (Fig. 3) rather than pure text. Therefore, it becomes crucial for designers to adopt an IT tool to effectively organize, manage and use this large amount of knowledge.

The aim of this research is to develop a space-centred guidance query tool based CAD systems to assist architects to effectively manage and use the information in design guidance and requirements at any moment during the briefing and design processes. This research specifically focuses on the healthcare building design, which is part of the large research project on healthcare built environment undertaken by the EPSRC-funded Salford Central for Research and Innovation at Salford University. A case study looking at the Alzheimer clinical area in a healthcare building is conducted as a showcase of this research. The design guidance and requirement for the Alzheimer and old patient clinical environments are kindly provided by our collaborator - Dr. Zeisel, who has conducted the long-term research in design guidance and requirement of the clinical environments for Alzheimer and old patients. Moreover, the scenario of expanding this space – centred design information management and implementation technology into more broad design areas is also depicted as a knowledge contribute to the development of IT-based design applications.

2. THE DEVELOPMENT OF THE DESIGN ASSISTANT TOOL

2.1 Space planning in Autodesk Architecture Desktop (ADT)

Space planning is the first step of new design from sketching and a very import action in the CAD based architecture design, especially in the conceptual design phase (Moss, 2002). Architects apply space planning functions to set up a number of function spaces required by users or clients, and also properly arrange these function spaces with traffic and common spaces to ensure that the overall floor layout is maximum functional and effective.

Today, most of architecture design CAD systems, such as Autodesk Architecture Desktop, Graphisoft ArchiCAD, and so on, have provided a series of functions to support designers to conduct spaces planning of conceptual design. Architecture Desktop has been adopted as the CAD platform in this study. In the conceptual design menu, the system can allow users to add, modify, convert and generate spaces. It also enables users to deal with space areas and boundaries. Here, we have a brief review of the main process of space planning in AutoDesk Architecture Desktop.

Before an actual space planning starts, it is essential to get a space criteria table from users requirement capture, which should include name and sizes of each function space that users want to be included in the building. Architects have to make their design approximately followed these space criteria. For space planning (Fig. 4), architects have to firstly define space styles, which represent different types and sizes of spaces. The space style is a crucial element in the development of this space centred CAD tool. Then architects can add spaces into a floor plan. Meanwhile, each space has to be assigned a tag with a series attributes, which ensure every space to have a unique name in the design. After this, architects have to adjust and arrange the layout of these spaces to make sure the overall design to be effective, functional, harmonious, creative, etc., which are what each architect generally wants to pursue in his design.

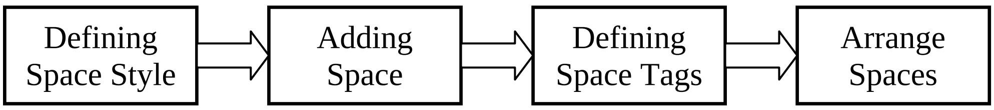

FIG. 4: Space planning process in ADT.

In this study, the space style is used as a key element to establish the connections between the space objects in ADT and the design guidance database.

2.2 Database design

In a space-centred building information model (Fig. 5), the overall building spaces can be detailed down to floor spaces and further to each individual space by following a hierarchic structure. From each individual space, detailed building components surrounding the space, such as walls, door(s), window(s) and their dimensions and materials properties can be retrieved. One space connects to other spaces through shared walls. This model illustrates the overall relationships of building elements, both physical elements, such as windows and walls, and virtual elements, like space) in this development. As described in the title, this development only focuses on space elements in building design, which are the part surrounded by dash lines in Fig. 5, to improve the implementation of design guidance in design process.

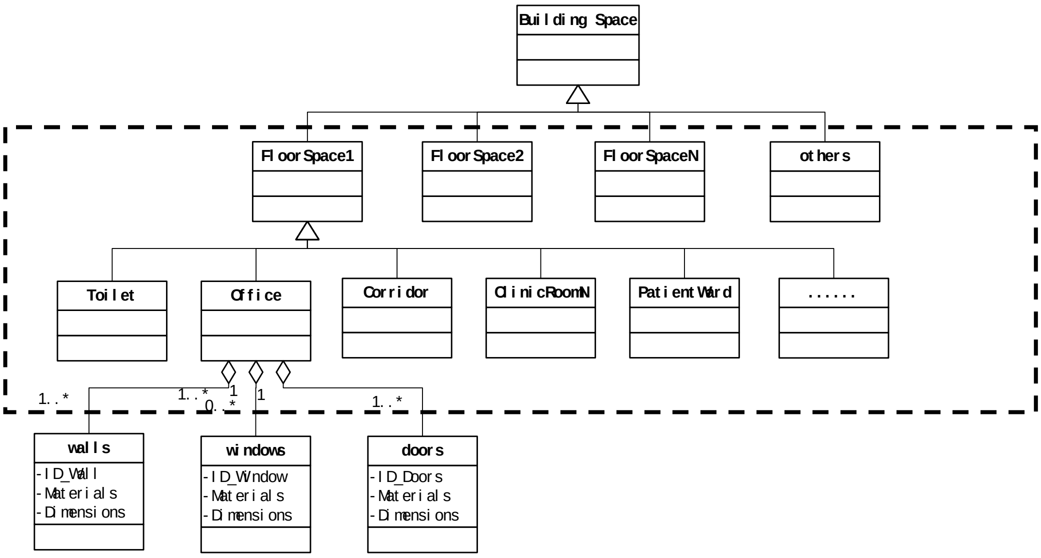

FIG. 5: Space-centred Building Information Structure

Based on this model, the design guidance of Alzheimer clinic environments has been classified and structured to store in the three database tables (Fig. 6). The database table – SpRules – lists out a number of different spaces, which may be designed in the Alzheimer clinic environments. Other two tables associated with the "SpRules" table contain the options of various space types and space sizes. In the SpRules database, it can not only store the information of design guidance, but also the image file name associated with the design guidance. Space types in the database tables have to be the standard name of space types, which should be consistent to the space type defined in ADT. The "ID" field in the "SpRules" table has a series of un-duplicated auto-numbers to ensure every record in the table unique.

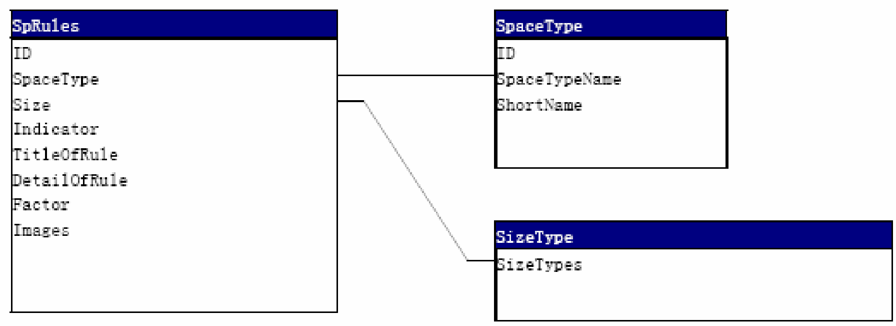

FIG. 6: Database tables and their relationship

2.3 System Architecture

This assistant tool actually provides an intermediate connection between spaces planned in Design CAD systems, such as Architecture Desktop in this case, and special design guidance for particular areas in healthcare building design. The diagram below (Fig. 7) shows the system structure of this tool. Starting from left of the diagram, a number of spaces with standard name of space types, which are initially uploaded from the tool, are defined in a CAD system firstly. Meanwhile, at the right end of diagram, a database is created with the table structure to be able to store all items of design guidance and requirements classified on various space types. This has been described in the database design. This assistant design tool plays a role to link each individual space to the relevant design guidance and requirement in the database. The main functions of this tool have been defined as follows:

1 To retrieve the special design guidance or user requirements related to the space type of the space entity selected from CAD systems;

2 To provide designers with a friendly interface of understanding and implementing these special design guidance, such as displaying the relevant images of some items in design guidance.

3 To enable users of this tool to score or prioritise the items in the special design guidance and user requirements. In this case, it only provides a function to enable designer to check the items, which have been fulfilled in the design and generate a report about the overall applications of the guidance.

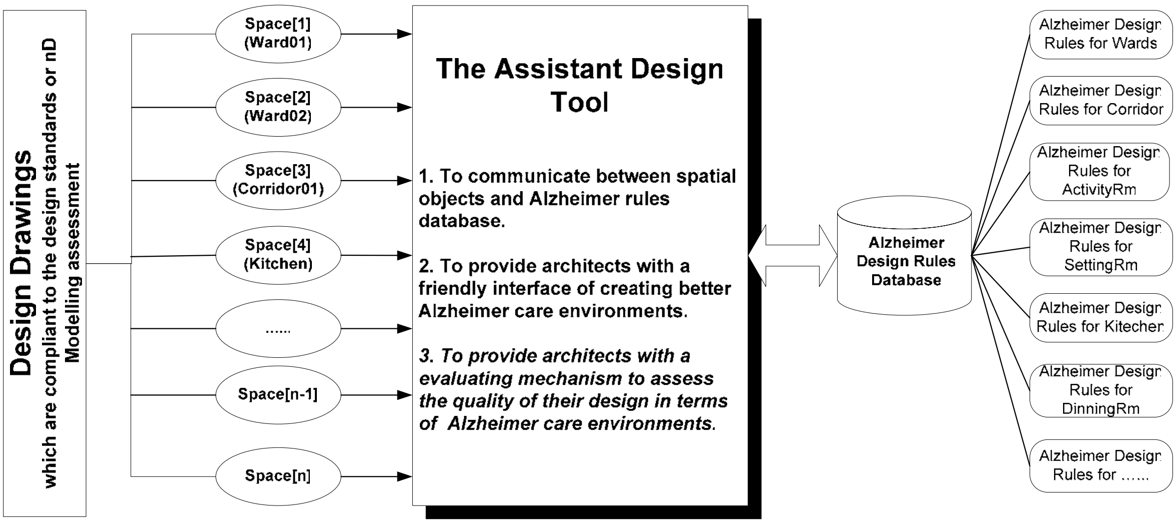

FIG. 7: The system structure of space-based design assistant tool

2.4 Functionality and Interface of the Tool

As described earlier, most today's CAD systems for architecture design have the functions to allow users to define and manage spaces in conceptual design. This development is based on Autodesk Architecture Desktop (ADT), which provides a systematic and friendly environment for the development based platform of Auto CAD (Fig. 8). The ADT can allow users to easily visualize design drawings in 2D/3D space. Visual Basic is the programming language adopted. A drop down menu is developed and integrated with ADT menus. This enables users to quickly access the functions of this tool as they work on ADT. The basic functions of this assist design tool allow users to easily input the new design guidelines (Fig. 9) and modify the existing guidelines (Fig. 10) with a friendly interface.

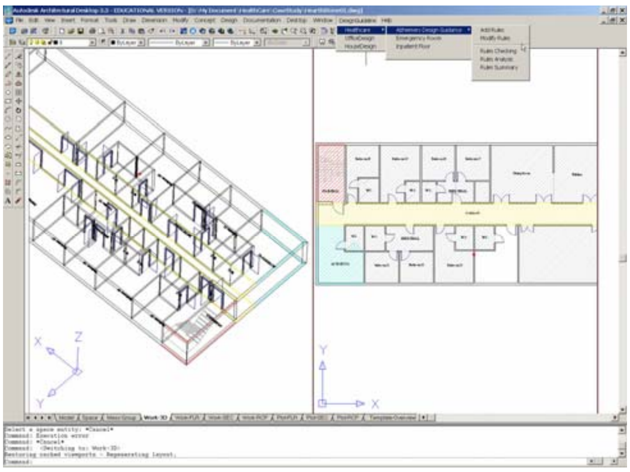

FIG. 8: The tool is based on the Autodesk Architecture Desktop (ADT) platform

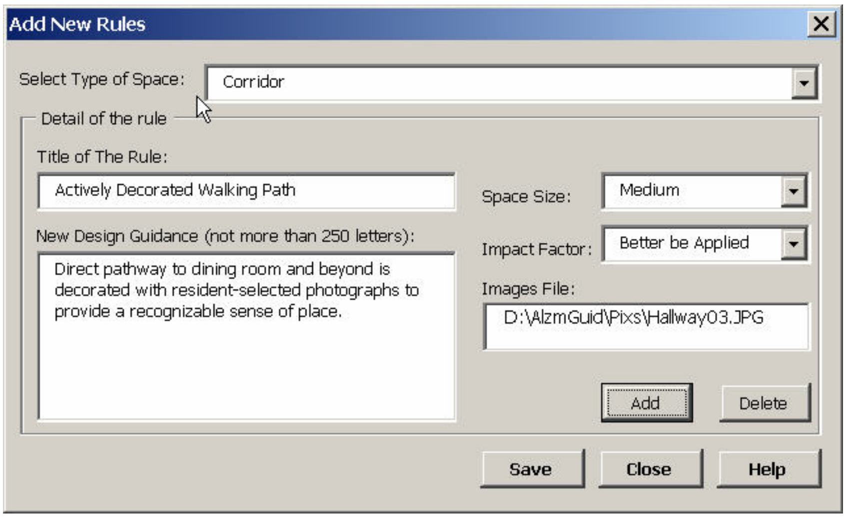

FIG. 9: The window for inputting new guidance

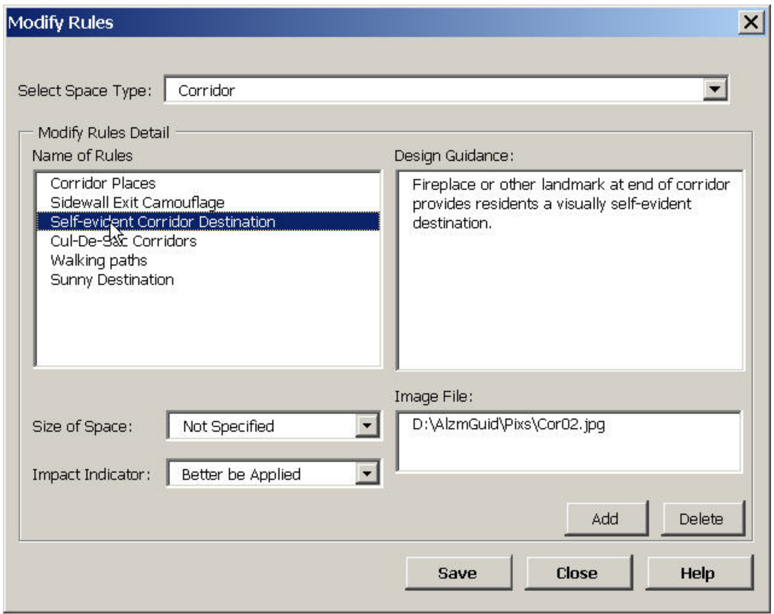

FIG. 10: The window for modifying the existing guidance

The Fig. 11 shows the interface to reveal the design guidance and requirement information related to a certain space, which can be picked up from either the plan drawings or 3D models. As drawings take shape, this tool can allow the designer to review their design and provide the opportunity for other stakeholders to take part in "testing" the design. As users move the high-light bar up or down to each title of listed guidance, the detailed content and the image of this selected item will be uploaded from the database table automatically. The images can be enlarged by double clicking on the picture. This enables users to see more details in a picture. By using this tool, users can check off which of the listed items have been fulfilled in the design. Eventually, an overall report about the implementation of the design guidance can also be generated in an Excel file. In early design iterations, design team use this report to review what they can do to improve design in the next stage, and also to consult with users or clients of the project. In some cases, the unchecked items may be a lower priority in the design. In consultation with users or project clients, the overall design has satisfactorily reached the "domain of acceptable responses" and is ready to be acted on. Such a decision is more likely at later stages of design. This function can also be used as a checking tool for design reviewers to evaluate design.

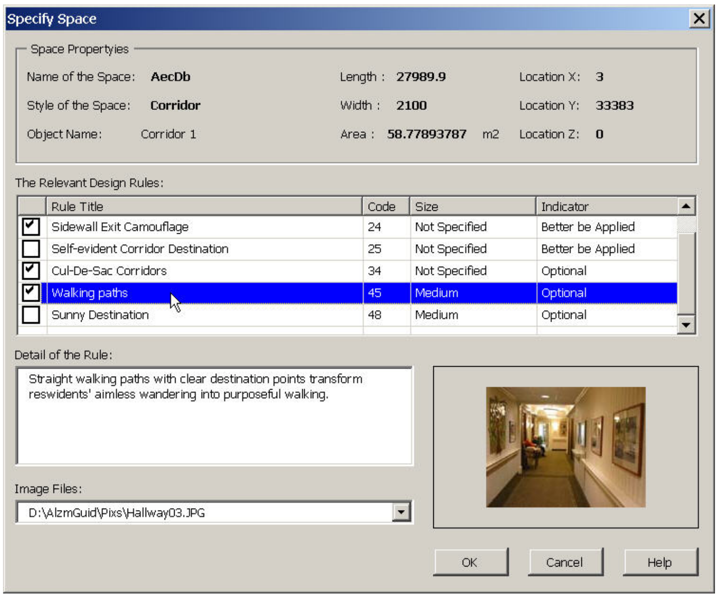

FIG. 11: The window for checking up the design guidance

2.5 Testing and Evaluation

This prototype tool has been tested and evaluated in two ways. Firstly, it has been tested in an architectural design firm, which has fifty architects specifically for healthcare building design. A small group of three architects from the firm actually applied this tool in a practical project designing a small primary care clinic centre. We helped them to install the tool in their Architectural Desktop packages. The architects used this tool initially to input a number of user requirements and design guidance regarding various space types. Then, they applied the checking function to retrieve the requirement and design guidance information during their space planning of the conceptual design. This enables them to make sure nothing being missed from the requirements and design guidance. And finally a report can be generated for the consultancy with their client. The observation and discussion were conducted during the trial in order to get users' comments on the issues of the functionality and interface of this tool. During the collaboration with this architecture firm, we also had an opportunity to meet their clients of the project. This is because we also wanted to know if this tool could benefit the design briefing of project clients, rather than conceptual design of architects only. In the meeting, we demonstrated the functions of inputting, modifying, retrieving and reporting user requirements, and asked the delegates of the clients to make their comments regarding design briefing. The issues addressed from this testing and meeting are listed as follows:

- It is generally agreed that the overall functionality of this CAD-based tool conceptually demonstrates an effective approach to embed the design guidance or user requirements in the design process;
- This tool can provide clients and project management teams with a mechanism to establish a requirement database for a building project. The database for the common requirements for certain types of buildings should be created to enable clients and project teams to pick up easily. This can avoid duplicated input of the requirements used in other projects;
- Basically, the interfaces of the tool are easily handled by most designers who are familiar with Auto CAD interfaces. However, a weakness is also identified that the functions of inputting and modifying the design can only deal with only one item each time. The batch or group processing function is needed for quick input and modification;
- The meaning of displaying the images associated to the items in the guidance is very useful, because it is consistent to the custom that architects archive their design knowledge and experience;
- The final report about the adoption of the guidance is particularly useful to architects and design specialists in design review, and consultancies with clients and users.

Apart from this practical testing, the prototype tool was also evaluated through demonstrations and discussions. As introduced earlier, this research is a part of the Healthcare Initiative project in SCRI. Thus, the prototype tool has been demonstrated in a number of research meetings and seminars organised by the project team and with participation of experts from both academia and industry, including experts from NHS Estates, the architects and the specialists in healthcare built environments, and so on. The feedback and comments made by the participants in the discussions following the demonstrations at the events have been collected and analysed. In addition to the issues identified in the above testing, other interesting issues were also spotted as follows:

- Some people also think that this tool can make contributions to knowledge transfer from older or retired designers to new designers within a design firm. It is also suggested that the sharing of the guidance database over the Internet or intranet should be considered in the next stage of this study;
- It is identified through this study that, although there is not an intelligent function to enable automatic implementation of checking of the design guidance or requirements, the architects and design specialists do not show much interest in this in reality. Regarding current IT applications in design, they may trust the works that result from their own intelligence rather than those from a "machine".
- The demand for this tool to work in other architectural design software packages, such as ArchiCAD, MicroStation and so on, rather than only in the Architectural Desktop or the AutoCAD-based software products, are also raised.

3. THE SCENARIO OF FURTHER DEVELOPMENT AND IMPLEMENTATION

3.1 The General Ideas

Although this tool has achieved the initial functionality of this pilot research, a scenario of further development and implementation is also considered. The Fig. 12 shows a scenario to expand this application to other parts of healthcare building design, such as emergency room, inpatient floor and so on, and even also to other types of buildings rather than only healthcare buildings, for instance, office buildings and residential houses.

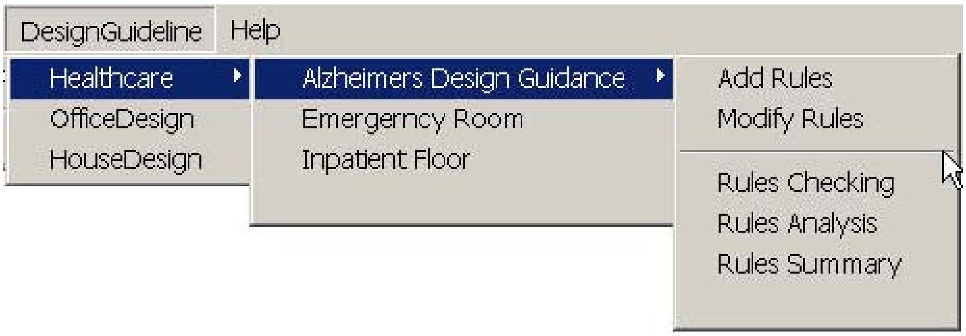

FIG. 12: The potential implementation of this space-centred design assist tool

In terms of healthcare building design, the implementation of this tool could be expanded from the currently single dimension of Alzheimer clinical environments to multiple dimensions of broad areas of healthcare buildings. In this scenario, an integrated data repository should be established to accommodate all design guidance and regular requirements and knowledge regarding various aspects (dimensions) of healthcare building design. This will also incorporate the nD modelling methodology and technology (Lee et al, 2003) to play and trade off the guidance and requirement knowledge in the data repository to achieve better decision-making of healthcare building design (Fig. 13).

In order to realise this scenario, some important technical barriers and issues have to be raised based on the experience of this development and other previous studies.

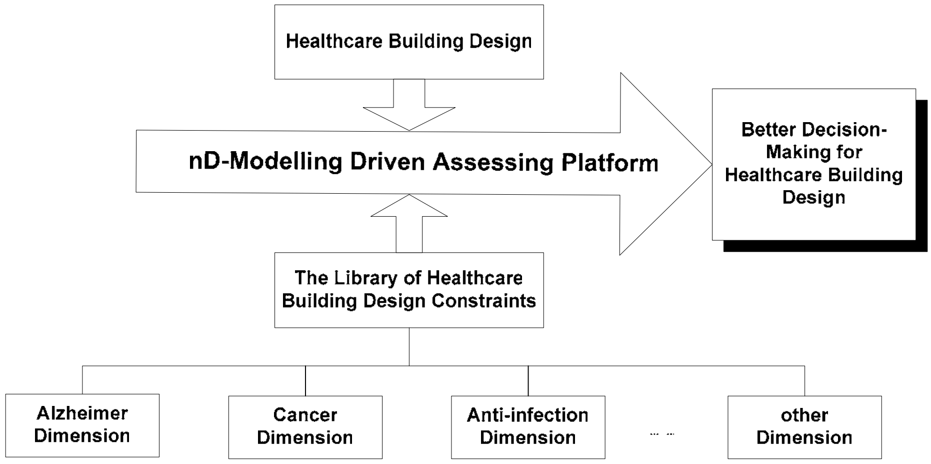

FIG. 13: A scenario of applications of this tool in the nD driven decision-making process of the healthcare building design.

3.2 Standardization and Classification

As described earlier, healthcare building design may involve hundreds of individual spaces and thousands of items of design guidance and requirement. Some of the guidance and requirements have to be compliant to all rooms of a certain type; some of them may only be applied on a certain room. Therefore, these design guidance and requirements are needed to be classified into different levels in order to meet different requirements for some types of spaces and some special rooms within healthcare buildings. Meanwhile, all of design guidance and requirement should also be standardized to incorporate with database structures. Many of design guidance and requirement are expressed in the plain English. For this application, a title and a unique ID code are need for each item in the design guidance and requirement so that they can be easily and accurately retrieved and avoid reiteration.

3.3 Network Deliverable

In future, this tool will be useful to various stakeholders rather than only the designer. These stakeholders may be located at different places. Therefore, this tool firstly must be network-based. Secondly, in cases that some stakeholders may use different CAD or even never use CADs, the original designs outcomes (plans, elevations and sections) have to be converted seamlessly into a kind of natural format. Industry Foundation Classes (IFC), which is an advanced standard format for the exchanges and sharing of building design information, could be used to deliver the design information across different stakeholders.

4. CONCLUSIONS

This paper has presented overall information about the space centred design assistant tool for the implementation of design guidance and user requirements. It firstly verifies that this space centred approach is fundamentally consistent to the CAD based space planning approach, which is embedded in the conceptual design tools of CAD systems. The database design and system architecture demonstrate the overall data and system structures and the systematic development process of this tool. The major functions and interfaces have also been described in detail. The advantages and weaknesses of this tool development have been described according to the feedback from the testing and evaluation of this tool. A further development scenario has been explored to aim to wider applications of this space-centred design-guidance-implementation tool and approach in the domain of building design. And this scenario also shows the potential integration of this study and nD modelling research, which is a highlighted research theme in the area of IT applications in the AEC industry.

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