

Research about building facility management system based on BIM

Chenjun Yang and Gang Wei

Engineering Research Center for Enterprise Digital Technology, Ministry of Education, Tongji University
Shanghai, P.R China

Abstract—This paper discusses about how to utilize current technologies to design and implement a building facility management (BFM) system based on 3D BIM model, satisfying modern intelligent building's demand for facility management (FM). Implementation methods of the system include: using Navisworks customized development technology to combine BIM technology with relational database so as to manage information of management objects and maintain tree-structure relation between them. We use C/S architecture to allocate tasks appropriately, use LOD (Levels of Detail) technology as a source of reference to accelerate model construction speed and utilize Navisworks .NET AIP to implement data visualization. The system provides an integrated management environment with abundant functionalities, excellent interaction and visualization capabilities. But there are still some disadvantages in system deployment and launch aspects.

Keywords- facility management; BIM; C/S architecture; Navisworks; customized development

1. Introduction

With the arrival of globalization, intelligence, and information age, information has become the foundation that leads the global economy. Under the influence of modern information technology, modern building facility management (BFM) has transformed into the management of facility information. Traditional management methods have been far from meeting modern intelligent building's demand for facility management (FM). During the operation phase of a building, a lot of facilities and space resources are left idle and wasted due to old management methods, even causing human lives and properties loss owing to lack of maintenance. How to provide an integrated, computable, visual and interactive environment for BFM to increase building facility and asset utilization rate and improve operator's economic benefit has become a quite significant and urgent research subject in FM field home and abroad.

There is very little development in BFM system field in china at present, while there are much abroad. The most famous one is ArchiBus. It is the top estate, infrastructure and facility management solution in the world. However, most of them are still based on two-dimensional (2D) models and users have to be equipped with some professional knowledge so as to understand the management objects and relevant information in 2D blueprint. In recent years, as the development direction of building information technology, BIM has grown into an application tool from an ideal concept, which brings various opportunities and challenges for the whole building industry, including operation and maintenance aspects of building.

With the upgrade of computer hardware, FM system based on 3D models will be possible. It provides better interaction and visualization capability than 2D systems, reduces user requirements, and greatly improves the visual effect and operation mode of management objects. This paper discusses about how to combine relational database with BIM technology to design and implement a FM system based on BIM, taking advantage of BIM software's strong three-dimensional rendering capability to improve the interaction

and visualization ability of traditional FM system, providing an integrated management environment with abundant functionalities.

2. Overall Concepttion of BFM system based on BIM

2.1. BIM

Building information model (BIM) refers to the physical and functional features of a facility under an open industry standard and relevant project lifecycle information in computable or calculable form. BIM is based on three-dimensional digital technology and it is project data models integrated with all relevant information about building construction project through a public standard, usually IFC (Industry Foundation Class) at present [1]. BIM is a digital representation of physical and functional characteristics of a facility [2]. BIM enable storing multi-disciplinary information within one virtual building representation [3]. As a new computer software technology, BIM has expanded to more software areas from CAD, such as engineering project cost estimating and schedule arrangement. It also contains potential to serve FM and other fields [1].

During the operation phase of building lifecycle, BIM could synchronously provide information about using condition or performance condition, occupancy condition and capacity of the building, how long it has been used and financial issue of the building. BIM provides digitally updated records and improves movement plan and management. It also promotes standard building model's adaption to commercial field condition. Physical information of the relevant building (such as construction progress, contractor or department distribution), and important financial data about leasable area, leasehold income or department cost distribution are easier to manage and utilize. And stable access to this information could increase income profits and improve cost management level [4].

2.2. Overall Architecture of the System

Since managing building facilities through 3D BIM is a characteristic of our system, the rendering effect and operation fluency level are very important to user experience. However, hardware performance of current pc is still the main limitation of displaying and rendering large 3D model fluently. Hence, C/S architecture is firstly chosen to assign graphic computation tasks of model rendering to client machines, the server machine taking care of DBMS and maintaining shared model files.

The system uses Navisworks, a product of Autodesk, as its model display component, SQL Server 2005 as its backstage database. The overall architecture of the system is shown in Fig. 1.

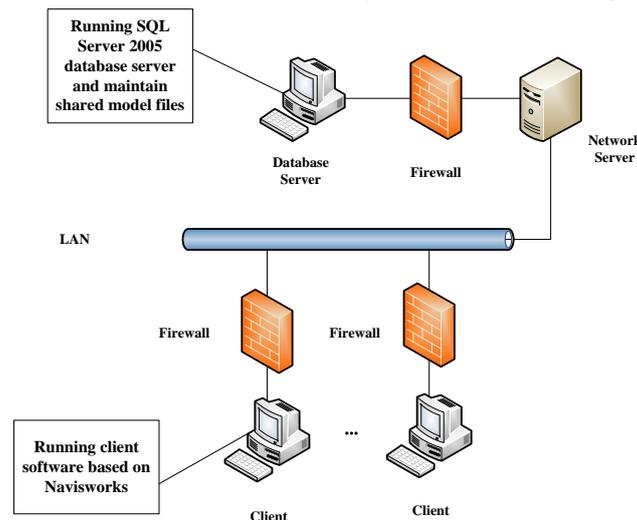


Figure 1. Overall architecture of the system

3. Functional modules of the system

Functional modules division of the system is shown in Fig. 2.

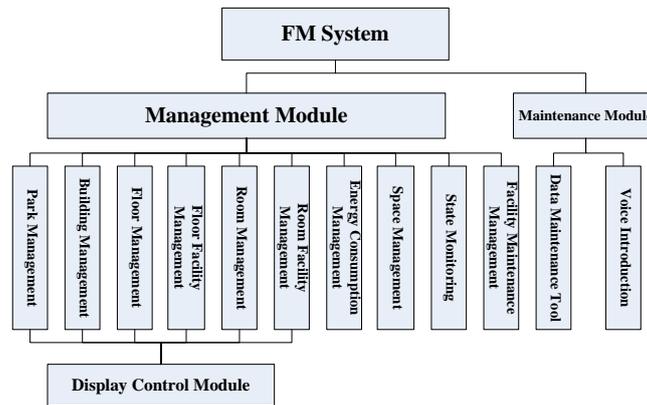


Figure 2. Functional modules division of the system

3.1. Park Management, Building Management, Floor Management, Floor Facility Management, Room Management, Room Facility Management

Our system classifies all the management objects into six categories and there are relations of subordination between them. For example, a floor definitely belongs to a building and a room belongs to a floor. These six modules directly manage and control the relational table corresponding to six categories respectively. Besides basic operations such as Insert, Update and Delete, they also provide various Query and Sort operations, Document Link and Report Export (exported as Excel document) functionalities. Selection states of records in table corresponding to each category keep synchronous with the selection states of management objects in Model View, which is enabled by another component named Display Control Module.

3.2. Display Control Module

This module takes the form of a tree-structure and each node corresponds to a management object. In order to further improve performance of the system, we used LOD (Levels of Detail) technology as a source of reference and designed three different display modes for this module. LOD technology reduces the geometrical complexity of the scene by simplifying details of the scenery successively to improve the algorithm efficiency, without influencing visual effect of the model [5]. Model View of the system will respond differently according to the current display mode when user clicks a tree node:

- 1) *Mass Mode*: Only model objects corresponding to the clicked node, its brother nodes and its parent and children nodes are displayed. (One level upward, the same level and one level downward)
- 2) *Management Mode*: Only model objects corresponding to the clicked node, its brother nodes and its descendant nodes are displayed. (The same level and multilevel downward)
- 3) *Reality Mode*: All subordinate objects of the model object corresponding to the clicked node are displayed. (Including both management and non-management objects)

The former two display modes only display currently managed objects and their closely related objects without significantly influencing the visualization and interaction ability of the system, hiding all other detail of the model, which reduces the amount of graphic computation so as to accelerate the model construction speed. Another functionality of this module is to make the selection states of management objects in Model View synchronize with the selection states of records in tables corresponding to six categories. So users could clearly see the corresponding relation between model objects and data records.

3.3. Energy Consumption Management

Different chromatic value of different colors and different transparency are used to indicate water and energy consumption of each floor. It also provides detailed data grid view, history data analysis and report export functionalities. Result of energy consumption visualization is shown in Fig. 3.

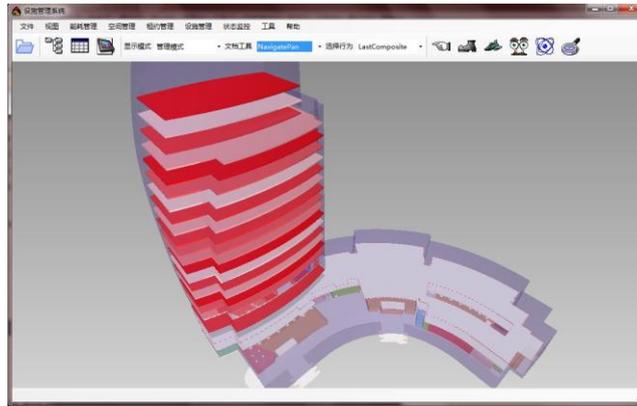


Figure 3. Visualization effect of electrical energy consumption of each floor, different chromatic value of red color indicates different consumption.

3.4. Space Management

Different chromatic value of different colors and different transparency are used to indicate occupancy rate of each floor, rent and estate fee of each room. It also provides detailed data grid view and room lease expiration reminder functionality.

3.5. State Monitoring

Different chromatic value of different colors and different transparency are used to indicate temperature, humidity and carbon dioxide level of each room. It also provides detailed data grid view. Result of room state visualization is shown in Fig. 4.

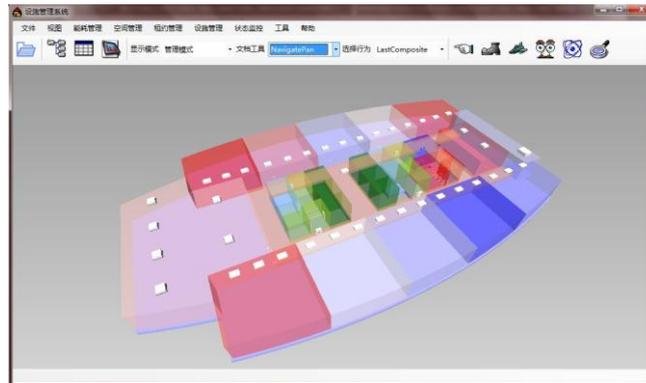


Figure 4. Visualization effect of room state, red color means the temperature is too high while blue color means the opposite.

3.6. Facility Maintenance Management

This module is responsible for managing maintenance history, warranty period and overhaul schedule data about floor facility and room facility, and it also provides reminder functionality.

3.7. Data Maintenance Tool

In order to establish corresponding relation between data records in database and management objects in shared models, a globally unique ID is assigned to each management object. This ID should be coded in an ad hoc way, for example: PXXX-BXXX-FXXX-RXXX-RFXXX, indicating its logical position in the model. The main functionality of this module is to check whether each model object with global ID (management object) in shared model has a corresponding data record in database and vice versa, thereby maintaining the consistence and integrity between shared model and database.

3.8. Voice Introduction

Each management object could be provided with an audio or video file as its introduction material. While this functionality is activated, the material will be played when its management object is clicked.

4. Key technologies and implementation methods

4.1. Navisworks customized development technology

Navisworks is a BIM software about construction progress management, collision detection and model browsing, developed by Autodesk. It is known for its excellent 3D model rendering capability among BIM software field. The latest version of Navisworks is 2011 and it offers new Navisworks .NET API to meet user's customized demand. The Navisworks .NET API is intended to replace the COM API for most use cases. Users of the Navisworks .NET API are able to [6]:

- Gain access to Application information
- Gain access to Model/Document information
- Perform simple operations on Navisworks documents (Open, save, execute plug-in) without having to fully load the main application.

There are three forms of Navisworks 2011 customized development:

4) *Plug-in*: Tools developed by users are added to Navisworks as plug-ins and they can only be executed after the main application has been fully loaded.

5) *Automation*: Navisworks can be started programmatically and possibly in a non visible state with the purpose of invoking functionality.

6) *Controls*: API is provided as controls, including a Document Control used to access Navisworks document and a View Control that displays building models through Document Control. They can be used by third-party applications on the same computer as an installed Navisworks.

Our system uses the third customized development form, along with some Core API to do some visual modification to model objects, usually color and transparency. The used API methods are shown below:

- Autodesk.Navisworks.Api.DocumentParts.OverridePermanentTransparency(items,transparency);
- Autodesk.Navisworks.Api.DocumentParts.OverridePermanentColor(items,colors);

4.2. Database design

Logical structure of the database: relational tables are created for six categories (park, building, floor, floor facility, room, room facility) respectively. Subordination relations between them are stored as foreign keys. Tree-structure of the display control module is constructed according to these foreign keys automatically. Two other tables are used to store data about floor energy consumption and room state.

4.3. Graphic user interface design

In order to improve the commonality and portability of our system, user could use the server name, database name, user name and password to configure the database connection. GUI is shown in Fig. 5. GUI of the system consists of menu bar, tool bar, organization tree (display control mode), model view and grid view.

5. Conclusion

BFM system based on BIM provides a friendly, easy-to-use, data-visualized management environment with abundant functionalities. However, due to the limitation of current PC hardware and customized development interface provided by BIM applications, our system still has some disadvantages. For example, it takes quite a long time to search and load all management objects from large building models, and Navisworks has to be installed in every client machines. With the update and development of computer hardware and software, FM system based on 3D models will become more and more popular, as a powerful tool for building operators to increase benefits.

6. Acknowledgment

This work was supported in part by the High-Tech Research and Development Program of China (Grant No 2009AA044501) and the Research and Development Program of Science and Technology Commission of Shanghai Municipality (Grant No 09DZ1122701).



Figure 5. GUI design of the system

7. References

- [1] Liang Feng and Huimin Lu. Design conception of project management information system based on BIM. Construction Management Modernization, August 2009, pp.362-366.(in Chinese)
- [2] National Building Information Modeling Standard (NBIMS), Overview, Principles and Methodologies, Version 1.0 – Part 1, http://www.wbdg.org/pdfs/NBIMSv1_p1.pdf.
- [3] Arno Schlueter, Frank Thesseling. Building information model based energy/exergy performance assessment in early design stages. Automation in Construction 18 (2009), pp.153-163.
- [4] Jianwen Zhang. BIM technology facilitates the building of harmonious industry. Survey And Design, September 2010, pp.38-40.(in Chinese)
- [5] Yanhong Shao. LOD technology and its algorithms. Software Guide, October 2008, pp.48-50.(in Chinese) Autodesk, Inc. Autodesk Navisworks 2011 .NET API Developer's Guide, 2010.