PRACTICAL USE OF INDOOR SPATIAL DATABASE

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ABSTRACT: Because of the development of advanced construction technology, the inner environments of building become more and more complicated, which may result in many problems. The administer may forget where they put up the certain picture, and search for it all over the building, or they underestimate the number of the visitors, and find the situation is out of control, while the pedestrian may get lost, and after making their efforts, they found they turned back to the origin point again. So it is very necessary to establish an indoor spatial database. On one hand, it is able to assist administrator to manage the property and human flow inside the building, on the other hand it could help the pedestrian find the way easily especially when they are not familiar with the building or there is an emergency. This paper focused on how to create the indoor spatial database including both static database and moving objects database. The static database is built on the basis of 3D building models, and the moving objects database gets information from many kinds of cameras and sensors installed in the building. And at the same time the paper discussed the practical use of indoor spatial database mainly in three aspects including consistency management, building restructure, and pedestrian navigation.

Keywords: Indoor space; database; navigation

1. INTRODUCTION

As the construction technique is more and more advanced, there are a great many complicated high-rise structures showing up one by one. For example, Burj Dubai, which became the world's tallest building on July 24, 2007, is still under the construction. And after being finished in 2009, it will exceed the height of 700 meters with more than 150 floors. On one hand, we really appreciate the great man-made marvels, on the other hand, we have to put into more efforts to deal with the inconvenience resulted from the complexity of the building structure. The administer may be busy in coordinating the resources in the building, but still have no idea of how to manage it well, or they underestimate the number of the visitors, and find the situation is a little out of control, while the pedestrian may get lost, and after making their efforts, they found they turned back to the origin point again. So it is very necessary to establish the indoor spatial database which is able to assist administrator to manage the property and human flow well inside the building as well as helping the pedestrian find the way more easily and quickly especially when they are not familiar with the building or there is an emergency.

This paper mainly contained four parts. The first part explained the structure of indoor spatial database. The main idea is that we can divide the whole building into several parts, and update the information of each part, and then put all pieces of information together to form a coherent whole. And the second part focused on how to create the indoor spatial database which can be divided into static database and moving objects database. The static database is often built on the basis of 3D building models, which usually contains the information of structure components, the equipment in the use, the supervision hardware, and other static objects. The moving objects database can provide continuous updated data about dynamic objects. It is assisted by Geographical information system (GIS) tools and advanced remote sensing technologies such as cameras, sensors and so on. The third part discussed the practical use of indoor spatial database mainly in three aspects including consistency management, the building restructure, and pedestrian navigation. At last, the paper stated the importance of the indoor spatial database, made the conclusion, and pointed out the future direction of indoor spatial database.

2. BACKGROUND

2.1 The Development of Spatial Database

Many researchers have been solving information spatial problems. Over the past 20 years there have been great advances in the technology used to display spatial information related to computer and GIS. In early 90s, many researches already discussed on how to build database for GIS by using computer tools, such as Walid G. Aref and Hanan Samet (1991), Claudia Bauzer Medeiros and Fatima Pires (1994), and so on. C.B. Medeiros (1994) gave a definition to GIS that GIS was a

database system that supports management of spatial data. They also realized that manipulation of spatial data is an essential function in both GIS (Demers 1997) and spatial information systems (Laurini and Thompson 1992). Sis Zlatanova and David Prosperi (2006) carried out a research on large-scale 3D Data integration, and Y.L Gao and David J.W (2008) brought out the idea of conceptual database model for spatial analysis and resource management.

2.2 The Necessity of Indoor Spatial Database

Nevertheless, most researches only focused on using GIS to capture the information of large-scale outside area. A considerable amount of efforts has been directed towards using spatial database for urban planning, route optimization, public utility network management, demography, cartography, agriculture, natural resources administration, coastal monitoring, fire and epidemics control, and so on (S. Aronoff, 1989). And with recent innovations in GIS visualization and ubiquitous computing technology, researchers start to think about using spatial information in the indoor environment. Some researchers used spatial information to find the optimal path in indoor spaces (Kim, B.H., 2007), some researchers used indoor spatial information to control the visitor flow (Ahn, B.J., 2008), and there are many other researches related to indoor spatial database.

Generally speaking, indoor spatial database have the following advantages.

- With the help of spatial database, administer can efficiently generate and exchange information to save the time;
- It seamlessly bridges the communication with the administrator and the occupant, which can give the occupant the better service;
- As information is collected from cameras and sensors instead of men, a great deal of cost can be decreased.
- Before some events or emergency taking place, useful models can be built to simulate real-world performance on the basis of indoor spatial database in order to search for optimal solutions ahead to avoid both materiel and spiritual loss.

Thus it is very necessary to make a research on how to establish indoor spatial database in both database structure and database category, and combine them into a whole system to provide adequate support to practical application so as to save time, labor, and money.

3. SPACIAL DATABASE

3.1 General Idea

A building often contains many things, such as building itself, the public utility, furniture, decoration, persons, and so on. Handling so many things at the same time may result in many mistakes. Thus, we introduce spatial database to store the inner spatial information of the building. In order to set up spatial database, the basic concept should be formed that all the persons and things should be treated as entities which have their own characters, and may have relationship with other entities. And every entity belongs to the certain category.

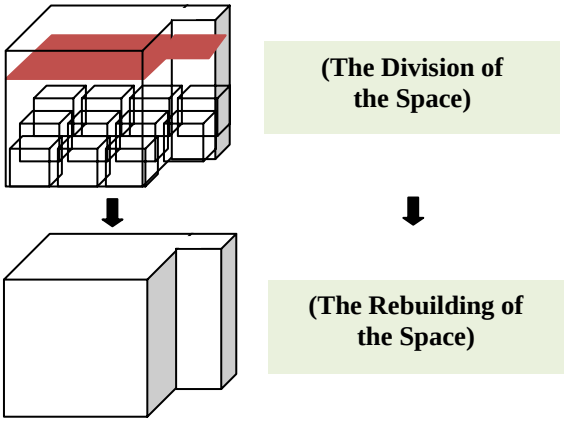


Fig 1. The Basic idea of Indoor Spatial Database

Based on the former concept, every building is considered as a big entity that could be divided into floor units, and each floor unit could be further divided into several small room units as arrays according to the building structure as showed in Figure 1. And each room unit has its own identity number and contains own specific database. When all separated databases get together, the coherent indoor information database is formed. This is the main concept of building special database structure.

3.2 Database Elements

Table 1. Three Basic Elements of Database

Element	Symbol
An Entity ● Is a person, place, or thing ● Should appear more than once	**Entity-Name** Entity-Name
Characters ● Is it static or dynamic ● Should it be used frequently ● Should contain more detail	**Character-Name** Character-name Character-name
A Relationship ● has the relationship with which ● has a parent entity or a child entity ● is dependent or independent	**Relationship-Name** Relationship-Name

There are three basic elements in the data modeling language (entities, data items, and relationships), which are designed to help the administrator examine the data from a variety of perspectives. Each of basic elements is represented by a different graphic symbol so as to indentify each category more easily and quickly. Table 1

summarizes three basic elements of information spatial database.

Entity is the basic nature. Database must be designed and maintained carefully to ensure that they can be operated properly. As large-size database may bring down the working efficiency, the object, which just shows up once, should not be included as an entity in the data model to make to database as small as possible. As regard to the total number of the visitor, although each one of the visitor only has a single instance, all the visitors can be regarded as a single object, and the information of this object will be a reference to the building management.

The character here is the elementary description of things, persons, events, and activities. As the moving objects need more efforts to update their information, the object should be classified as static status or dynamic status at first. Then according to their using frequency, we can divide them to different importance levels. Any necessary information of the object should be stated in the character description.

Relationship means objects may communicate with each other for information or the certain actions. Changes to one object have no influence on other objects' character, because the characters are self-contained, or encapsulated, within each one. But there may be some relationship among objects. For example, some objects' locations are next to another objects, some objects are affiliated to another one, and some objects can only survive only when some other certain objects exist in the building. And it is worth noticing that the relationship must be considered with respect to the variety of the location and time.

3.3 The Structure of Spatial Database

Table 2. The Structure of Spatial Database

Class	Elements
Building	B-Name → B-Char → B-Rel
Floor	F-Name → F-Char → F-Rel
Room	R-Name → R-Char → R-Rel
Space	S-Name → S-Char → S-Rel

As shown in Table 2, spatial database mainly contain four categories, including building, floor, room, and the space in a room. And different symbols are used to present different elements.

In the building category, the entity describes the name, the geographic location, and the general skeleton map of this building. The character includes the 3D building model. And the relationship contains the information such as the owner, the connect situation with the neighbor buildings and facilities.

In the floor category, the entity describes name, the position, and the plan of this floor. And the character includes the maintenance information, utilization situation, abnormal condition that detected by sensors and other necessary information on each floor. The relationship mainly describes the connections between the current floor and the neighbor floors such as the pipe connection, communication connection, evacuation passage connection, and so on.

In the room category, the entity describes the room number, and the detail position of each room. The character of the room is similar with the floor category which includes the maintenance information, utilization situation, abnormal condition that detected by sensors and other necessary information, and the IDs of the occupant who are frequently come in and go out of there. The relationships of rooms are much complicated than those of floors, which do not only include the information of the owner or the renter of this room, but also include the connection with the neighbor rooms, especially the distance between two adjacent rooms. As the distances between two adjacent rooms are recorded, the network of rooms could be built in the computer which can form the floor network, and then the whole building network. Thus, the possible route between two arbitrary points can be easily calculated on the basis of building network.

In the space category, the entity describes the name, position of the object in the room, such as components of the structure, equipment, furniture, sensors, and so on. The character includes the necessary information of objects such as the function, nature, installation time, utilization situation, current status, and so on. The relationship here refers to the spatial connection. For example, the supervision scale of the certain camera suggests the connection between the camera and space in the charge of the camera, so is the relationship between the space and sensors. And if there is a person in this space, the relationship is that this person belongs to this space.

In this order, the indoor spatial database is set up by a systematic approach. And it is convenience for the stepwise searching and other operation.

4. BUILDING INDOOR SPATIAL DATABASE

4.1 General Process

The general process of establishing spatial database is illustrated in Figure 2. It starts with the collection of static data and moving object data from various sources. The data are stored in the temporary database, and then the accuracy and necessity of the data are analyzed. In this process, large amounts of data are abandoned to eliminate error and save data space. The remained data is sent to the next process. Some data are directly stored in the spatial database, while the other data are used to generate 3D

visualization or management knowledge. All the data results ultimately form the indoor spatial database. The spatial database can be used as decision-support tools to provide solutions to different kinds of problems or unexpected emergencies.

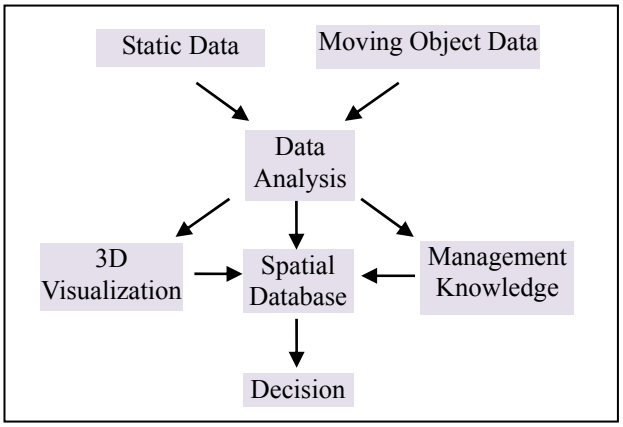
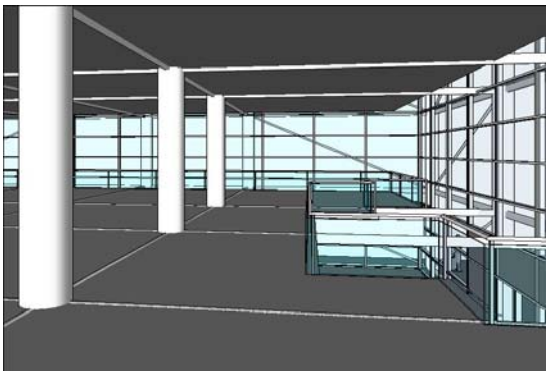


Fig 2. Establishing Indoor Spatial Database

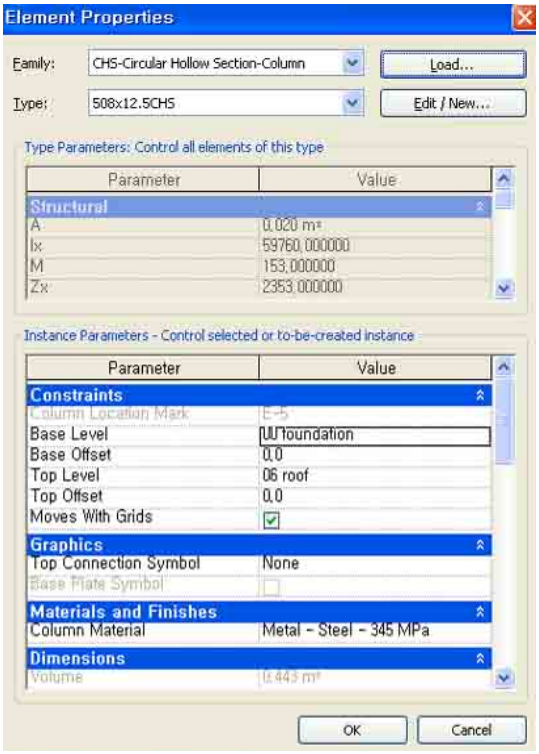
4.2 Static Data

Static data here includes the information of the object that won't move, or the object that will stay in a position for a long period, such as the component of building structure, the furniture and decoration in each room, and so on. The data must be presented to users. This presentation can be accomplished as a literal expression or image model by using different methodologies and visualization tools.

3D software provides a powerful and convenient way of conveying spatial information through vivid 3D models by reconstructing the interior scene of the building as in Figure 3(a). In this figure, each component of building structure can be easily identified. At the same time, the database in the form of tables or literal statement is necessary. Actually, some kinds of 3D software have a function that they can automatically form database when create 3D as shown in Figure 3(b). The element property of every component is recorded in the detail, which contains the information such as length, width, material ID number, constraint condition, and so on. Actually, such a large database is not needed, but more useful database can be built by extracting the useful parts from it.



(a)



(b)

Fig 3. 3D Building Model

4.3 Moving Object Data

As regards to some moving objects, especially human, we wish to be able to retrieve their current position. And because they are keeping moving, we also want to track their ways, and predict their future trend to prepare for a possible human flow control. Of course, there is no need to capture a single object which may only appear once in the system. So we need to build moving object database to describe the current status and predict future movement of the human flow. For this purpose, GIS tools, remote sensing devices and smart technology are widely used to obtain these moving objects data, and continuous update the data.

For example, we installed several infrared module sensors and cameras at the gates of H.Y Plaza in the first floor, and got the number of human flow there from 0:00 to 23:59 on the certain day as shown in Figure 4. At the first, we checked the accuracy rate of these data to judge if they are proper for the later use. The blue line shows the measured number of persons, and the red line shows the real number. From these figures, we could find that the measured numbers are approximately the same with the real numbers, so the measured number was credible and could be used for the long-term research. Then we collected more data of the human flow there. After enough data are collected, the regulation of the human flow in the building can be found out. And according to the regulation, we could predict the number of the person during the certain period in the weekday or weekend, and make a previous plan for daily administration. And also, these devices can update the latest information of the human flow inside the building to support the management.

Fig 4. Human Flow in H.Y Plaza

In this way, all those data are temporarily stored and analyzed, and then only the necessary data are stored in the indoor spatial database.

5. PRACTICAL USE OF INDOOR SPATIAL DATABASE

5.1 Consistency Management

The indoor spatial database can be applied in building consistency management such as information about composition, facilities, equipment, usage, maintenance, and so on. The convenience and cost-cutting features of indoor spatial database can give manager a great advantage to manage building well, and perform similar activities better than before. The challenge nowadays for database management and building intelligence management is information integration. The reason why this is a challenging task is that classifying and analyzing a great deal of data is not an easy work, not to mention properly use them into practice, and manage well.

Nowadays, more and more top-grade buildings are not just used as an office, or just as apartment. They combine the functions of office, apartment, and shopping mall to meet the growing demanding of various types of the people. The multiple functions are always accompanied by the management problem. If a building is the combination of shopping mall and apartment, just depending on the border guard to ensure the safety for the resident is far from the requirement. The more advanced methods are required to determine who are allowed to enter or exit the building, where they are allowed to exit or enter, and when they are allowed to enter or exit. Indoor spatial database assisted with GIS tools can solve this problem. It may include cards, fingerprints and readers, PINs (a personal identification number) and keypads, and egress motion detectors. This can exclude undesirable persons and record the entrance information in the database.

5.2 Restructure

Any restructure should be implemented on the basis of the comprehensive understanding of the former structure to ensure the safety of the building restructure and the rationality of the plan. In some restoration projects of ancient architectures, even the exact position and shape of every brick should be recorded, and then the brick is replaced with the similar one. Only depending on the manual operation may result in considerable amount of work and confusion in the implementation, not to mention the time and the cost. As mentioned before, we can record any necessary information of the object in the character detailed description in the indoor spatial database. With the help of indoor spatial database, we can find what we need, which parts can't be removed, which parts should be replaced without worrying about the data mistakes. And another advantage is that we can use spatial database to simulate the process of reconstruction to make each process proper and rational, and ensure that the operation is right and effective, or find a much better way to improve the plan and save cost.

5.3 Navigation

In a building with complex structure, the navigation is necessary, not to mention the importance of navigation in the emergency situation. Since the occupant can easily remember the place when they already see it, not just hear of it, visualization is considered as a means of facilitating the navigation. As the navigation is used so frequently in some tourist places, 3D navigation has already been adopted there.

Meanwhile, the ability to communicate effectively and efficiently between the occupant and the information spatial database is very important. To achieve this goal, sensors are widely used to detect the latest information which will be sent to indoor spatial database. And wireless devices are popular used to transmit the information to the pointed destination. In this way, the servicer can give the information to the occupant exactly and quickly, while the occupant can require for the information with more convenience. So the meaning of building the real-time indoor spatial database for navigation is crucial.

6. CONCLUSIONS

Because of the advanced technology, the inner environments become more and more complicated. We may use more time, labor resources, and money in dealing with this complex situation by using traditional methods, or after spending so many efforts on them, we still find it hard to identify and control the situation. Thus a new methodology should be found out to deal with them with high efficiency. For this purpose, indoor spatial database is introduced to organize the data more logical and effective.

This paper highlights the benefits related to using indoor spatial database. The basic idea of this paper was that we could divide a building into four categories including building category, floor category, and space category, and then sort the information for each category, and integrate the information of every part to get the whole indoor spatial database at last. And the basic three elements of database are entity, character and relationship. Each category has its own entity, character and relationship. The network of the building can be created on the basis of it. As regard to the data management, the data can be classified into static data and dynamic data. Both static data and dynamic data need continuous update. The dynamic data are often assisted by GIS tools and remote sensing technologies. At last, this paper discussed the practical application of the indoor spatial database.

This paper brought out a conceptual idea of constituting indoor spatial database. As indoor spatial database have some many advantages that it is believed that in the near future this technology will be widely used to facilitate the building identification and management in the indoor area.

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