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A System Concept for 3D Human Flow Management Based on 3D Spatial Information

Jayoung Yoon*¹, Byungju Ahn², Jaejun Kim³, Gwanggook Lee⁴ and Whoiyul Kim⁵

¹ Ph.D. Candidate, Department of Sustainable Architectural Engineering, Hanyang University, Korea

² Assistant Professor, Department of Architectural Engineering, Jeonju University, Korea

³ Professor, Department of Sustainable Architectural Engineering, Hanyang University, Korea

⁴ Ph.D. Candidate, Department of Electrical and Computer Engineering, Hanyang University, Korea

⁵ Professor, Department of Electrical and Computer Engineering, Hanyang University, Korea

Abstract

A controller who is responsible for safety makes decisions concerning measures for visitor safety using a human-based decision-making process. Many potential accidents that could be caused by human error lurk in the process. These accidents can be reduced by changing from a human-based to technology based decision-making process. A technology-based decision-making process can draw a controller's attention to trouble spots by data filtering, alarm filtering, and so on. The controller can thus obtain information on the occurrence of possible accidents proactively.

The objective of this study is to suggest a system for 3D human flow management using a technology-based decision-making process. The system is divided into two parts: a 3D spatial information system and a human motion detection system. The former is built from 3D CAD and a geographic information system, and the latter is developed from image processing. This study shows the direction of system development and the method of application, and describes the contribution of the system.

Keywords: Spatial information; human flow; 3D CAD; 3D GIS; image processing

1. Introduction

1.1 Background and Goals of the Research

In the construction industry in the 21st century, the production system has moved from a one-way system embracing all stages from planning and design to disposal, toward interactive systems that focus on the improvement of people's quality of life and connect the consumers with the producers. In today's society, consumers have ever-higher levels of income and education. Following advances in architecture and production technologies, their expectations and demands are higher. In an attempt to meet the requirements of supply and economy, the construction industry has increasingly built multicomplex buildings.

With the increased diversity of facilities in a building, the indoor and outdoor space becomes more complex and the number of users increases, decreasing the operational efficiency of the building and causing inconvenience to users, ultimately reducing their

quality of life. In addition, there is a greater risk of large accidents or disasters. These problems must be resolved. In such situations, the controllers in charge of the safety of users resort to monitoring systems such as CCTV to capture information about occurrences that require action, and their actions are based on such information. If a controller perceives the situational information properly, he or she is highly likely to take proper action. If this is not the case, the controller may not even realize there is a potential problem. Because the decision-making process is human based, there is always the possibility of accidents or disasters caused by human errors.

This problem can be solved by changing from a human based to technology based decision-making process. With this change, the controller can perceive the situational information more proactively and ultimately reduce the possibility of accidents or disasters caused by humans. Thus, in this study, the authors suggest the concepts of a management system with which to manage user flow and explain its developmental directions, utilization plans, and expected effects.

1.2 Scope and Contents of the Study

This study describes the concept and expected effects of a management system used to manage human

*Contact Author: Jayoung Yoon, Ph.D. Candidate, Department of Sustainable Architectural Engineering, Hanyang University, Haengdang-dong 17, Sungdong-gu, Seoul, 133-791, Korea
Tel: +82-2-2220-4058 Fax: +82-2-2296-1583
E-mail: nyx80@hanyang.ac.kr

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flow.

The research was divided into two parts: a 3D spatial information system and a human motion detection system. The 3D spatial information system consists of 3D CAD and a Geographic Information System (GIS), and the human motion detection system is developed from image processing.

The study shows the system development and expected effects of the system. During the system development, the authors examined the need for the management system suggested in the study, the components of the system, the component technologies required, and methods of system development. The utilization plans, expected effects, and developmental directions were then reviewed to assess the expected effects of the system.

2. Need for a System to Manage User Flow

Controllers in charge of user safety resort to monitoring systems such as CCTV to capture information about circumstances that require action, and base their action on such information. A controller who perceives the situational information correctly is highly likely to take proper action. However, if perceptions are not correct, the potential problem may not be recognized. Because this decision-making process is human based, there is always the possibility of accidents or disasters caused by human error.

A controller can only prevent an accident by paying constant attention to the image information and then evaluating and categorizing the values of the information. However, events do not give prior warning. The controller must watch the monitor for a long period of time to detect events that cannot be anticipated. It is hardly possible to give total undisturbed attention every second.

Such a problem can be solved by changing from a human based to technology based decision-making process. Technology can filter the image information and generate warning signals according to the situation, thus reducing the possibility of human error by the controller. The controller can then perceive the situational information more proactively in real time and ultimately contribute to reducing the possibility of human-caused disasters.

3. A 3D Human Flow Management System

3.1 3D Spatial Information System

The first part of the 3D Human Flow Management System is the 3D spatial information system. The authors' study suggested the integration of a 3D CAD system with a GIS.

The 3D CAD system is a design tool and contains the configuration and attribute information of the various materials used in construction (e.g., pillars, crossbeams and slabs). However, the authors are not designing a production system but a system to manage user flow inside a building. To derive information about

user locations or vertical transport facilities (staircases, elevators and escalators) inside such a building, indoor spatial information rather than material information from the 3D CAD is required. That is, what is required is the configuration, attributes, and phase information (e.g., the elevator hall is located between the staircase and a restroom) of a variety of spaces.

At the same time, the system requires the configuration, attributes, and phase information about the outdoor spaces provided by the GIS in order to manage the flow of users outside the building. Integration of the 3D CAD system and the GIS will meet these needs. For this integration, the study suggested a 3D spatial management system. It consists of the integration of the 3D CAD and GIS or the integration of the database of indoor and outdoor spaces, as well as an application system to manage the database. The database can be integrated by developing and linking a transformer application for the database of indoor space information from the 3D CAD and saving the indoor space information as a layer of the outdoor space information generated by the GIS. Thus, when a user approaches a multicomplex building, the system can track his or her route from outside to inside.

Commercial 3D CAD systems include the Revit by AutoCAD and ArchiCAD. The latter was used in the study because it is more specialized for building design than the former. It can also transform the 3D design information using IFC into spatial information. IntraMap3D was chosen as the GIS system; it is a commercial system developed by the Korea geoSpatial Information and Communication Co., Ltd. Its efficacy has been proved through many applications in Korean GIS projects.

The study implements geometry translation between the 3D CAD and the GIS and has largely resolved the technical differences in geometry. This shows that file translation is a pragmatic and efficient approach to integrating the two systems.

File translation involves the conversion of data from one file format to another. It converts the 3D CAD data to a GIS data format and vice versa. DXF can be used as the intermediate file format. Because of differences in the 3D CAD and GIS data models and file formats, the user must specify the syntactic and semantic mapping. Unfortunately, the process is not flawless, and data are often lost. Loss of information because of

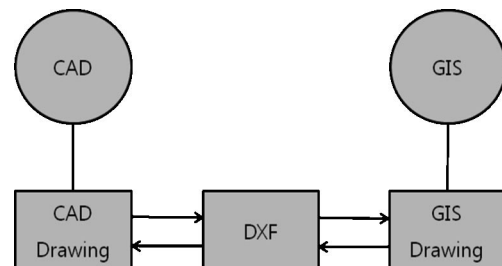


Fig. 1. File Translation (Maguire, 2003)

translation cannot be ignored, but with careful attention it can be minimized.

Tight integration will require a combined solution at the data representation level. Currently, 3D CAD-GIS integration projects tend to be project specific and case by case. In the authors study, integration of data for the COEX Mall, a large complex building in Seoul, Korea was attempted. Figs.2. and 3. show the results.

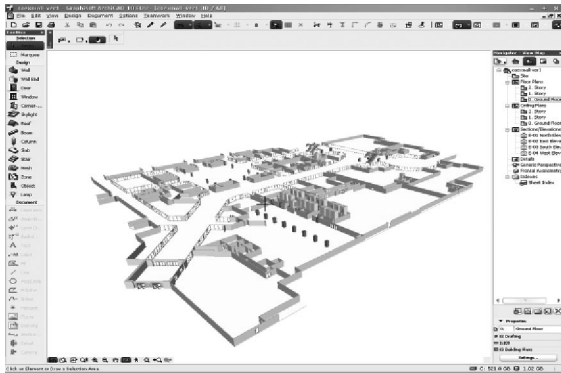


Fig.2. 3D CAD View of COEX Mall

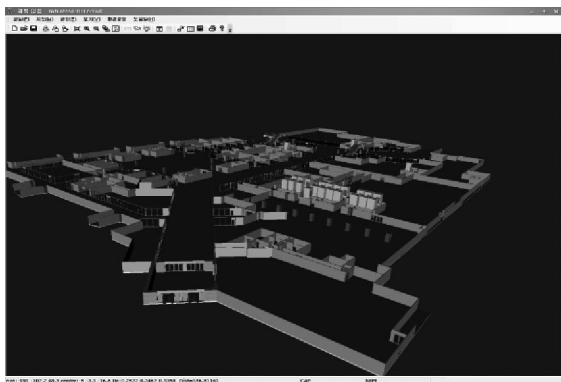


Fig.3. 3D GIS View of COEX Mall

Model conversions are seldom based on pure geometric translation, so semantics is important. An efficient way to integrate two different systems is to achieve interoperability between them.

3.2 Human Motion Detection System

The second part of the 3D Human Flow Management System is a human motion detection system.

Tags, sensors to detect tag signals, and a management system are required for automatic tracking and management of an object's location. Some examples include Radio Frequency Identification (RFID), Smart Card, and navigation systems. However, there are limits to the use of these technologies in managing user flow in a multicomplex building, because an unknown number of people use the building, and they cannot be forced to carry tags.

Thus, a technology that can detect the movement of people without the use of tags is required. In the authors study, a system to detect people's movements using image processing was suggested.

The basic principle of the technique is as follows.

First, color cameras are installed at appropriate locations in the multicomplex building and photographs taken at frequent intervals. If there is a moving object in the continuously photographed images, preprocessing is undertaken to remove noise and regulate the brightness of the image. The traveling object is then isolated from the background to detect its movement and recognize it. If the traveling object is a person, the hair contours that are unique to individuals are recognized by using pattern-matching techniques. Thus, it can be established whether multiple images are of the same individual or how many people are moving. Postprocessing is used to remove the background. The postprocessed images are compared with the images from other time slots to produce a motion vector. The current technologies involved allow for about 60% accuracy.



Fig.4. An Example of Foreground Segmentation

In the authors study, the object detection system was focused on pedestrian flow; that is, the number of people moving in and out through a gate or a passage per unit time. Low-level image features extracted in the virtual gate are used as clues in estimating the pedestrian flow. Because this method is based on simply integrating low-level features in the gate and does not employ any detection or tracking, the computational burden is very low. In addition, a feature normalization process helps the proposed method to be robust to viewpoint changes. For this reason, the authors believe the proposed method can be easily applied to existing CCTV systems. Fig.4. shows an example of the proposed method, while Fig.5. shows a block diagram of the authors' approach. For every input frame of the video, foreground segmentation and motion vector computation are performed to obtain low-level image features. Feature normalization is performed to compensate for the influence of the perspective projection. Once the foreground image is normalized, the number of pixels in the virtual gate is counted. In this pixel-counting step, a motion vector is employed to distinguish the moving directions of each moving pixel (or blob). Finally, based on the number of counted foreground pixels on the virtual gate, the number of people passing through the gate is estimated.

3.3 Integration of 3D Spatial Information System and Human Motion Detection System

There are two major stages in the development of the authors 3D human management system. Stage 1

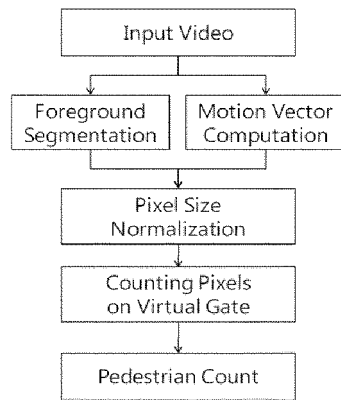


Fig.5. Procedure for Detecting and Tracking Pedestrians

aims to develop the 3D spatial information system and the human motion detection system. Stage 2 aims to integrate the two systems.

With respect to the management technologies of indoor spatial information using 3D CAD, spatial information was defined and categorized, the phase relationships of spaces were defined and categorized, and the algorithm for extracting spatial information from the 3D CAD information was developed. The detailed research included a literature study on the categorization of spatial information in a building and phase relationships, which was followed by definition and categorization of the phase relationships between the 3D spatial information and the actual space. IFC was used to develop an algorithm to extract the spatial information from the 3D CAD information systematically.

With respect to the management of outdoor spatial information using GIS, the indoor spatial information databases of 3D CAD and the outdoor spatial information databases of GIS were integrated, and the 3D SICS engine was developed. The detailed research included developing a transformation to integrate the indoor spatial information databases of 3D CAD and the outdoor spatial information databases of GIS.

For the human motion detection system, the camera locations for human motion detection were selected, and the algorithm for human motion detection was

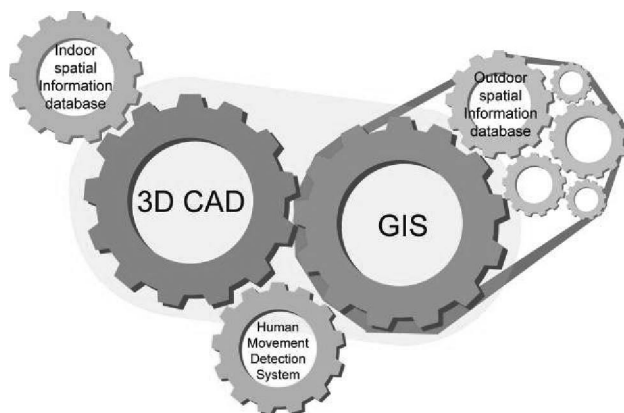


Fig.6. Integration of 3D Spatial Information System and Human Movement Detection System

developed. The detailed research contents include a review of the installation locations, intervals, and field of view for the cameras, as well as examination of the changes to the lighting conditions and population density inside the building for the algorithm of human motion detection.

Fig.6. shows the concepts of integration of the 3D spatial information system and the human movement detection system.

Stage 2 involves pilot testing and system supplementation. For the detailed research, the results of Stage 1 were combined to develop a prototype 3D human flow management system. An interface was developed to deliver the information collected by the system to its users. After drawing the 3D CAD map for the space, pilot tests were run, and diverse raw data were collected. Analysis was then conducted to find any problems so they could be resolved to improve the system.

With this system, problems can be solved by changing from a human based to technology based decision-making process. The latter filters the image information through the system and generates warning signals according to the situation, thus reducing the possibility of human errors by the controller. The controller can then perceive the situational information more proactively in real time, and the system thus ultimately contributes to reducing the possibility of man-made disasters.

After reviewing previous studies, it was concluded that no systems had been developed to manage indoor and outdoor user flows by integrating the 3D CAD, GIS, and human motion detection systems. Similar results were found for the GIS industry, where there was no system developed to integrate and manage the indoor and outdoor spatial information of a building.

A study similar to the present one was found in the civil engineering sector, where a solution to manage a facility using ubiquitous technology was suggested. Lee Geung-yeong (2004) presented an object-based facility management solution using 3D GIS/CAD integration for UFM at an international symposium of the Korean FM Society. Her solution targeted the civil engineering facilities to estimate the expected effects of increased maintenance and repair and to promote understanding of a complex building by providing visual information about the building.

4. Utilization Plans and Expected Effects

4.1 Utilization Plans of 3D SICS

Fig.7. describes the utilization plans for the 3D human flow management system suggested in this study.

The figure shows how cameras and interfaces are installed to allow human motion detection in a virtual multicomplex building.

Inside the building, many cameras are installed in each space (such as hallways, staircases, elevator halls

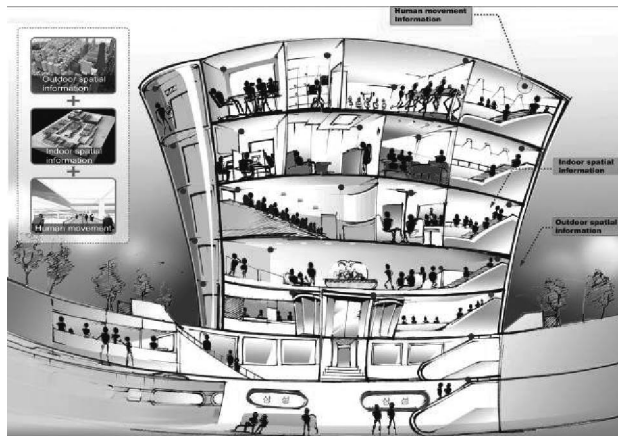


Fig.7. Utilization Plans for 3D Human Flow Management System

and escalators). The images taken by the cameras are sent to the human motion detection system, where they are processed. The 3D human flow management system analyzes the image processing results and produces and manages information about the number, density and movement directions of the building users. It also displays this information through the interface in real time.

4.2 Expected Effects of 3D Human Flow Management System

There are more and more areas where 3D CAD is applied in producing and managing information for construction. However, it has limitations when used to manage user flow rather than to produce spatial information, because the design information concerning materials is not required in managing user flow. What is required is information about the spaces generated out of combinations of materials. In addition, a system should exist to manage the information. Thus the significance of the 3D human flow management system can be found in its efficiency regarding information management.

The 3D spatial information system can be used to express information about the inside and outside of a building, its basement, surrounding environment and phase relationships with other buildings in a realistic manner in a digitized virtual space, as well as to manage it. As a framework, it can also contribute to a higher quality of life when combined with other application systems capable of using such information.

The human motion detection system can be an effective approach to managing an unknown number of users in a real-time and systematic manner.

4.3 Later Development of 3D Human Flow Management System

This section is devoted to future 3D human flow management systems and related areas in terms of integration of sensor technologies and additional technological advances.

First, an indoor navigation system could be developed. It could help a user located inside a huge

building such as a multicomplex building travel to the required destination by providing the required information. The related technologies include the indoor spatial information databases of the 3D spatial information system, the tracking technology of the human motion detection system, technology for optimal route search inside a multicomplex building, and a portable interface.

Second, a security management system could be developed to prevent unauthorized people from entering a controlled area. The related technologies include the indoor spatial information databases of the 3D human flow management system, the tracking technology of the human motion detection system, portable tags, tag-detecting sensors, and an application system.

Third, a facility management system could be developed to manage structural changes to the materials (e.g., pillars, crossbeams, slabs, and walls) of a building. The related technologies include the 3D design information, the indoor spatial information databases, change detection sensors, and application systems.

Fourth, a traffic flow and parking management system could be developed to provide users approaching a building in cars with information about the traffic volume in the parking lot and the locations of available parking spaces.

Fifth, a disaster prevention and management system could be developed. It would notify the controller and users when there is a fire inside a building. The related technologies include the indoor spatial information databases of the 3D human flow management system, fire detection sensors, and an application system.

Finally, an indoor environment management system could be developed to manage the air quality inside a multicomplex building. The related technologies include the indoor spatial information databases of the 3D human flow management system, Indoor Air Quality (IAQ) sensors, and an application system.

5. Conclusion

A controller in charge of user safety in a multicomplex space uses human-based decision-making processes to assess situations and take appropriate action. The processes however, have an inherent possibility of human error and resulting disaster. This problem can fortunately be solved by changing from a human based to technology based decision-making process. With the change, the controller can perceive situational information more proactively, ultimately reducing the risk of human-caused disasters.

Understanding such needs, this study has suggested a 3D human flow management system, which manages user flow in a multicomplex building by using technology-based decision-making processes, and the authors have explained its developmental directions,

utilization plans, and expected effects.

The suggested 3D human flow management system integrates 3D CAD, GIS and image processing, and can be used to make buildings more intelligent and multifunctional.

The study also pointed out future research directions in 3D human flow management system development as follows.

- (1) An algorithm to extract spatial information from 3D CAD information should be developed.
- (2) A direct data converter should be developed for the integration of 3D CAD and GIS.
- (3) Technologies to increase the accuracy of a human motion detection system should be developed to define the number of people traveling in groups more accurately.
- (4) Interfaces of diverse forms should be developed to provide users with the information captured by the 3D human flow management system.
- (5) Diverse application systems should be developed to expand the utilization scope of the 3D human flow management system.

References

- 1) Garibotto, G. and Cibeï, C. (2005) 3D scene analysis by real-time stereovision, image processing. IEEE International Conference, Vol. 2, pp.105-108.
- 2) Yeo, H-g. (2005) Cities and complexes, architecture. Korean Architecture Society, 49 (11), pp.71-73.
- 3) Lee, Gye-shik (2004). Practical Approaches to Construction of a U-City, Samsung SDS.
- 4) Choi, Yun-ho (2005). U-Life of U-City Citizens, Samsung SDS.
- 5) Han, Il-ho (2006). Overview of the Automatic Object Tracking Technologies, La-Terra.
- 6) Lee, Geung-yeong (2004). A 3D Object-Based GIS/CAD Solution of Facility Management for UFM. The international symposium of Korean FM Society.
- 7) S. Zlatanova, D. Prospero (2005). Large-Scale 3D Data Integration. New York: Taylor & Francis.
- 8) J. L. Spipes (2005). Spatial Technologies-Integrating CAD and GIS, <http://gis.cadalyt.com/>
- 9) Autodesk (2004). CAD and GIS – Critical Tools, Critical Links.
- 10) B. Wu and R. Nevatia (2005). Detection of Multiple, Partially Occluded Humans in a Single Image by Bayesian Combination of Edgelet Part Detectors. Proceedings of the Tenth IEEE International Conference on Computer Vision (ICCV'05) vol.1, pp.90-97.
- 11) O. Sidla, Y. Lypetsky, N. Brandle, and S. Seer (2006). Pedestrian Detection and Tracking for Counting Applications in Crowded Situations. Proceedings of the IEEE International Conference on Video and Signal Based Surveillance. pp.70-75.
- 12) T. -H. Chen, T. -H. Chen, and Z. -X. Chen (2006). An Intelligent People-Flow Counting Method for Passing Through a Gate, Robotics, Automation and Mechatronics. 2006 IEEE Conference, pp.1-6.
- 13) C. Stauffer, W. E. L. Grimson (1999). Adaptive background mixture models for real-time tracking. International Conference on Computer Vision, Colorado, USA.
- 14) Gwang-Gook Lee, Byeoung-su Kim, Whoi-Yul Kim (2007). Automatic Estimation of Pedestrian Flow. Proceedings of ACM/ IEEE International Conference on Distributed Smart Cameras.