

CAMPUS SPACE MANAGEMENT USING A MOBILE BIM-BASED AUGMENTED REALITY SYSTEM

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Abstract. In South Korea, the changing paradigm of family composition toward single-person households and nuclear families has caused the decrease in number of students, which has led to the need for change in the qualitative, rather than quantitative, management of spaces and facilities on university campuses. In particular, since 2005, the merging of universities have accelerated, which has brought up the need for a system that facilitates the management of integrated university systems. Accordingly, universities now require efficient system operation based on three-dimensional and data visualization, unlike the document-based management of facilities and spaces in the past. Users lack a sense of responsibility for public facilities, causing difficulties such as energy waste and frequent movement, as well as damage and theft of goods. This study aims to form an AR-based interface using the ANPR algorithm, a computer vision technique, and the position-based data of the GPS. It also aims to build a campus space management system to overcome the limitations of current systems and to effectively and systematically manage integrated building data. In addition, for module test verification, the prototype is applied to actual campus spaces, and additional demands for campus space management in the AR application are identified and organized.

Keywords. Augmented reality; Campus space management; BIM; CAFM (computer-aided facilities management); user experience (UX).

1. Introduction

In South Korea, the changing paradigm of family composition toward single-person households and nuclear families has caused the decrease in number of students, which has led to the need for change in the qualitative, rather than quantitative, management of spaces and facilities on university campuses. In particular, since 2005, the merging of universities have accelerated, which has brought up the need for changes in college education. For this reason, universities are not in

the position to insist on perpetual expansion of spaces and facilities, and now require efficient system operation based on three-dimensional and data visualization, unlike the document-based management in the past.

Due to the characteristics of universities, the management of facilities of on-campus spaces requires periodical review every six months. Also, users lack a sense of responsibility for public facilities, causing difficulties such as energy waste and frequent movement, as well as damage and theft of goods. In addition, log data such as information on entries and exits may be obtained for effective utilization in space management, but they are treated as volatile data, and are not utilized. Such data are built into existing space management systems, but there are difficulties in obtaining effective information on the site situation. Therefore, this study intends to build a BIM (Building Information Modelling)-based campus space management system by applying the technology of ANPR (Automatic Number Plate Recognition), which is a vision algorithm, and position-based data of the GPS (Global Positioning System) to an AR (Augmented Reality)-based interface environment. The goal is to overcome the limitations of current campus space management systems, reduce inefficient budget investment, and manage integrated building information more effectively and systematically.

1.1. RANGE AND METHOD OF RESEARCH

This study is on the development of a system for more efficient campus space management by applying the technology of ANPR, which is a vision algorithm, and position-based data of the GPS to an AR-based interface environment, and was focused around Hanyang University.

The research proceeded in the following method.

Firstly, the introduction examines the study's background, purpose, range, and methods.

Secondly, the current state of space management systems are theoretically examined, and the concept and characteristics of AR are explained. Then, the characteristics and necessity of AR in campus space management are identified.

Thirdly, in order to build a space management system that utilizes the ANPR algorithm and GPS data, the methods of visualizing data applicable to AR, building BIM-based data, and developing a mobile application are examined.

Fourthly, a structure is established for a campus space management system and a prototype is built and applied to Hanyang University, verifying the system.

Lastly, the significance of this study and its limitations in the process are presented for future research.

2. Theoretical Analysis

The inspection team, management team, energy manager, and asset manager of Hanyang University, which is the subject of application for this study, were interviewed. It was found that not only the current floor plan, space, energy, and asset information of each building are managed by different databases and teams, but there was also no single integrated model or system that had been built.

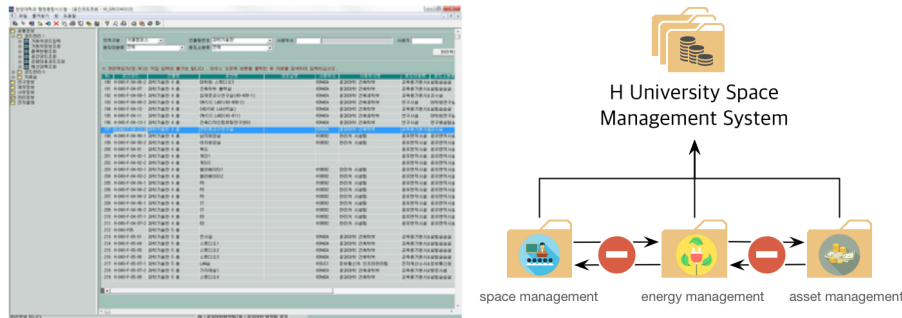


Figure 1. Administrative management system of Hanyang University.

As shown in figure 1, the database of Hanyang University’s overall space management system was founded on two-dimensional graphic information and text, and was managed by being dispersed into three aspects: 1) space management, 2) energy management, 3) asset management. There was no single integrated system for the database managed in this way, and the information was stored as Excel files.

The greatest difficulties for managers were: 1) Difference in information between the site and in the office, and having to manually rebuild the situation and information changing on site, 2) absence of a single integrated system and organized management system, 3) budget issues that increase every year, 4) lacking sense of space privatization of managers and users, and 5) lacking manpower capable of using the system. These five items were chosen. Also, the necessity of building an additional system was being recognized, but there were opinions that additional costs and manpower investment were burdensome.

2.1. CONCEPT OF AR

AR (Augmented Reality) is a field derived from VR (Virtual Reality), the research on which was begun by the development of the see-through HMD (head-mounted display) by Ivan Sutherland in 1968. In VR, the user generally is immersed in a virtual environment, so the user cannot see the actual environment, but in AR, the user can see actual surroundings, where the actual environment and virtual objects are blended. In other words, VR shows the user a replacement of the actual world, but AR is different in that it shows the user the actual world supplemented with virtual information by synthesizing virtual objects into the actual world, and has the feature of providing the user with a better sense of reality compare to VR.

According to Milgram, the greatest difference between VR and AR is the degree of approach to reality.

The Real Environment is the reality in which we currently live and exist; Augmented Reality is the synthesization of virtual information based on reality; Augmented Virtuality is the synthesization of reality based on virtuality; and Virtual Reality is the design of figures and graphics using the PC. The range of these concepts altogether is referred to as “Mixed Reality.”

The application of the ANPR algorithm and GPS data technologies on the AR interface is presented in figure 2.

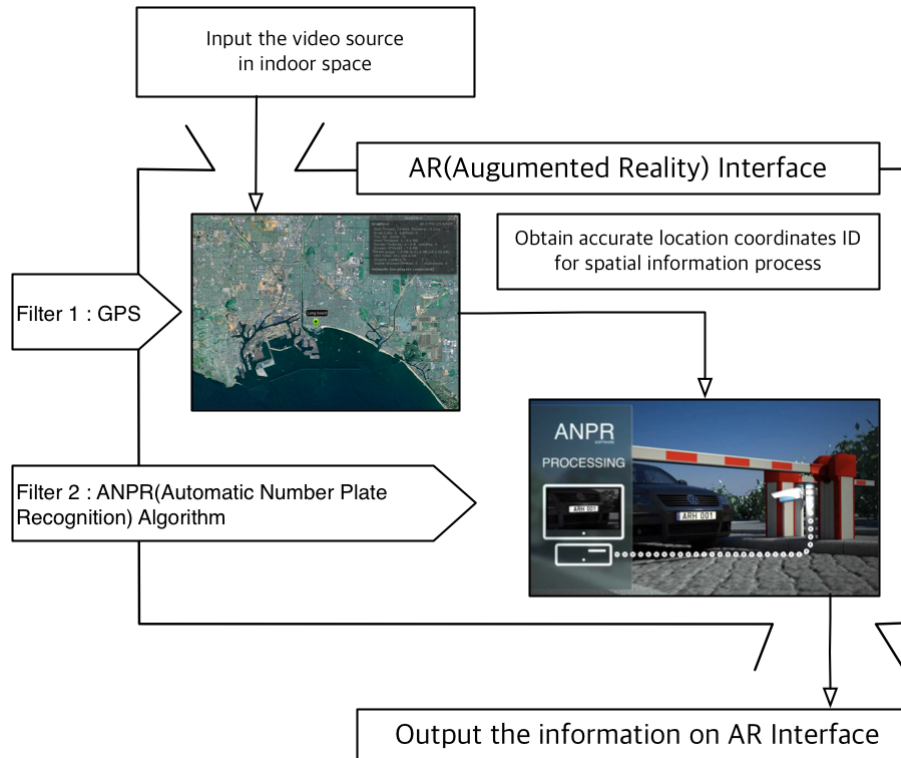


Figure 2. The Application of ANPR Algorithm and GPS Base Information Technology within the AR Interface.

The ANPR algorithm is also known as the vehicle license-plate recognition algorithm, and must go through the process of machine learning in order to recognize numbers and character information. The numbers and letters must have the same font style for better rate of recognition. The process of machine learning is a process that raises the system's rate of recognition by repetitively learning character data through all cases. If the numbers and letters have different font styles, a repeated DB operation is required for recognition.

2.2. ROLE OF AR IN CAMPUS SPACE MANAGEMENT

In this study, an AR interface is presented as a response to the current limitations of campus space management, and the space management data that can be actualized with AR is built with the following four types of data.

First, spatial data can be utilized. With spatial data utilization, system users, such as the administrator and manager, can obtain information of each room with a mobile device without a separate document or equipment on site, and correct errors. In addition, the administrator can access information on rooms that are being used incorrectly or without approval, which can even have an effect on on-campus safety.

Second, energy management data. Energy management data is generally maintained by being divided into the three areas of city gas, electricity, and water supply and sewerage. The place of use, purpose, used amount, and cost are managed for these areas, and energy management data have been in the form of volatile data. These data can be visualized, and with plots, the comparison of energy usage among different rooms, comparison of usage to the previous month, and target energy reduction can be digitized to change members' awareness and reduce inefficient use of budget. Also, real-time energy usage can be checked to prevent safety accidents such as blackouts and fires in heating and air conditioning systems.

Third, entry and exit data. Entry and exit log data are generally also managed as volatile data, which the campus has been unable to create added value with. However, by visualizing entry exit data using AR can have the effects of 1. Efficient space distribution, 2. Prevention of unnecessary space expansion, and 3. Theft prevention. The "Policy Study Report of 2008" by the Ministry of Education states that the greatest reason of difficulty in efficient space utilization on campus is the friction among campus members. The amount of usage in each room for each time frame can be visualized into a plot, which can be utilized as objective evidence.

Fourth, asset information. The asset information of each room is compiled by the manager of each area, who checks each room every six months, and the final document is written up by integrating this information. However, documents that are distributed/overlapped in a small scale in this way lack reliability, and contain many errors with respect to the actual site. If the asset information for each room is visible in real time using AR, and if it can be edited immediately, these errors can be diminished, and there will be less of a need for a large amount of manpower.

3. Building a Space Management System Utilizing the ANPR of the AR Environment and GPS-Based Technology

In order to apply the prototype to Hanyang University, this study developed the concept by applying the ANPR algorithm to the school's room numbers. Afterwards, the data dispersed across each area were integrated and a server was made to manage them. The four types of data that were applied to the AR interface are: 1. entry and exit data for each room, 2. energy management data, 3. asset management data, and 4. construction data for each room. The database applied to the server was stored as an Excel file as shown in figure 3, but it was converted into a JSON file to make the data lightweight. The JSON file was uploaded to the server and synchronized with the system.

3.1. BIM DATA CONSTRUCTION USING GPS-BASED POSITION DATA

Hanyang University's building information is organized into a CAD file. A building with four floors underground and 7 floors above was selected, the model data for which was constructed using Autodesk Revit 2016. This allows for easy editing and changing of the geometric and non-geometric data on space, which is a merit of BIM. Not only that, but the BIM data is systemized into a DB, so that by setting the ANPR and GPS as the trigger, the data required by the system can be obtained from the BIM model. The data for each room can be extracted from the

3.2. MOBILE APPLICATION UTILIZATION

The server is responsible for connection to a network that has a different role from monitoring and controlling the entire network, such as printer control and file management. Then, the server performs service according to the client's request, and plays the role of operating in the form of distributed processing that mutually inputs one or more application programs. Generally, it plays the role of managing information on the internet, and the server provides information by the request of the client. That which processes the information provided is the client. To effectively apply the system structure of this study, the mobile device equipped with sensors for GPS and ARPN application along with a camera becomes the client.

Basically, for the system in this study, the GPS and ARPN are synthesized in 1. The JSON file of non-geometric data and 2. BIM-based geometric data, synchronizing the geometric and non-geometric data, in order to construct an AR space management system that utilizes LBS.

Based on this, the UI implemented in the mobile device is shown in figure 5.

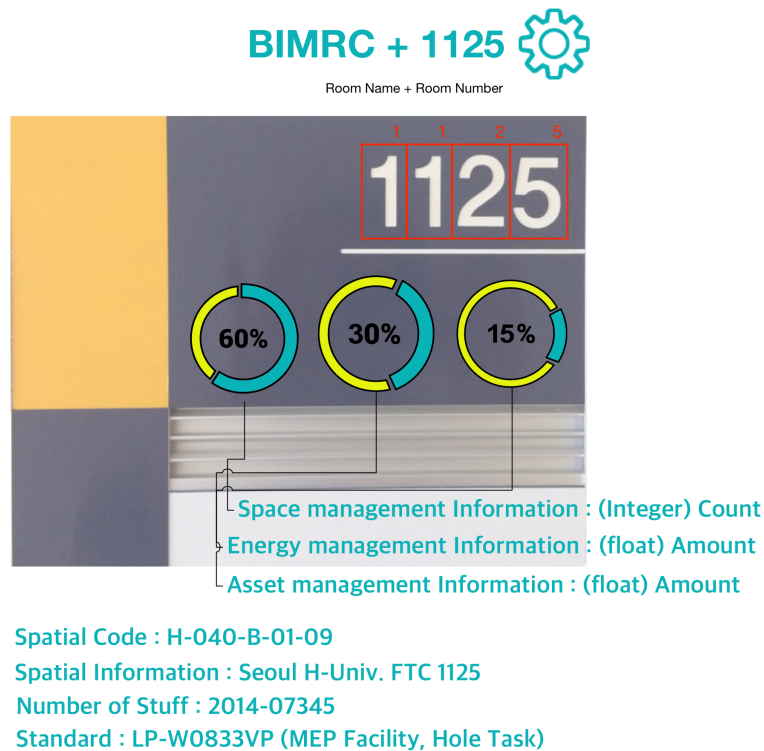


Figure 5. UI interface for the AR system.

4. Campus Space Management System Utilization

The application built in section 3 is installed and run on the user's mobile device. When a room number is scanned in front of a room corresponding to space management, a virtual grid is formed with the corresponding room number plate as the reference point. The constructed space management information is implemented in the AR interface using Unity 3D and OpenGL, and the user's vertical and horizontal location data is found. Here, the horizontal data is the location information using the GPS, and the information of the building that the user is currently located in is temporarily stored in the mobile device. Then, considering that GPS does not recognize altitude, the vertical data, the room number, and the information of the corresponding floor recognized by ARPN, are grouped with the horizontal data, which is transmitted to the server from the mobile device. Finally, in the server, the space management information corresponding to the room for which the location data was received, using the received vertical and horizontal data values, is presented in the AR interface. Figure 6 shows the overall framework of the system.

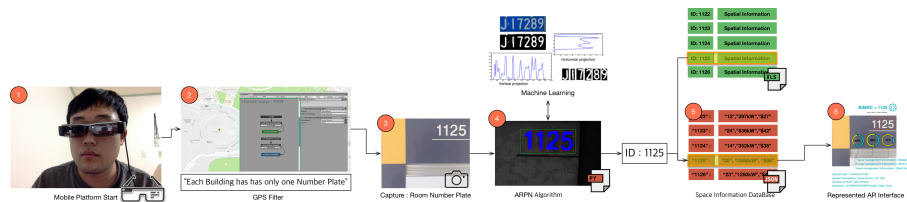


Figure 6. AR Space Management System Framework.

4.1. SYSTEM UTILIZATION

In this study, the room on the eleventh floor of Hall A and the fourth floor of Hall B of Hanyang University, the subject of this study, were selected as the target places of space management. An experiment was done on the implementation of AR by bringing the management information of Room 413 on the fourth floor and Room 1125 on the eleventh floor of different buildings from the server. First, the management target is identified, and the user runs the mobile application at the location of management. At the beginning of the execution of the program, the camera screen appears, and the room number is scanned. When the room number is scanned, the data values that track the current position are computed, and the information of the room that is about to be managed is displayed, and the manager checks the input/output information, as well as the energy and asset data. Then, if there is incorrect information, a part to be edited, or new information to be added, the setting modifies the data in real time. The information is then automatically updated by the server, which then synchronizes the mobile device. In the same order, when moving to the next place for management, and the room number is tagged again, the information corresponding to the place is managed.

5. Conclusion

This study developed a space management system for a university campus that uses LBS and AR technologies, and constructed a prototype by applying this system to the rooms of different buildings of Hanyang University. Based on this, the following conclusions can be drawn.

First, it overcomes the limitations of existing campus space management systems, and enables efficient and intelligent building management through systematic management of building information. In addition, it cuts unnecessary budgets, and is much faster and efficient to exchange and manage modified information.

Second, the study proposed the means to support an intuitive and natural building information search method by introducing it into the building management system in the AR interface environment. Most of the information implied in the space is not readily apparent to the naked eye. However, if the building information is expressed in the real environment in the AR environment introduced in this system, when there is a problem in the actual building management, it can sufficiently be corrected without manual work, and it is also possible to prevent and prepare in advance.

Third, there is a high possibility of expanding the application range of the system and creating added value. The system in this study contains information and functions in the manager's perspective. However, it can also contain various information in the same way, expanding users to not only administrators but also students, professors, and visitors to campus. There is a high possibility that it will become useful by providing various data.

Future research will be on building and uploading additional databases of spatial data, such as electricity, facilities, and safety to the system. Currently, the system is built on four types of data: 1) construction data, 2) energy data, 3) entry and exit data, and 4) asset data. However, the fields of specialization for space management on campus manage more diverse and greater amounts of data. In addition, updates will be needed to manage the customized data required by each use, with the assistance of experts in work processing for space management.

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