# RETRIEVING AND BROWSING INFORMATION OF BUILDING EQUIPMENT USING AUGMENTED REALITY TECHNIQUES

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**Abstract.** Current research on AR (augmented reality) tends to focus more on fields other than architecture. However, the AR technology will also affect architecture and will become more powerful than it is now. In this study, we have attempted to develop a new system called 'Building Scanner' that recognizes an area and information of building equipment frequently on a single floor using AR techniques and enables a user to browse/retrieve more naturally and easily. For this system, our study proceeds in the following three steps; 1) Develop an object-oriented CAAD system, 2) Develop building equipment database and input system, and 3) Visualize 3D building equipment data on AR. We believe that our attempts can generate a new powerful tool with a wide range of applications for architecture. Further research includes improving information of building equipment input methodology, user interface designs for the Building Scanner, and constructing other information for broader applications, etc.

## 1. Introduction

### 1.1. BACKGROUND AND PURPOSE

Recently numerous approaches are taking place on AR (augmented reality) that provides more naturally visualized information mingling the physical world with the virtual data. In the field of architecture, information that users can obtain from the building is generally restricted only to the users themselves, space, or building exterior. In other words, people cannot access the building information directly such as plumbing and building structure marked on the drafts. Rather, they roughly guess usage, shape, and finishing of buildings with the information they have. Although we have found several research on architectural AR system, most of them only focused on the specific area where virtual data and real world were overlaid without the whole understanding on the relations and linkages of every space in a building.

Therefore, as a part of developing applications on augmented reality in architecture, we explore how to use AR techniques to retrieve information of building equipment with an easier yet more natural way. In this regards, we have developed a 'Building Scanner' system that frequently recognizes an area and information of building equipment using AR techniques. Besides, we suggest various architectural applications using this system.

### 1.2. METHODOLOGY AND SCOPE OF PROCESS

The system, called 'Building Scanner' that we have built through our research, proceeds in the following three steps.

First of all, we developed an object-oriented CAAD system to input the building structure information effectively. When a user draws a 2D floor plan on this system, it also recognizes each component's attributes. Then it automatically generates a 3D model from the 2D plan. Secondly, we created a new method to input information of building equipment into the structure that we have drawn in the first stage. Thirdly, real-time space recognition within the building takes place using AR techniques. When a user with a see-thru HMD (Head Mounted Display) looks at a specific area inside the building, the system recognizes where he/she looks. Also, 3D building equipment data is overlapped in the projected area. We implement this system with the aid of ARToolkit (Billinghurst, M., et al, 2001) developed at the University of Washington.

In this paper, we try to visualize the 3D building equipment data as a prototype among various possible approaches.

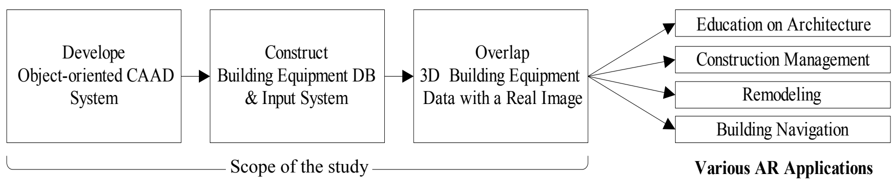



*Figure 1. Process and Scope of the study*

## 2. Related Works

In this chapter, several research on the augmented reality in architectural approaches are shown and also weak points in these research are also pointed out.

### 2.1. WHAT IS AUGMENTED REALITY?

Augmented reality combines real and virtual objects in a real environment and runs interactively in real time. It also registers real and virtual objects with each other. In other words, an AR system supplements the real world with virtual (computer-generated) objects that appear to coexist in the same space as the real world. The two ways to supplement information are by adding virtual objects and removing real objects.
Milgram (Milgram and Kishino, 1994) describes a taxonomy that identifies how augmented reality and virtual reality works are related. He defines the Reality-Virtuality continuum shown in Figure 2.

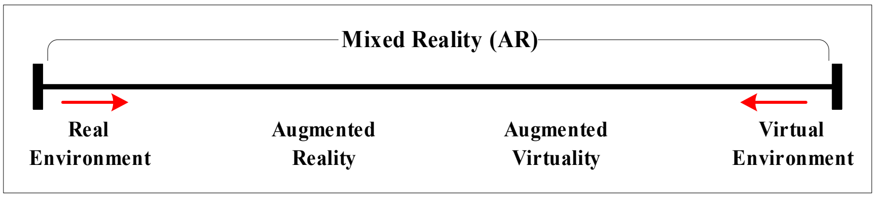



*Figure 2. Milgram's Reality-Virtuality Continuum*

### 2.2. WHAT IS ARTOOLKIT?

ARToolKit, developed by the University of Washington HIT Lab, is an open source vision tracking library that enables the easy development of a wide range of AR applications. Some of the features of ARToolKit include calculating camera position and orientation relative to physical markers in real time and, overlaying 3D virtual objects on a captured image by using single or multiple tracking markers.

*Figure 3. Examples of ARToolKit Application*

### 2.3. ARCHITECTURAL APPLICATIONS ON AUGMENTED REALITY

The Computer and User Interface Lab at Columbia University has developed several AR systems for use in structural engineering and architectural applications.

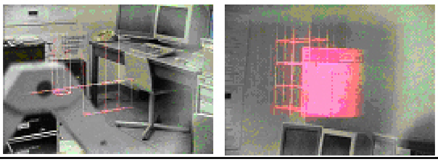
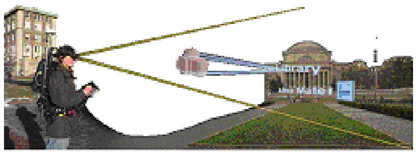
The first, called "Architectural Anatomy" overlays a graphical representation of portions of the building's structural systems over a user's view of the room in which they are standing (Feiner, S., et al., 1995). This system can be used effectively in teaching architectural technology. Another AR application is KARMA (Knowledge-based Augmented Reality for Maintenance Assistance) (Feiner, S., et al., 1993). KARMA is a prototype system that is used to explain simple end-user maintenance for a laser printer by using a see-through HMD.

MARS (A Mobile Augmented Reality Systems for Exploring the Urban Environment) acts as a campus information system, assisting a user in finding places and allowing to query information about items of interest, like buildings, statues, etc (Feiner, S., et al., 1997). As the user looks around campus, the see-through HMD overlays a textual label on campus buildings. The user can interact with the system to bring up information related to any building.

The Tinmith project team at the University of South Australia developed a Tinmith-Metro system that allows users to control a 3D constructive solid geometry modeler for building graphical objects of large physical artifacts, such as buildings, in the physical world using an augmented reality wearable computer (Wayne Piekarski, et al., 2001).

We have found many research on augmented reality in the architecture domain. Most of them were, however, applied within the limits of the specific areas where AR techniques were applied to. In other words, the lack of understandings of relations among various spaces on one floor plan took place. Consequently, when visualizing 3D building data in augmented reality, it is critical to understand relations among the whole space of a building plan in a much wider scope and that is one main reason we developed the Building Scanner system.

TABLE 1. Various research on architectural Augmented Reality

| Architectural Anatomy | MARS |
|---|---|
|  |  |
| KARMA | Tinmith-Metro |
|  |  |

## 3. The Object-oriented CAAD system

### 3.1. CONCEPT OF A STRUCTURED FLOOR PLAN

For many years, various research on developing intelligent CAAD systems to manage building floor plans effectively have been done (Yessios, 1986; Kalay et al., 1995; Choi, 1997). In such systems, a floor plan is structurally well-defined to have some hierarchical components. Since space and form are the two main aspects in describing a building, they are represented together in a system. To make it more effective, an object-oriented approach is considered where each building component is an object from the view of an object-oriented paradigm. That is, the object has its own data and methods of how to behave in certain situations.

### 3.2. A BUILDING DATA MODEL FOR AN OBJECT-ORIENTED CAAD SYSTEM

The hierarchical and object-oriented structure of the building data model plays an important role in containing design information for each design project during the design process. Figure 4 illustrates a building data model developed through the study.

A project consists of a site and one or more buildings. Each building includes several plans that also have building components such as walls, columns, slabs, and spaces. In this study, we mainly focus on walls and spaces. Each wall can have openings and two wall surfaces inside and outside. A space generally has a single ring, but may have several rings as it contains holes inside. Several wall surfaces form a closed polygon represents a ring.

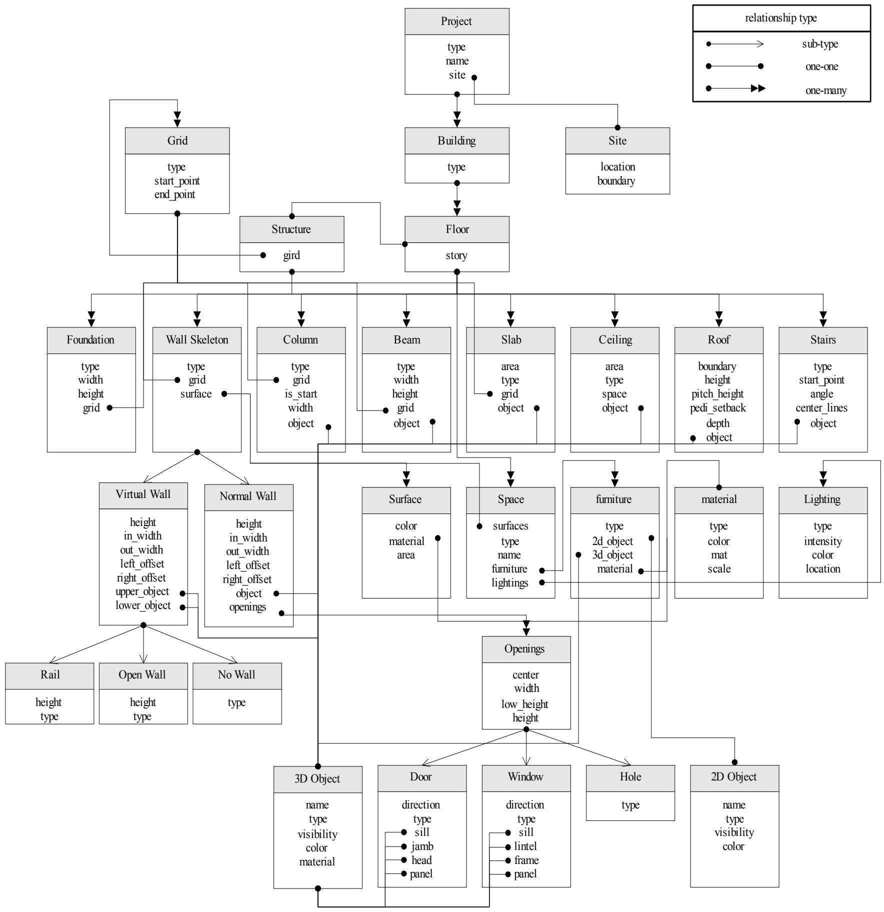



*Figure 4. The building data model for the object-oriented CAAD system*

## 3.3. IMPLEMENTATION OF THE OBJECT-ORIENTED CAAD SYSTEM

This object-oriented CAAD system has 3 different modes: a structure mode, a location modeling mode, and a model mode. Each mode functions differently but they are successfully linked together to convert one mode into any other when needed.

### *3.3.1. Structure Mode*

The Structure Mode deals with a structured floor plan. The drawings are not just a collection of geometric elements anymore; they consist of building components such as space, wall, and surface. Because of the automatically stored data structure, it is possible to see the position of one area in relation to another.

*3.3.2. Location Modeling Mode*

Location Modeling Mode handles user's location in a building plan. In this mode, one or more users can be placed on the 2D floor plan. When a user sees virtual building equipment data in a specific space within a floor plan, the location modeling mode allows the user to find exactly in which spaces the user is located among whole spaces in a single floor plan. That is, this mode defines relationships between the architectural building itself and a user. Moreover, a user's field of vision is automatically calculated while the closest walls and openings within a space where user stands are detected.

*3.3.3. Model Mode*

A Floor plan drawn from the structure mode can be generated into a 3D model at model mode. At the same time, openings such as doors and windows are considered in this stage.

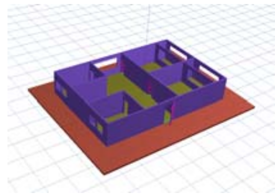
| Structure Mode | Location Modeling Mode | Model Mode |
|---|---|---|
|  |  |  |

Figure 5. *Various modes in the object-oriented CAAD system*

## 4. Developing A Building Equipment Data Model and An Input System

Building Equipment, which makes a building function effectively, is one of the essential factors in the field of construction like building structure and design. Because of its complexity in building equipment drafting, it is not easy even for experts to refer to the information when needed for maintenance etc. To find a better way out of this difficulty, we have constructed a building database on a three-dimensional basis, and then building equipment information is added to the database. When managing a building, three-dimensional building equipment data can be visualized easily using AR techniques. In this way, diverse problems occur in building equipment such as water leaking from a pipe might be detected and solved easily.

In this chapter, we are going to describe how to construct a building equipment database and to develop an input system in object-oriented CAAD systems to overlap 3D building equipment data with a real building image.

4.1. BUILDING EQUIPMENT CLASSIFICATION & INPUT METHOD

As shown on Figure 6, we have classified building equipment into four groups, and each group has several detailed equipment. By doing so, it is effective to control and layer building equipment data as group units.

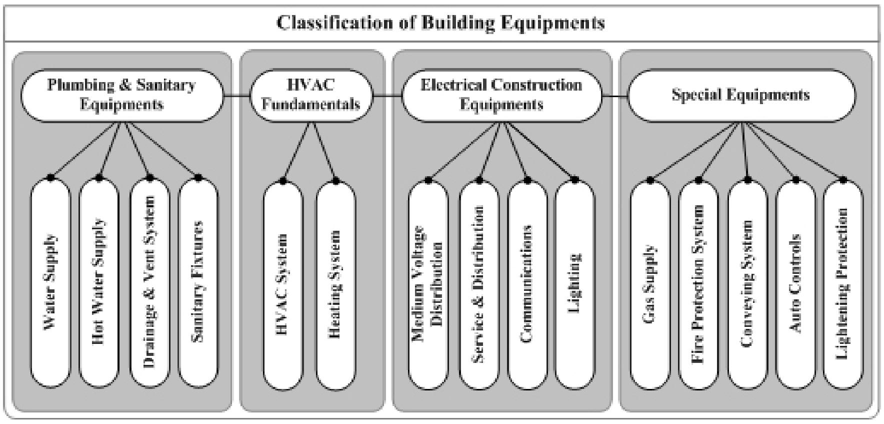



*Figure 6. Classification of building equipment*

There are two different ways to input building equipment data in the object-oriented CAAD system.

We can either import existing 3D building equipment modeling data or directly draw it on our CAAD system. In this study, we decided to draw building equipment data manually to see the results of the 3D building equipment modeling test. Building equipment data are expressed using their node and edge information basically. Other components such as joints and sanitary fixtures are made from existing 3D modeling tools like form-z and 3DsMax. These components are stored up so that they can be used when necessary.

Even now, it is very challenging to create building equipment data into 3D model in the field of building construction equipment and various attempts have been made to tackle this issue. A new method of inputting building equipment data on object-oriented CAAD systems should be developed.

4.2. A DATA MODEL FOR BUILDING EQUIPMENT

Building Equipment Model is composed of four different building equipment groups and an equipment database. Each group is connected to building equipment system that contains pipe groups. A pipe group has one or more equipment nodes, pipes, and objects. If a node needs a specific joint, it is loaded from the joint database. Pipes drawn from node information require detailed section, material, and supply information which is also loaded from each database. A hierarchical and object-oriented building equipment modeling is possible through this well-constructed building equipment data structure. Figure 7 illustrates a data model for building equipment modeling.

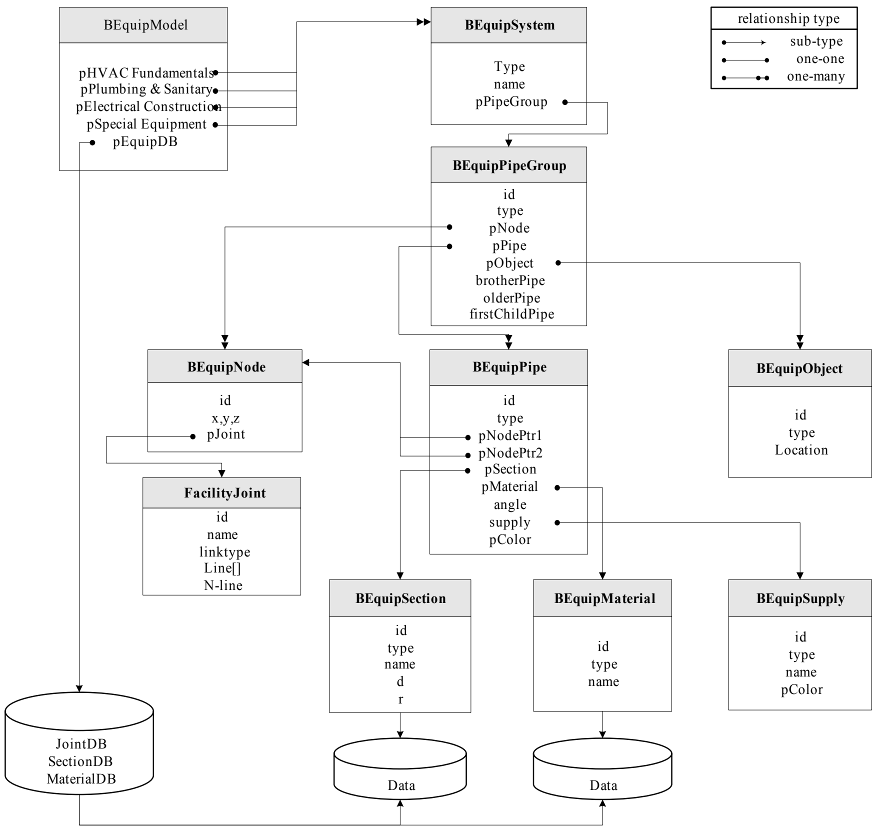



*Figure 7. A data model for building equipment*

## 5. Visualization of 3D building equipment data on Augmented Reality

To accomplish browsing 3D building equipment data in augmented reality, we have developed a 2D floor plan editor on the object-oriented CAAD system. Then we constructed a data model for effective building equipment data management. After inputting building equipment data, these two different information on a building plan are three-dimensionally generated within the object-oriented CAAD system. Because we are focusing mainly on how to retrieve and browse architectural information of building equipment more accessibly with an easier approach, in chapter 5, several ways of visualizing building equipment data using ARToolKit is demonstrated. We are currently working with the version 2.52 with web camera among many different versions of ARToolKit provided. Figure 8 shows the outline of our research process.

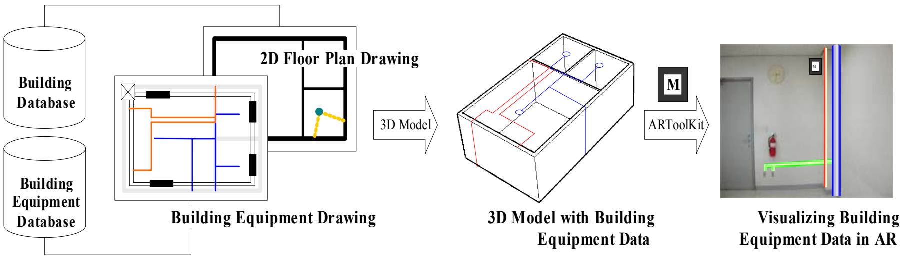



*Figure 8. Process of building equipment visualization*

5.1. EXPERIMENTS ON VARIOUS MARKER APPLICATIONS

For better ways of recognizing 3D data and using AR markers, we have been trying to experiment with marker designs. The following 4 markers have been developed through this study.

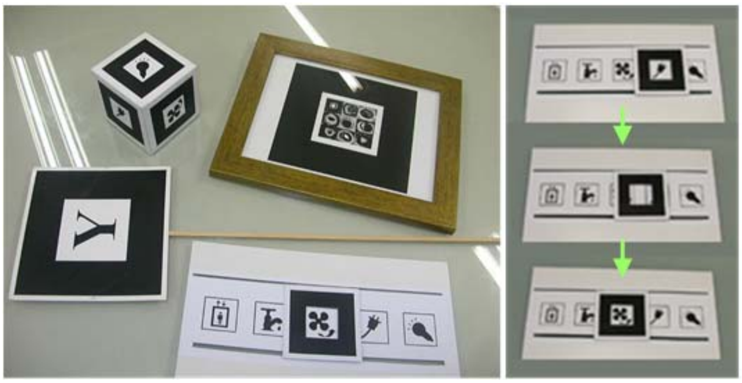


*Figure 9. Various Markers used in the study*

5.1.1. Stick Marker

A stick marker was used in our first trial for the AR visualization. In this process, a user needs to hold the stick marker and place the marker up the required position. This method was found to be unsuccessful in attaining accurate results as it relies on the steadiness or unsteadiness of a user's hand.

5.1.2. Artistic Frame Marker
Next, we used the so-called artistic frame marker to supplement the stick marker's demerits. Artistic frame marker makes it possible to be placed anywhere. The system recognizes the marker's relative coordinates from the designated building equipment data's coordinates, so it automatically calculates the difference between them, and draws the data in augmented reality. At the same time, we intended this marker to function not just as an AR marker but as a work of art. So we made an effort to design it with more artistic touch than the ordinary AR marker.

5.1.3. Slider Marker
Thirdly, we decided to display many kinds of building equipment according to the classifications of building equipment for the user to understand 3D building equipment data much more clearly. Slider marker is a group of different marker patterns with a mobile black frame. As a black frame is moved along the marker pattern, and that a marker pattern perfectly fits the frame, the building equipment data matches the pattern is displayed.

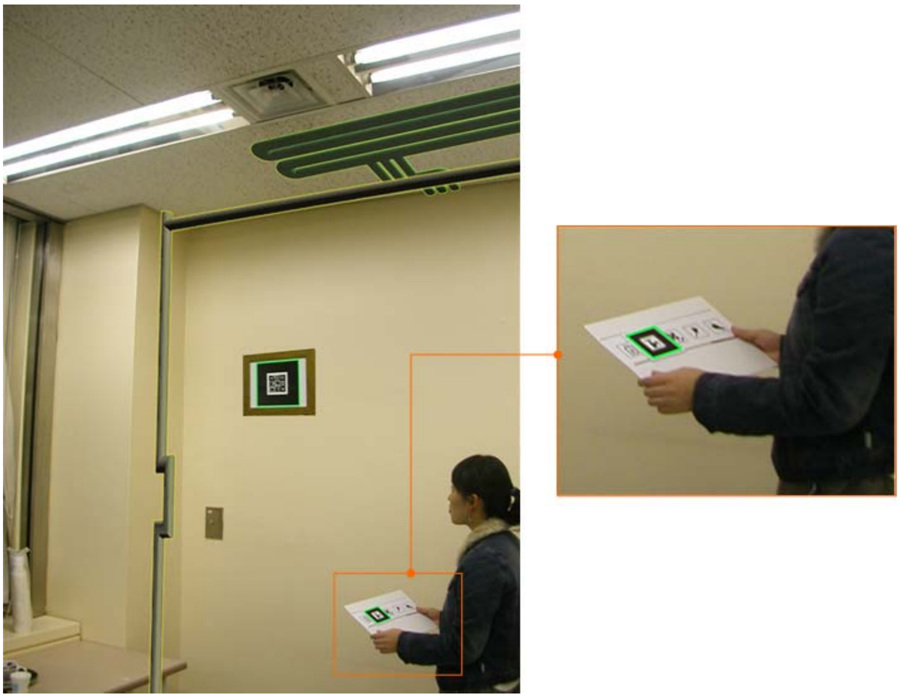


*Figure 10. AR experiment using artistic frame marker and slider marker*

5.1.4. Mini Cubic Marker

In our study, virtual data is generally drawn in actual scale on augmented reality. That means, here, a user sees 3D virtual data such as pipe laying fit an area where he/she is located. In other words, it is too large to see all sides of the virtual data. Mini cubic marker displays a miniaturized 3D building equipment data so that a user can see any part of the data by rotating the marker. In this case, only the top side of mini cubic marker pattern is detected for AR display. So if you want to see other building equipment data, all you have to do is to turn the cubic marker and place different marker patterns on the top side of the cube. To make it work, interaction between the mini cubic marker and the original main marker posted on the wall is necessary. We are currently proceeding with this stage to make an interactive AR interface.

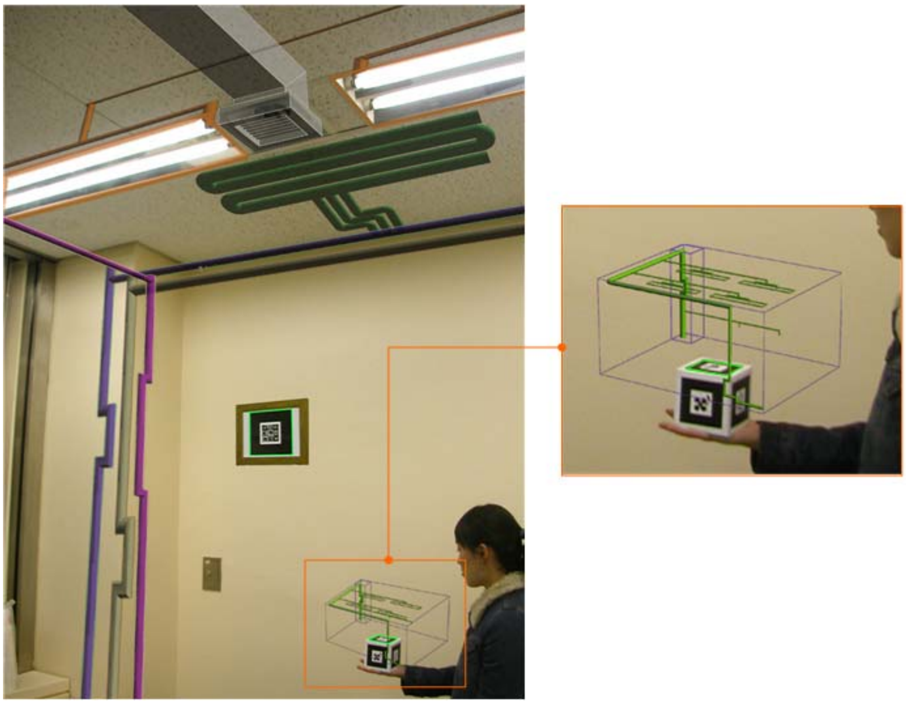


*Figure 11. AR experiment using artistic frame marker and mini cubic marker*

5.2. THE INTERFACE AND IMPLEMENTATION

Currently we are under development to unify all the systems mentioned above, i.e. Building Scanner. Figure 12 shows a photomontage of expected results throughout this study. ‘A’ of the figure 12 is the object-oriented 2D CAAD View that creates a general building and its structure. ‘B’ shows the 3D Model Viewer that makes a 3D building model generated with information from the 2D building data. ‘C’ of the figure is for the AR Building Equipment Data Browser View where real world and virtual building data combine. In part ‘C’, we are making an effort to design and implement the interface of the AR view. The interface includes brief attributes of selected building equipment and 2D CAAD WIM (World In Miniature) which helps the user to grasp his/her location within a building plan. Finally in part ‘D’, attributes of building Equipment and general building information is presented in detail for a better understanding of the user while browsing building equipment.

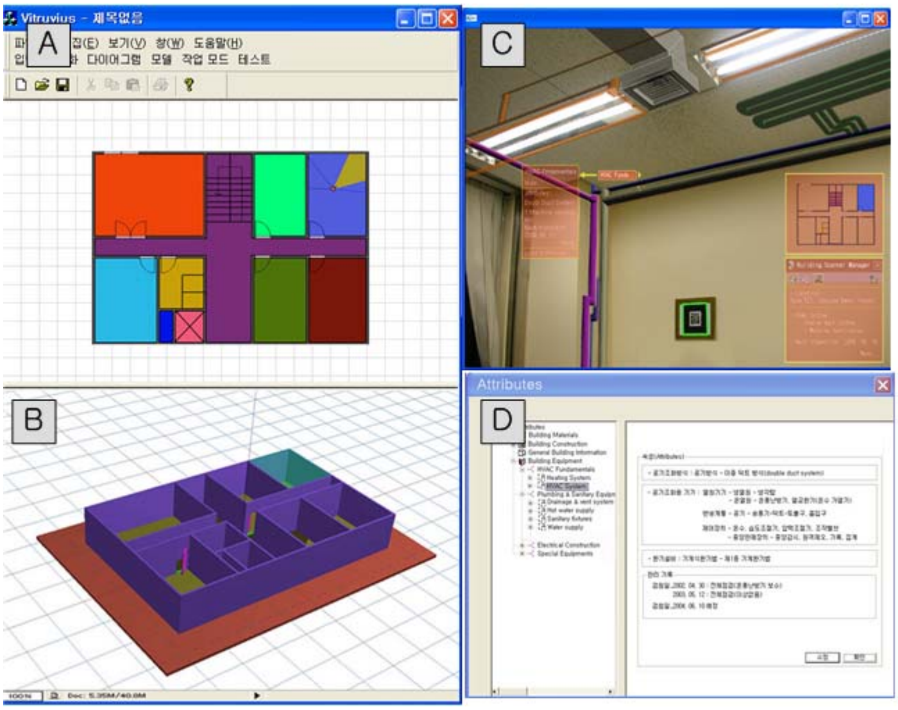



*Figure 12. The Interface of Building Scanner*

**Conclusion**

Generally speaking, it seems that numerous approaches on AR application have been exploited in fragments, so applying the AR techniques in practical use in the architectural domain has not been easy so far. In this regard, by unifying the 2D CAAD system and AR system, we believe that the Building Scanner system described in this paper will contribute to the practical field of architecture or design. The prototype system developed in this study has demonstrated that such an application can be very successful. Other applications of such an augmented reality system in architecture also need to be explored such as remodeling, construction management, and architectural e-learning. Our final goal lies in developing generalized methodology on visualizing information of building equipment in any kind of building plan.

For the future works, first of all, it is necessary to develop input methodologies on information of building equipment. Moreover this would require very precise tracking and also issues relating to the interface design for presenting information to the user with HMD. The CAAD system in this study was limited to draw only single floor plan. Multiple floors or several buildings, however, should also be considered to broaden the application like visualizing the construction progress. In addition to this, it is also possible to study city navigation in urban domains using GPS.

## Acknowledgements

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