CONSENSUS MAKING WITH VIRTUAL MODEL FOR CONSTRUCTION PROJECT

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Abstract

This paper introduces the efficient application of Virtual Reality (VR) in the Architecture, Engineering and Construction (AEC) industry, instead of using conventional plastic models. We use the VR as a tool to help achieve consensus, which is called Virtual Model (VM). The VM consists of digital models added by digital information about the project, such as CAD drawings, digital maps of periphery, scanned aerial photos, on-site digital pictures and documents.

The three pilot trials of the VM are illustrated in the paper. Those are; (1) an on-going land readjustment project in Osaka, (2) a concrete dam construction project in Fukushima, and (3) a large-scale soil borrowing project in Wakayama.

1. Introduction

Virtual Reality (VR) , is a technology to create virtual space with reality in the computer. It has been developed and mainly used in the entertainment industry. Thanks to the low cost and high performance of the personal computer (PC), the PC has been a popular tool for the VR application. For example, among the Internet-related technologies, the Virtual Reality Modeling Language (VRML), is one of the typical VR applications[a, b].

This paper introduces the efficient application of the VR instead of using plastic models and drawings, which are generally used in various stages of the construction process. We use the VR as a substitution of the plastic models regularly used in the AEC industry, which is called Virtual Model (VM). The VM is defined as the subset of the VR, which partially realizes a part of the characteristics of the VR. In the research, the VM is chosen because the use of the VM allows construction project participants to more understand the contents of the project than the VR does. It is also appropriate for personal computers today to handle the amount of data the VM needs. The VM is made by VRT of Superscape, a UK based software company. A desk-top PC is used as hardware.

2. VR(Virtual Reality) and VM (Virtual Model)

2.1 Virtual Reality

The VR consists of two words. The first term, VIRTUAL, means that it doesn't exist in fact, but it has effect which is equal to its existence as a function. The second term, REALITY, means that it actually exists. That is to say, the VR is defined as the real world composed by computers[c].

Moreover, according to Zeltzer in MIT[d], the VR has three major characteristics as follows:

(1) PRESENCE: to exist in virtual space,

(2) INTERACTION: to have communication channels with the computer, and

(3) AUTONOMY: to exist under a certain rule in virtual space.

2.2 Mock-Ups

2.2.1 Physical Mock-Up(PMU)

Physical Mock-Up (PMU) is the conventional plastic model. In the past, the PMU and drawings were used as a tool for consensus making procedures among construction project participants. As for using PMU in the AEC industry, the PMU along with paper drawings has been used to discuss the design of the project. Using PMU helps the participants grasp the whole image of the project, but it is difficult for them to understand it in detail. Moreover, it would be almost impossible for them to understand the project outline, even if they had some experience.

As far as a large-scale project is concerned, the PMU could be comprehensive and too large size to handle. Therefore, people have to go where the PMU is located and discuss about it when the scale of the PMU is too large.

In terms of constructing the PMU, the production of mock-ups is usually subcontracted to the outside such as design studios. If the clients require a change to the project, they must send the PMU to design studios once again. When the participants want to share the mock-up, they have to make another one completely from the beginning.

2.2.2 Digital Mock-Up(DMU) and Virtual Mock-Up(VMU)

Digital Mock-Up (DMU) is the three-dimensional CAD model in the computer. In the Automobile industry, the DMU is popularly implemented for the design, development, production and sales promotion of vehicle. The DMU is the technology to summarize the final plan of the design. The DMU is used to make the clay model in actual size in the development process of a vehicle[e]. The DMU is used to help achieve consensus among only participants engaged in the business in a closed environment. In other words, the DMU has a little "presence" of the characteristics of the VR. However, it does not have interactivity.

Virtual Mock-Up (VMU) is a part of the DMU, which is regularly used in the VR space. The VMU can be moved interactively in the virtual space. The production of the VMU usually needs costly engineering work stations or graphics work stations. Therefore, the use of the VMU in the AEC industry is not suitable.

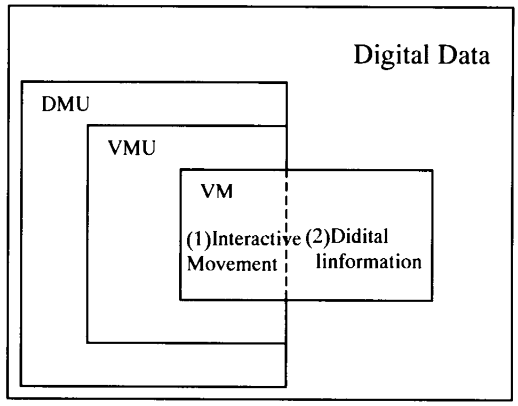

Figure 1 Mock-Ups and VM

2.3 Definition of VM(Virtual Model)

The Virtual Model (VM) consists of the following two functions. They are interactivity of the VMU and attached digital information about the construction project such as CAD drawings, digital maps of periphery, scanned aerial photograph, on-site digital photos and documents. Figure 1 shows the relationship among DMU, VMU and VM.

The four advantages exist in the VM application for the construction project. They are;

(1) smooth exchange of requests and opinions regarding construction project,

(2) efficient understanding of the project outline,

(3) practical use with PC's including the use of the Internet, and

(4) sharing among the unspecified participants.

The word, Virtual Model (VM), is defined in this paper to emphasize the difference between the VM and the VMU in the VR space. Also this paper mentions that the VR technology such as the DMU and VMU are very useful in case of carrying out the collaborative designs or works. The use of these technologies in the AEC industry is not so easy because the tool (limitation of hardware) and the technology (software) of the VR are not sufficient for the practical use. Moreover, every person has his own image and opinion for the projects, so he does not positively exchange opinions with other participants. Therefore, we have proved its possibility of the application of the VR technology in the AEC industry based on a series of research[f,g,h,i]. The existence in the virtual space as a model in the computer means the Presence, and the interactive motion of the viewpoint means the Interaction. So, the VM has some capability of the VR technology.

In terms of the VM production, in-house designers can mainly make the VM. So, it is possible for the designer to change and arrange objects in the VM space during meeting and discussion among the construction participants and neighborhood. It may save time and cost of the construction project.

The VM can be interactively moved in the virtual space, so it allows people to image the complete construction project. Besides, the presentation of the VM can be implemented in anywhere and anytime with a PC.

2.4 Characteristics of Virtual Model

The VM has four principle characteristics as follows.

(1) **Interactive movement.**

The VM can be set up both any viewpoints and the track of the viewpoint's movement like taking video. The User can change the viewpoint at anytime. Figure 2 shows the example of the movement from the north to the south in the VM space. Thus, the user can freely move in the VM space and can use it like a video.

(2) **Integration with digital data.**

Figure 3 shows the virtual office integrated with CAD drawings, on-site digital photos and pamphlet

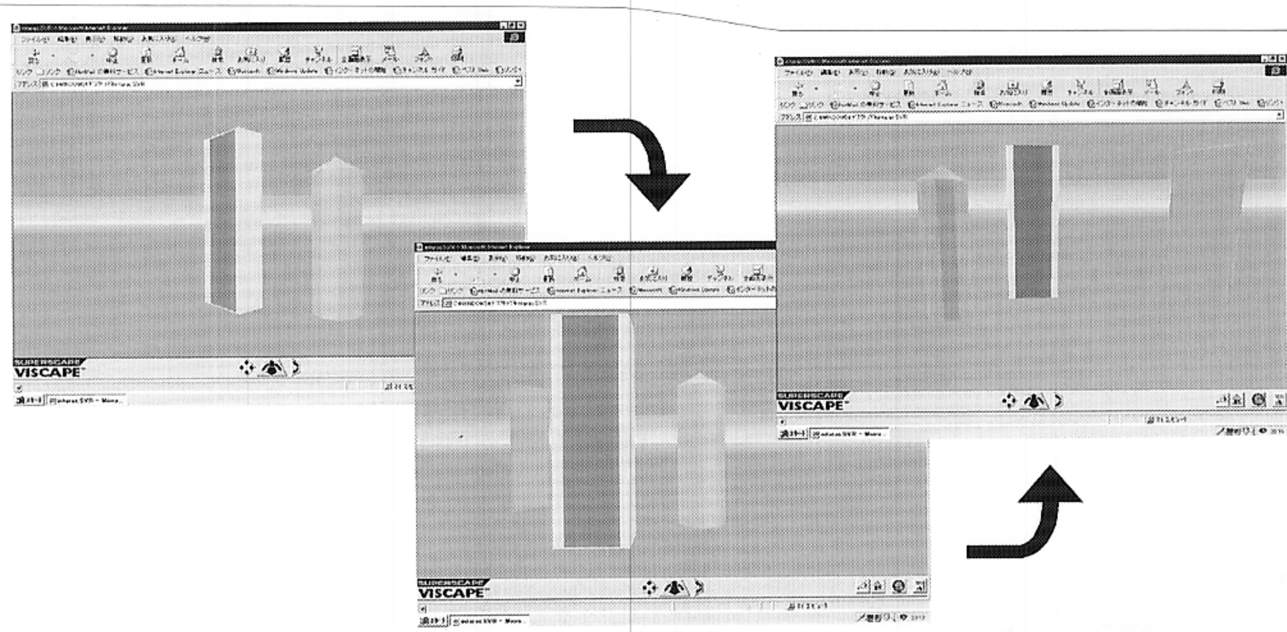

Figure 2 Interctive Movement

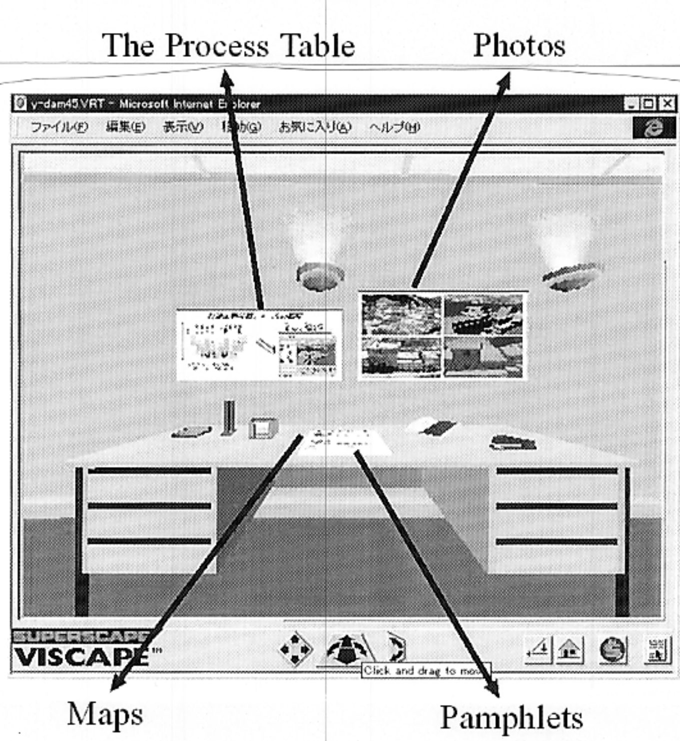

Figure 3 Integration with Digital data

about the construction project. So, the user can not only see the VM space but also get information about the construction project.

(3) Control by script.

For examples, the three-dimensional structural models in the VM space can be turned on and off, moved or erased. Figure 4 shows control by script, for example. The user can turn off the center object with a mouse click. Moreover, the objects in the VM space are easily moved and erased. The shape and color of the objects are changed, so the user can examine the landscape of the area and compare the plans of arrangement and before and after construction status.

(4) Use on the World Wide Web (WWW).

The VRT data can be downloaded and viewed within the Internet browsers on the computer. The VM data can be changed from normal file format (*.vrt) into archive file format (*.svr) The file size comes to one-fifth of the original one. The user can download the plug-in software (Superscape Viscape 5.0) from the Superscape Web Site[j]. Figure 5 shows the example of the VM used on the WWW. The VM is shared and viewed by unspecified people.

3. Case studies

3.1 Readjustment Project[f,g,h,i]

3.1.1 Overview

A major US-based recreational facility is being constructed in the middle of a heavily industrialized bay area in Osaka (Figure 6). This project is the division of an area which is about 156.2ha. The term of this enterprise is from August 1995 to March 2002, and its cost is estimated about 640 million dollars.

It is the main concern for clients and developers

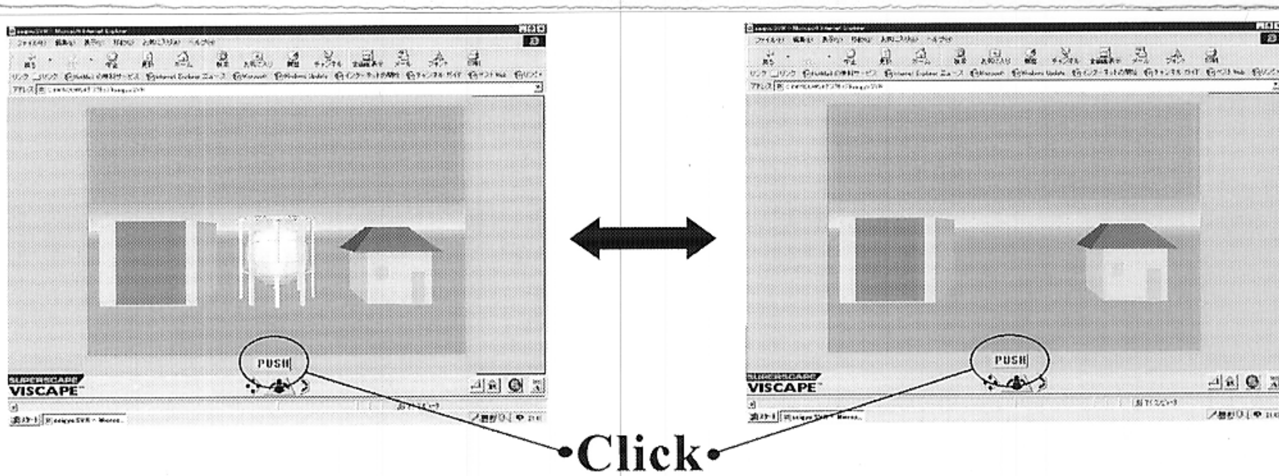

Figure 4 Control by script

Figure 5 Use On the WWW

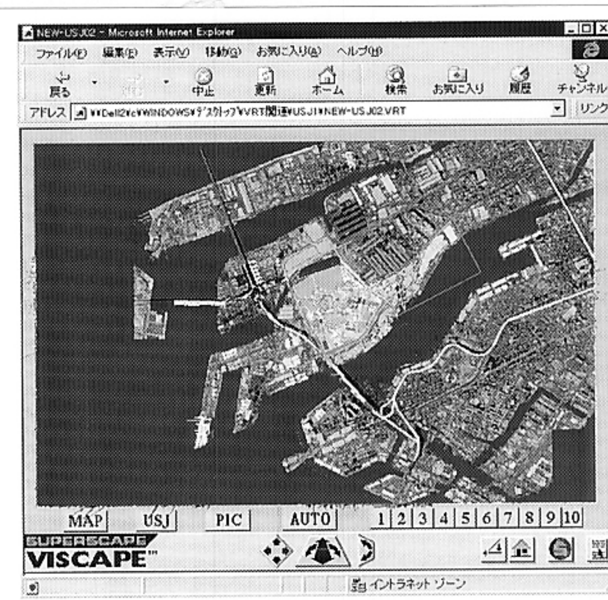

Figure 6 Osaka City

of the park itself and the land readjustment project in the vicinity whether the scenery from or around the park is pleasantly match to the existing environment. The project is in the phase of the preparation of land and the design-build contracts of the park have been ordered. The project is in the designing stage.

3.1.2 Results of Application

On this application, the VM is used; (1) to understand the outlines of the project, (2) to reuse the factories or the site of it, (3) to compare the change of landscape with the park constructed, (4) to understand the relation of position between the industrial park and the its periphery.

In the application of the VM, it was mainly used for marketing to enterprises. Konoike Construction Co., Ltd. took the presentation to the clients of the industrial park and to the 19 enterprises which have their factories or real estates around the construction site(Figure 7, 8 showed for examples). As a result of this presentation, we got several answers. From the list of activities for marketing by the VM, the three principal advantages by using it are found as follows; (1) high appraisal of using at PC level (9 enterprises), (2) there is value of investigation/they want to use it (6 enterprises), (3) easy to understand/interest (8 enterprises). The VM generally received high appraisal. Actually, Konoike Construction Co., Ltd. got the job by using VM for the marketing of the project. In these, it is said that the VM is very efficiency for the use of the presentation of construction project in designing stage. Another, in the point of helping to understand the outline of a project, there is more value than the conventional models and drawings. Further, for the construction participants it is very suitable to discuss about the project. In other words, it is said that the VM is necessary to achieve consensus.

3.2 Tajima-Dam Construction Project[k,l,m,n]

3.2.1 Overview

The Tajima dam is a multi-purpose dam located in Fukushima Prefecture, northern part of Japan's main island, as a part of comprehensive development project of Takano River. The dam is a gravitational concrete dam, 36.0m in height. It stores 523,000m^3 of water, controls floods and provides functions of water supply for drinking and agriculture. The construction work started in October 1996 and will be completed in March 1999. The dam construction consists of whole bunch of different activities such as excavation, improvement of rock-bed, casting dam concrete and existing river re-routing. Each work has its own technicians and crews. Extreme effort is needed to coordinate such a variety of specialists. Moreover, the delay of an activity may cause serious delay in the whole project since the site is located in the snowy region in Japan. The construction work has to be discontinued in winter.

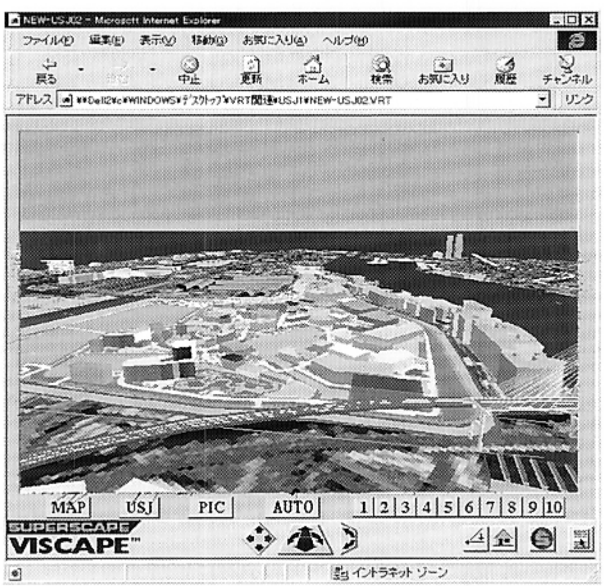

Figure 7 The Park turned on

Figure 8 The Park turned off

3.2.2 Visualization of lift scheduling with the VM

The output of lift schedules from the Lift Schedule Planner (LSP), proprietary software, can be visualized three-dimensionally. The LSP calculates casting schedules for a concrete dam in accordance with environmental, geographic and temporary work conditions. The VM visualizes the result of calculations. The VM allows engineers to analyze what-if scenarios of lift schedules side-by-side on the same computer screen. The Figure 9 shows the flowchart of the VM. There are two phases to visualize the schedule. At the first phase (Block A), the LSP system creates a lift schedule with the Microsoft Excel work sheet format. At the second phase (Block B), three-dimensional lift models linked with the schedule data written out as a CSV file in the first phase are rendered and can be visualized in real-time from any view points on the screen.

3.2.3 Making procedure of the VM in Block B

The three-dimensional CAD objects of each lift were modeled to represent its actual casting process. The CAD models were slightly changed and imported to the VM. To save physical memory space of the computer, the geographic data had to be simplified. Superscape Control Language (SCL) was used to script the lift schedule data import and linking procedure. The SCL is the original scripting language for the VRT, which based on the C language. A line of the CSV file consists of date cast, lift cast and volume of concrete. The program reads the CSV file, linking the data and CAD models of lifts together. It is possible to visualize concrete casting sequence along with the place and concrete volume cast day by day. A variety of information such as the rough sketch and digital picture of current status of the project can be involved in the system. Engineers and general public can share the project information on the Web.

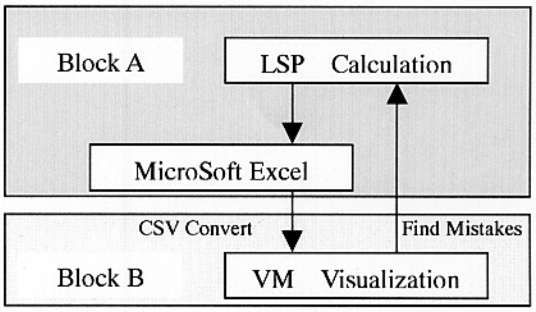

Figure 9 Flowchart of LSP with the VM

3.2.4 Effect of lift scheduling with the VM

The VM enables to visualize any portion of the casting site at any level of progress anytime from any point of view before actual construction activities take place. Thus, it is easier to specify flaws or misinterpretations on the lift schedule since every lift can be three-dimensionally visible. Once a problem is found, the lift schedule can be re-calculated with the LSP system and the revised version of the lift schedule can soon be visualized with the VM only by re-importing the CSV data file.

The actual lift schedules tend to be changed due to the weather condition, resource availability and so on. Simply preparing another lift schedule can realize a side-by-side comparison on the computer. When there are alternatives available, the better lift schedule can be chosen by comparing them.

3.2.5 Analyzing lift schedules in three dimensions.

Even though this particular application could not practically be evaluated at the site office, the results of lift scheduling were three-dimensionally visualized at Tajima dam for the first time. Visualizing lift schedules

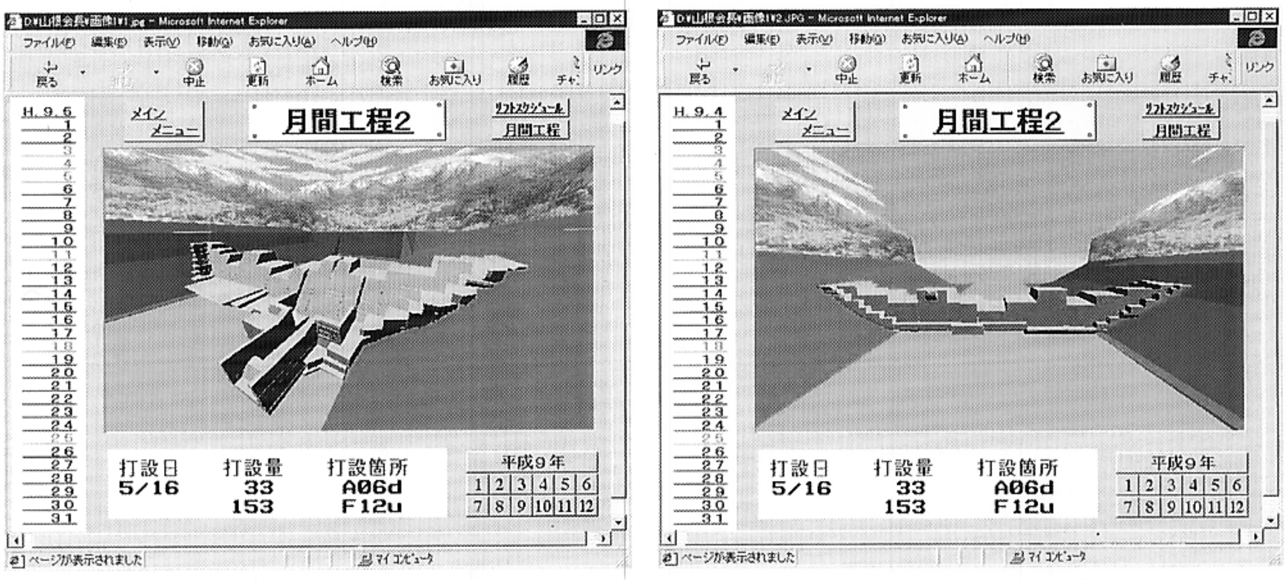

Figure 10 Concrete Casting Site

in three dimensions to help realize schedule optimization was the main point for the application. Moreover, no matter what information can also be added to the VM since it could be digitally attached to it.

The VM visualized the three-dimensional result of LSP. Figure 10 shows the concrete casting site at a certain date, May 16^{th} for example. It can visualize every concrete casting site and the shape of the placing lift from start to completion of the construction from any point of view, allowing engineers to make sure the progress, work status and shape of the concrete casting work. In addition, it enables site engineers to study lift schedules by visualizing future work status anytime.

3.3 A Large-Scale Soil Borrowing Project[o,p]

3.3.1 Overview

Since construction is a large scale and a great amount of area is involved, it seemed to be impossible to plan and examine by only two-dimensional drawings and plastic models. The VM allowed designers and engineers to view the entire site in detail and to simulate actual construction activities according to proposed construction plans. Moreover, temporary construction facilities could be constructed in the VM, allowing selecting appropriate construction methods and effect on site surroundings.

3.3.2 VM for construction plan

The VM was chosen for the project. Entire landscape of the area consists of maps, aerial photographs, and three-dimensional objects such as the soil borrowing site, the airport and bridges (Figure 11). The overall goal is the VM that provides relevant people with the vision of suggested new facilities in the context of the already existing environment while they are freely moving about in the scene and can turn them on and off at any given time. The VM in this project is able to show the each step of construction and the status of facilities before and after proposed.

4.Conclusion

This paper introduced the VM as a tool to achieve consensus instead of using conventional plastic models and drawings in the AEC industry. We illustrated three applications of the VM. It proves that the VM is practically enough to use on construction project through the applications. The important things are found in this paper.

In chapter 2, we described that the three characteristics of the VR; (1) PRESENCE, (2) INTERACTION and (3) AUTONOMY and the difference among Mock-Ups (Physical Mock-Up, Digital Mock-Up, and Virtual Mock-Up). And we introdused and defined the Virtual Model. In this context, we illustrated the relation among the DMU, the VMU and the VM.

We also illustrated that the VM has the four major purposes to use efficiently on construction project in chapter 2. They are; (1) smooth exchange of requests and opinions regarding construction project, (2) efficient understanding of the project outline, (3) practical use with PC's including the use of the Internet, and (4) sharing among the unspecified participants. And we cleared the four principle characteristics of the VM with figures; (a) Interactive movement, (b) Integration with digital data, (c) Control by script, and (d) Use on the World Wide Web (WWW).

In a land readjustment project, Konoike

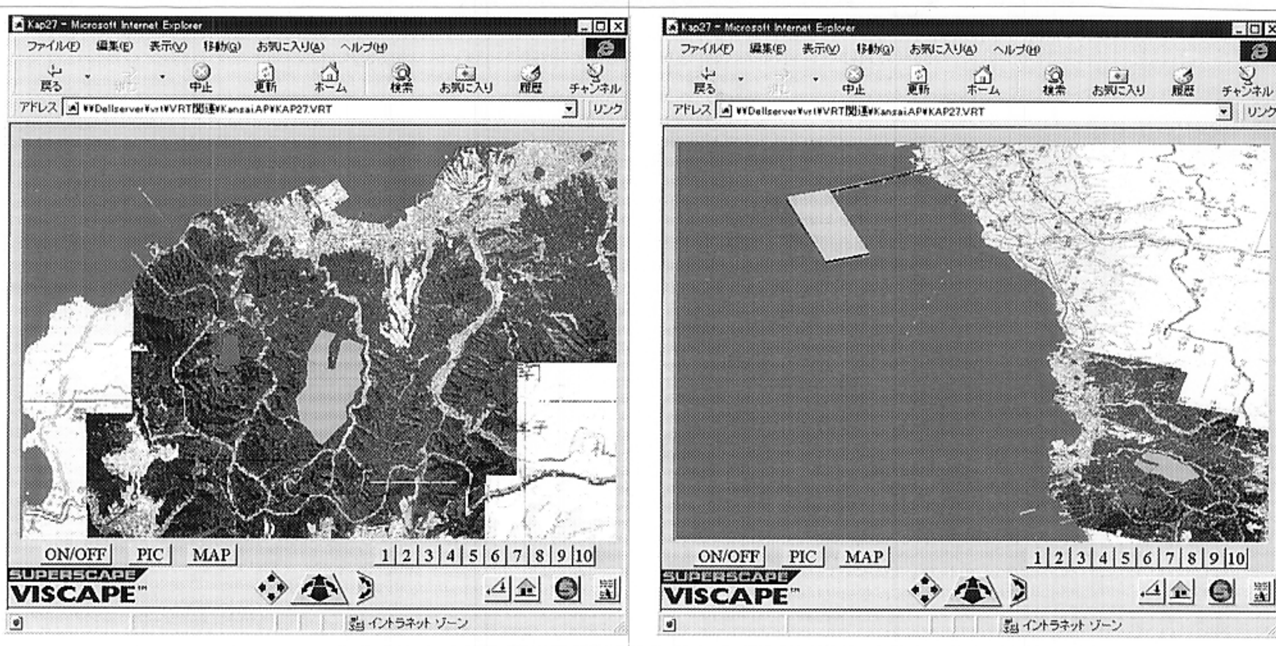

Figure 11 VM for Construction Plan