VIRTUAL REALITY WITH STEREOSCOPIC VISION AND AUGMENTED REALITY TO STEEL BRIDGE DESIGN AND ERECTION

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ABSTRACT

This paper presents how virtual reality (VR) with stereoscopic vision and augmented reality (AR) technologies can be applied to and can enhance the user performance of design and erection planning of steel girder bridges. First, in this research, a product model for representing steel girder bridges was developed, based on Industry Foundation Classes (IFC) of International Alliance for Interoperability (IAI). In order to control 3D objects in the CAD world effectively, we thought stereoscopic vision would be needed in the CAD environment. Thus, we developed a virtual reality (VR) CAD system for detailed design of steel girder bridges by using the developed product model, Java 3D, liquid crystal shutter glasses, infrared emitter unit, etc. Although the VR-CAD system demonstrated its feasibility and effectiveness, better user interface than a mouse was necessary to capture, move, and control objects in the virtual world on the display monitor. Thus, we applied the electro-magnetic sensor system for capturing, moving, and controlling 3D objects in the virtual world. This system can be used for interference checking among girders and surrounding objects such as buildings, trees, poles, and other structures.

For further improvement, we applied the augmented reality (AR) technology to erection planning of steel girder bridges. We developed a simple prototype by using ARToolKit, a HMD with a video camera, and markers. The prototype showed the effectiveness of the idea of using AR to erection planning as a preliminary system.

KEY WORDS

virtual reality, augmented reality, stereoscopic vision, steel bridge, product model, IFC.

INTRODUCTION

Product models represent the geometry and attributes of products and facilities based on the object oriented paradigm. To view, control and modify the product model, a 3D CAD system is usually used as a major user interface. However, it takes a long time and much effort for the user to acquire the ability to use 3D CAD systems, and it is hard to control 3D objects

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when there are many objects laid out in a complex manner. Although a perspective view image on a flat display monitor, generated from a 3D model, can be viewed as a three-dimensional image, most viewers cannot feel immersed in the virtual world because the image lacks true cubic effect. Thus, we believe that the virtual reality (VR) technique with a stereoscopic vision should be used to enhance the usability of 3D CAD systems.

Virtual reality is a realistic simulation by a computer system using interactive software and hardware. The requirements for virtual reality include virtual world, immersion, sensory feedback, and interactivity. The virtual world can be realized as a three-dimensional space by using computer graphics. The user can feel immersed in the virtual world by using a special display system. Feedback and interaction can be realized by using a sensor system connected with the virtual world and the user.

We have been developing a product model for representing steel plate girder bridges by expanding Industry Foundation Classes (IFC) of International Alliance for Interoperability (IAI 2006). To view, control, and modify this product model effectively, we developed a VR-CAD system. In this system, graphics are generated by using Java3D. To generate stereoscopic views, liquid crystal shutter glasses and an infrared emitter unit are used. Sensor systems including a electro-magnetic wave transmitter and receivers are used to realize sensory feedback and interactivity. We used this system to design a steel plate girder bridge to verify the methodology and the system.

Although the developed VR-CAD system demonstrated its feasibility and effectiveness, we realized that the mouse operation of the system had a problem and needed drastic improvement as a user interface with the 3D virtual world. Therefore, we applied the sensor system for allowing the user to grab, move, and control each member of a steel plate girder bridge by moving a magnetic sensor in a 3D manner. We applied this VR-CAD system with the sensor system to check the interference between the member which the user is moving and the surrounding objects such as other members of the bridge, buildings, trees, construction machines, etc., for erection planning. This application showed the effective use of the VR-CAD system.

Next, we started to study the application of augmented reality (AR) technique to steel girder bridge erection planning support. The idea is we can create a new video image by mixing a real view and virtual image linked with a tangible object on which a special mark on it. We developed a simple prototype for checking interference among design objects such as steel girders and surrounding objects such as buildings in order to support erection planning.

In this paper, we describe the development of the product model for steel girder bridges based on IFC, VR-CAD application for design and erection planning and AR utilization for erection planning.

A PRODUCT MODEL FOR STEEL GIRDER BRIDGES

We have been developing a product model for steel girder bridges by adding some classes to IFC of IAI (Yabuki et al. 2004a, 2004b). The current product model is based on IFC2x2. For this research, we added three classes, Bridge, PlateGirder, and OtherSteelBuiltupElement, as subclasses of IfcSpatialStructureElement (Figure 1). The Bridge class represents the whole bridge superstructure. Thus, it is natural to locate this class at the same level of IfcBuilding.

PlateGirder and OtherSteelBuiltupElement classes represent objects contained in the Bridge class. Those classes are linked with the Bridge class by using IfcRelContainedInSpatial-Structure. In addition, as a subclass of IfcElement we added CivilStructureElement, which has subclasses of SteelStructureElement and SteelShapeElement. SteelStructureElement class can represent elements such as webs and flanges. SteelShapeElement class represents general steel shapes such as I, H, box, angle, pipe types.

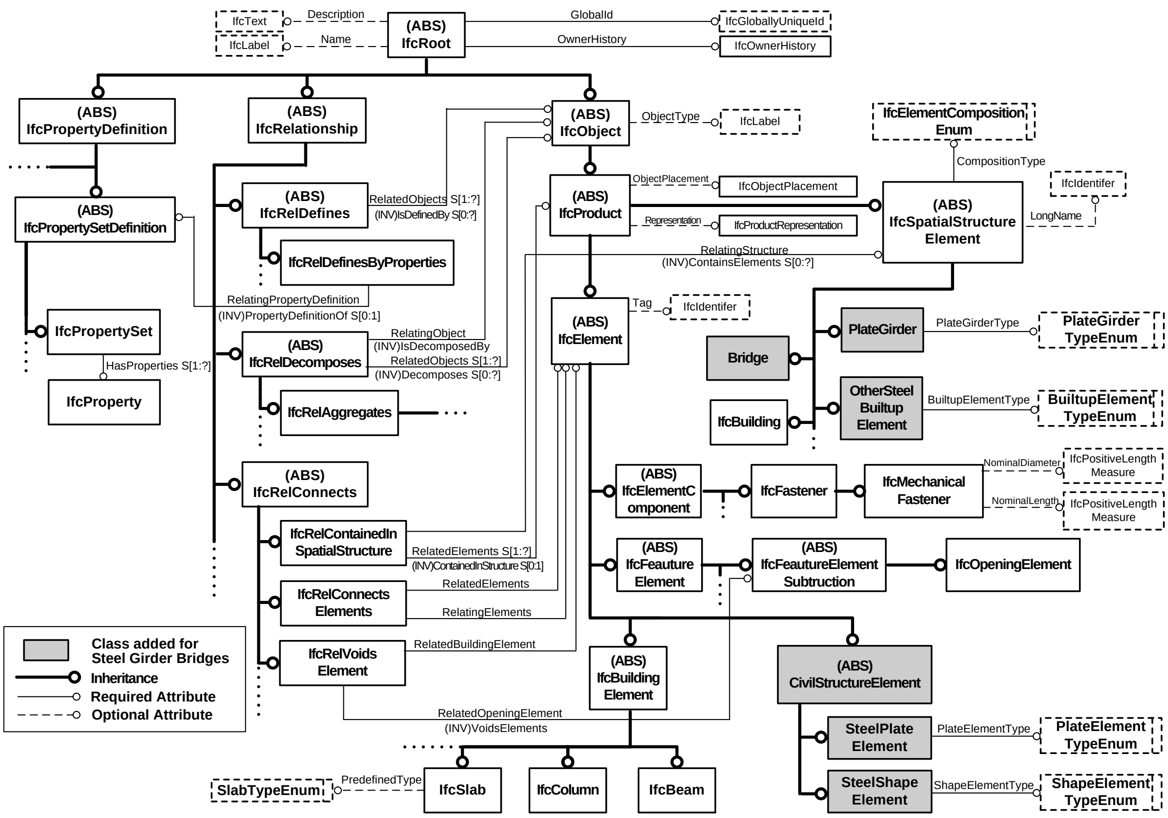

Figure 1: A part of the developed product model for steel girder bridges

VR-CAD FOR DESIGN OF STEEL GIRDER BRIDGES

Virtual reality is a realistic simulation by a computer system using interactive software and hardware. The requirements for virtual reality include (1) virtual world, (2) immersion, (3) sensory feedback, and (4) interactivity. The virtual world can be realized as a three-dimensional space by using computer graphics. The user can feel immersed in the virtual world by using a special display system. Feedback and interaction can be realized by using a sensor system connected with the virtual world and the user.

3D computer graphics is a computing technique for rendering images of objects in the three-dimensional space. Most typical 3D computer graphics include OpenGL and DirectX. DirectX is an application program interface (API) for Windows, and was developed by Microsoft. On the other hand, OpenGL does not depend on particular hardware or operating systems. Thus, we considered choosing OpenGL for implementation. However, OpenGL is a library of the C language. Since we used Java as a system development language, we studied GL4Java, one of the OpenGL Java bindings, with which Java programs can call OpenGL libraries, and Java 3D, which is a 3D graphics API for Java 2 developed by Sun Microsystems (Java3D 2006). Because we cannot use a mouse to control objects in GL4Java, we decided to use Java 3D.

Although a perspective view image on a 2D display, generated from a 3D model, can be viewed as a three-dimensional image, most viewers cannot feel immersed in the virtual world because the image lacks true cubic effect. It is necessary to generate two different images: one is for the right eye and the other for the left one in order to enable true three-dimensional viewing. Such images can be generated by using Java 3D and can be shown on various VR display systems such as liquid crystal shutter glasses, head mounted display, 3D liquid crystal display without glasses, IMAX, CAVE, etc. We used CrystalEYES3 of StereoGraphics as liquid crystal shutter glasses (Stereographics 2006). The shutters of these glasses synchronize with the computer display showing right and left images alternately at more than 120 Hz by using the infrared emitter unit. More than one viewer can see the images three dimensionally if they wear the glasses.

We developed a VR-CAD system for detailed design of steel girder bridges. The system architecture is shown in Figure 2. Figure 3 shows computer graphics images of a steel girder bridge for right and left eyes respectively. Figure 4 shows the user interface of the developed VR-CAD system. The selected web’s color changed to yellow and its dimensions and attribute data are shown in the left windows.

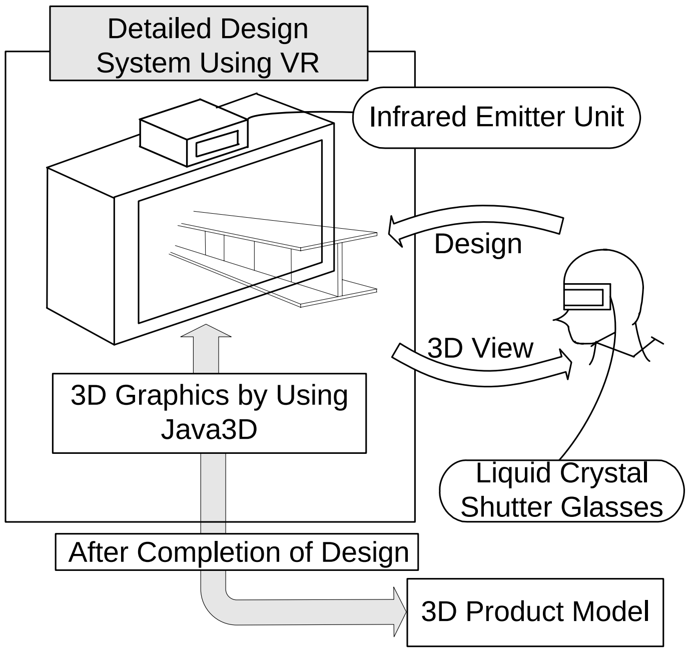

Figure 2: System Architecture of the VR-CAD

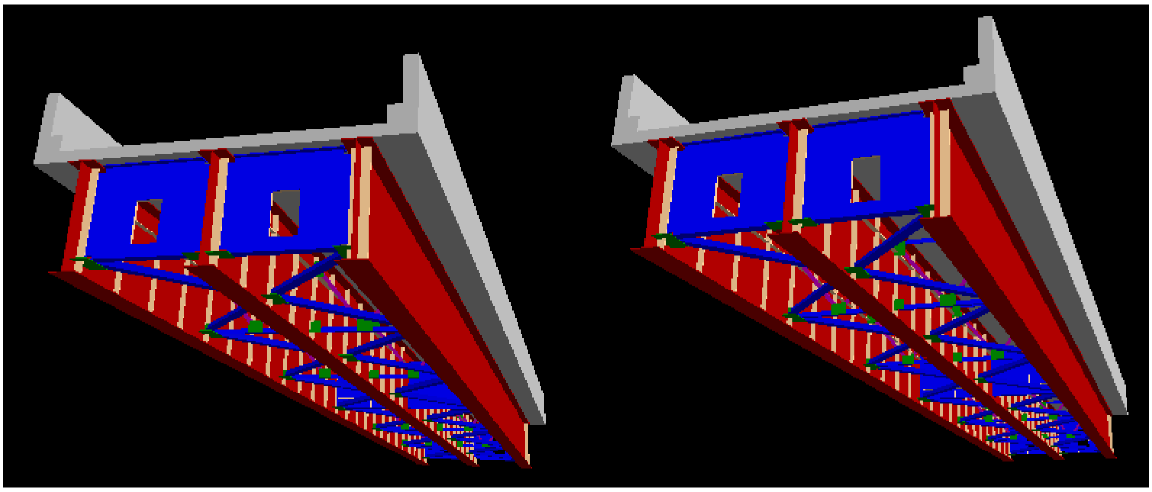

Figure 3: CG Images of a Steel Girder Bridge for Left and Right Eyes Respectively

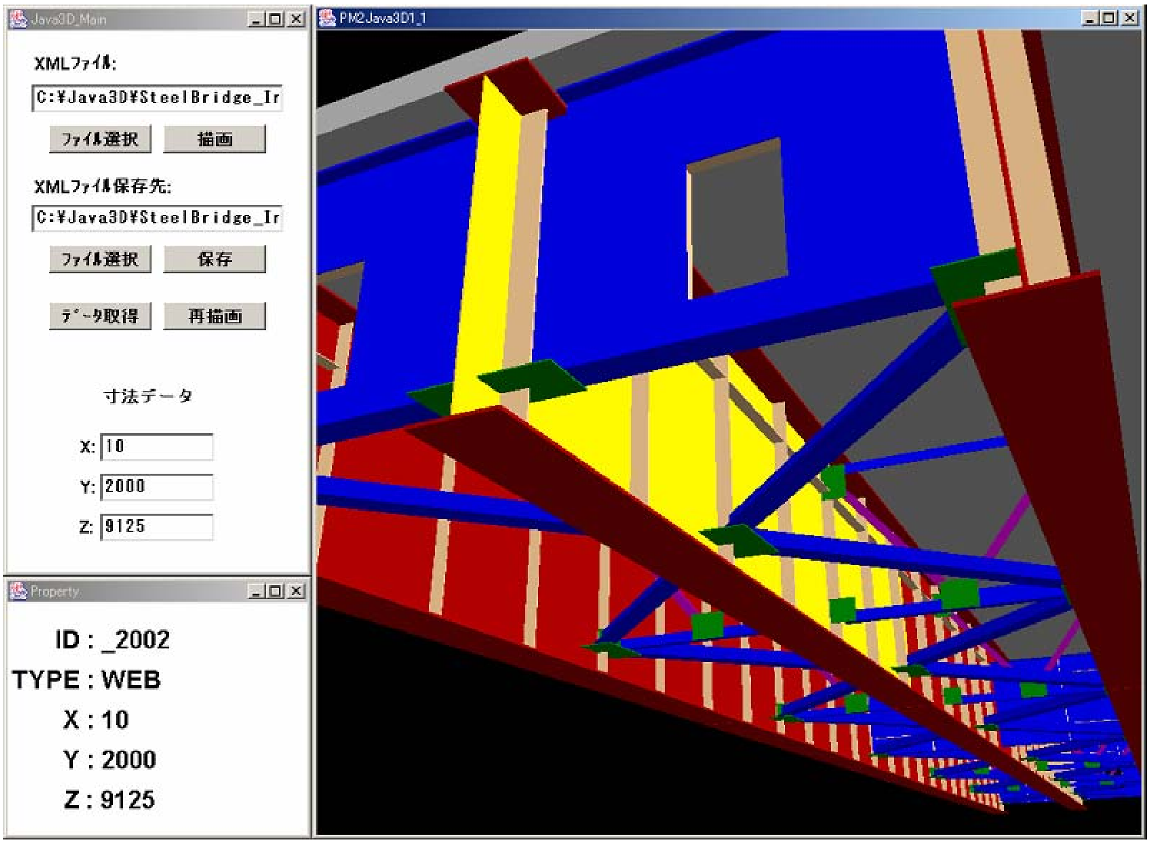

Figure 4: A Screen Shot of the VR-CAD System

ERECTION PLANNING SUPPORT USING VR

The VR-CAD system described in the previous section can enhance the design process effectively by stereoscopic view generation. However, since the computer mouse was used to capture, move, and control objects on the screen, we thought that more appropriate user interface would be necessary in order to move objects in the 3D world. This type of system would be especially needed to plan erection of bridges because the user should make sure that moving girders and members would not interfere with other objects such as buildings, various poles, and other structures. To develop an erection planning support system, we used FASTRAK of Polhemus (Polhemus 2006) as a 3D sensor system as well as Java3D, liquid crystal shutter glasses, etc. Figure 5 shows the general layout of the system. FASTRAK consists of a 3D position measuring sensor, transmitter, and receivers.

In the erection planning support system, each member data of steel girder bridge is retrieved from the steel bridge product model and rendered in the virtual world constructed in Java3D. A moving member to be installed at an appropriate location in the virtual world can be simulated by moving the receiver of FASTRAK. Furthermore, the user can feel immersed with stereoscopic views in the virtual world by wearing the liquid crystal shutter glasses.

In this system, if a moving object in the virtual world touches other objects such as buildings, trees, construction machinery, etc., the color of the moving object changes for giving an alert to the user as shown in Figure 6.

Sensor systems such as transmitters and receivers can realize sensory feedback and interactivity. Within the boundary of such sensor system, the user can change the viewing direction and location by just moving his or her head or fingers without typing commands from a keyboard. We used FASTRAK of Polhemus as a sensor system. Since the radius of the boundary of FASTRAK is about 1 m, viewing location is limited to 2 m, which is too small considering the size of typical bridges. Thus, we magnified the distance in the sensor area with some factor so that the user can view bridges from any point in the virtual world.

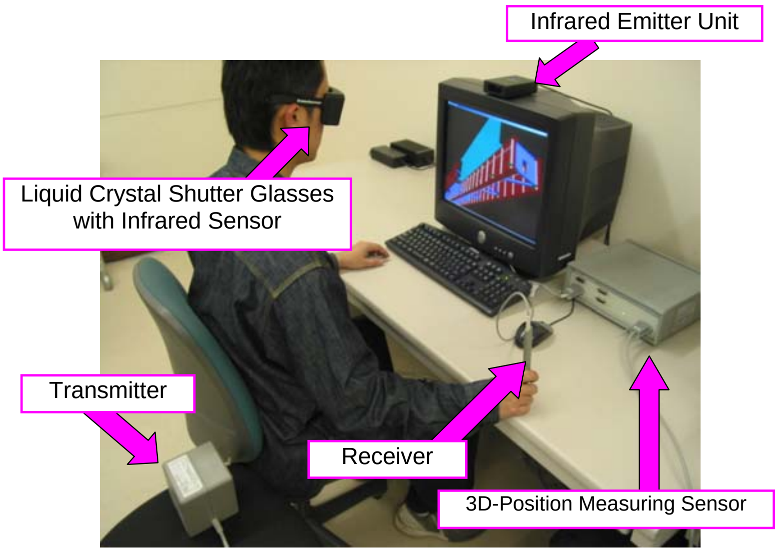

Figure 5: Erection Planning Support Environment Using VR

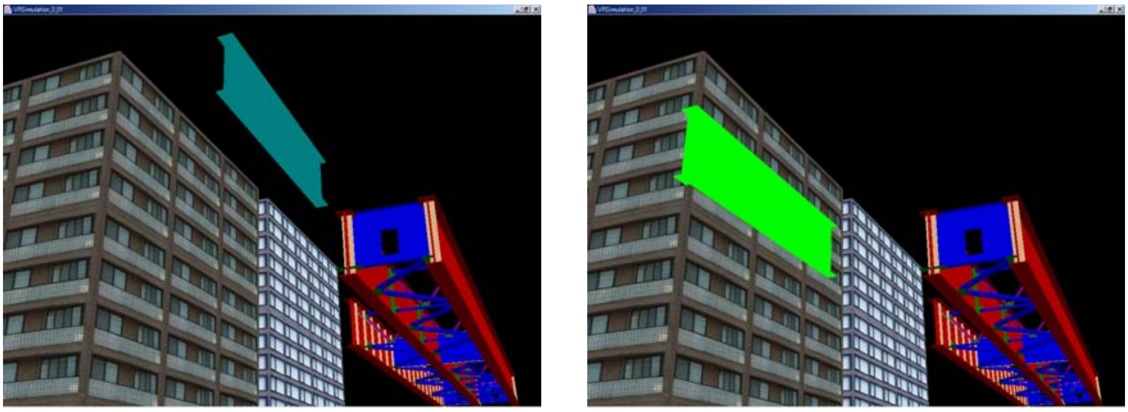

Figure 6: A Girder is Moved by the User and Touched with the Building.

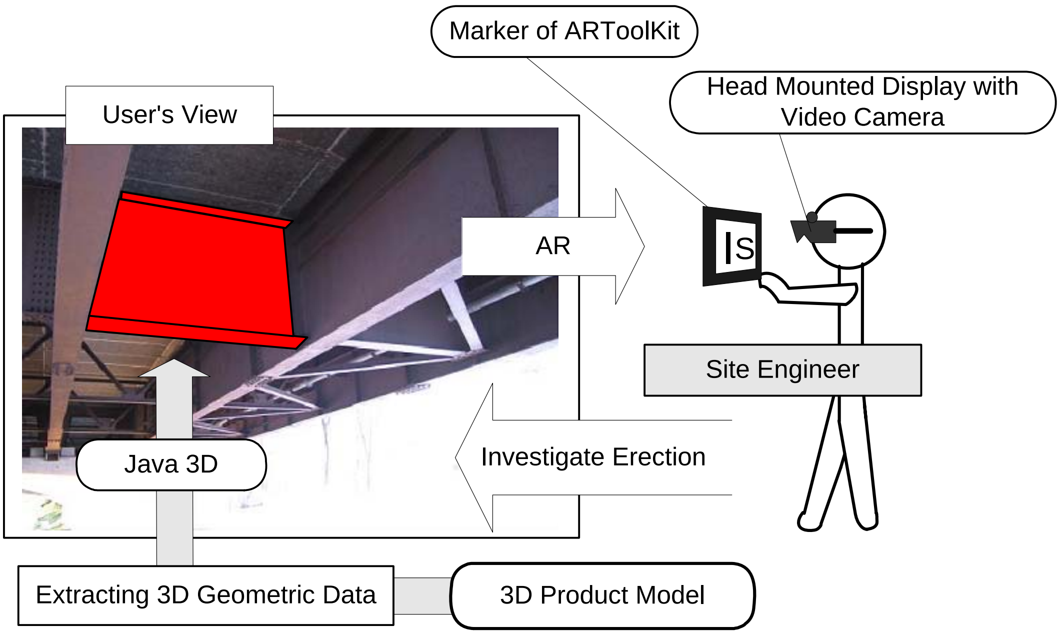

Figure 7: The Objective Image of the Erection Planning Support System Using AR

ERECTION PLANNING SUPPORT USING AUGMENTED REALITY

VR-CAD with the magnetic sensor system is effective to plan erection of steel girder bridges as described in the previous section. However, it is not always easy to obtain 3D model data of all the buildings, trees, poles, and other structures surrounding the steel bridge to be erected. Therefore, we started to investigate the application of augmented reality (AR) technology. In this study, we developed an interference checking system as the first step toward the erection planning system using AR. The objective image is shown in Figure 7.

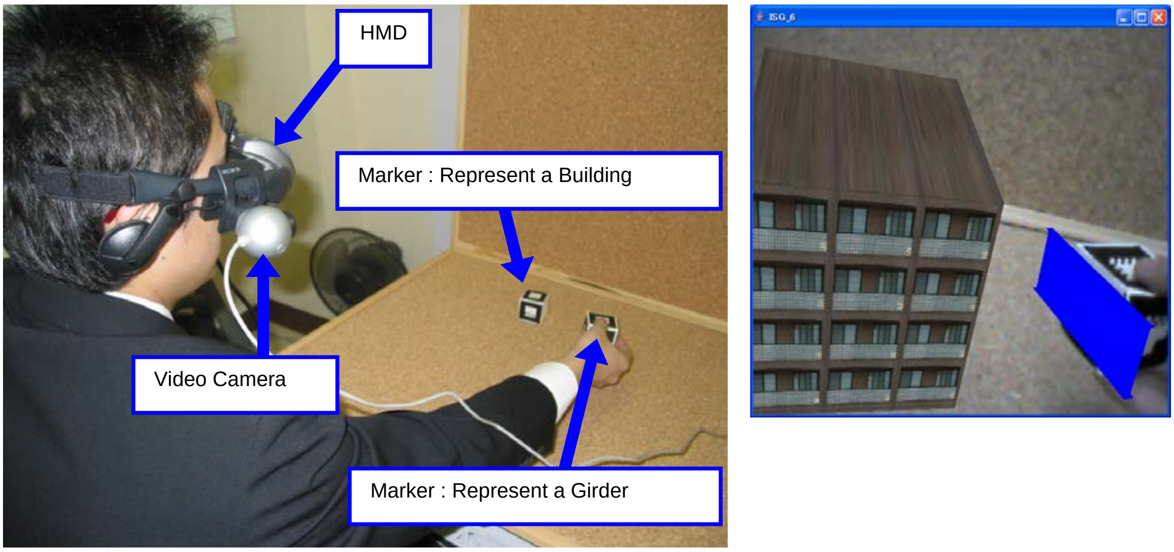

Figure 8: The User Wearing a HMD and aVideo Camera (Left) and the Screan Shot Image the User Is Watching, While Moving the Marker Representing a Girder

AR technology provides a facility to overlap the real video images with virtual images created by using a 3D CAD system. This can be done by showing a special marker to the video camera. The marker is linked with a designated object and the system shows the object image on the marker of the video screen.

In this research, we used ARToolKit, which is a set of open source libraries for AR, developed by Sato et al. (ARToolKit 2006). If a 2D square marker is shown on the video screan image, the system measures the location, inclination, etc. and inspects the pattern of the marker, and displays real time the 3D computer graphics image corresponding to the marker on the video display.

The developed interference checking system consists of a head mounted display (HMD), a video camera attached to the HMD, Java 3D, jARToolKit (jARToolKit 2006) for Java 3D, and markers. Figure 8 shows a photograph of the user wearing the HMD with the video camera and holding markers. The HMD displays an image as shown in Figure 8. The left marker is linked with a building image and right one is with the steel girder to erect. When the girder touches the building in the virtual world, the system changes the color or the girder object for giving alert of the interference to the user. As this is a preliminary system, we intend to enhance the system in the future work.

CONCLUSIONS

In this research, we developed a product model for steel girder bridges based on IFC2x2 of IAI for representing 3D geometry and attribute data of all the members of the structure so that interoperability of the data should be realized. Then, we developed a VR-CAD system for detailed design of steel girder bridges by using the developed product model, Java 3D, liquid crystal shutter glasses, infrared emitter unit, etc. Although the VR-CAD system demonstrated its feasibility and effectiveness, better user interface than a mouse was necessary to capture, move, and control objects in the virtual world on the display monitor. Thus, we applied the magnetic sensor system for capturing, moving, and controlling 3D objects in the virtual world. This system can be used for interference checking among girders and surrounding objects such as buildings, trees, poles, and other structures.

For further improvement, we applied the AR technology to erection planning of steel girder bridges. We developed a simple prototype by using ARToolKit, a HMD with a video camera, and markers. The prototype showed the effectiveness of the idea of using AR to erection planning as a preliminary system.

At the moment, the user cannot use the VR-CAD and AR-CAD simultaneously and should employ the VR-CAD mainly for design and the AR-CAD for checking construction procedures. We are integrating the VR and AR CAD systems to generate a future CAD environment, using new IFC-BRIDGE product model developed and modified through Japan-France collaboration.

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REFERENCES

ARToolKit (2006). http://www.hitl.washington.edu/artoolkit/

IAI (2006). http://www.iai-international.org/index.html

jARToolKit (2006). http://jerry.c-lab.de/jartoolkit/

Java3D (2006). http://java.sun.com/products/java-media/3D/

Polhemus (2006). http://www.polhemus.com/fastrak.htm

Stereographics (2006): http://www.stereographics.com/products/crystaleyes/body_crystaleyes.html

Yabuki, N., Kotani, J., and Shitani, T. (2004a). “A Steel Bridge Design System Architecture using VR-CAD and Web Service-based Multi-Agents.” *Proceedings of the Xth International Conference on Computing in Civil and Building Engineering*, Weimar, Germany, 8pp (CD-ROM).

Yabuki, N., Kotani, J., and Shitani, T. (2004b). “A Cooperative Design Environment Using Multi-Agents and Virtual Reality.” *Proceedings of the First Conference on Cooperative Design, Visualization, and Engineering (CDVE)*, LNCS 3190, Springer-Verlag, 96-103.