VIRTUAL REALITY SHIP SIMULATOR

Jeong-Bin Yim
Faculty of Maritime Transportation, Mokpo National Maritime University, KOREA
E-Mail: jbyim@mail.mmu.ac.kr

ABSTRACT

This paper describes prototype Virtual Reality Ship Simulator (VRSS) that we have recently developed next-generation training equipment based on the virtual reality (VR) technology. The inherent defects of conventional ship simulators are enormous costs and difficult system upgrade due to the system construction, such as large mock-up bridge system, wide visual presentations. In this paper, to cope with those problems, we explored VR technologies that can give realistic environments in a virtual world. Then we constructed prototype VRSS system, which is, consists of PC-based human sensors, and Databases set having 3D object models and coefficients of Head Related Transfer Functions (HRTFs). 3D-WEBMASTER authoring tool was used as Virtual Reality Modeling Language (VRML). Using the VRSS system, we constructed Port and Passage Simulator for the harbor of INCHON in Korea, and Ship and Sea State Simulator for an arbitrary given sea environmental states by user. Through many simulation tests, we testified the efficiency of developed prototype VRSS by subject assessment with five participants. Then, we present results on the simulation experiments and conclude with discussion of evaluation results.

1. INTRODUCTION

Over the last years, simulator training has proved to be an effective educational method when training personnel, especially where an error of judgment can endanger life, environment, and property. A computerized simulator can compress years of experience into a few weeks, and give knowledge of the dynamic and interactive processes typical for the real ship handling. Proper simulator training will reduce accidents and improve efficiency, and give the deck officers the necessary experience and confidence in their job situation.

The onboard training of future marine officers is more difficult because of repeated reductions of crew. This left little or no time for onboard operational training. Installing real equipment is one way of solving the problem, but unfortunately, its far too expensive. A well-designed computerized simulator will give the same training facilities. Although computerized simulator has many merits, most of the computerized conventional simulator arose many problems that will utilize enormous costs. It is due to the system architecture composed with huge bridge mock-up system having real navigational equipments, wide visual presentations, and high-powered hydraulic moving controllers [1],[2]. In this paper, as one of the substitute proposal to cope with those problems, Virtual Reality (VR) technologies are considered and proposed Virtual Reality Ship Simulator (VRSS) as next-generation ship simulator.

Virtual reality (VR) represents computer interface technology designing to leverage natural human capabilities. Today's familiar interfaces such as a keyboard, mouse, monitor, and GUI are force to adapt to working within tight, unnatural, two-dimensional constraints. VR technologies are guide to interact with real-time three-dimensional (3D) graphics in a more intuitive, natural manner. This approach enhances user's ability to understand, analyze, create, and communicate. Today's advanced VR interfaces let them look and move around inside a virtual model or environment, drive through it, lift items, hear things, feel things, and in other ways experience graphical objects and scenes much as might experience objects and places in the physical world. As a result, VR serves as a problem-solving tool in these days. Thus we believe that the VRSS can give economical profit and flexible upgrade compared with those of the conventional ship simulator [3]-[7].

The prototype VRSS, developed in this work, was consists of PC-based human sensors and 3-dimensional database on the object-oriented operating environment. Using the prototype VRSS system, we constructed Port and Passage Simulator for the harbor of INCHON in Korea, and Ship-Sea State Simulator for an arbitrary given sea environmental states by user. Through many simulation tests, we testified the efficiency of developed prototype VRSS by subject assessment. Then we discussed on the efficiency of the system

2. DESIGN METHODOLOGY

2.1 DESIGN CONCEPTS

The very last target of this study is to implement Virtual Reality Ship Simulator (VRSS) associated with the organization of core technologies as shown in figure 1. Navigational Expert System (NES) is designed to training the trainees independently with trainer in a virtual world. Multi-Networking System (MNS) is to ensure the multi-user participant environment. Three-dimensional Object Modeling (TOM) is to construct dynamic and real-like virtual world. Man-Sensor Interfacing (MSI) is to occur interaction with virtual environment. This concept is derived from extensive informal observations of virtual environment participants, along with some preliminary formal investigations[8]-[12].

In this work, we set the scope of this study to develop prototype VRSS which adopting TOM and MSI except for NES and MNS, and it is suitable for the single-user simulator but extendable to the multi-user simulator by adding the latest technologies in further.

2.2 STEREOSCOPIC VIEW

The nominal human have two eyes with intra-ocular distance of 6.0cm~7.0cm, and thus recognized real things as stereoscopic view in brain. The virtual display also has similar process of the human viewing process. Figure 2 shows principle of stereoscopic view in virtual display.

In figure 2, instead of viewing directly an image presented on a CRT screen, the virtual display creates only a small physical image and projects this image into the eyes by optical lenses and mirrors so that the original image appears to be a large picture suspended in the world. A personal virtual display system, the HMD as shown in figure 2(b), usually consists of a small image devise as Liquid Crystal Display (LCD) glass mounted on headgear, and small optical elements, which magnify, collimate, and project this image via mirror combiner into the eyes such that the original image appears at optical infinity. We achieved a binocular virtual display with two image sources and projection optics, one for each eye. With a partially reflective combiner, a mirror that reflects light from the image source into the eyes, the display scene can be superimposed onto the normal physical world.

When combined with a head position sensing system as Head-Tracking Sensor as in figure 2(b), the information on the display can be stabilized as a function of head movement, thereby creating the effect of viewing a circumstance or virtual world, which surrounds the user. This ambience creates the feeling that user is immersed in a computer simulated environment, that is, the feeling that experiencing the computer simulation from the inside, not merely passively observing it from the outside.

2.3 THREE-DIMENSIONAL AUDITORY

Processing sound image in virtual environment, in the same way that the pinnae of the ear manipulate a sound waveform, can create an acoustic virtual display. This acoustic virtual display technique involves preserving the frequency-dependent interaural time and intensity information with precise measurements of Head-Related Transfer Function (HRTFs): the listener-specific, direction-dependent acoustic effects imposed on an incoming signal by the outer ears[13]. Figure 3 shows the HRTFs measurement using one loudspeaker and one Dummy Head Microphone (DHM) in an anechoic chamber, and producing mechanism of 3D sound by convolution summing a monaural sound object with HRTFs coefficients.

DHM is an HRTF measurement device duplicated normal human head and inserted two probe microphones into the both ear canals. With the HMD facing forward toward the speaker (0 degrees azimuth), the speaker was positioned such that a normal ray projected from the center of the face of the speaker bisected the interaural axis of the HMD at a distance of 1.0 meter. The spherical space around the HMD was sampled at elevation from -40 degrees (40 degrees below the horizontal plane) to +90 degrees (directly overhead). At each elevation, a full 360 degrees of azimuth was sampled in equal sized increments. The increment sizes were chosen to maintain approximately 5-degree great-circle increments. A pair of HRTFs or pinnae transforms is then measured at 710 locations.

After HRTF measurement successfully, we applied linear system theory to analyze the measurements in the frequency domain and gather pairs of digital filters for each location. HRTF database, as a table of location filters, is then constructed from the pairs of HRTFs by first transforming them to the frequency domain, removing the spectral effects of the original loudspeakers and headphones using Fast Fourier Transform (FFT) techniques, and then transforming back to the time domain.

When display virtual sound image as shown in figure 3(b), a monaural sound object is first digitized and then convolved with HRTFs. Monaural digitized sound can thus be transformed to spatially localized binaural sound presented through stereo headphones to the subject. By using the instantaneously measured HMD position to select a library of HRTF coefficients, a localized sound, which is stable in space, can be generated. These sound objects can be used either separately or as an overlay of 3D visual objects.

3. SYSTEM DESCRIPTION

3.1 HARDWARE CONFIGURATION

Figure 4 shows the configuration of prototype VRSS system explored in this study. The prototype VRSS is consists of three major components as: Operating Part (1), which having Sever, Pentium-PC, and two databases for the 3D shape model and the HRTFs coefficients. The events, received from Client, are to be managed by Server and stereo scenes and 3D sound are generated through Computer Interface. I/O Part (2), which includes a stereographic board, a stereo soundboard, an A/D board, and an I/O interface board. These interface boards allow the I/O sensors to connect with existing VGA card in Pentium-PC. Sensing Part (3), which constitutes with several input and output sensors, e.g. LCD glass, a Head Tracking Sensor, a Hand Tracking Sensor, Headphones, and a Microphone.

3.2 SOFTWARE CONFIGURATION

To create real-time interactive VR worlds in VRSS, we used 3D-Webmaster that is a software tool for designing interactive 3D world developed by Superscape Inc. The procedure on the VR world creations is presented in figure 5. The creation of frame objects is done in the four editors, Shape Editor, World Editor, Image Editor, and Sound Editor. Then the object's attributes are to be designated in the Object Control process. At the last, the objects are running in the Runtime Module.

3.3 VRSS SYSTEM

Figure 6 shows main window of VRSS system developed in this study. This system is to simulate harbor of INCHON area located in the west side of Korea, and to visualize ship and sea state. The system partitioned into three sub-windows as; Visualization of Navigation Area (1), Inchon Port and Passage Simulator (2), and Ship and Sea State Simulator (3).

The Visualization of Navigation Area is to view detailed coastal features by using 1:100,000 scale digital map. This digital map is captured by satellite and then applied digital signal processing theory to extract Digital Elevation Model (DEM) and color interpolation.

Inchon Port and Passage Simulator is consists of Northern Port Simulator, Southern Port Simulator, Inner Port Simulator, and Passage Simulator. Thus, the user can view more detailed feature of landscape of that ports. The entrance scene of the virtual Inner Port and the virtual Passage are presented in the figure 7 and figure 8, respectively.

Ship and Sea State Simulator is to visualize sea and ship state according to sea environmental parameters given by user or telecommunication networks. In this work, we used environmental setup table as shown in figure 9. Environmental parameters are composed with the information of the vessel and weather. Vessel factors are includes as particular of ship such as course, speed, length, breath, and height. Weather factors are includes such as direction of wave, height of wave, visibility, and clouds. Figure 10 shows one of the simulation results according to the environmental parameters given by user.

4. EXPERIMENTS AND EVALUATIONS

4.1 EXPERIMENTS

Figure 11 shows virtual bridge of own ship having 3D cybernetic officer and real-like navigational equipments. In this work, the own ship was modeled as type of a general cargo vessel with capacity of 30,000 DWT, speed of 0 to 30knots. 3D cybernetic officer, who is aged 35 and can wandering around in the bridge by pre-build sequences, or by user control handling. In addition, the virtual bridge was installed with virtual equipments such as cybernetic ECDIS, cybernetic ARPA/RADAR, and cybernetic Gyrocompass, so on. All of those are act as if individual equipments in a real bridge, thus real-like virtual bridge environment can be obtained by using the objects.

To simulate for the overtaking situation we prepared other ship model that is modeled almost same as own ship, and carried out simulation experiments. Snap shots, which are taken from the scenes appeared during this simulation, are shown in figure 12. Scenes in figure 12 are present the relationship between 'the vessel to be overtaken' and 'the vessel intending to overtake' according to the International Regulations for Preventing Collisions at Sea.

4.2 EVALUATIONS

Five subjects (three man and two woman) ranging in age from 20 to 27 were participated in this experiments to assess the ability of proposed prototype VRSS. Participants are putting on the HMD and operating the virtual ship. After finishing the simulation experiments, we asked each subjects about the feeling of naturalness impressed during in simulation. As results, most of them reported that comfortable and natural-like virtual world scene was seen and very interesting simulation was experienced due to interaction with virtual objects. Especially they can be obtain the knowledge of navigational rules, and realize many phenomena between vessel particular and weather factors, with very impressible and easily.

5. SUMMARY

In the paper, we explored the application of virtual reality technologies to implement next generation Virtual Reality Ship Simulator (VRSS), and developed prototype VRSS with man-sensor interfacing devices and object-oriented 3D operating environment. With the developed prototype VRSS, we carried out simulation experiments for the overtaking situation at sea, and ship-sea state simulation. Then determined the effectiveness of the system through subject assessments. It became apparent that the prototype VRSS gave attractive and interesting ship simulations with ease of learning navigational rules and ease of comprehension of relationship between vessel particular and weather at sea. This led the results that the proposed simulator system could be adequate to next generation ship simulator.

REFERENCES

[1]. Technical Manual for *TRANSAS MARINE SIMULATOR SYSTEMS*, Transas Marine Company, 1996.

[2]. Technical Manual for *Raytheon PATHFINDER/ST ECDIS C20*, Rytheon Marine Company, 1995.

[3]. Gene Bylinsky, "The Marvels of Virtual Reality," *FORTUNE*, pp.94-100, 1991.

[4]. Michael Bajura, Henry Fuchs, and Ryutarou Ohbuchi, "Merging Virtual Objects with the Real World: Seeing Ultrasound Imagenary within the Patient," *Computer Graphics*, Vol.26, No.2, pp.203-210, 1992.

[5]. Tony Reveaux, "Virtual Reality gets Real," *NEWMEDIA*, pp.32-41, 1993.

[6]. Tim Studt, "Reality from Toys to Research Tools," *R&D Magazine*, pp.19-21, 1993.

[7]. Jeong-Bin Yim, Sang-Jib Lee, "A Basic Research on the Implementation of Ship Handling Simulator Using Virtual Reality Technology," *Proceeding of Journal of the Society of Maritime Safety*, 1997, pp.3-18

[8]. Jeong-Bin Yim, "3-D Sound-Field Creation Implementing the Virtual Reality Ship

Handling Simulator(I): HRTF Modeling," *The Korean Institute of Navigation*, Vol.22, No.3, 1998, pp.17-25.
[9]. Jeong-Bin Yim, "3-D Sound-Field Creation Implementing the Virtual Reality Ship Handling Simulator,(II): Sound-Field Control," *The Korean Institute of Navigation*, Vol.22, No.3, 1998, pp.27-34.
[10]. H. Matsumuta, M. Inaishi, S. Tsuruta, H. Imazu and A. M. Sugisaki, "Basic Research on an Expert System for Navigation at Sea," *Journal. Of Japan Institute of Navigation*, pp.31-38, 1989..
[11]. Jeong-Bin Yim, Hyeon-Jong Kim, Young-Sup Ahn, "Virtual Reality to Implement Next Generation Ship Simulator," *Proceeding of KIN-CIN Joint Symposium '99 in Mokpo, Korea*. 1999, pp.135-145.
[12]. Jeong-Bin Yim, Meong-Oh Yoon, Hyeon-Jong Kim, "Development of Training Simulator by Virtual Reality," *Proceeding of IAIN/ION meeting 2000 in San Diego, USA*, 2000.06.
[13]. Jeong-Bin Yim, Chun-Duck Kim, Seong-Hoon Kang, "Lower-order ARMA Modeling of Head-Related Transfer Functions for Sound-Field Synthesis Systems," *Journal of Acoustical Society of Korea*, Vol.15, Nu.3(E), 1996, pp.37-44.

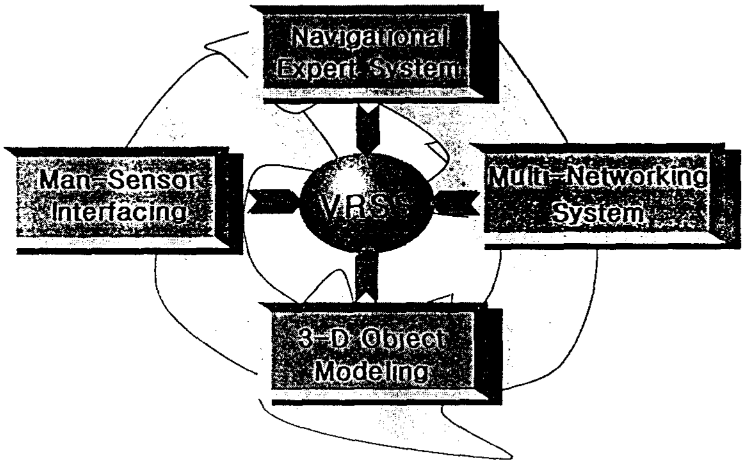
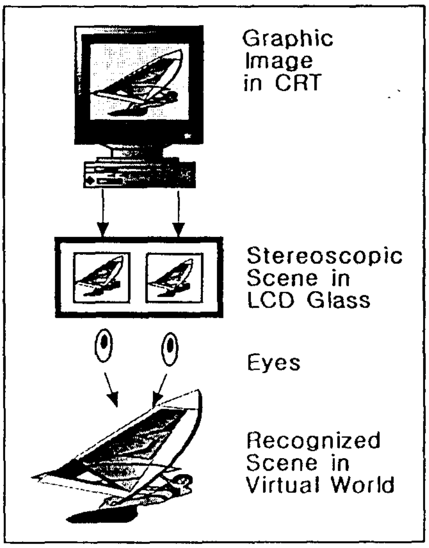
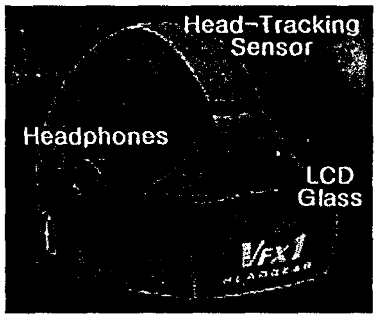


Figure 1. Organization of core technologies to implement full-mission Virtual Reality Ship Simulator (VRSS).





(a) (b)

Figure 2. Principle of stereoscopic view in a virtual display (a), and the appearance of Head-Mounted Display (HMD) device (b).

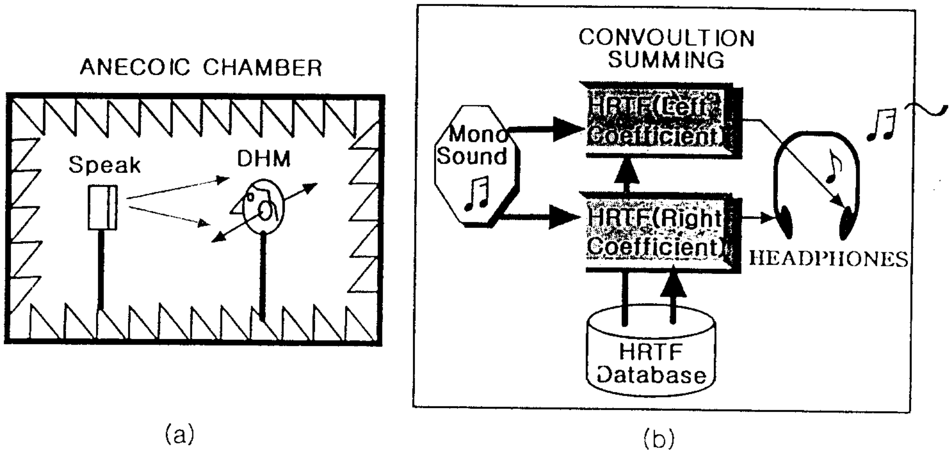


Figure 3. Principle of three-dimensional sound display. HRTF measurement in an anechoic chamber (a), and producing 3D sound by convolution summing a monaural sound object with HRTF coefficients (b).

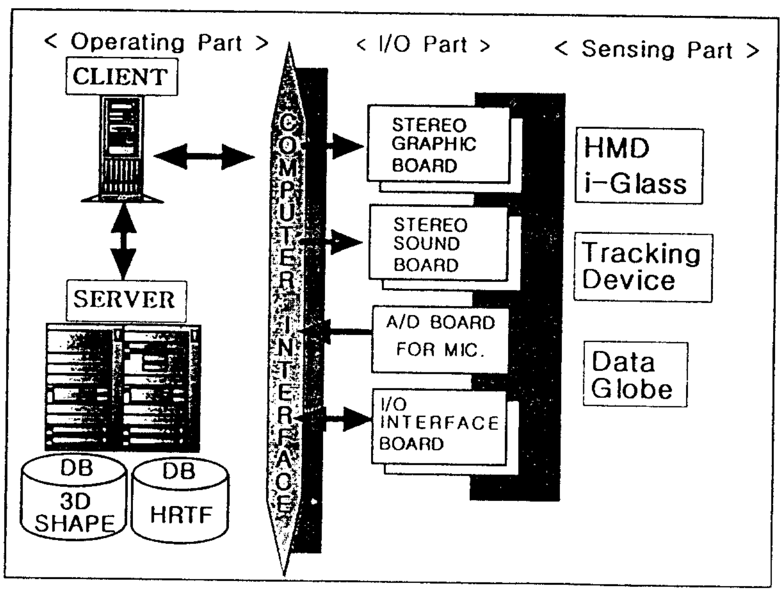


Figure 4. Configuration of prototype VRSS system, developed in this work.

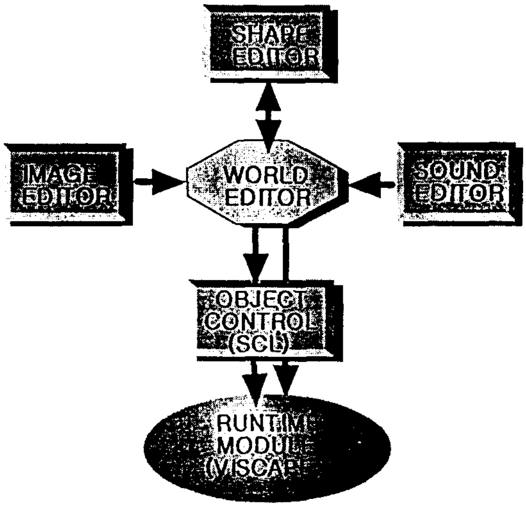


Figure 5. Procedure to create virtual world using 3D-WEBMASTER tool.

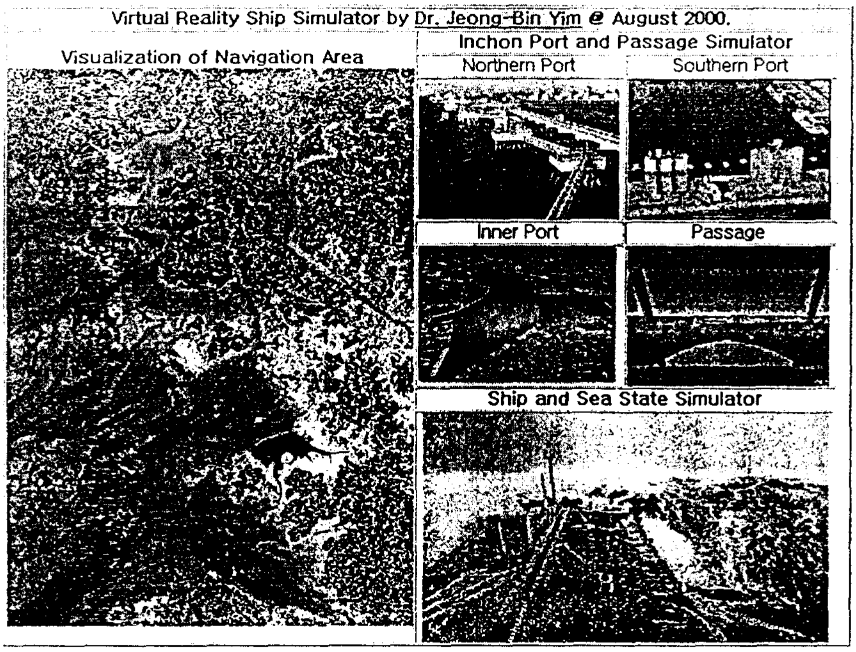


Figure 6. Main window of VRSS system. Sub-window for the Visualization of Navigation Area using detailed satellite map (left), Sub-window for the Port and Passage Simulator on the harbor of INCHON (top right), and Sub-window for the Ship-Sea State Simulator to create arbitrary given sea environmental states by user (bottom right).

Figure 7. Entrance scene of the virtual inner port of harbor of INCHON in the Inchon Port and Passage Simulator.

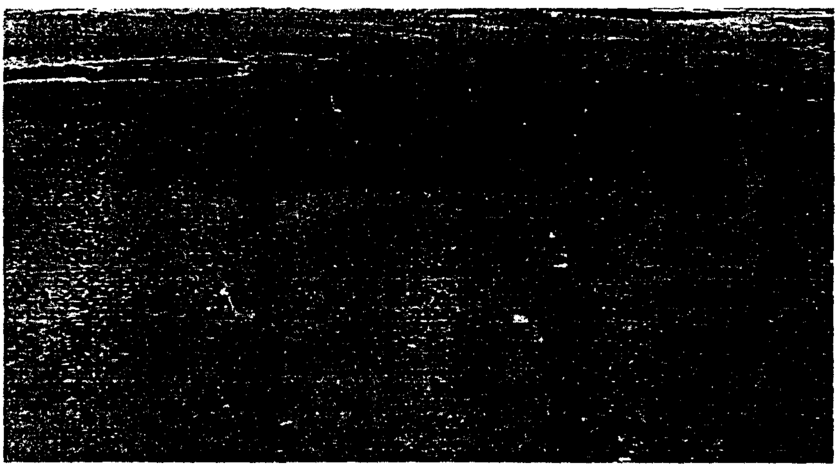


Figure 8. Entrance scene of the virtual passage of harbor of INCHON in the Inchon Port and Passage Simulator.

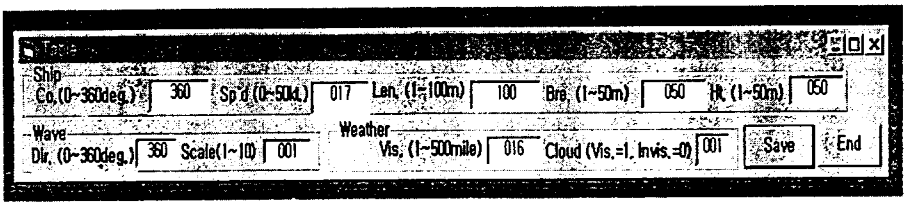


Figure 9. Parameter table to set a ship's particular and sea state in the Sea and Ship State Simulator.

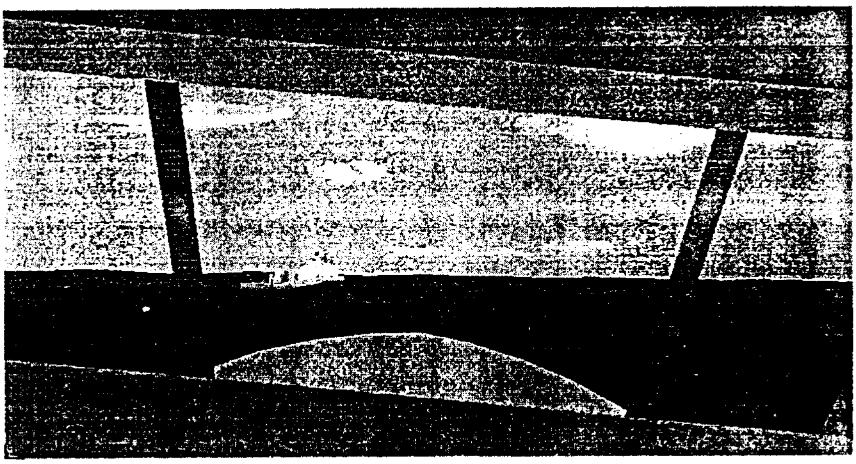


Figure 10. One of the simulation results using the Sea and Ship State Simulator according to setting values of ship's particular and sea state.

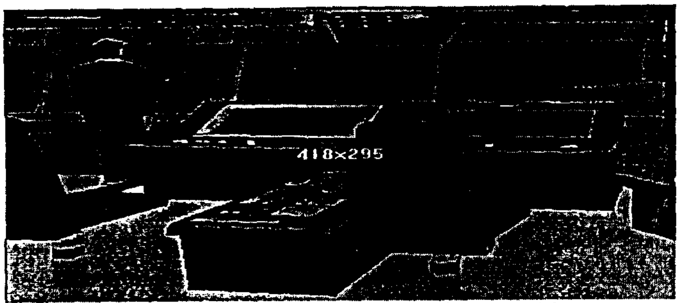


Figure 11. Virtual bridge of own ship.

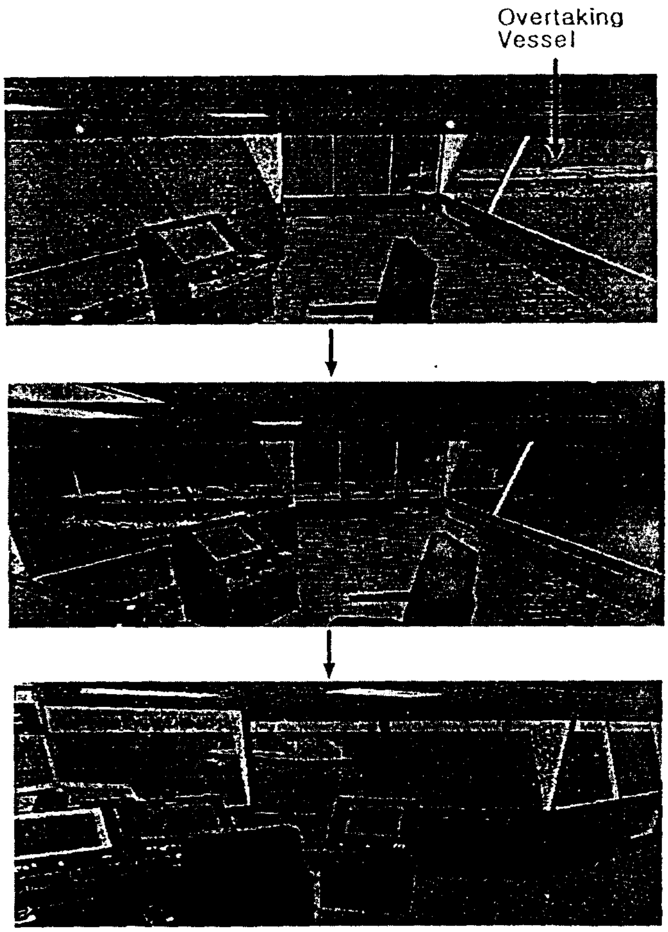


Figure 12. Scenes taking in during overtaking simulation using the Inchon Port and Passage Simulator. The following ship start overtaking (top), just abeam (middle), and finish overtaking (bottom).