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A Study on the Development of Computer Based Training Simulator for Aids to Navigation Using Virtual Reality Techniques

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가상현실 기술을 이용한 항로표지 CBT 시뮬레이터 개발에 관한 연구

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〈목　차〉

Abstract

This paper describes prototype Aids to Navigation Simulation System (AtoNSiS) that we have recently developed Aids to Navigation (AtoN) training equipment based on the virtual reality technology. To produce an enhanced AtoN simulation experience, three-dimensional (3D) cardinal and lateral buoys are created, and then build up the virtual 3D waterway world according to the guidelines of IALA (International Association of Lighthouse Authorities) in region B. The AtoNSiS have Simulation Module (SM) and Explanatory Module (EM). SM is to learn about the IALA-B system using virtual navigation world varying with environmental factors. EM is to view more detailed marker characteristics using 3D objects. In this work, we present system design concepts, development processes, and simulation experiments of prototype AtoNSiS. Results from tests and evaluations with five subjects provide practical insight on the importance of AtoNSiS.

요 약

이 논문에서는 가상현실 기법을 적용한 항로표지 훈련장치로서, 프로토 타입의 항로표지 시뮬레이션 시스

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템(AtoNSiS) 개발에 관하여 기술하였다. 항로표지에 대한 시뮬레이션 경험을 향상하기 위하여 3차원으로 측방표지와 방위표지를 제작한 후, IALA-B 방식에 의거한 가상의 3차원 항로를 구축하였다. 이 연구에서 개발한 AtoNSiS는 시뮬레이션 모듈(SM)과 설명 모듈(EM)로 구성하였는데, SM은 다양한 해상환경 변화가 가능한 가상의 항해 공간을 사용하여 IALA-B 시스템을 학습하기 위한 기능을 갖는다. EM은 생성한 3차원 측방 및 방위표지를 이용하여 각 표지들의 상세한 특성을 학습하기 위한 기능을 갖는다. 이러한 AtoNSiS에 대한 설계개념과 개발과정 및 시뮬레이션 실험 등을 나타냈다. 5명의 시청자를 대상으로 실험한 결과 AtoNSiS가 유용함을 알 수 있었다.

Ⅰ. Introduction

The main purpose of an Aids to Navigation (AtoN) is to provide a visual and auditory signals to mariners. During daytime hours, sunlight reflecting off the surface materials of the buoy provides the signal energy to the mariner. Factors that influence visual detection include the buoy shape, position, color and alphanumeric labels. Once detected, these same factors convey specific information useful for a variety of navigational purposes. Knowledge of the different types of AtoN is very important for safety to deck officers.

The simulator training is one of the effective educational methods 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. Proper simulator training will reduce accidents and improve efficiency, and give the deck officers the necessary experience and confidence in their job situation. The best training condition is to give human interaction with simulation objects such as model ship, model markers of AtoN, model RADAR, and model waves at sea etc. Virtual Reality (VR) technologies can arise these effects sufficiently [1,2].

VR represents computer interface technology designing to leverage natural human capabilities. 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 [3]-[14].

Aids to Navigation Simulation System (AtoNSiS) is one of the ongoing application of VR high technologies. AtoNSiS is a training simulator to train lateral and cardinal systems conform to the International Association of Lighthouse Authorities (IALA) guidelines, located in IALA region B. The main object of this study is to develop a low-cost, readily available AtoNSiS for training entry-level cadets to reduce the amount of sea-time training. AtoNSiS is mainly designed as web based training aids that provide computer-based training (CBT).

The prototype AtoNSiS was organized into two modules, Simulation Module (SM) and Explanatory Module (EM). The SM is to learn the IALA-B system in the virtual waterway world composing with object-oriented 3D models such as 3D ship, 3D AtoN markers, and 3D buildings etc. In that virtual world, a trainee can exercise much as might experience in real-like navigation situation, and then acquire navigation skills in the virtual waterway including 3D cardinal and 3D lateral markers. The detailed characteristic of physical world markers appeared in the window of EM. EM consists of 3D shapes of markers, nautical charts, and information for the IALA-B system. During in the SM simulation process, a trainee can find detailed characteristics of markers in the EM, simultaneously.

An assessment of the prototype AtoNSiS was discussed including the usability of the AtoNSiS for cadets training and evaluations of the virtual world performance. The paper concludes with a summary of the study with recommendations for the future work and improvements.

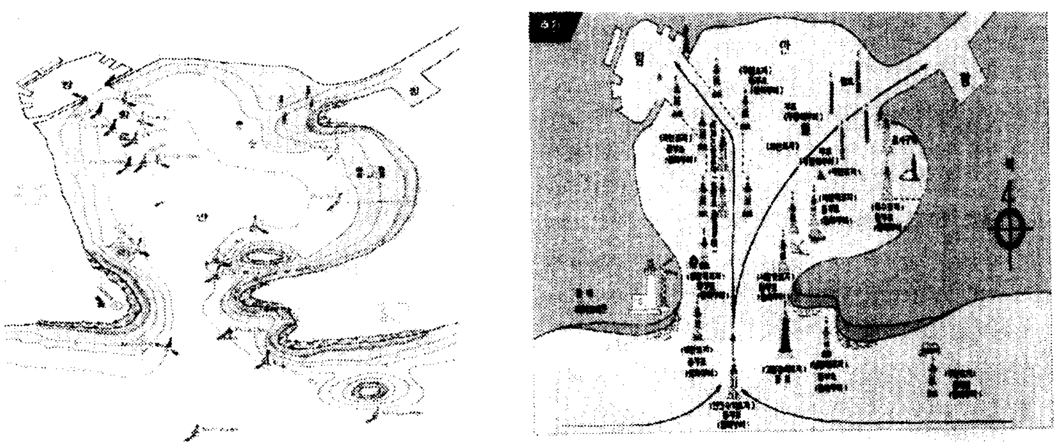
II. System Design

A. Design Concepts

A VR training environment offers unique advantages such as scenario generation, real world replication, true interaction with 3D virtual objects, and improved skill acquisition from in-the-loop learning. Trainees can hone skills and learn rules of Aids to Navigation (AtoN) without risk, and they can train until they reach training targets. As curriculum needs change, the simulated environment can be easily modified to meet new items. Because the VR environment doesn't wear out and can be re-used without limits, training costs shrink. AtoNSiS is the impressive training system to put the trainees in the loop. A concept ional nautical chart and fictitious nautical chart according to IALA-B system are represented in the figure 1.

As mentioned in the Introduction, if trainee can touch, see and feel those of markers shown in the nautical chart, then training effect should be steadily increasing. With reference materials such as in the figure 1, we designed prototype AtoNSiS that provides interaction with 3D AtoN markers in a virtual world. We believe the AtoNSiS will give the best training challenges, which include the following:

(1) To become familiar with the principals of the IALA-B System.
(2) To be able to interpret IALA-B system.
(3) To recognize the characteristics of buoys, daybeacons, and lights.
(4) To be able to relate a visible IALA-B to its charted symbol and locate its position on a nautical chart.



(a) (b)

Figure 1. A nautical chart showing a waterway (a), and fictitious nautical chart (b).

(5) To be aware of the Light List and its value for identifying IALA-B.

B. Virtual World Creation Concepts

Over the past few years, the number of reports on VR applications in use for the simulator has been steadily increasing. In particular, training application and hazardous situations are proving to benefit from the use of virtual environments. This is largely because VR can now offer affordable training solutions. In addition, object-oriented frameworks and open component technology can improve simulation capabilities dramatically by enabling the production of simulation applications that are customized to specific users and processes.

Some of the key benefits expected from the virtual world based simulation architecture are Interactive simulations and web-based simulations. Today's simulations are typically batch-oriented, with separate activities for simulation set-up, simulation execution, and post-processing of the results. In fact, these activities are often accomplished with different proprietary products linked together with input/output files, resulting in complex integration steps to adapt one system to another. Furthermore, the World-Wide Web (WWW) is quickly becoming the platform of choice for software applications.

Virtual Reality Modeling Language (VRML) is one of the solutions to accept the above states in the day. VRML is a file format for describing interactive 3D objects and worlds. VRML is designed to be used on the Internet, intranets, and local client systems. VRML is also intended to be a universal interchange format for integrated 3D graphics and multimedia. In this work, virtual waterway worlds in AtoNSiS are created using 3D Webmaster [15]. It is one of the authoring programs of VRML. It gives the ability to populate the user worlds with moving ship and animated objects that can be equipped with programmable behavior. 3D Webmaster has Viscape as VR browser running a virtual world. 3D Webmaster have many benefits which adequate to build prototype AtoNSiS as following:

(1) Use of common file formats such as svr, vca, wrl, bmp, pcx, gif, jpeg and wav. Therefore, pre-build objects such as 3D models, images, photographs, and sound waves are easily applicable to build virtual environment.
(2) Full HTML integration with a Java interface to give developers two-way communication between the 3D Web Page and a Java Applet or some JavaScript.
(3) Object control functions by special programming language, e.g. SCL (Superscape Control Language) which is similar in many respects to the popular programming language C. It is used to control objects within the virtual world, and is used to perform actions, which could not be performed by the automatic rotations or movement functions. Each object in the world can have its own attached SCL program, which is executed once per frame.

Ⅲ. Aids to Navigation

A. Lateral Markers

AtoN is man made objects created to help mariners determine their position and safest course [16]-[19]. These can be in the form of buoys, lights, ranges, and day beacons. The buoys and beacons in Korea conform to the International Association of Lighthouse Authorities (IALA) guidelines and are located in IALA region B. They are sometimes referred to as the IALA-B system.

In this system, there are lateral and non-lateral markers. The lateral markers indicate navigable channels by their position, shape, coloring, numbering and light characteristics. The non-lateral markers are informational and regulatory markers. To navigate safely using the lateral markers, a ship should pass between the red and green. Returning from sea, the red markers are on right and the green are on left. Lateral Buoys and waterway markers are shown in the figure 2.

In the International system, navigation aids mark the edges of channels to tell which way open is. They are called day beacons if unlighted, lights if lighted at night, or buoys if they are floating. Some buoys are also lighted for identification at night. Floating red markers are called 'nuns' and are triangular. They are numbered with even numbers. Floating green markers, on the other hand, are called 'cans', are square or shaped like a large can, and carry odd numbers.

Preferred channel markers or junction markers as in the figure 3, indicate the preferred channel at points where the waterway splits or branches off in another direction. If we are returning from sea and see a preferred channel marker that is red over green, to stay in the main channel we would consider the marker as if it were a red marker and keep it on our right. However, if intended destination is the waterway branch consider the marker a green marker and leave to port side.

B. Cardinal Markers

Cardinal Markers as shown in the figure 4, indicate where to find the safest water. The buoys are flat-topped, painted with yellow and black horizontal bands, and may have a topmark that is made up of two black cones. If lighted, the cardinal buoys have a white light. The pattern of colors on the buoy shows whether the safe water lies north, south, east, or west of it.

Cardinal buoys indicate the location of the safest and deepest water by reference to the cardinal points of the compass. There are four cardinal buoys: North, East, South and West. The points of the topmark cones point toward the black parts of the buoy. The number of short light

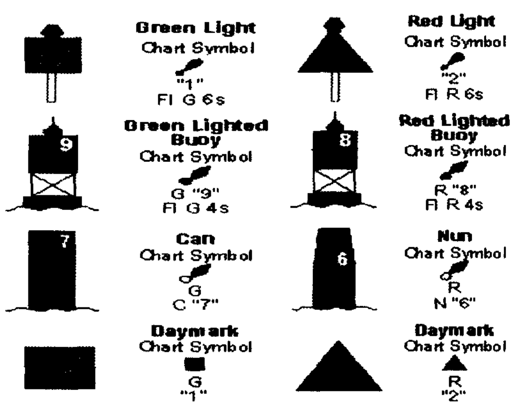


Figure 2. Lateral markers. Port side lateral system (the left figures) and starboard side lateral system (the right figures), as seen entering from seaward.

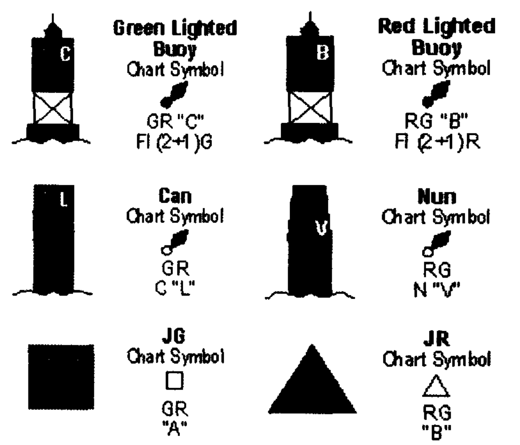


Figure 3. Preferred channel markers or junction markers. Preferred channel to starboard (the left figures), and preferred channel to port (the right figures).

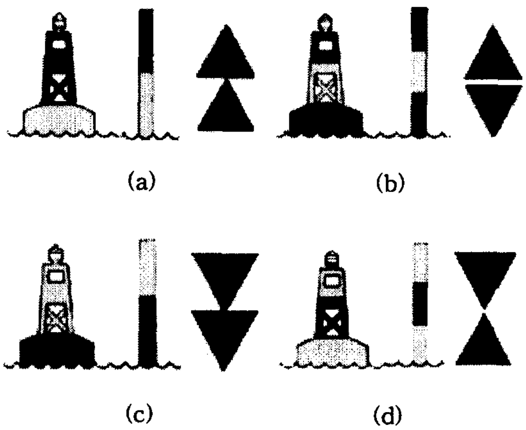


Figure 4. Cardinal markers. North marker (a), East marker (b), South marker(c), West marker (d). Each figure has body shape, pillar spar and topmark, from left to right, respectively.

flashes in each group on the east, south, and west cardinals is the same as the hour at the corresponding point on a clock face.

C. Other Waterway Markers

Red and white vertically striped buoys (called 'fairway buoys') mark the middle of the channel, and can be passed on either side. Red and green horizontally banded buoys (called 'bifurcation buoys') show where a channel divides. The shape and color at the top indicate whether it should be left to port, or to starboard, when going upstream. Other buoys indicate anchorages, moorings, controls, isolated hazards, etc.

D. 3D Marker Modeling

We created 3D marker objects modeled to create virtual waterway environments as shown in the figure 5. All of the objects are structured into object-oriented database and sharing in the virtual world each other.

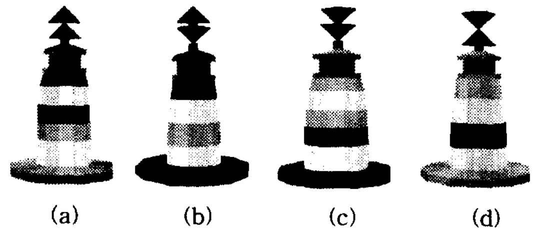


Figure 5. Examples of 3D-objects modeled to create virtual waterway environments. North marker(a), east marker(b), south marker(c), and west marker(d).

Ⅳ. System Implementation

A. Node Manipulation Layer over EAI

AtoNSiS program was based on VRML and Java cooperation. The Java is generating and operating through External Authoring Interface (EAI) VRML world where visual data of AtoNSiS program are displayed. Since the limited possibility of EAI we have decided to implement a special layer between EAI and Java as shown the in figure 6. The purpose was to create a system of classes above EAI.

These classes will be represented by single type of nodes. This approach is simplified the creation of arbitrary type node by a creation of class instance. Advantage of this layer implementation is easy access to parameters of node and this access is performed by means of existing class methods. In addition, the approach eliminate frequent mistake; the attempt to change or read

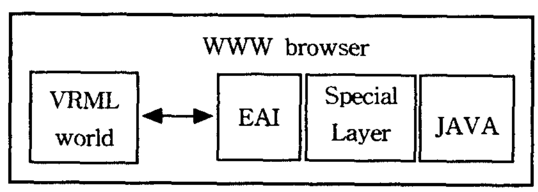


Figure 6. Implementation system block scheme.

node non-existing parameters. Probably the greatest contribution is a possibility to create a special node.

EAI defines an interface between VRML world and environment. This interface allows following functions: sending event into node of VRML (*ExposedField* and *EventIn* only), reading last script funds in parameter node (*ExposedField* and *EventIn* only), generating new node from string or from URL address, obtaining information about events generated from parameters (only *EventOut*), searching named nodes; only existing in already opened VRML and tagged by statement DEF.

One instance of class represents one particular node in VRML. The constructor contains all necessary code for communication with VRML scene via EAI. For example, the creation of *Point-Light* node with default parameter can be done via following code:

Sun=new VrmlPointLight(fvrmlBrowser);

Where *fvrmlBrowser* refers to a browser class.

Access to parameter of existing node is handling by class methods that are represented by that node. Methods are tagged by names of parameters according to VRML specification. Methods for reading and changing parameters have identical names. A method for parameter changing has structure:

void classinstance.parametername(value)

and for parameter reading:

void classinstance.parametername(void).

The following piece of code shows how to get a radius from *PointLight* and to increment it by 10.

float param=Sun.radius(): // reading parameter
Sun.radius(param+10): // changing parameter

The layer above EAI makes possible a creation of a special construction (for example node + JavaScript). The approach to these constructions is the same like to normal node (for user this construction will be new node type). For example a node *Shipview* is a special node calculating from two input position parameters a turn angle of a second position observed from first position.

B. AtoNSiS Implementation

Suitable tools for AtoNSiS presentation are VRML. This language is very restricted from point of view of intelligence but on the other hand, it makes possible to modify VRML world using external program via EAI. Suitable language for this external program is Java. Probably the greatest advantage of the simultaneously using VRML and Java is the possibility to display VRML browser and Java applet on some HTML pages.

The Java part is implemented as an applet. The applet has to be placed into the same HTML page where is the VRML browser window, it is the only way to external program can communicate with an embedded VRML world. The applet provides interaction with user and communication with VRML scene. This application is based on classical learning process: simulation and education. The first mode is Simulation Module(SM). In this mode user can set-up various environmental sit-uation. User knowledge of AtoN recognition can be verified by responses to test questions. The second mode is Explanatory Module(EM). In this mode, the scene is generated in cooperation with SM. A user can respond to questions appeared after the simulation had started.

VRML browser provides the entire ship animation. On start the Java applet provides just scene creation for VRML browser, it is to create a node hierarchic structure in dependence on user scene setting. When encounter two ships, the brief description of hierarchy follows.

The position interpolators **PositionInterpolator** (class *VrmlPositionInterpolator*) control the ship movement. Each ship has own interpolator. The timing data from **Timer** (class *VrmlTimeSensor*) was routed into the interpolator by **Routs** (class *VrmlRout*) and the ship positions in ranging from starting to ending are interpolated by these timing data in range from 0 to 1. These positions are routed to **Ships** as their new positions (class *Ship*). These positions are simultaneously routed into a **Special node**, which is intended for user position and orientation calculating (class *VrmlTransform*). It is calculated user position and orientation to see second ship from actual positions of both ships. The result values are forwarded by routs to **Viewpoint** (class *Viewpoint*). The **Viewpoint** is a node represent scene point of view. Finally, **Viewpoint** and **Timer** are connected. The reason of this connection is a fact that a simulation is started by **Viewpoint** selection. When **Viewpoint** is selected send actual time to **Timer** and it starts to generate a number from 0 to 1 over given time. All above mentioned parts are nodes in VRML scene and their detail scheme is on figure 7.

V. AtoNSiS

A. Initial Selection

Applet GUI(Graphical User Interface) consists of three menu: (1) Mode selection menu, (2) simulation control menu, (3) setting environment menu. After starting execution, file initial two separated windows allowing starting scene are displayed as in the figure 8. The left window is a

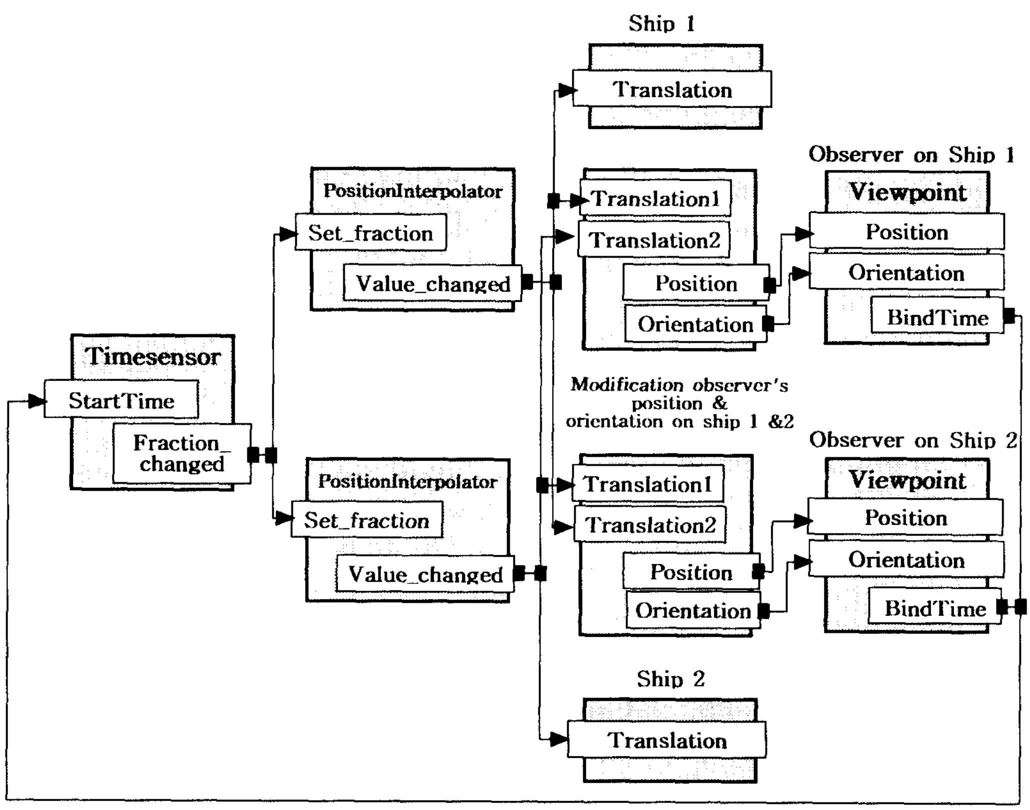


Figure 7. Animation scheme for synchronized movement of two ships and corresponding viewpoints.

part of Simulation Module (SM) to simulate virtual waterway world. The right window is a part of Explanatory Module (EM) to display detailed shape of markers shown in the fictitious chart.

AtoNSiS can create various situations such as sunrise, sunset, daytime, set fog, and viewpoint movement etc. The menu tables, as shown in the lower left bottom, are provided to set the environmental factors. 'Fog setting' is to set the fog phenomena that can control visibility from 3miles to over 50miles. With the 'View setting', viewpoints can be move from inner bridge to other world. 'Time setting' is to choose the navigation time such as daytime, sunrise, sunset, and nighttime. By clicking one of the items, virtual world changed to new world immediately.

B. Simulation Module (SM)

To view the virtual waterway more dramatically, all of the scenes are displayed as seen in the virtual bridge as shown in the figure 9. There are two kinds of control tools: Maneuvering keys (crossed arrows) and Resetting icons (circle icons). Using Maneuvering keys, the user can wander around the virtual world. If push the Maneuvering keys to forward direction then model ship move toward. If push the Resetting icons then all parameters will change to initial environments. Using SM the trainee can get the rule of IALA-B system with nautical charts shown in the EM window.

C. Explanatory Module (EM)

EM is to descript simulation areas and detailed maker characteristics with nautical chart and 3D marker objects as shown in the figure 10. When clicking or pointing one of the marker appeared in that chart, and maker specifications are indicated

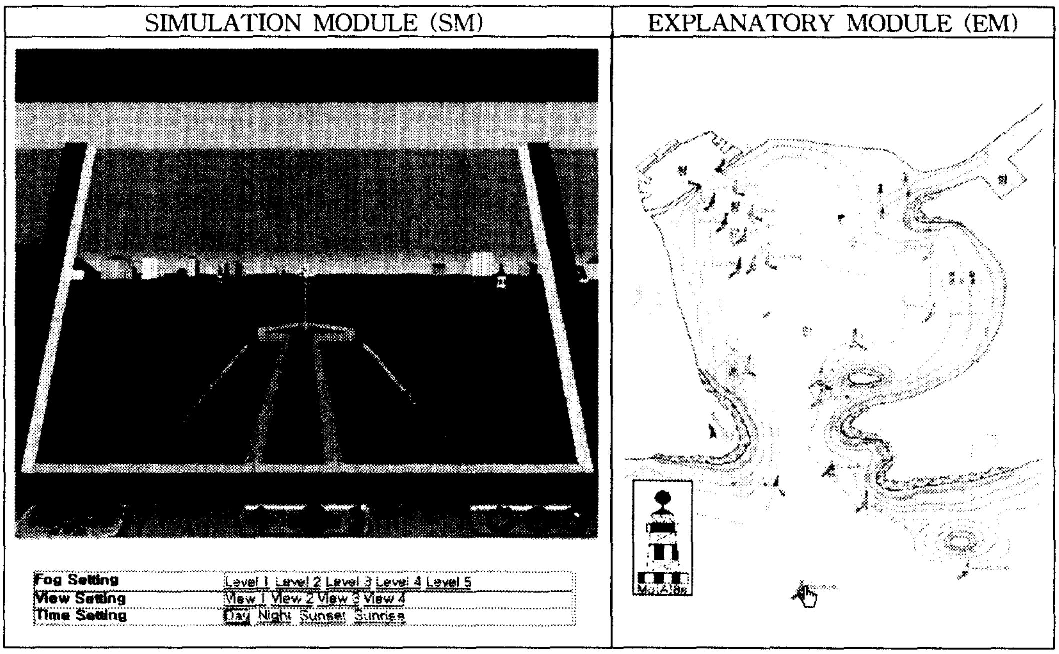


Figure 8. Initial operation window. The left window presents Simulation Module function and the right window presents Explanatory Module function.

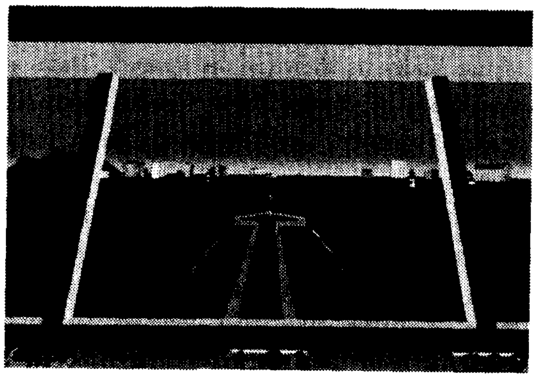


Figure 9. Simulation Module (SM) operation.

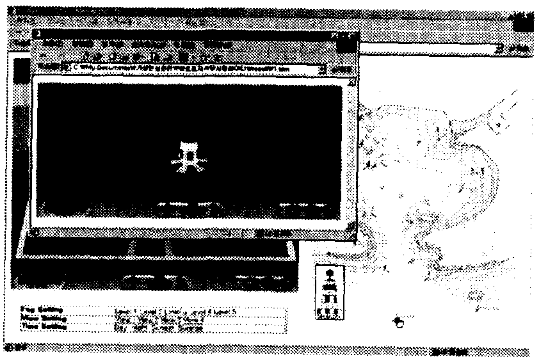


Figure 10. Explanatory Module (EM) operation.

in a small index window. Therefore, user can recognize detailed marker characteristics such as shapes, colors, and rhythm of lights so on.

Ⅵ. Experiments and Evaluations

A. Evaluation Environments

The primary purpose of this assessment was to evaluate training effectiveness and interactive effects. Five university seniors, three men and two women, are participated in the test. Their experience year of onboard is ranged from 6 to 10 months. Assessment tests were conducted with only one subject in attendance at a time. Prior to conducting some tests, each subject was required to complete a pre-assessment survey. Immediately after completing each assessment test, a post-assessment survey was filled out as well. The subjects were instructed not to discuss their impressions of the AtoNSiS with each other to prevent slanting the opinion survey results. During the formal evaluation, each subject was asked to evaluate his ability to view and interact with various objects.

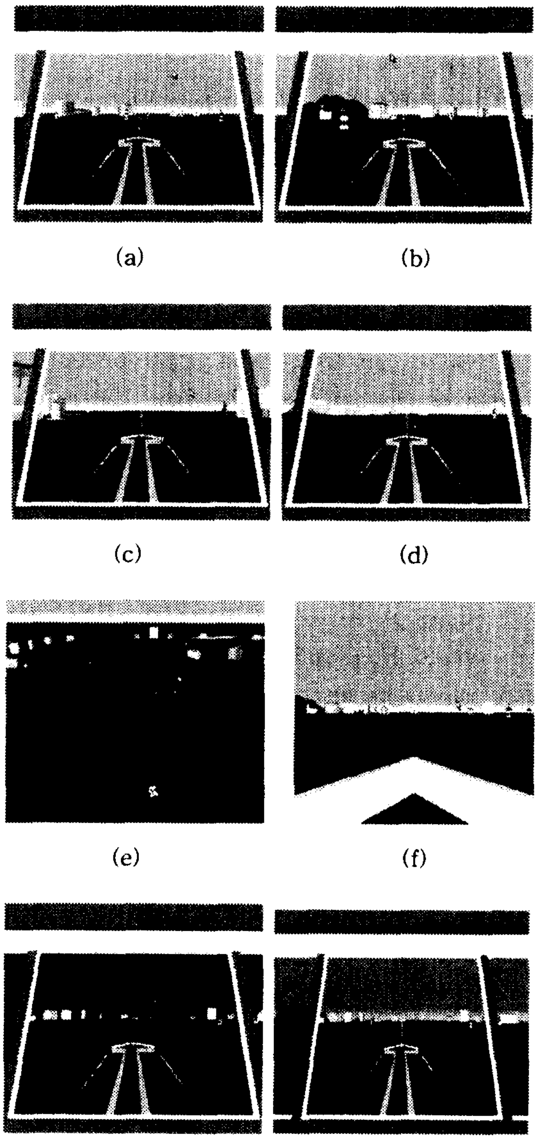
B. Simulations and Evaluations

Figure 11 represents snapshots taken in during simulation test varying with environmental factors. Figures from (a) to (c) are represents harbour perspective when ship going to a port. Figure (d) is a result of fog setting to 20miles. Figure (e) and (f) are scenes when changing viewpoints from whole world to ship's forecastle position, respectively. When set the time to night and sunrise are shows in (g) and (h), respectively. Figure 12 shows a photograph taken in during simulation training.

As results from tests, five subjects can acquire knowledge for about the marker roles in IALA-B system using AtoNSiS. The subjects commented that Aids to Navigation was appeared correctly and they can be merged well in the virtual waterway environments.

Ⅶ. Conclusion

Described implementation shows how to use VRML and Java cooperative system in practical application. We have shown the role of VRML and Java control applet for AtoN(Aids to Navigation) training purpose. As results from subject assessment for the developed AtoNSiS, it became apparent that the system gave attractive and interesting simulation experience. This led the results that an



(a) (b) (c) (d) (e) (f) (g) (h)

Figure 11. Snapshots taken in during simulation tests varying with environmental factors. Harbour entrance(a), in waterway(b), entering a port(c), fogging state(d), skyscape of the whole world(e), scene in a forecastle(f), scene of night time(g), scene of sunrise(h).

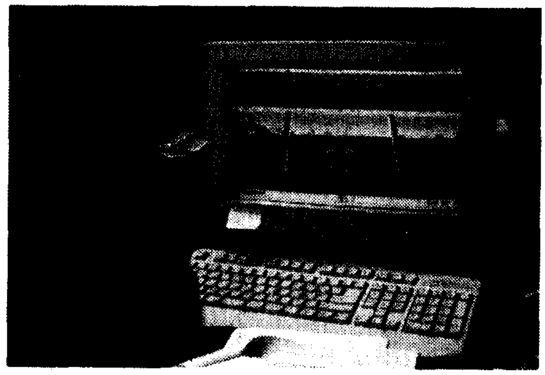


Figure 12. Photograph taken in during simulation tests.

ease of learning the rules of IALA-B and an ease of comprehension of AtoN characteristics by AtoNSiS.

We are going to further extent the system to implement full mission Virtual Reality Ship Simulator (VRSS) having ship handling functions at calm sea and in waves. The next version should allow a direct communication between instructor and recipients. In addition, interactive devices should combine with the virtual world to enhance more interactive environments.

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