論　文

Personal Computer Based Aids to Navigation Training Simulator Using Virtual Reality Modeling Language

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〈CONTENTS〉

Abstract

This paper describes recently developed PC based Aids to Navigation Training Simulator (AtoN-TS) using Virtual Reality Modeling language (VRML). The purpose of AtoN-TS is to train entry-level cadets to reduce the amount of sea-time training. The practical application procedure of VR technology to implement AtoN-TS is represented. The construction method of virtual waterway world, according to the guidelines of International Association of Lighthouse Authorities (IALA) is proposed. Design concepts and simulation experiments are also discussed. Results from trial tests and evaluations by subject assessment, provide practical insight on the importance of AtoN-TS.

1. INTRODUCTION

The main purpose of Aids to Navigation (AtoN) is to provide 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. It is reason of why the worldwide maritime education academies are needed to develop AtoN training simulator, in these days.

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 three-dimensional (3D) model ship, AtoN objects, and waves etc [1]~[11].

Fortunately, Virtual Reality (VR) technologies can give such a human-machine interaction using 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, 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 [12]~[15].

AtoN Training Simulator (AtoN-TS) is one of the ongoing applications of VR high technologies. The goal of this study is to develop a low-cost, readily available AtoN-TS for entry-level cadets to reduce the amount of sea-time training. The main object of AtoN-TS is to train lateral, cardinal, and other buoyage system conform to the International Association of Lighthouse Authorities (IALA) guidelines, located in IALA region A and B. AtoN-TS is mainly designed as web based training aids that provide computer-based training. AtoN-TS is organized into four modes: (1) Menu Mode, (2) Learning Mode, (3) Simulation Mode, and (4) Buoyage Characteristics Changer. The Menu Mode is to select training area and environmental factors using GUI (Graphical User Interface) window. The Learning Mode is to learn all of the IALA buoyage system with 3D maker models. Especially this mode has three sub functions: Buoyage System Learning, Charted Symbol Learning, and Scene Generator. The Simulation Mode is to acquire safety navigation skills in the virtual waterway world which having object-oriented 3D models such as a model ship with maneuvering function, model buoy markers with light characteristics, and geographical features etc. In the virtual waterway world, a trainee can exercise much as might experience in real-like navigation situation, and then acquire navigation skills in the virtual waterway. The buoy characteristics such as period, phase and color is can be change using the Buoyage Characteristics Changer as user demand.

The paper concludes with a summary of the study with recommendations for the future work and improvements.

2. DESIGN METHODOLOGY

2.1 SIMULATOR REQUIREMENTS

The commercial simulator, in general, should comply with relevant certificates issued by appropriate international or national authorities. AtoN-TS is also designed in compliance with the following international standards:

- International Regulations for Preventing Collisions at Sea, 1972
- International Convention on the Safety of Life at Sea, 1974
- International Convention on Seafarers' Training, Certification and Watch-keeping, 1978, with 1995 amendments
- IMO Resolution A.817 (19). Performance

standards for electronic chart display and information systems. Adopted on 23 November 1995
- IMO Model Course 6.09. Training Course for Instructors, 1997
- IMO Model Course 7.01. Master and Chief Mate, 1997
- IMO Model Course 7.03. Officer in Charge of Watch, 1997
- Bridge Team Management Course ware. Warsash Maritime Centre (UK), 1997
- Maritime Education and Training (A Practical Guide). Published by the Nautical Institute, London 1997
- Bridge Procedures Guide, International Chamber of Shipping, Third edition 1998
- Standard for Certification of Maritime Simulator Systems. DNV AS. RP-DTP-23 1999 Rev.1, 01 September 1999

2.2 DESIGN CONCEPTS

Basic concepts of training system

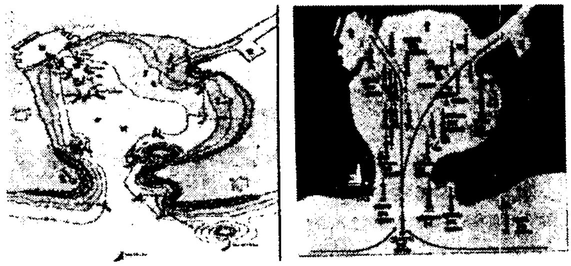
A VR training environment offers unique advantages such as scenario generation, real world replication, true interaction with 3D virtual objects, and improved skill acquisition from in-the-loop learning. Trainees can hone skills and learn rules of AtoN without risk, and they can learn until they reach training targets. As curriculum needs change, the simulated environment can be easily modified to meet new items. Because VR environment doesn't wear out and can be re-using without limits, training costs shrink. Thus, AtoN-TS is the impressive training system to put the trainees in the loop. While the conventional training aid of IALA buoyage system is only a conceptional nautical chart and a fictitious nautical chart as shown in Figure 1.

As mentioned in the Introduction, if trainee can touch, see and feel those of markers shown in the chart of Figure 1, then training effect should be steadily increasing. VR based simulator as AtoN-TS can accomplish those of interactive environments. The expected effects from the use of AtoN-TS are listed as followings.

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

Virtual world creation method

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.



〈Figure 1. Conventional training aids to train IALA buoyage system. A nautical chart (Left) and a fictitious nautical chart to explain the meaning of the nautical chart (Right).〉

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 conditions. VRML is a file format for describing interactive 3D objects and worlds, and is designed to be use on the Internet, Intranet, 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 are created using 3D Webmaster [16]. It is one of the authoring tools of VRML, and gives the ability to populate the user worlds with moving ship and animated objects that can be equipped with programmable behavior. In addition, 3D Webmaster has Viscape as VR browser running a virtual world.

2.3 VRML

A VRML file consists of the following major functional components: header, scene graph, prototypes, and event routing. The contents of this file are processed for presentation and interaction by a program known as a browser [17]~[21].

Header: for easy identification of VRML files, every VRML file shall begin with #VRML V2.0 <encoding type> [optional comment] <line terminator>. The header is a single line of UTF-8 text identifying the file as a VRML file and identifying the encoding type of the file.

Scene graph: it contains nodes, which describe objects and their properties. In addition, it contains hierarchically grouped geometry to provide an audio-visual representation of objects, as well as nodes that participate in the event generation and routing mechanism.

Prototypes: it allows the set of VRML node types to be extended by the user. Prototype definitions can be included in the file in which they are used or defined externally. Prototypes may be defined in terms of other VRML nodes or may be defined using a browser-specific extension mechanism.

Event routing: Some VRML nodes generate events in response to environmental changes or user interaction. Event routing gives authors a mechanism, separate from the scene graph hierarchy, through which these events can be propagated to effect changes in other nodes. Once generated, events are sent to their routed destinations in time order and processed by the receiving node. This processing can change the state of the node, generate additional events, or change the structure of the scene graph.

A VRML file generator is a human or computerized creator of VRML files. It is the responsibility of the generator to ensure the correctness of the VRML file.

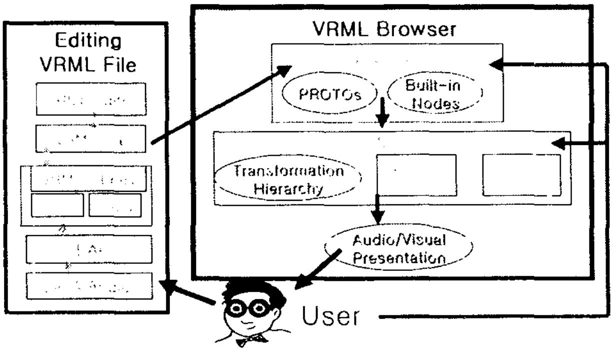
2.4 VIRTUAL WORLD CREATION

The interpretation, execution, and presentation of VRML files will typically be undertaken by a mechanism known as a browser, which displays the shapes and sounds in the scene graph. This presentation is known as a virtual world and is navigated in the browser by a human or mechanical entity, known as a user. The world is displayed as if experienced from a particular location; that position and orientation in the world is known as the viewer. The browser provides navigation paradigms (such as walking or flying) that enable the user to move the viewer through the virtual world.

In addition to navigation, the browser provides a mechanism allowing the user to interact with the world through sensor nodes in the scene graph hierarchy. Sensors respond to user interaction with geometric objects in the world, the movement of the user through the world, or the passage of time.

Figure 2 illustrates a conceptual model of a VRML browser. The browser is portrayed as a presentation application that accepts user input in the forms of file selection and user interface gestures. The three main components of the browser are: Parser, Scene Graph, and Audio/Visual Presentation.

The Parser component reads the VRML file and creates the Scene Graph. The Scene Graph component consists of the Transformation Hierarchy (the nodes) and the Route Graph. The Scene Graph also includes the Execution Engine that processes events, reads and edits the Route Graph, and makes changes to the Transform Hierarchy. User input generally affects sensors and navigation, and thus is wired to the Route Graph component (sensors) and the Audio/Visual Presentation component (navigation). The Audio/Visual Presentation component performs the graphics and audio rendering of the Transform Hierarchy that feeds back to the user.



〈Figure 2. Conceptual model of a VRML browser.〉

AtoN-TS program was mainly based on the VRML and Java cooperation. The Java is generating and operating through External Authoring Interface (EAI) with VRML world where visual data of AtoN-TS program are displayed. Since the limited possibility of EAI, we have decided to implement a special layer between EAI and Java as shown in Figure 2.

3. IMPLEMENTATION

3.1 AIDS TO NAVIGATION

IALA system

AtoN is special structures like lighthouses, lightships, beacons, buoys, etc that are used to enhance safety by providing more opportunities to obtain LOP's (Line Of Positions). The International Association of Lighthouse Authorities (IALA) prescribes these lights and markers across the world. In 1977, this IALA endorsed two maritime buoyage systems putting an end to the 30 odd systems existing at that time. Region A (IALA A) covers all of Europe and most of the rest of the world whereas region B (IALA B) covers only Korea, Japan, America, and Philippines.

Fortunately, the differences between these two systems are few. The most striking difference is the direction of buoyage. All markers within the IALA system are distinguished by: shapes, colors, topmark and lights. During daytime identification of AtoN is accomplished by observing: location, shape, color scheme, auxiliary features or markings. During the night, we use the features of the AtoN's light to both identify it and ascertain its purpose. There are three features to describe the light: color, period, and phase. Figure 3 show the international buoyage region A and B [22]~[24].

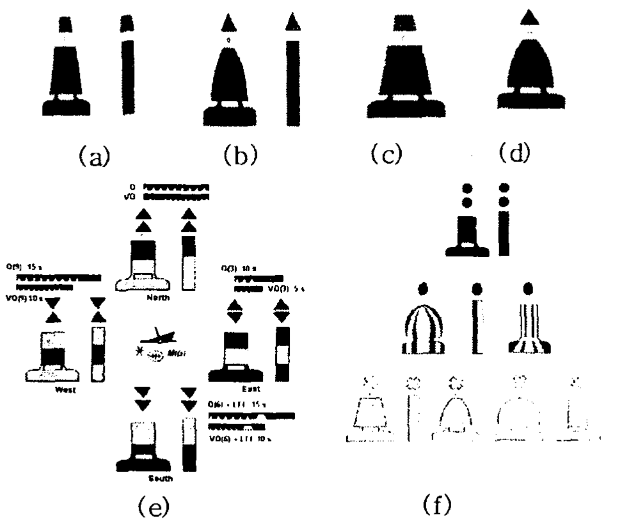
〈Figure 3. The international buoyage region A and B.〉

Five types of navigation buoys

Lateral and Preferred Buoys and Marks : The location of lateral buoys defines the borders of channels and indicates the direction. Under IALA A red buoys mark the port side of the channel when returning from sea, whereas under IALA B green buoys mark the port side of the channel when sailing towards land. Red buoys have even numeration plus red lights and green buoys have odd numeration plus green lights. Lateral Buoys and waterway markers are shown in Figure 4 (a) and (b). Generally when two channels are meet one will be designated the preferred channel (Figure 4 (C) and (d)).

Cardinal Buoys : The four cardinal buoys (Figure 4 (e)) indicate the safe side of a danger with an approximate bearing. For example, the West cardinal buoy has safe water on its west and the danger on its east side. The topmarks consist of two black triangles placed in accordance with the black/yellow scheme of the buoy. When a new obstacle needs to be marked, two cardinal buoys will be used to indicate this 'uncharted' danger. The cardinal system is identical in both the IALA A and IALA B buoyage systems.

Marks indicating Isolated Dangers and Safe Water : This type of buoy (Figure 4 (f)) indicates the position an isolated danger, contrary to cardinal buoys, which indicate a direction away from the danger. This safe water buoy is vertically striped. These marks are for example seaward of all other buoys (lateral and cardinal) and can be used to make landfall. Lights are usually calm and white.



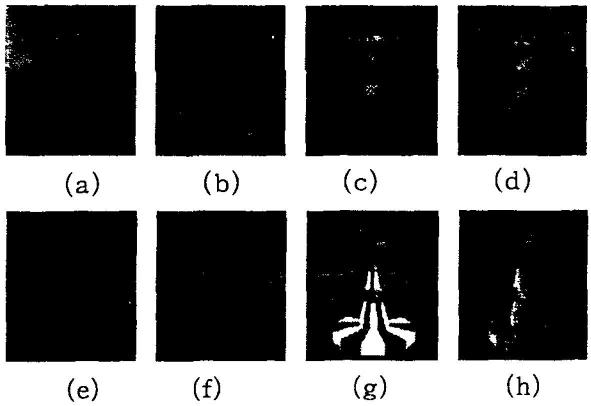
〈Figure 4. Five types markers and buoys. Port side lateral marker (a), Starboard side lateral marker (b), Preferred channel to starboard (c), Preferred channel to port (d). Cardinal markers: North, East, South, and West (e), Isolated danger marker, Safety water marker, and Special marker, from top to bottom (f).〉

Special Buoys and Marks : This type of buoy (Figure 4 (g)) has not an actual navigation purpose. Most of the time, these yellow buoys indicated areas uses by navy or pipelines or surfing.

3.2 SYSTEM DESIGN

3D Marker modeling

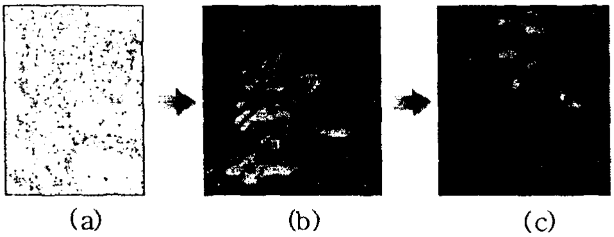
Five different types of IALA buoys and markers are modeled by VRML authoring tools as 3D Webmaster. In modeling process, light control programs are inserted into the lighted buoys to be display their characteristics. In addition, all of the 3D model objects are structured into object-oriented database and sharing in the virtual world each other. Figure 5 shows some samples of 3D buoy models, constructed in this study.



〈Figure 5. Samples of 3D lighted buoy models. Port hand lateral Marker (a), Starboard hand lateral marker (b), Preferred channel to port (c), Preferred channel to starboard (d), West cardinal marker (e), Isolated danger marker (f), Safe water marker (g), and Special marker (h).〉

Geographical shapes and ship modeling

Geographical shapes and coastal features are also important objects to create real-like scene in a real world. This modeling process have three steps (Figure 6): scan a real paper chart, then extract the frames of geographical features, and add texture and colors to the frame files using rendering function of VRML browser.



〈Figure 6. Procedures to create 3D geographical shapes. Scanning real paper chart (a), extracting the frame of geographical features (b), and adding texture and colors (c). 〉

In addition, real-like 3D model ship is also need to create navigational environments in a virtual waterway space. Bulk Carrier (45,000 DWT, LOA 183m, height 40m, breath 32m) was selected as a reference model ship. Figure 7 shows constructed 3D model ship and mock-up control console model. This 3D model ship has the maneuvering characteristics as shown in Table 1. The two SCL programs, to response the steering order and to response the engine order, are attached into the 3D model ship. Thus, user can drive the model ship as like a Ship Handling Simulator which is widely used in the maritime academy in the day.

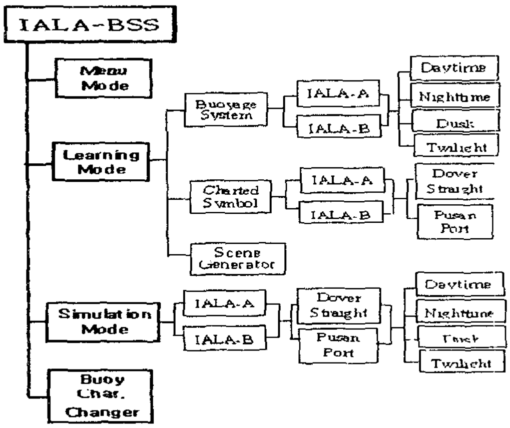
〈Figure 7. 3D model ship of Bulk carrier (Left), and 3D model mock-up control consol (Right). 〉

Table 1. Maneuvering characteristics of 3D Ship

Class	Order	Action
Steering	Port	Turn to port with 0.05/order
	Starboard	Turn to Starboard with 0.05/order
Engine	Stop	Ground speed 0 knot/hour
	Dead Slow Ahead	Ground speed 4 knots/hour
	Slow Ahead	Ground speed 8 knots/hour
	Half Ahead	Ground speed 10 knots/hour
	Full Ahead	Ground speed 13 knots/hour

3.3 MENU MODE

Applet GUI(Graphical User Interface) consists of two menu: Learning Mode and Simulation Mode. Learning Mode consists of three sub functions: Buoyage System Learning, Charted Symbol Learning, and Scene Generator. After starting this mode, other mode selection window is appeared in a window. Virtual world environments (daytime, nighttime, dusk, and twilight) and simulation areas (Strait of Dover or Port of Pusan) are also selectable in this Menu Mode. The structure of menu selection is shown in Figure 8. Thus, a user can test and simulate several kinds of mode and navigation environments by change the time, weather condition, IALA region, and exercise area etc.

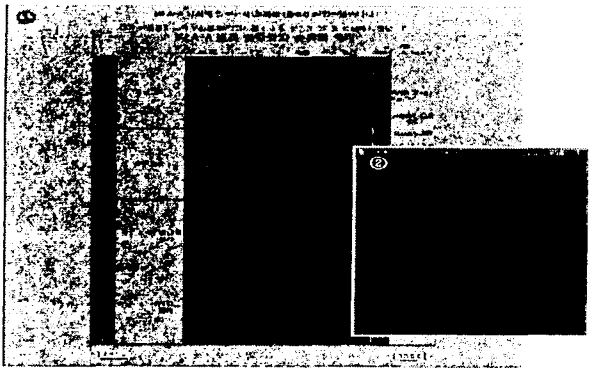


〈Figure 8. Structure of menu selection mode. 〉

3.4 LEARNING MODE

Buoyage System Learning

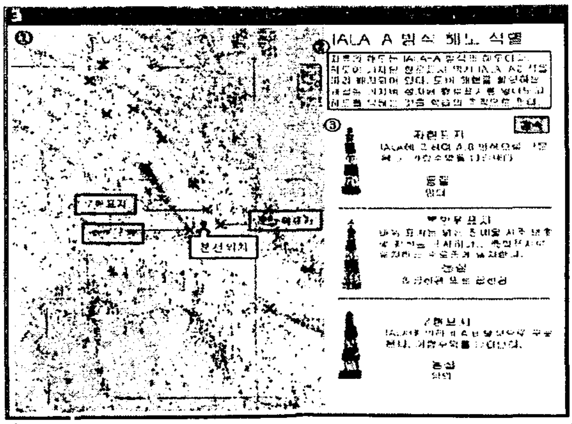
Buoyage System Learning is to descript detailed characteristics of makers and buoys with phase, period, and color. When starting the learning mode, different types of buoys are appeared in the area ① of Figure 9. When clicking or pointing one of the marker the detailed characteristics and shapes are appeared in the small box type window as shown in ② of Figure 9. Therefore, user can recognize more detailed marker characteristics such as shapes, colors, and rhythm of lights etc.



〈Figure 9. Results of executing the mode of Buoyage System Learning 〉

Charted Symbol Learning

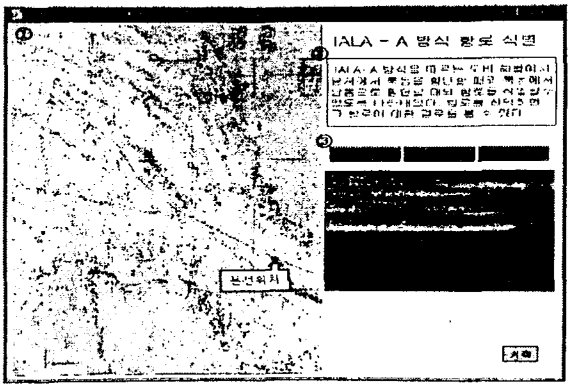
When starting Charted Symbol Learning, exercise areas are appeared in the window with related chart and buoyage symbols as shown in Figure 10. The window is divided into three areas: chart display area, explanation area, and charted symbol display area, as shown in ①, ②, and ③, respectively. The explanation area is to display the purpose of this mode. When executing this mode, the mark move along with safety passage automatically, and then display related symbols with their means and characteristics. After finishing in this mode, the user can select next mode by click the 'Continuous' button.



〈Figure 10. Operating result of executing the mode of Charted Symbol Learning 〉

Scene Generator

To give more understandable cues for about buoyage system and safety navigation skills, Scene Generator (Figure 11) are provided. This mode divided into four areas: chart area, explanation area, passage selection area, and animation area as shown in ①, ②, ③, and ④, respectively. The purpose of this mode is presented in the explanation area ②. Several types of port or passages are selectable in the passage selection area ③. When executing this mode, the mark move along with safety passage automatically, and then display pre- structured animation scenes which can be seen in the mark position as in ④.



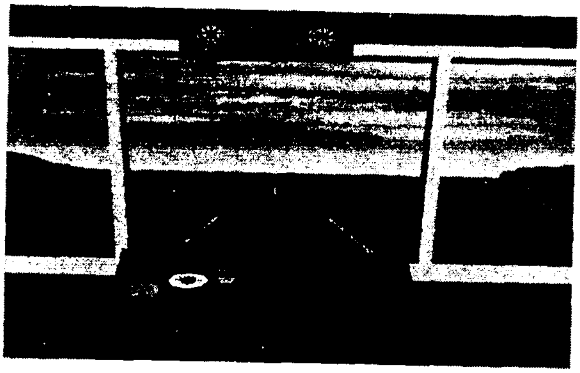
〈Figure 11. Operating result of executing the mode of Scene Generator 〉

3.5 SIMULATION MODE

Using the Simulation Mode (Figure 12) the user can drive the 3D model ship with virtual controllers. This mode divided into four areas: fixed view point selection area, simulation area, ship control area, and view point moving area, as shown in ①, ②, ③, and ④, respectively. View points look at the forecastle, bridge, left wing bridge, right wing bridge, and compass deck are can be change using rectangular buttons as in ①. While all around scenes can be obtainable using the various moving bars shown in ④.

To view the virtual waterway more dramatically, initial scenes are displayed as seen in the bridge. When give an engine control order

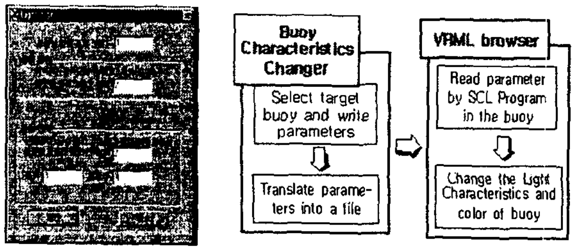
(Stop Engine, Dead Slow Ahead, Slow Ahead, Half Ahead, and Full Ahead) the model ship move toward direction with a speed shown in the Tabe 1. This engine control order is given by the control icons shown in ③. Course change of the model ship is given with rudder control icon (right and left arrows) shown in ③. If user clicks the right arrow icon, then the model ship turn to starboard with 0.05 degree/one click. If click the left arrow icon, then the model ship turn to port with 0.05 degree/one click. With these controllers, the user can make maneuvering of the 3D model ship.



〈Figure 12. Operating result of executing Simulation Mode 〉

3.6 BUOY CHARACTERISTICS CHANGER

IALA Buoyage system has many different characteristics according to their purpose. As like the small correction in a paper chart, the 3D model buoys are also need to change their light characteristics and colors. Using the Buoy Characteristics Changer, user select target buoy and write color, light period and duration into the GUI window table (Figure 13). These parameters are translated into a file and sent to the VRML browser, then the SCL program of related 3D buoy read the parameters and create characteristics change event.



〈Figure 13. The GUI window table (Left) and the change procedures (Right) 〉

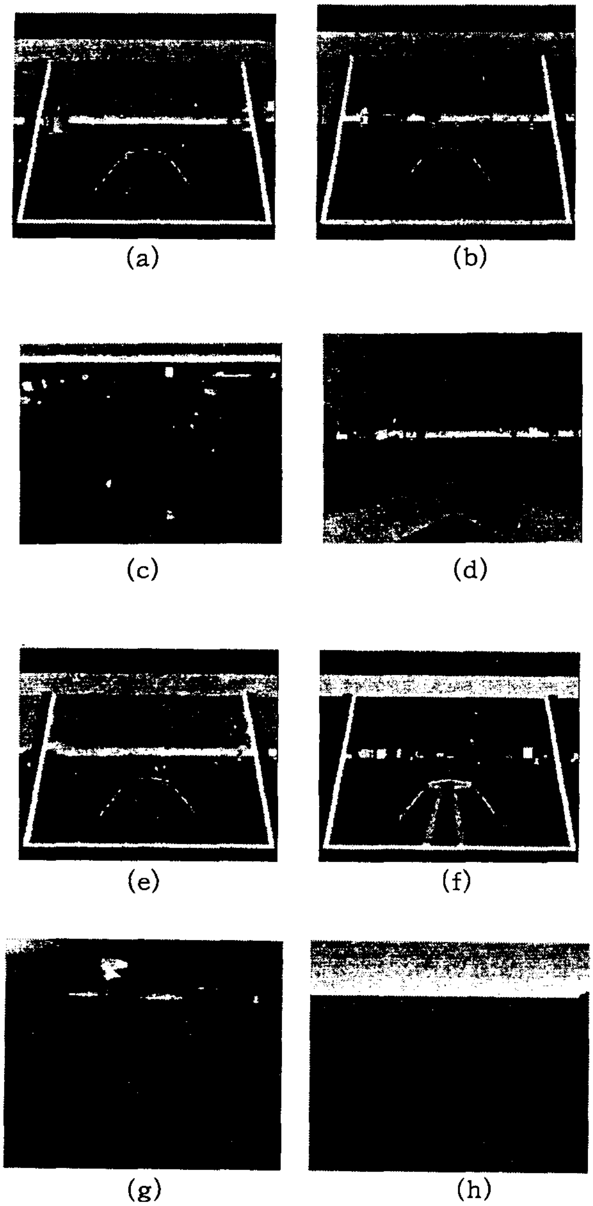
4. EXPERIMENTS AND EVALUATIONS

4.1 EVALUATION ENVIRONMENTS

The primary purpose of this assessment was to evaluate training effectiveness and interactive effects. Five university juniors, four men and one woman, are participated in the test. Their have no experience year of onboard. 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 AtoN-TS 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.

4.2. SIMULATIONS AND EVALUATIONS

Figure 14 represents snapshots taken in during simulation tests varying with environmental factors. Figure (a) and (b) shows harbor perspectives to test a scene assessment. Figure (c) and (d) represents the change effect of viewpoint. Figure (e) and (f) is to test environmental effects such as set fog, nighttime, and sunrise. In addition, Figure (g) and (h) is to assess the degree of natural features of 3D models putting in a virtual waterway.



<Figure 14. Test scenes. Harbor entrance (a), port entrance (b), change viewpoint to zenith (c), change viewpoint to forecastle (d), set fog (e), nighttime (f), Port of Busan (g), and Strait of Dover (h) >

As results from tests with five subjects, they can obtain the marker roles in IALA buoyage system with easy of learning comparing with the case of text book learning. Within 2 hours, all of the subjects are successfully accomplished the course of study on the IALA A and B buoyage systems, whereas it takes more than 6 hours to complete this course in a normal case. In addition, subjects commented that IALA model buoys and markers are appeared correctly and they can be merged well in the virtual waterway environments which having interaction effects with 3D objects. The other tests such as system stability, multi user participation, and stereoscopic view creation are under testing.

5. CONCLUSIONS

Described implementation shows how to use VRML and Java cooperative system to the practical application of Aids to Navigation Training Simulator (AtoN-TS). As results from subject assessment for the developed AtoN-TS, it became apparent that the system gave attractive and interesting simulation experience. This led the results that an ease of learning the rules of IALA buoyage system and an ease of comprehension the characteristics of buoy and marker.

We are going to further extent the system to implement full mission Virtual Reality Ship Simulator (VRSS) having the mathematical maneuvering model of a real ship 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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