Visual-Aid Teaching Materials in Linkage with Ship-Handling Simulator Educational Application of Ship-Handling Simulator

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ABSTRACT

The fundamental knowledge and understanding about ship handling are indispensable for students of navigation course. Especially in steering, different movement such as kick, turn, heel, will arise simultaneously for a short time in a transition stage until it goes into steady turning motion immediately after taking rudder. In order to realize more effective education about steering, we developed a simulation system as an educational teaching material, which enables display of many phenomena in accordance with turning motion. In this integrated steering simulation system (ISSS), output data obtained from a ship-handling simulator were processed and displayed on the animation, which is easy to understand visually. Five sub-windows are displayed on the main screen of the ISSS: hull movement and vector; locus of hull; position of pivoting point; heeling; time series data such as ship's speed, turn rate, heel angle, drift angle and transition of pivoting point. Concerning with the educational effect of this steering simulation system, the experiment was conducted and the effectiveness was verified by the test and the questionnaire. It can be said that the group, which received the lecture using the ISSS was able to understand the simultaneity more correctly about the phenomenon simultaneously generated in the initial stage of turning motion comparing with the group, which received the lecture in classroom without using this simulation system.

1. Introduction

A ship-handling simulator has been used as a tool to simulate real ships for training purposes, but it is now expected that ship-handling simulators will be used as a teaching material to support lectures in classroom at maritime education and training institutions.

In a subject involving ship-handling theory, not only ship-handling skills but also a theoretical understanding of ship motions is indispensable. Experience gained through the use of a ship-handling simulator enables students to empirically understand ship motions. However, it is difficult to help students understand the dynamic mechanism behind the generation of ship motions.

To use a ship-handling simulator not only for training but also for education, it needs to be improved so that calculation outputs from the ship-handling simulator are processed into the visually understandable dynamics information shown additionally.

It is considered to be instrumental for providing students with deep and solid understanding of the theory of ship motions to combine experience gained through the use of a ship-handling simulator and visual-aid information that can display the dynamic mechanism of ship motions in a visually understandable form. We already developed the Integrated Anchoring Simulation System (IASS) for a visual-aid teaching material when ship is anchoring (Inoue K., Usui H. and Ma R. 2002).

During steering operations, in particular, a variety of phenomena occur simultaneously in a brief time, including: drift, turning, speed reduction, displacement of pivoting point, kick, drift angle, heeling, etc. Lectures in classroom using a blackboard can only explain these individual phenomena, one by one, occurring simultaneously after the rudder is taken, separately, so it is not easy to have students correctly understand that these phenomena are occurring simultaneously.

From these points of view, the authors have developed an Integrated Steering Simulation System (ISSS) that is capable of processing a variety of dynamic data outputted from a ship-handling simulator into a visually understandable form of animation, displaying the processed information on a 50-inch display screen.

To validate the usefulness of this system for promoting students' achievements, an experimental study was conducted with the subjects of students in Kobe University of Mercantile Marine.

2. Function of the ISSS

2.1 System Configuration

Work Station O2 manufactured by Silicon Graphics was used for developing ISSS. C language was used for developing programs. Motif was used as a user interface library. OpenGL was used as the graphic library for displaying graphics. The ship-handling simulator of Kobe University of Mercantile Marine was also used as a simulator to be linked to the ISSS.

Fig. 1 shows the system configuration of the ISSS. This system is composed of the Management Section that receives data covering moment-to-moment ship's positions, course and speed, and transmits data received to each display, and the Displays Section displays an animation after processing of received data into graphic information.
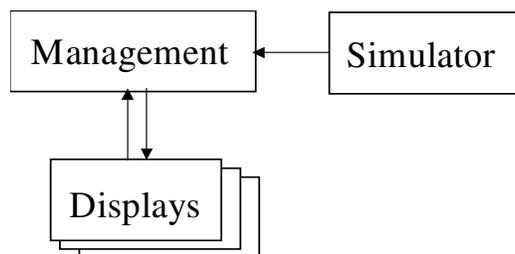
Figure 1: System configuration of the ISSS

2.2 Composition of Displayed Screen

Fig. 2 is a photo showing the 50-inch display unit of the ISSS, which is installed on the port side of the bridge mockup of the ship-handling simulator.

Figure 2: 50-inch display unit of the ISSS installed in bridge mockup

Fig. 3 shows a screen displayed on the 50-inch display unit of the ISSS, which is linked with the ship-handling simulator.
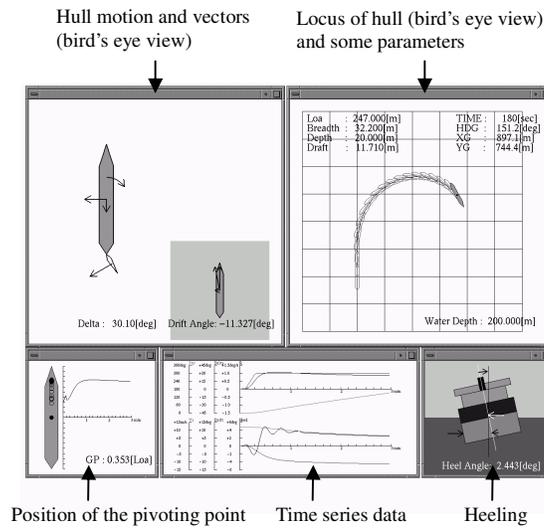
Figure 3: The 50-inch display unit of the ISSS

At each sub-window of the screen, normal pressure acting on the rudder, force and moment acting on the centre of gravity of the hull, ship position and posture, ship's speed (speed component in the longitudinal direction: u, speed component in the transverse direction: v, composite velocity vector: Vs), turning angular velocity, drift angle, changes in position of pivoting point and heeling angle, etc. are displayed as both numerical information and animation.

Viewing the screens of this newly developed system, students can learn correctly and effectively a variety of phenomena generated simultaneously in a brief time in association with steering attempts, while experiencing steering operations with the ship-handling simulator.

The contents of the individual sub-windows displayed on the screens of this ISSS are as follows:
(1) Ship Motions and Vectors (see Fig. 4)

Delta : 30.10[deg]   Drift Angle: −11.327[deg]
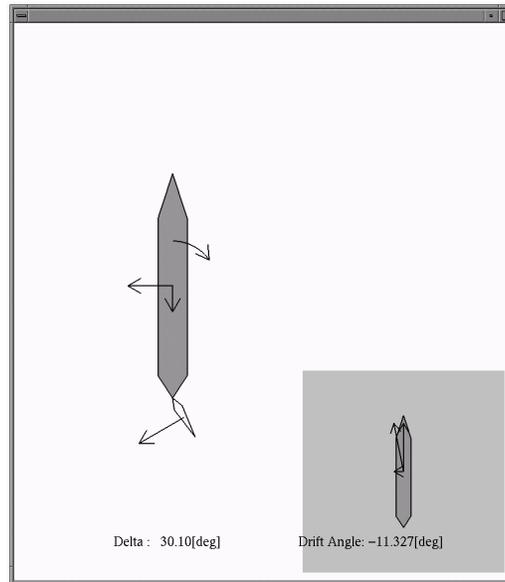
Figure 4: Ship motions and vectors

This screen displays a bird's eye view of the motions of the rudder and the hull. In addition, the normal force acting on the rudder and the longitudinal and the transverse component of the force acting on the centre of gravity of the hull in association with steering attempts and turning moments are shown with arrows. For ship's speed, the longitudinal velocity component (u), the transverse velocity component (v) and the composite velocity vector (Vs) are shown with arrows at the right-hand corner of the same screen.

The lengths of arrows of these forces, moments and velocities change according to their magnitudes. As a consequence, ship motions and dynamic forces acting on the hull can be seen with continuous animation graphs. Viewing these screens, drifts of the ship due to steering operation, turning motion, speed reduction, and generation of kick and drift angle at their initial stage can be studied.

(2) Tracks of Ship's Motions (see Fig. 5)

This screen displays tracks of the ship's motion. Together with the current position and posture of the ship, past ship's posture and tracks of the centre of gravity of the hull are displayed at specific time intervals. In addition, numerical information on the conditions set for simulation such as length, breadth, depth, draft of the ship and depth of water, time elapsed, position of the centre of gravity of the hull and heading direction is displayed.
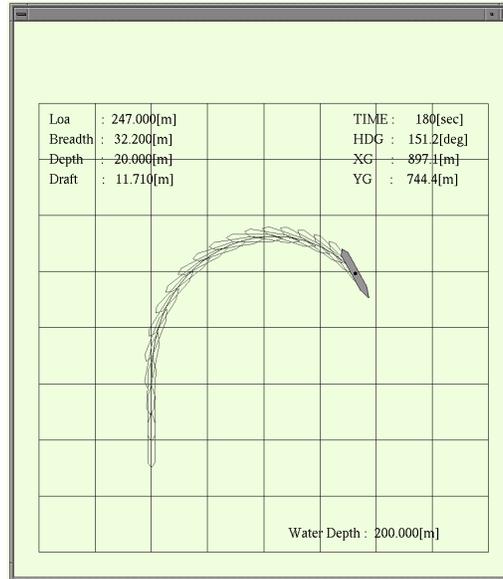
Figure 5: Tracks of ship's motions

Viewing sub-window (1) and sub-window (2) at the same time, it is possible to understand what force and moment would act on the hull when the ship assumes a certain position in the intended turning motion. Furthermore, concepts such as final diameter, maximum advance, maximum transfer, final turning radius and reach after a steady state of turning motion can be studied. Besides, the effects of differences in conditions such as ship size, rudder angle, draft, and depth of water, the magnitude of stern kick and the water area that the ship occupies can also be studied.

(3) Position of Pivoting Point (see Fig. 6)
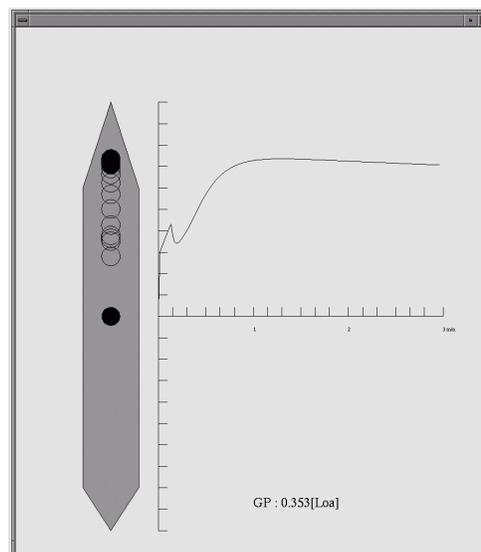
Figure 6: Position of pivoting point

The current positions of the centre f gravity of the hull and the pivoting point are displayed. And, the tracks of the moving pivoting point with time are also displayed. This allows students to learn how the position of the pivoting point moves in association with the developing turning angular velocity after the rudder is taken.

(4) Time History Data (see Fig. 7)
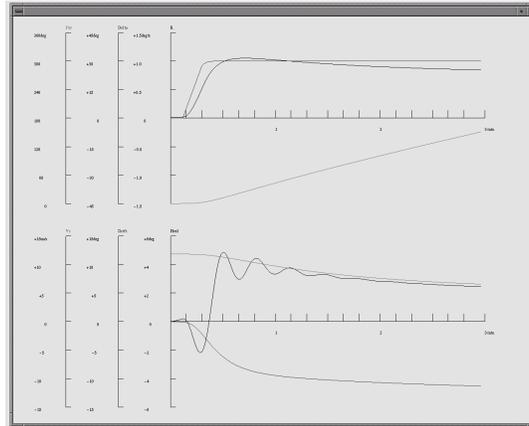
Figure 7: Time history data

The changes of heading direction (φ), rudder angle (δ), turning angular velocity (r), ship's speed (Vs), drift angle (β), and heeling angle (θ) are time-historically displayed. With these displays, the students can learn the relationships among various factors involved in the ship motions during turning operations. For instance, relationships among changing phenomena such as developing turning angular velocities in association with the changing heading direction, generation of drift angles and decreasing ship's speed due to increasing turning angular velocities can be studied.

Furthermore, by simultaneously viewing sub-window (4) and sub-window (1) or sub-window (2), relationships among various factors of ship motions throughout all phases of turning motion from the transient initial state to the steady state can be studied.

(5) Heeling of the Hull (see Fig. 8)

Vectors of rudder forces, the lateral components of the water pressure and centrifugal forces are shown with arrows, and at the same time, the states of heeling of the hull are displayed with an animation. The students study the changing heeling motions of the hull from the transient initial state of turning motions to the steady state thereof.

By simultaneously viewing sub-window (5) and sub-window (4), the students can study the relationship between the changing heading direction and the changing heeling angles of the hull in association with the developing turning angular velocities. On animated displays, heeling angles are multiplied by a factor of five for emphasized presentations, so that changes in heeling angles of the hull can be readily sensed. Actual heeling angles of the hull are displayed numerically.
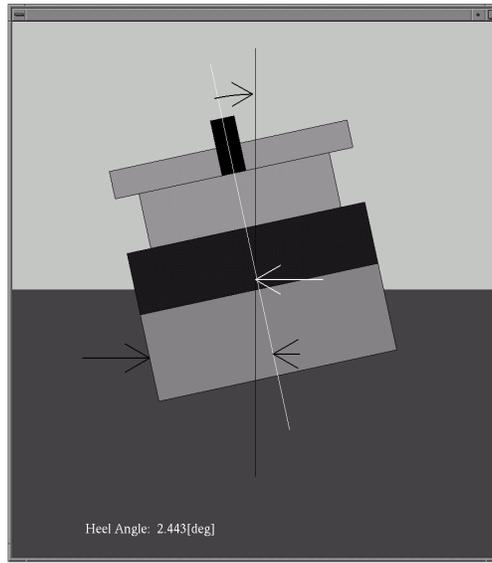
Figure 8: Heeling of the hull

2.3 Learning of Steering Operation Using the ISSS

It has become possible for students to correctly and efficiently view on the display of the newly developed ISSS such post-steering phenomena as drift, turning, speed reduction, displacement of pivoting point, kick, drift angle, and heeling as they occur simultaneously in a brief time, while experiencing steering operations with the ship-handling simulator. Here, explanatory notes are given on practical learning with the simulation using the ISSS under the procedural sequence of events.

(1) Steering simulation with a ship-handling simulator
Prepare a scenario simulating the scenery of sheet of graph paper as shown in Fig. 9. This attempts to allow a student to visually judge the motions of the own ship and the size of the occupied water area during steering operation on the basis of changes of scenery projected on the horizontal screen of the ship-handling simulator. Under the initial conditions of ship size, draft, depth of water, speed and rudder angle, the own ship proceeds straight on, and takes the specified rudder angle when the ship comes to the origin of the coordinate axes.

Figure 9: Scenery of sheet of graph paper

(2) Experiencing steering operation
Experience the real feeling of the ship's motions from the changing scenery projected on the horizontal screen of the ship-handling simulator. At this moment, the students physically experience slow–moving ship motions and the size of occupied water area that is necessary for making a turn.

(3) Learning with the ISSS
The students learn a variety of post-steering phenomena of motions and their dynamic mechanism that are generated in a brief time after the rudder is taken such as drift, turning, speed reduction, displacement of pivoting point, kick, drift angle, heeling, by viewing numerical information and animated graphic information displayed on the screen of the ISSS.

(4) Real-time lessons and replayed lessons
The ISSS features the capability of offering students to acquire ship-handling experience and an opportunity to study the dynamic mechanism of steering operation through linkage with the ship-handling simulator. Accordingly, the students can replay lessons under a variety of preset conditions with the ship-handling simulator. On the other hand, if the results of a simulation are stored in a data file, replayed lessons are available if the ISSS is used alone with slow or fast reproduction.

3. Education Effects of the ISSS

3.1 Experimental Study

It is not easy for students to learn and understand the relationship among a variety of post-steering phenomena of motions and their dynamic mechanism in a systematic way that are generated in a brief time after the rudder is taken until a steady state of turning motion is reached

When a lecture on ship-handling theory including steering operation is given in a classroom, explanations refer to figures and sketches drawn on a blackboard. However, it is not easy to have students understand the dynamic mechanism of such ship motions as turning motions using fragmented and static figures drawn on a blackboard.

To provide solutions for these difficulties, this system aims at providing experience-oriented education and training by combining a steering operation using a ship-handling simulator and a visual-aid teaching material that is capable of displaying the dynamic mechanism of ship motions in a visually understandable form.

It is anticipated that the levels of the students' understanding of the dynamic mechanism concerning why and how a ship turns would be enhanced and the students' understanding of the ship motions during making a turn would be deepened.

Under these circumstances, an attempt to verify the educational effects of this system was made to assess how this system helps improve the students' understanding of steering operation, using 24 subjects chosen from among students of the first year, second year, third year and fourth year of Kobe University of Mercantile Marine.

Note, however, that the students of the third year and the fourth year have completed the subject of ship-handling theory including steering operation. The students of the first year and the second year have not received the subject of ship-handling theory including steering operation, but they have steering experience onboard a training ship.

In the experimental study, the subjects were divided into two groups. One is Group A, representing those who receive ordinary classroom lecture using a blackboard, and the other is Group B, representing those who receive lecture using the ISSS. The composition of each group is given in Table 1.

Table 1: Groups detail

Group	Juniors & Seniors	Sophomores & Freshmen	Total
	Had learned steering before	*Had not learned steering before*	
Group A	5 persons	7 persons	12 persons
Group B	5 persons	7 persons	12 persons

Paper tests were carried out in which examinees were requested to choose phenomena that simultaneously occur at the initial stage of turning motions of a ship from multiple alternatives. The results of the paper tests are given in Table 2.

Table 2: Right answer rate of each group

Group	Right answer rate		Total
	Had learned steering before	*Had not learned steering before*	
Group A	80.0 %	14.3 %	41.7 %
Group B	100.0 %	85.7 %	91.7 %

As can be seen from Table 2, there were no distinct differences in the achievements of the students of the third year and the fourth year, and between those students who had lecture merely with a blackboard and those students who had lecture using the ISSS.

However, the students of the first year and second year showed different results; i.e., the members of the group that received lecture using the ISSS could understand more accurately than the members of the group that had lecture merely with a blackboard.

It may be deduced from the above discussion that the educational effects of the ISSS are particularly significant for beginning students of the first year and the second year.

3.2 Students' Comments on the ISSS

Comments on the ISSS were solicited in the form of free descriptions from those students who received lecture using the ISSS. Shown below are the comments received from the students.

(1) Points considered to be good:
- It was readily understood what would occur simultaneously while a ship is engaged in turning motions.
- The changing conditions of heeling motions of a ship were readily understood.
- The relationship between the forces acting on the hull and the heeling motion could be understood well.
- The conditions of the entire process of turning motions of a ship were readily understood.
- Using the temporary stopping function of the simulator, simulation can be stopped to better confirm ship motions.
- Forces created in a ship can be understood time-historically.

(2) Problems or points to be improved
- The numerals and symbols on screens are too small and could not readily be read off.
- It would be much better if three-dimensional presentations were available.
- It would be better if the ISSS lecture were given together with a blackboard lecture.
- It would be better if the ISSS could be handled by the student without assistance.

On the basis of the above discussions, all of the students who used the ISSS gave positive support for lecture using the system, although there is room for improvements in the method of conducting lecture and the contents of display, so it may be concluded that the usefulness of the ISSS as a visual-aid teaching material has been verified.

4. Concluding Remarks

The general practice in traditional lectures using blackboards and textbooks on dynamic phenomena such as generation of kick, displacement of pivoting point, generation of drift angle, which are simultaneously occurring immediately after the rudder is taken was to explain them one by one in a sequential manner. However, it is extremely difficult for students, particularly those with little experience on board, to come to grips with these phenomena as simultaneously occurring events.

The Integrated Steering Simulation System (ISSS) has been developed to provide solutions just for these problems. By providing a lecture utilizing this system linked to the ship-handling simulator, it has become possible to enable students to learn more easily and empirically understand the fundamental phenomena for steering operation.

The educational advantages using this system are as follows:
(1) Conventionally, a ship-handling simulator has been used mainly as a training tool. Experience with a ship-handling simulator alone is not sufficient for effective education and training of students. More effective education and training can be realized if the Integrated Steering Simulation System (ISSS) linked with a ship-handling simulator is utilized as an empirical visual aid teaching material.

(2) By displaying animated graphic information on the multiple displays, the students can visually understand the dynamic phenomena occurring simultaneously at steering operations of a ship. By displaying the forces and moments acting on the hull with elastic arrow marks, in particular, the students can easily understand the mechanism of ship motions during steering operations.

The authors have, in addition to the Integrated Steering Simulation System (ISSS), developed an Integrated Anchoring Simulation System (IASS) dealing with the swinging motions of a ship at anchor through computer simulation techniques [1], and its educational effects have been verified.

The idea of developing such simulation techniques and innovative visual-aid teaching materials in linkage with ship-handling simulators is expected to contribute greatly to broadening the application areas of ship-handling simulators in the future.

REFERENCES

1- Inoue K., Usui H. and Ma R. (2002): Development of an Integrated Simulation System for Analyzing the Swinging Movement of a Ship at Anchor and Its Application for Educational Use, *Proceedings of 3rd General Assembly of the International Association of Maritime Universities*, 9.1-9.9, Main, USA