Development of an Integrated Simulation System for Analyzing the Swinging Movements of a Ship at Anchor and its Application for Educational Use

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Abstract

As we know, due to wind action, a ship at anchor sways periodically, and this characteristic movement can be called a swinging pendulum movement._It is very difficult to understand and to explain such a complicated phenomenon. To help understand this difficult phenomenon, the authors developed the integrated simulation system (ISS) for educational use.

ISS uses various outputs which, when produced from a mathematical model simulating a ship at anchor, create an animation. This simulation system is a visual educational system, which not only has the function of simulating a ship at anchor, but°also displays changing forces in real-time. The system can also estimate the danger of dragging anchor and show how the anchor-dragging mechanism works.

To verify the educational effect of ISS, an experiment was performed, with impressive results. Students felt that a lecture supported by ISS was easy to understand and believe that it is necessary. The improved educational effect when studying the swinging movement of a ship at anchor was confirmed using animations produced by ISS. As a visual study resource, ISS and its animation provide a better understanding than a typical lesson in a classroom because of its simplicity.

We believe that ISS cannot only be used for educational purposes, but also as an assessment system for experiments that evaluate the safety of a ship at anchor. Such a system may be useful to researchers in other field. This paper only discusses ISS s educational use and now efforts are being made to increase its usefulness.

1.Introduction

As we know, due to wind action, a ship at anchor sways to the right and the left periodically like a pendulum. This movement is characteristic of anchoring ships and can be called a swinging pendulum movement.

This movement occurs with regularity of the drifting motion in the horizontal direction along with a combination of rapid yawing motions at both sides of the swinging pendulum movement. The hull sways like a pendulum from right to left and from left to right, just like a figure-of-eight (8). Moreover, in the process of this movement, impact force acts on the anchor at both sides of the orbit. Such swinging pendulum movement and impact forces acting on the anchor are produced by the combination of external force of the wind, hydrodynamic force that acts on the hull and restoring force of the anchor cable.

It is, therefore, very difficult to understand and to explain such a complicated phenomenon of ships at anchor, especially to our students who only receive explanations in lectures with some illustrations.

However, to assure the safety of ships at anchor, knowledge about the relations of these forces, understanding of the dynamic mechanism of the swinging movement and the relationship between hull posture in a swinging movement and changes of force acting on the anchor are very important to students who will become seafarers in the near future.

To help them to understand such a difficult phenomenon, the authors developed the integrated simulation system (ISS) for educational use.

ISS uses the various outputs which, when produced by a mathematical model simulating a ship at anchor, shows the animation displays. This, in turn, makes it easier to understand the complexities involved when a ship has to anchor and can also analyze many phenomena in accordance with the anchoring.

This simulation system is a visual educational system, which not only has the function of simulating a ship at anchor, but°also displays graphically swinging pendulum movement in animation to help students learn how a ship at anchor swings and understand the relationship between changes of anchor chain tension and hull postures. The system can also estimate the danger of a dragging anchor and show how the anchor s dragging mechanism works. So, it can also assess the potential danger of a dragging anchor and can analyze the mechanism of a dragging anchor.

2.Development of an Integrated Simulation System for Anchoring Ships

2.1 Introduction of the System

This integrated simulation system was developed by means of O2 workstation manufactured by Silicon Graphics, Co. Ltd. Its development language is Computer Language C. The user interface is Motif and the graphic library for displaying images is OpenGL. The composition of this system is shown in Figure 1.

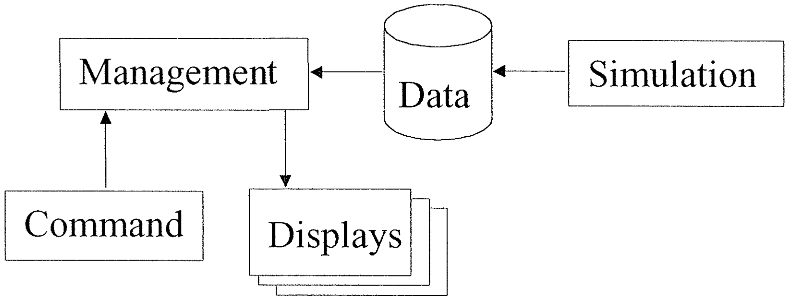

Fig.1 Composition of the system

This system consists of five sections such as simulation, command, management, data and displays section. The simulation section calculates ship motion by a mathematical model simulating a ship at anchor. The command section receives and transfers user s operational commands to the management section. The management section reads the data that are transferred from the simulation section, and relays them to the display section. The management section also computes all the correlative data for displaying and transmits the computed results to the display section to be shown on the display window.

Signal showing the end of drawing process returns back to the management section to let it transmit the new data for the next drawing process.

2.2 Function of the System

This system has three different modes for displaying. Figure 2 shows an example of education mode. This display mode is designed for educational use. It gives us informations for understanding of dynamic mechanism of the swinging movement of a ship at anchor.

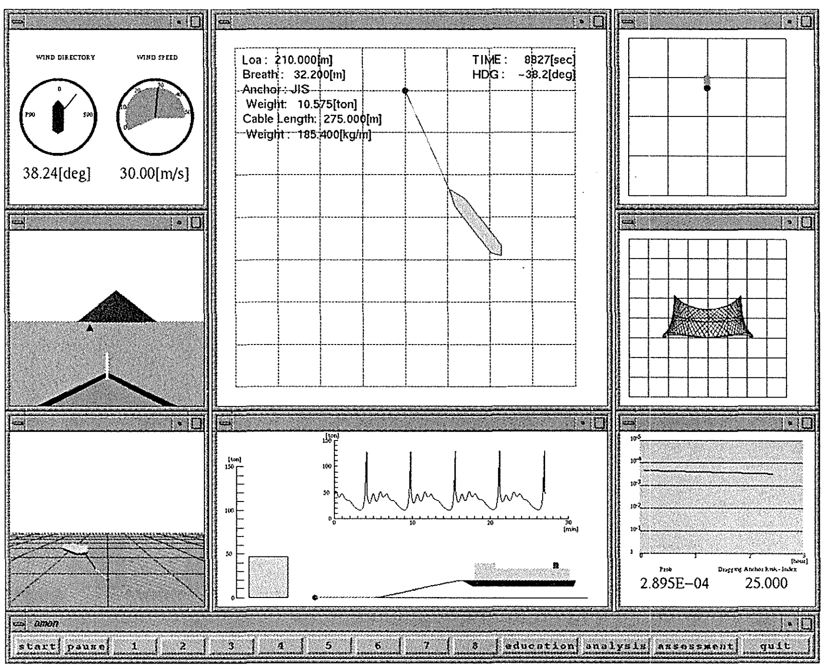

Fig.2_An example of a display for education mode

Figure 3 shows an example of analysis mode. This display mode is designed for movement-analysis of a ship at anchor. It gives us informations of phenomenon that forces and moments acting on a hull and anchor chain influence to the swinging movement of a ship at anchor.

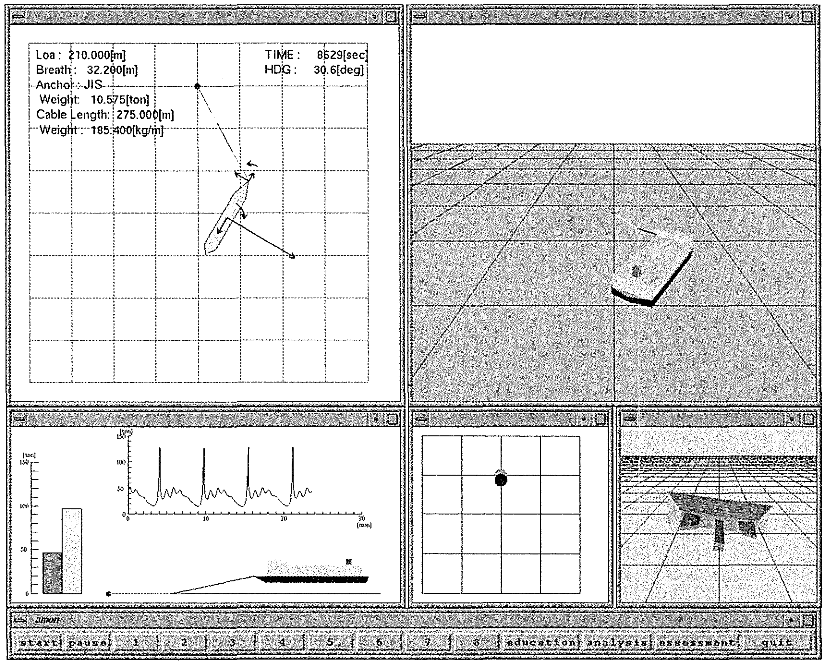

Fig.3_An example of a display for analysis mode

Figure 4 shows an example of assessment mode. This display mode is designed for safety assessment. It gives us informations of the mechanism of dragging-anchor due to the swinging movement of a ship at anchor.

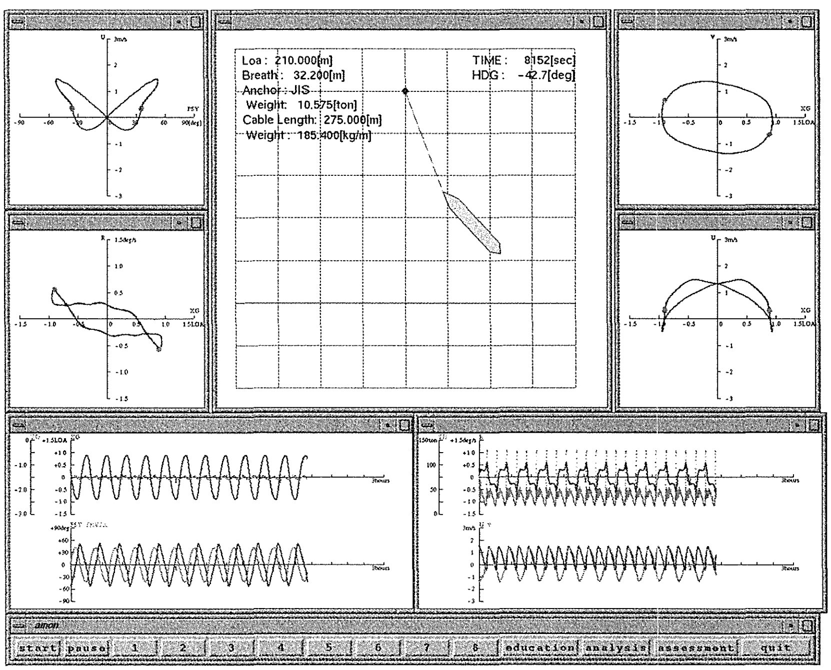

Fig.4_An example of a display for assessment mode

2.3 Function of Education Mode

The operation buttons on the user interface are arranged at the bottom of the screen. A user pushes a button to start, suspend and close a screen or choose one of the screens at his or her will. The display window can be changed to educational, movement-analysis or safety-evaluation-aimed ones. Educational window is fixed as a starting one. The display contents are as follows:

(1) Swinging movement display (of two dimensions) of a ship at anchor (bird's-eye view);
(2) Wind direction and wind velocity indication;
(3) Hull movement orbit (center of gravity, bow and stern);
(4) Anchor chain tension (by time series);
(5) Anchor movement orbit;
(6) Swinging movement display of three dimensions (viewpoint: bridge);
(7) Swinging movement display of three dimensions (viewpoint: windward);
(8) Probability of anchor dragging and anchor_dragging risk index numeral .

2.4 Display Windows

(1) Swinging movement display (of two dimensions) of a ship at anchor (bird's-eye view)

Swinging pendulum movement is described graphically in animation to be seen from the sky. Students can see not only a swinging track statically but the postures changing continuously of the hull second by second. This helps students learn how a ship at anchor swings.

Besides, this window shows the parameters used for simulating calculations, which provides them of a good opportunity to observe the change of the movement caused by different settings of the parameters. Seeing the heading angle changing by time, they also can know how to estimate a ship movement by the changing of heading angle.

(2) Wind direction and wind velocity indication

Changes in wind direction and wind velocity are basic information for mariners to judge the swinging movement of a ship at anchor. Students must learn the relationship between the swinging movement and the wind direction shift on the display and the display (1).

In addition, they learn how to judge the ship movement by monitoring wind direction as well as wind velocity.

(3) Hull movement orbit (center of gravity, bow and stern)

Concerning to the center of gravity in the hull, its bow and stern, their loci are displayed. The hull posture at every fixed time is also displayed on this window. This shows students clearly the typical swinging movement is that of a figure of eight, and they can know well how large the deflection range and the occupied water area can be.

(4) Anchor chain tension (by time series)

Changes of anchor tension can be shown graphically as time goes on. They can see its tension change in real-time. And they can study changing process related to sudden and steady tensions and the relationship between changes in the tension and hull postures. They can see how changeable the part of the chain lying on the seabed is while a ship is swinging.

(5) Anchor movement orbit

External forces affecting to anchor and its chain, when stronger than their holding power, causes anchor to slide on the seabed. This window shows the locus of such a sliding anchor before it finally turns over and starts to drag. Students can observe the states of hull posture and chain tensions when an anchor starts to slide.

(6) Swinging movement display of three dimensions (viewpoint: bridge)

This gives the scene mariners have when standing on the bridge. Even a well-experienced seafarer can t easily have a clear perception of swinging movement, because the ship movement is too slow. Thus, students must learn wind direction is essential source of information to know the swinging movement at anchor exactly.

(7) Swinging movement display of three dimensions (viewpoint: windward)

This window shows the relation between an anchor holding the seabed well and a hull moving regularly on the sea surface.

(8) Probability of anchor dragging and anchor_dragging risk index number

Authors have already proposed two parameters as the indices to quantify a probability: one is the probability of anchor dragging and the other is anchor dragging risk index number. These parameters let us know how the safety of a ship varies as time goes on and what factors can be to affect to the safety of a ship at anchor.

3. Educational Effect of the System

3.1 Experiments on the System s Educational Effect

When a lecture about the movement of a ship at anchor is given in the classroom, an explanation is often given with some figures drawn on a blackboard.

However, when talking about a dynamic phenomenon such as the swinging movement of a ship at anchor, it is important to note that various forces are inter-related. It is, therefore, not easy to make students aware of the relationship between such forces and figures drawn on the board.

To understand the dynamic movement of a ship at anchor, it is important to display the composite action. From this we can recognize that visual educational system, which can show graphically the movement in animation, is necessary. This integrated simulation system (ISS) was developed from this viewpoint.

The visual display windows of ISS make it easier for students to understand the movement regularity of a ship at anchor. They will also come to know the relation between wind direction and the hull s posture, as well as the relation between a hull s movement and the tension on the anchor. Through these windows, students will understand the whole process and the reasons why a ship changes her posture in wind, and how the anchor changes from holding well to dragging.

To verify the educational effect of the ISS, we conducted an experiment. It was performed with 20 students from the third grade of the nautical study course at Kobe University of Mercantile Marine. Each of them gained a score between 75 points and 80 points in the final test for a lecture on theory of ship handling.

The 20 students were divided into four groups of A, B, C and D, and took part in a two-day program. Each group had five students and each group s schedule was as follows:

The 1st day:

Group A: The group received only the usual lecture in a classroom.

Group B: The group received the usual lecture in a classroom first, and then received a lecture using ISS animation.

The 2nd day:

Group C: The group only received a lecture using ISS. No usual lecture was given in the classroom.

Group D: The group received a lecture using ISS first, and then a usual lecture in a classroom.

One instructor gave explanations to the four groups on the movements of a ship at anchor. After whole program of each group, a test shown in Figure 5 was given to the students on the swinging movement of a ship at anchor. The test results are shown in Table 1.

Table 1_ The test results of each group

Group	Lecture	Average Score
Group A	Only received lecture in classroom	78.5
Group B	Received lecture in classroom first and ISS lecture	90.6
Group C	Only received ISS lecture	90.0
Group D	Received ISS lecture first and a lecture in classroom	93.8

On Table 1, the average score column shows the average score of the test on every group. We found a large difference between groups A and groups B, C, D in their scores. Clearly, group A gained the lowest score, while groups B, C, D s comprehensive results were higher. This is understandable due to them receiving a lecture using ISS.

On the other hand, when comparing the scores of group A and group C, it can be said that the educational effect of ISS animation is impressive. It can deepen understanding of the complex phenomenon much better than having only a lecture in a classroom.

We also carried out the Levene statistical official approval using the SPSS software between each two groups A&B, A&C and A&D with every student s scores. It was examined in 95% of the reliability. In the Levene official approval of the same dispersion, each probability is 0.447, 0.524, and 0.817, and F value is 0.640, 0.444, and 0.057.It can be said that the ISS lecture is certainly effective according to these result.

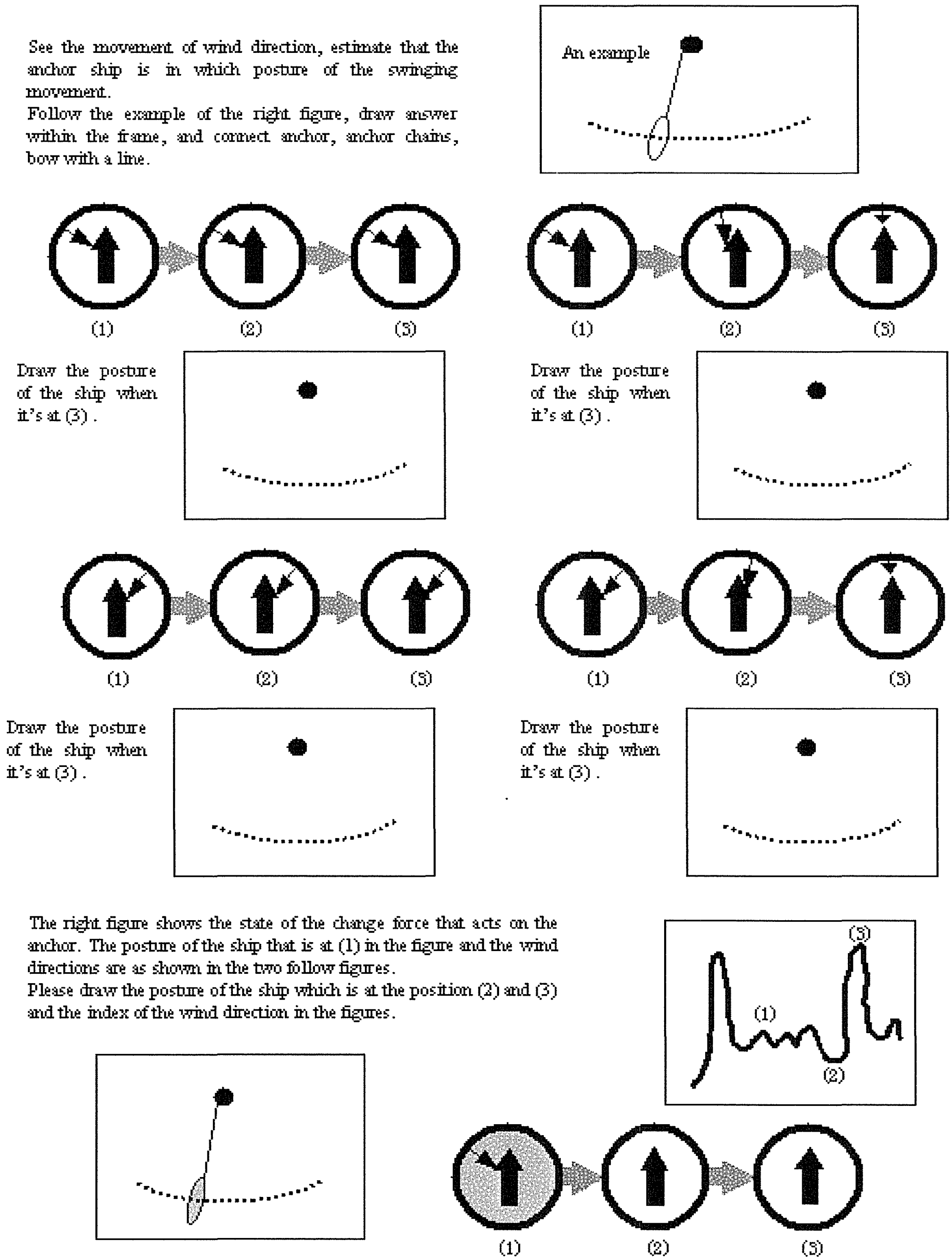

Fig. 5 The test of the swinging movement

3.2 Results of Questionnaire

Questionnaire was given to the students of groups B and D who received both lectures. Ten questionnaires were distributed and there were nine replies. The following are the results.

The questionnaire had four questions.

(1) Question "which lecture is more useful to you for understanding the swinging movement: the usual lecture or the animation-lecture using ISS? Why? Everyone chose the animation lecture and their feelings are recorded in Figure 6.

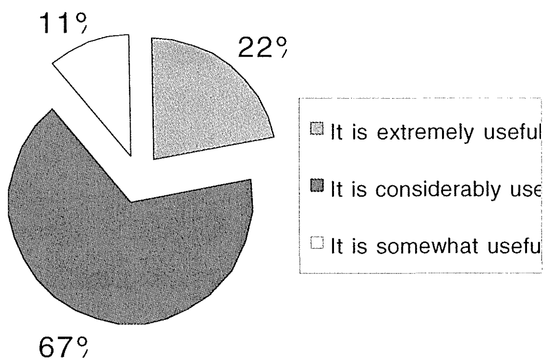

Fig. 6 Results of question one

(2) The results are shown in Figure 7 for the question "which point was most useful for you to understand the swinging movement in detail?"

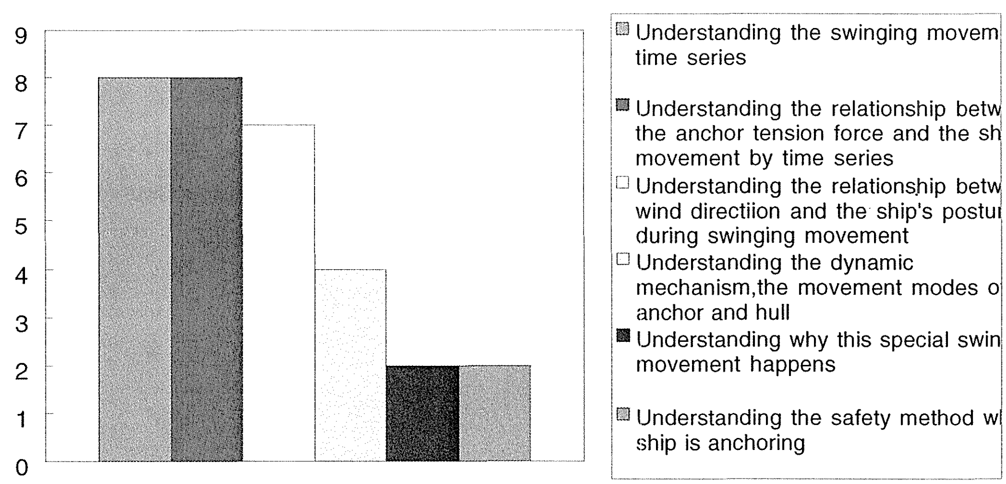

Fig.7 Results of question two

(3) The answers to the question "Would you prefer to receive the lecture with ISS animation first or the lecture in a classroom as usual first? Choose which you believe to be most effective" are shown in Figure 8.

(4) For the question of the two kinds of lecture, do you think that only one is enough or that both are necessary? the answers are shown in Figure 9.

Regarding the free answers in the questionnaire, five out of nine respondents gave the free answer. The results are shown in Table 2.

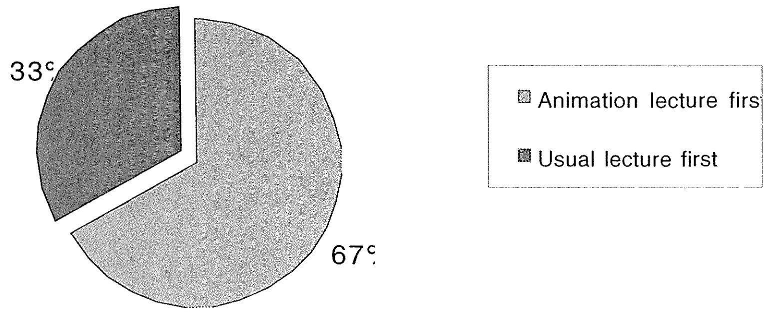

Fig.8 Results of question three

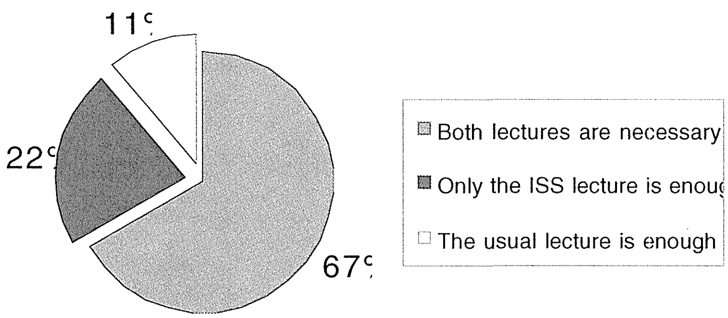

Fig.9 Results of question four

Table 2: The Results of free answers

Feel Positive, 3 persons	The lecture with ISS is easy to understand and believe that it is necessary; the ISS display the hull s movement very well.
Problems,1 person	In the lecture using ISS, there are no relevant documents. Maybe one could understand the explanation better when annotated on the blackboard.
Advice, 1 person	How about linking the lecture with ISS and the training-experiments on ship handling.

3.3 Investigation with Questionnaire

The better educational effect from studying the swinging movement of a ship at anchor was confirmed using the animations of ISS. As a visual resource, ISS and its animation can lead to a better understanding than a typical lecture in a classroom because of its simplicity.

Furthermore, it was effective to give an oral explanation when students see animations of ISS.

We also believe that it is important to combine other audio-visual aids such as videotape etc. However, since the auxiliary teaching materials according to the animation of ISS are still insufficient, it is now time to start to compile teaching-materials for our ISS.

Before students conduct practical experiments on ship anchoring aboard our training ship, maybe they should be given a lecture with the ISS animation. The students would feel more at ease and make fewer mistakes during such an on-board experiment, especially for those who have not prepared for ship training.

As mentioned above, we can see that ISS as a visual educational system, is useful for understanding the swinging movement of a ship at anchor, and is useful for deepening anchoring-safety knowledge.

4. Conclusions and Future Study Directions

This system can be positioned as an added-value application system of a ship-handling simulator.
The new ISS can analyze the swinging movement of a ship at anchor and impacts of forces on hull, anchor, anchor chains, etc. It cannot only be used for educational purposes, but also for assessing experiments on safety evaluation for a ship at anchor. Such a system may be useful to researchers in other field.
In the present paper, only the educational use of ISS was verified and now efforts are being made to increase its usefulness.

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