A Method Quantitatively Evaluating on Technical Progress of Students in Ship Handling Simulator Training

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ABSTRACT

A current problem in maritime education and training using a ship handling simulator is how to judge quantitatively and objectively the skill progress of trainees for collision avoidance maneuvers without depending on an instructor's experience and subjectivity. The skill of performing a collision avoidance maneuver can be judged from the following three points: (1) timely action, (2) suitable operation, and (3) satisfactory result. In the present paper, whether collision avoidance action was taken in a timely way is evaluated with TCPA; whether a suitable operation was performed is evaluated by changes of heading angle; and, whether the result is satisfactory result is evaluated by Environmental Stress Value (ES value) and Time to Collision (TTC) which can be judged from the viewpoint of reducing risk of collision and stranding. A collision avoidance maneuver in a narrow water area is taken up in the case study. A total of 80 repetitions of simulator experiments were conducted systematically, and the validity of these objective indices was examined.

1. Introduction

Education and training using a ship handling simulator (SHS) are already practiced globally. However, there is an important problem outstanding in education and training using a SHS. That is, it is necessary to propose an objective evaluation method to judge the technical skill-improvement of a trainee in the process of SHS training, without depending on the experience of instructor subjectively.

The author has applied an Environmental Stress model (Inoue, 1999 & 2000) to solve the problem in the execution process of SHS training, and has introduced a methodology for judging the results of the skill improvement for a trainee from the viewpoint of absorbing ship handling difficulty imposed on a trainee (Inoue and Ohno, 1998).

In this research, in addition to the evaluation from such a viewpoint, an objective risk evaluation index, which pays attention to the exclusion of latent risk in the process of collision avoidance manoeuvres, was newly introduced.

2. Skill Improvement for Collision Avoidance Manoeuvres

As for education and training using a SHS, it is commonly aimed at improving skills for evasive actions against collision and stranding by an officer on watch. Although there are many education and training elements required of an officer on watch, these are roughly divided into two categories; one element is action required of an officer (mariners' attitude), and the other is a technical element (ship handling technique). The former corresponds to lookout, checking ship's position, handling instruments, information exchange, regulation compliance, voyage plan and an emergency measures, etc. The latter corresponds to collision avoidance manoeuvres using main engine and rudder, etc.

Although the skill of collision avoidance manoeuvres covers the whole process including detection of another ship, determination of collision risk, selection of collision avoidance action, execution, and confirming of maneuvering result, we focus here on three points: (1) timing, (2) which collision avoidance manoeuvres were performed, and (3) the results of collision avoidance manoeuvres.

We believe that a judgment on the skill by which collision avoidance manoeuvres were completed is made from three viewpoints of: (1) good timing, (2) suitable operation, and (3) good result.

3. Numerical Index of Judging Skill

Here, judging whether collision avoidance manoeuvres were performed with good timing is evaluated with TCPA, whether suitable operation was taken is evaluated by measuring the changed angle of own ship's course. These are the indices used from so far. On the other hand, on whether or not the result was sufficient result, apart from using only DCPA, we introduced the Environmental Stress Value (ES value) and Time to Collision (TTC) as indices of evaluation.

Introduction of these indices is intended to judge the whole process of a series of collision avoidance manoeuvres from the viewpoints of both difficulty and safety, rather than a judgment only from the DTPA between 2 ships as the final result. ES value is a numerical index indicating the ship handling difficulty imposed on a mariner due to geographical restrictions of water area and/or traffic congestion (Inoue, 1999 & 2000). Fundamentally, it is thought that the ship handling difficulty is directly proportional to danger of an accident. Therefore, the potential danger, which remains in a series of navigation processes, can be measured by reading changes of ES value.

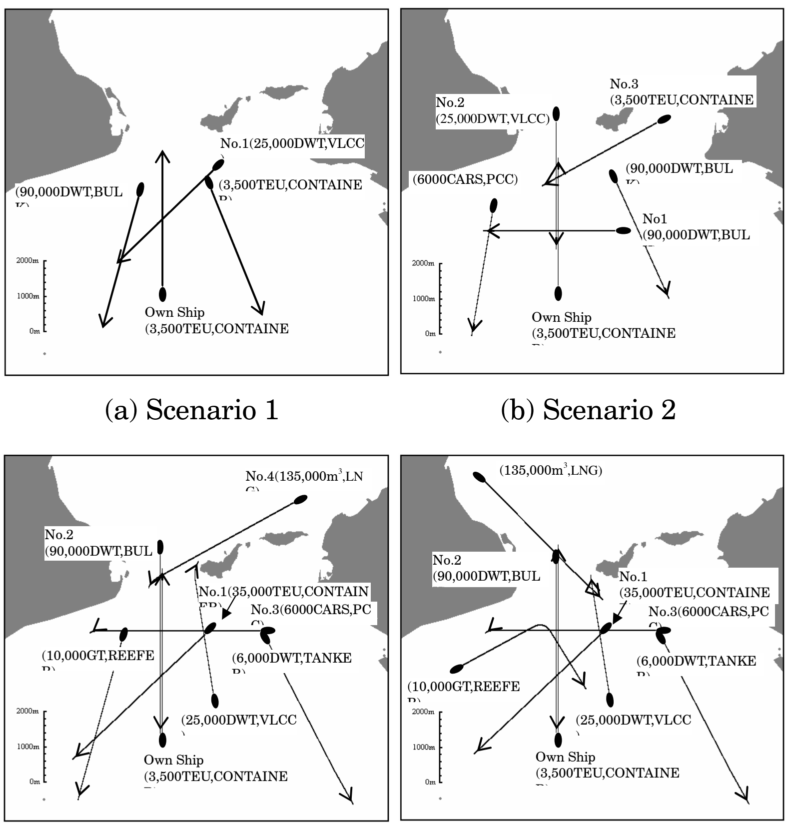
The ES value is expressed with the range of 0-1000; the stress ranking is as: from 0 to 500 is negligible; from 500 to 750 is marginal; from 750 to 900 is critical, and 900-1000 is catastrophic. On the relation between this stress ranking and the acceptable level, an ES value of 750 or more is a state that is unacceptable for mariners.

TTC is calculated from Potential Area of Water (PAW, predicting tracks when presupposing that the states of operation and the states of external forces continue unchanged) (Inoue et al, 1998). Based on this concept of PAW, the TTC is calculated for every fixed time section from the time when the predicted track collides with another ship or an obstacle. This TTC is a numerical index indicating the potential risk of each time section of navigation. It can be judged that the danger of an accident is high when the value of TTC is close to zero.

4. SHS Experiment on Evaluation of Skill Improvement

4.1 Execution of Experiments

The SHS of Kobe University of Mercantile Marine (KUMM) was used for the experiment evaluating of trainee's skill improvement, and 4 scenarios were used in the experiment. In each scenario, own ship encounters other ships in a narrow water area, as shown in Fig.1. Each scenario uses a 3,500TEU container ship as own ship passing through the narrow water area at 12 knots and a course of <000>. It encounters other ships in succession.



(a) Scenario 1 (b) Scenario 2

(c) Scenario 3 (d) Scenario 4

Figure 1: Four scenarios

Environmental conditions are no wind, no current, and daytime with clear visibility. Subjects are four students of KUMM. Although they are qualified as Third Grade Maritime Officer (Navigation), they have no experience on board as officers. These students had experienced the ship handling with a SHS in the past, and were already familiar with the equipment of this simulator. In implementing the experiment, distance and direction of a target ship are read from radar or repeater compass, the necessity of collision avoidance manoeuvres are judged by the subject, and the steering order to avoid a target ship is given to the helmsman. In addition, the ARPA function of radar is not used and the trainee performs collision avoidance manoeuvres mainly by changing own ship's course and not using the main engine as much as possible. Before the experiment, they were given the following information: confirmation about how to treat radar (such as distance, direction, range, and fixed distance marker, etc.), introduction of the sea area with a chart, and presentation of pilot card of own ship. Experiments were repeated 3 times for different scenarios in one day, but the number of repetitions was not informed to avoid a psychological influence.

Having used scenario 1, 2, 3, and 4 as one set, 5 repetitions of that set were conducted for one student. We also laid out a suitable schedule for the experiment at appropriate time intervals: after the 1st set of experiments was conducted, then after passing through 4 or 5 days the 2nd set of experiments was conducted.

4.2 Evaluation of Skill Improvement

4.2.1 Skill Improvement with Start Timing of Collision Avoidance Manoeuvres and Changed Angle of Course

Only through experience do beginners acknowledge that if any action to avoid collision is delayed for target ships, own ship approaches too close to another ship resulting in operational difficulty and risk of collision. They learn the necessity of commencing early action to avoid collision. Consequently, using the same scenario, it is considered to be a skill improvement for trainees to take more TCPA for other ships as the experiments proceed.

Fig. 2 shows the change of initial TCPA as the training proceeds. And it shows the total average for 80 trainings with the 4 students. TCPA taken appears to a rise to the right, i.e., trend that a larger TCPA is taken as the training proceeds, is shown.

Fig. 3 shows the changes in heading angle's average for 80 trainings with the 4 students as the number of times of training increases. Although it seems that 30 to 40 degrees could be taken as an average for the changed angle of course, it is almost uniform, and the correlation with the number of times of training is not clearly found.

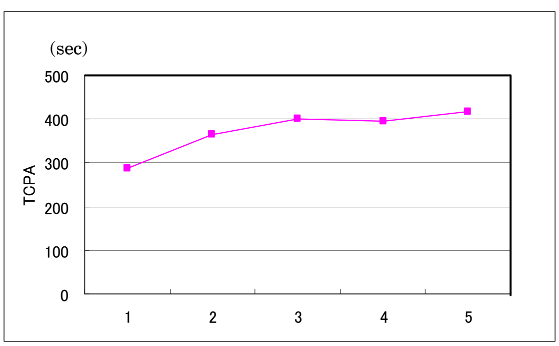


Figure 2: Overall average of TCPA

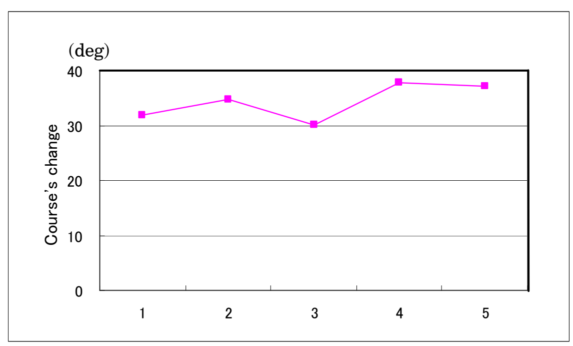


Figure 3: Overall average of the changes in heading angle

4.2.2 Skill Improvement with the Change of ES Value

ES value becomes larger when a navigation water area is restricted and traffic is congested. If a mariner performs sufficient collision avoidance manoeuvres well, the ES value decreases.

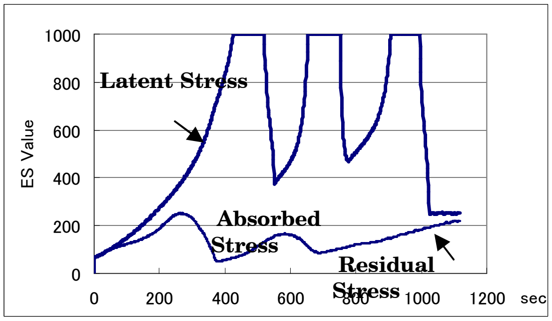


Figure 4: Illustration of output of ES value

Fig. 4 shows the ES value output for own ship underway as a pattern diagram. Under the designed operational and traffic environments in the scenario, the ES value calculated when navigating at a given speed and course without any action to avoid collision (shown as bold line) is defined as latent environmental stress, and the ES value calculated under the same scenario with the action taken in a timely and appropriate way (shown as thin line) is defined as residual environment stress.

The area between latent and residual environmental stress is considered to be the result of stress absorption by a mariner's collision avoidance manoeuvres.

Therefore, it is possible to evaluate skill improvement by judging the increase of stress absorption as the experiments proceed.

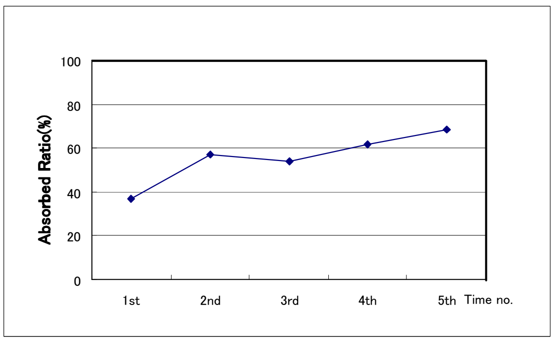


Figure 5:
Overall absorbed ratio of ES value

Fig. 5 shows how the amount of stress absorption changed as training proceeds. And it shows the total average for 80 trainings with the 4 students.

The vertical axis of the figure shows the ratio of stress absorption, which is calculated by the amount of integration of output ES value of residual environmental stress as numerator, and the amount of integration of latent environmental stress as denominator. It is clear that the ratio of stress absorption has an upward tendency as the number of times of training increases.

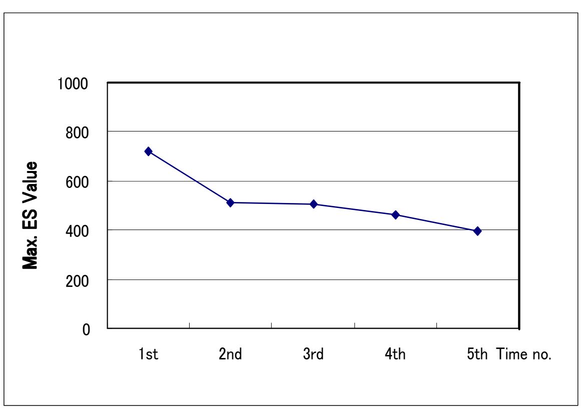


Figure 6: Average maximum ES value

Fig. 6 shows the change of maximum ES value as the number of times of training increases. And it shows the total average for the 80 trainings with the 4 students. It is considered that the maximum ES value has a downward tendency as the number of times of training increases.

As can be seen from the analysis results, the results of experiments show a certain increasing trend for stress absorption, and a certain decreasing trend for maximum ES value. That is, it is considered that the results of the experiments express the skill improvement of the students in accordance with the meaning of each index.

4.2.3 Skill Improvement with Change of TTC

In education and training using SHS, it is important to judge whether ship handling by a trainee is safe, and development of an index that can determine safety improvement systematically is desired.

DCPA is a typical yardstick, but this evaluation factor judges only a spot for one ship after collision avoidance manoeuvres, and it is possible that some subjective factors will enter into the evaluation, especially when setting a limit for DCPA.

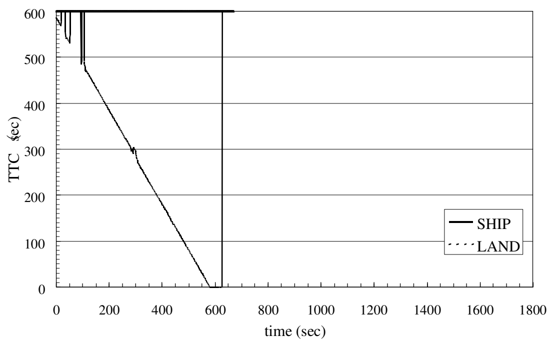
A mariner needs to handle own ship in the process of overall navigation considering the reduction of risk of collision with another ship or contact with land in collision avoidance manoeuvres. So, it is necessary to evaluate the achievement of safety in the ship handling process when evaluating the skill improvement of a collision avoidance maneuver.

From such a viewpoint, TTC is introduced as an objective numerical index showing the potentiality of a risk of collision or stranding in each time section of navigation. Danger of collision or stranding can be judged with the value of TTC and it is dangerous when the value is close to zero.

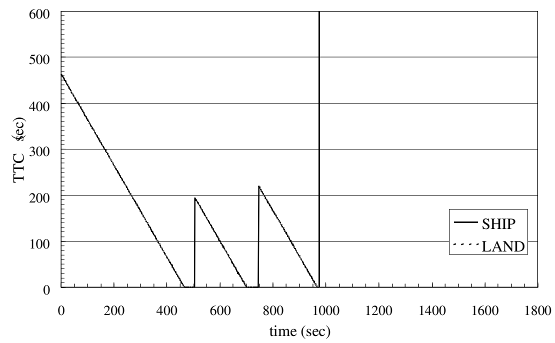
So, dangerous ship handling can be confirmed if the TTC value approaches zero in the process of navigation. In the calculation of TTC, the value outputted was less than 600 seconds. A period of 600 seconds corresponds to a distance of about 2 miles at 12 knots.

Fig. 7 shows the latent risk, when the own ship sails at the predetermined course and speed without any collision avoidance manoeuvres. In fact, a mariner decreases this danger by performing collision avoidance manoeuvres suitably and in a timely way. Therefore, it enables the educational result of skill improvement to be evaluated by calculating how much this danger decreased as the number of trainings increased.

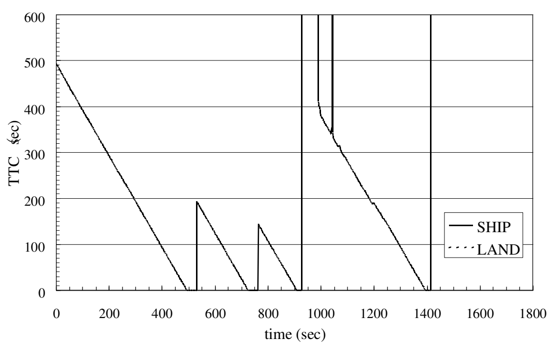
The solid lines in Fig.7 show the risk of collision with other ships and the dashed lines show the risk of stranding. The upper part of Fig. 7 is for scenario 1, the second is for scenario 2, the third is for scenario 3 and the lower is for scenario 4. Here, skill improvement is judged with the reduction ratio of TTC, which is calculated by taking time integration by second for TTC in Fig. 7 as a standard value.



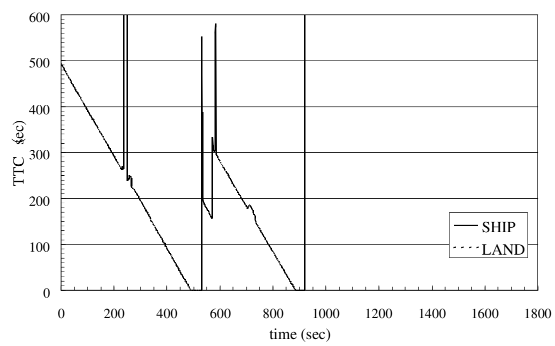
(a) Scenario 1



(b) Scenario 2



(c) Scenario 3



(d) Scenario 4

Figure 7: TTC (ship & land) results without collision avoidance maneuvers

Fig. 8 shows an example of TTC result when a student takes collision avoidance manoeuvres. In Fig. 8, the solid line shows risk of collision with other ships, and the dashed line shows risk of stranding. From this figure, it is observed that the risk of a near miss with other ships or approaching close to shore during a collision avoidance action is detected by objective numerical information through the TTC.

Fig. 9 shows the average risk reduction ratio of TTC for 20 trainings with 4 students for each scenario as the number of times of training increases.

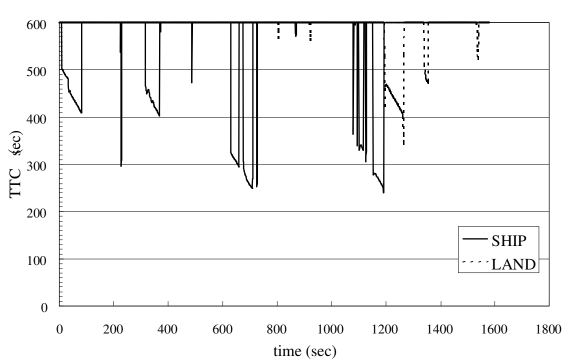


Figure 8: An example of TTC (ship & land) result with collision avoidance maneuvers on scenario 3

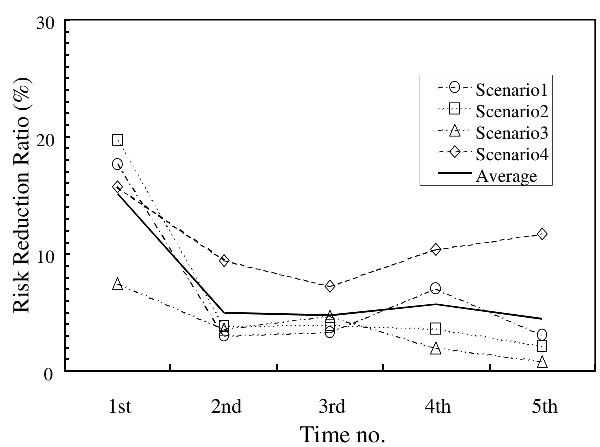


Figure 9: Risk reduction ratio

When students have eliminated the risk of collision and stranding from the process of collision avoidance manouevres, the risk reduction ration is close to 0%. So that, it is expected that the risk reduction ratio decreases as the number of times of training increases.

In Fig.9, the value of the risk reduction ratio of TTC for each scenario shows a tendency of decrease. However, the results of scenario 4 do not indicate the simple tendency of decreases. It was observed that students had made efforts to find out safer manoeuvring thorough trial and error because of the difficulty in the scenario 4 than others.

5. Conclusions

In this paper, we focus on such implementation phases of collision avoidance as timing, method and result of collision avoidance manoeuvres. A new approach is attempted to evaluate skill improvement from the standpoint of objective evaluations of risk exclusion behind the process of collision avoidance manoeuvres, adding to evaluations of ship handling difficulty.

The judgment of skill in a collision avoidance maneuver is from (1) timely action, (2) suitable operation, and (3) satisfactory result. The following evaluation measures are introduced: the initial TCPA for timely action, heading angles altered for appropriate operation, and Environmental Stress Value (ES value) and Time to Collision (TTC) for a satisfactory result.

Taking collision avoidance manoeuvres in a narrow channel as examples, 80 experiments with 4 students using a ship handling simulator were carried out systematically, and the effectiveness of the indices was discussed.

As a result, it was again confirmed that both judgment by TCPA used so far, and judgment by ES value proposed before were effective. In particular, newly introduced TTC as a judgment index was found to be effective for evaluating skill improvement of collision avoidance manoeuvres in terms of safety.

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