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Applying Collision Avoidance Expert System to Navigation Training Systems as an Intelligent Tutor

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Abstract

To enhance the skills of captains and improve the existing training technologies, it is very important and urgent to research and develop an intelligent navigation training system. Therefore we propose to incorporate a collision avoidance expert system into real-time ship handling simulator to provide intelligent decision-making support for navigation training. The intelligent tutor aims to assist the trainee to master necessary skills for handling ship in complex navigating environments such as open sea, restricted waterway, and rough sea conditions by sharing multiple captains' experience. In this paper, the developed collision avoidance expert system will be outlined, then the proposed intelligent decision-making support for navigation training will be presented in details.

1 Introduction

The recent huge maritime casualties and their environmental impacts, especially the stranding of EXXON tanker in Alaska, showed that human error in ship navigation is one of the primary causes leading to accidents. In order to reduce maritime accidents and human errors in ship navigation, it is very important and urgent to improve the skills of navigators and develop advanced navigation support system for ship operations. A considerable amount of effort has been paid to the development of advanced navigation support systems. For example, an integrated navigation system (INS)[4] which is considered as a next generation navigation system was developed at Hiroshima University in Japan. This INS incorporates the developed Collision Avoidance Expert System (CAES) [2][3] as an intelligent decision-making support function to assist the operator to avoid collision during ship navigation. T. Tran et al [1] proposed to use a collision avoidance system to improve the efficiency and safety of marine transport, namely Marine Avoidance Navigation, Totally Integrated System (MANTIS). Furthermore, the most recent Canada's newest hi-tech ships collision incidents warn us that only making hi-tech ships alone is not sufficient for improving ship navigation safety. It is important for the captains be adequately trained to handle the hi-tech ships in different complicated waterways. At present, much effort is focusing on developing 3-D visualized ship-handling simulators, which can simulate real-time navigating environments and ship handling scenarios. In such an environment the navigators could have the real feeling and learn how to operate ships. There have been a lot of achievements using ship-handling simulators to train seafarers and to investigate the navigation safety [5][6][7]. Although existing ship-handling simulators can be a useful means for training navigators, it does not provide decision-making support to trainees nor advise the trainee how to handle a ship in complicated situations. It remains that training is carried out under the instructions of a trainer. Trainees operate the ship following the trainer's instructions. To alleviate these shortcomings, we proposed to incorporate collision avoidance expert system into existing ship-handling simulator as an intelligent decision-making support system for navigation training, particularly for collision avoidance, in order to effectively train the navigators and improve their skills. In this paper, the developed collision avoidance expert system is first outlined in Section 2; then the proposed intelligent decision-making support for navigation training will be presented in Section3. Conclusions and future work are given in the last section.

2 Collision Avoidance Expert System

Collision Avoidance Expert System [2] was developed to assist ship navigators in their decision-making process to avoid collision. It is a rule-based knowledge base system. It was designed based on hierarchical architecture and modularized knowledge structure as shown in Figure 1. The top layer in the system is the inference control, which is responsible for the control of the inference procedure. The second layer is the main knowledge bases, which include the classification of target ships, the prediction of target ships' action, the identification of the method of collision avoidance, and the establishment of course-line way-points. The third layer contains knowledge modules of every knowledge base. The fourth layer includes the preliminary knowledge modules such as traffic regulation, identification of target ships, and so on. The system consists of the following main inference sequences:

(1) Prediction of target ship's scheduled action

First, the system uses a knowledge base to classify the navigation environment into one of three categories: open sea, coastal, or route navigation. The prediction of the target ship's scheduled action depends on this classification. In the case of open sea or coastal navigation the target will maintain its current course and speed, and in the case of the route navigation, it will follow the navigating route.

(2) Classification of target ships

After the computation of collision risk of target ships, the target ships are classified as the most dangerous, the dangerous, the restricting, or the indifferent ship depending on their risk of collision. A dangerous ship is defined as a ship having risk of collision that exceeds the safe level when both ships maintain their scheduled course lines. In the case of several dangerous ships, the most dangerous ship has the highest risk among dangerous ships. A restricting ship is defined as a ship that will cause no danger if own ship and target ship maintain their scheduled course lines, but it will frustrate the action of own ship if it takes the collision avoidance action for a dangerous ship. The target ship that lies outside the maneuvering space of the own ship is defined as the indifferent ship.

(3) Prediction of target ship's collision avoidance action according to the classification of the ship

For the dangerous ships and restricting ships, their collision avoidance actions are predicted by using the same approach and knowledge base as that of the own ship. The predicted actions of collision avoidance of target ships will be incorporated into the procedure when own ship's action of collision avoidance is formulated.

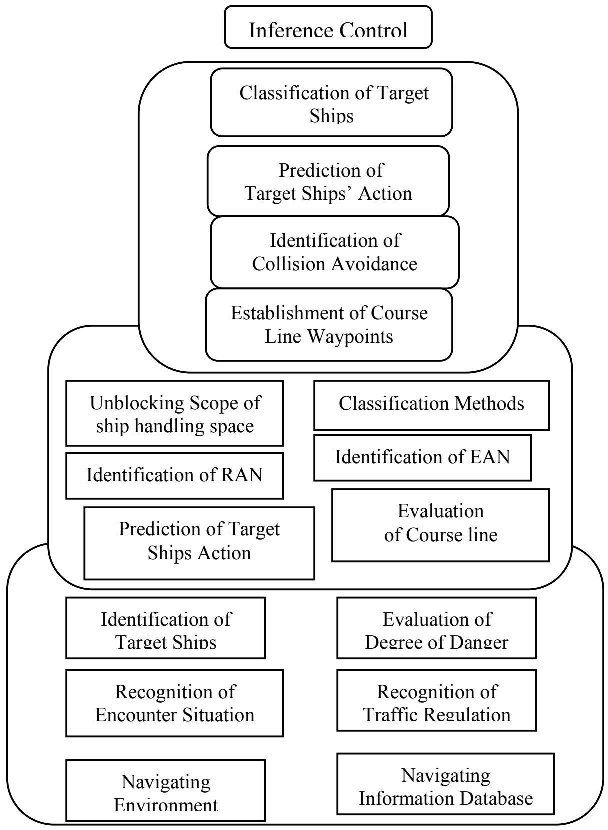

Figure.1 The Architecture of the Collision Avoidance Exert System

(4) Establishment of the course line way-point as collision avoidance action

The action of collision avoidance of own ship is formulated basically against the most dangerous ship. The action in the own ship maneuvering space is evaluated considering the prediction of the action of the dangerous ships and the restricting ships. As a result, the most efficient and feasible action is selected.

3 Intelligent Decision-Making Support for Navigation Training

3.1 Weakness of Existing Navigation Training Systems

Existing navigation training systems such as ship-handling simulator are used to help the trainees to master basic navigation skills and traffic regulations before they go to practice on broad. The training is carried by providing realistic navigation environment and ship encounter situations under the instruction of experienced navigator. However, existing training systems do not provide automatic decision-making support for handling complex encounter situations. The trainee can't share the multiple captains' navigation experiences for handling ship in complicated situations, and the decision for collision avoidance is still made by instructor or trainee.

To overcome such shortcomings, we apply the developed collision avoidance expert system to existing navigation training systems, ship-handling simulator, to provide intelligent decision-making support for collision avoidance as an intelligent tutor. Such decision-making support is capable of automatically solving the problems in ship navigation for different encountered situations and complicated waterways. It is able to instruct the trainees how to take a collision avoidance action, and how to handle ship to execute the recommended actions for collision avoidance. It also shows the trainees the supporting information such as the application of traffic regulations, the encounter situation, the risk level of own ship or other ships. Such supporting information that will explain the current situation can assist trainees to understand collision regulations and marine safety regulations, and help trainees to master the basic navigation skills. It will make it possible for trainees to easily learn different captains' experience obtained in their navigation career.

3.2 Intelligent Decision-Making Support for Navigation Training

With the developed collision avoidance expert system, the navigation training systems could provide effective decision-making support information and recommend a proper action for collision avoidance. The decision-making support information includes target ship classification, encounter situation on the scheduled course line, the risk distribution around scheduled course line, and so on.

(1) Target ship classification

Each target ship is classified into dangerous ship, restricting ship and indifferent ship in terms of its risk to own ship. The dangerous ship is one that potentially causes the collision if both ships maintain their current speed and course; the restricting ship is one that prevents own ship from performing action for collision avoidance; and the indifferent one has no threat whatever alteration of course own ship makes.

(2) Encounter situation on the scheduled course line

This support information indicates the encounter type between dangerous or restricting ship and own ship, e.g., own ship overtaking, and so on. Using such supporting information, the trainee may easily classify the encounter relation between two ships at instant looking at the CRT.

(3) Risk distribution around the scheduled course line

This support information is aiming at helping trainee to analyze the risk situation around scheduled course line. In the real navigation, the ship has destination and scheduled plan. The captain hopes to keep the ship following the scheduled plan and not deviating so far from it. Figure 2 shows such support information.

(4) Recommendation of collision avoidance action

Using the above support information is useful for trainee to master and analyze the risk situation around scheduled course line. However, the final action for collision avoidance needs to be decided by trainee or instructor. It is desirable for the training system to be able to recommend a proper maneuvering action for collision avoidance in order to instruct the trainee how to determine the effective action in case of potential collision. Using CAES, it is possible for training system to recommend a proper action for collision avoidance to trainee. Figure 3 shows an example of the recommended collision avoidance route and risk distribution around the scheduled course line. The risk distribution information helps to explain the reason of the recommended collision avoidance action.

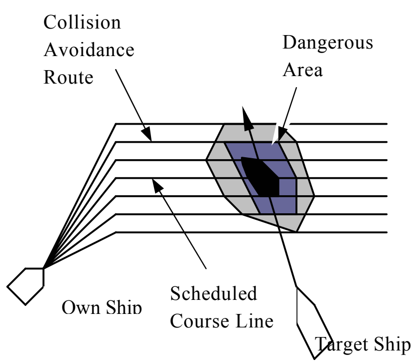

Figure.2 Risk Distribution around Planed Route

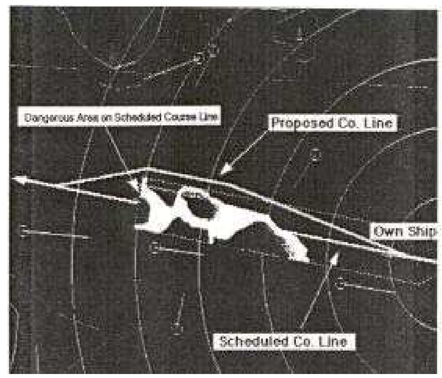

Figure.3 Example of Recommended Course Line

3.3 Intelligent Navigation Training System Archtecture

The system architecture is designed based on a multi-tired distributed system. As shown in Figure 4, the system consists of three tires: decision-making support graphic user interface and information display layer, knowledge-based system for collision avoidance layer, and ship-handling simulator layer. The software components in different layer are connected with TCP/IP network. The graphic user interface provides all interactive operation for trainee to get the necessary information. The knowledge-based system for collision avoidance is the core of CAES, which provides all decision-making procedure and monitors current own ship status in terms of navigation environment and encounter situations. Ship-handling simulator is used to provide realistic navigation environment and ship-handling scenario. It provides the necessary realistic navigating date for CAES to make decision.

4 Future Work and Conclusions

In this paper, the authors proposed to incorporate a collision avoidance expert system into a real-time ship-handling simulator in order to provide intelligent decision-making support for navigation training, as an intelligent tutor. Using the developed CAES and ship-handling simulator, we implement the proposed intelligent navigation tutoring system. From the training operation, it can be pointed that CAES is effective to provide the necessary decision-making support to help trainee to master navigation skills and learn how to handle ship in complex encounter situation. According to authors' experience, it is necessary for navigation training system to be able to provide information of underwater environment. To this end, we are investigating the application of marine geographical information system (MGIS) to the navigation training system. Therefore the future work is to apply MGIS to the navigation training system and provide the underwater information in order to instruct the trainee how to handle more complex navigation situation. Another important task for future work is to provide safety-evaluation function for on-line evaluation of ship-handling action.

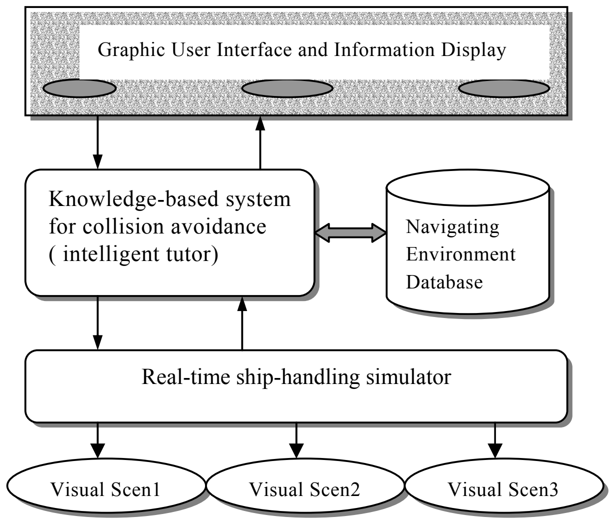

Figure.4 Architecture of Navigation Training System

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