Research on Ship Collision Avoidance Expert System in big data Era

Jinqiang Tong*
Shandong Jiaotong University, Weihai, Shandong, China

*Corresponding author: zx742717769@yeah.net

Abstract. In the era of big data, in order to effectively reduce or avoid the occurrence of ship collision accidents caused by human errors, adapt to the development trend of ship Manning reduction, promote the research of ship automation, and ensure the safety of ship navigation at sea, based on the in-depth study of the principle of ship collision avoidance, this paper uses expert system technology and a large number of quantitative research results of ship collision avoidance, A more reasonable and complete knowledge base of collision avoidance is established, and a collision avoidance expert system is designed and partially implemented, which can help the ship's pilot to make decision of collision avoidance in real time and realize automatic collision avoidance under certain conditions.

Keywords: Feature matching, ship collision avoidance, expert system, collision risk

1. Introduction

The prevention of collision accidents is an important link to ensure the safe navigation of ships, and is the primary responsibility of ship drivers in navigation duty. The problem of ship collision avoidance has been highly valued by experts and scholars in the navigation field.

With the development of social economy and the substantial increase of world trade volume, the marine transportation business is increasingly busy, and the demand for all kinds of ships is increasing, which results in the increase of the density of ships at sea and the congestion of routes, and objectively increases the probability of ship collision. The frequent collision accidents between ships not only cause huge loss of life and property, but also seriously pollute and destroy the marine ecological environment, which has a bad impact on the development of maritime industry.

The research on ship collision avoidance has a long history. Since ships began to move on water, people began to discuss the problem of ship collision. It has been more than 2000 years since the earliest Rhode sea method. Generally speaking, the history of ship collision avoidance research can be roughly divided into three stages. The first stage is to form various collision avoidance rules by summarizing the experience and lessons of collision avoidance and collision at sea. Countries negotiate to formulate, modify and improve the universal and effective collision avoidance rules. The second stage is to explain and understand the collision avoidance rules, and the third stage is to conduct quantitative research on the collision avoidance rules, With the progress of society and the development of science and technology, a variety of navigational aids have been developed to assist in the collision avoidance of ships, as well as the collision avoidance automation research being carried out today,
which is also an inevitable trend in the development of collision avoidance research. In fact, there is no obvious demarcation line between these three stages. They are interrelated and interact with each other. The development of navigational aids often follows the existing rules and the usual practices of seafarers, and the emergence of navigational aids will promote the revision of the rules.

The language of the international rules for preventing collisions at sea is highly concise and generalized, which uses many qualitative and fuzzy terms and concepts. Different people may have different understandings. In order to avoid possible misunderstandings and correctly use the rules, it is necessary to make authoritative and unified interpretation of the rules.

In the era of big data, ship collision avoidance expert system is the result of practical application of expert system technology in the field of ship collision avoidance. Based on rich collision avoidance knowledge, it simulates the thinking process of collision avoidance experts applying international rules, experience and knowledge of collision avoidance at sea, and automatically infers according to known conditions. Deduce to help or replace the ship's pilot to make decision and even avoid collision. Theoretically, the collision avoidance expert system can collect the experience and knowledge of many experts, and make quick and accurate judgment on the specific situation and collision risk according to these knowledge, and give the same decision-making as the collision avoidance expert.

2. Key technology

Expert system is a kind of knowledge-based and intelligent computer software system. It summarizes the knowledge and experience of human experts in a specific field, stores them in a proper form in a computer to establish a knowledge base, and uses appropriate control strategies to simulate the thinking process of human experts in solving problems. According to the known conditions, reasoning and deduction are carried out automatically to solve the problems that need to be solved by human experts in the past.

The expert system should have the following functions

1) Store the knowledge needed to solve the problem store the initial data of specific problem solving and all kinds of information involved in the reasoning process, such as intermediate results, objectives, assumptions, etc

2) According to the current input data, using the existing knowledge and according to certain reasoning strategies, solve the current problems and control and coordinate the whole system

3) Be able to make necessary explanations for reasoning process, conclusion or system's own behavior

4) Provide maintenance means such as knowledge acquisition, machine learning and modification, expansion and improvement of knowledge base

5) Provide a user interface, which is not only convenient for the user to use, but also convenient for analyzing and understanding various requests of the user.

![Package safety load format diagram](image)

**Figure 1.** Package safety load format diagram

The general structure of the expert system is as shown in the figure, including six parts of knowledge base, inference engine, comprehensive database, human-machine interface, interpretation program and knowledge acquisition program. Knowledge base, inference engine and comprehensive
database are the main contents of most expert systems at present, and knowledge acquisition program, explanation program and special human-machine interface are the three modules that all expert systems are expected to have, but they are not all realized. The packaging safety load format is shown in Figure 1.

The comprehensive database stores the initial data, solution state, intermediate results, assumptions, objectives and final solution results of the problem solving.

Under certain control strategy, the inference engine can identify and select the useful knowledge in the knowledge base to solve the current problem.

The knowledge base is used to store the expertise provided by domain experts. These specialized knowledge includes book knowledge, common sense knowledge related to the field and enlightening knowledge extracted from expert experience. The problem solving of expert system is carried out by using the special knowledge provided by experts to simulate the thinking mode of experts. The quantity and quality of knowledge in the knowledge base are the key factors affecting the performance and problem solving ability of expert system.

In the construction of knowledge base of expert system, it is used to replace knowledge engineer to acquire special knowledge automatically, realize the automatic learning of expert system, and constantly improve the knowledge base.

The development process of expert system can be divided into five stages: recognition, conceptualization, formalization, implementation and testing.

In the cognitive stage, the domain problems are analyzed to determine the scope, types and important characteristics of the problems to be dealt with, as well as the functions and effects to be achieved.

In the conceptualization stage, we conceptualize all kinds of expertise needed for problem solving, determine the relationship between concepts, divide the tasks, and determine the control process and constraints for problem solving.

In the formalization stage, the concepts, relationships between concepts and domain expertise that have been sorted out are described in a formalized method suitable for computer representation and processing, and appropriate system construction technologies are selected.

The structure of knowledge base, reasoning rules and control strategy are determined, and the problem solving model is established. In the implementation phase, the established formal model is
mapped to a specific computer, and an executable prototype system is built by selecting the appropriate language or tool.

In the test phase, by running a large number of examples, the correctness and performance of the prototype system and other system objectives are detected, and the results are returned to the above stages for necessary modification and improvement.

3. Design of ship collision avoidance expert system in big data era

With the development of collision avoidance research and artificial intelligence technology, it is an inevitable trend to develop an automatic and Intelligent Collision Avoidance Expert system. A complete collision avoidance expert system should have the following functions.

Collection function. Information is the basis of decision-making, and the acquisition of collision avoidance information is the fundamental guarantee of scientific and reliable collision avoidance decision-making. The information here includes the static information that needs to be input manually, such as the ship's static parameters, Captain, loading conditions, environmental information visibility, sea area, etc., and the dynamic information of the ship and the targets in the monitoring sea area that can be obtained directly through radar, and other collision avoidance instruments or sensors.

The function of analysis and processing is to analyze and process the collected collision avoidance information to get all kinds of information needed for collision avoidance decision-making. For example, the relative speed, relative speed direction, heading angle, safe passing distance, collision risk, etc. of the two ships shall be determined according to the static and dynamic parameters of the ship and the reliable information of the target ship provided by radar, etc.

Automatic collision avoidance decision function. The decision-making of ship automatic collision avoidance is the key to realize the automation of ship collision avoidance.

3.1 Establishment of knowledge base

Knowledge is the basis of intelligent activities, and the size and quality of collision avoidance knowledge base are the key factors to determine the level and performance of collision avoidance expert system. The research of the whole expert system is around the acquisition, representation and utilization of knowledge.

Knowledge acquisition is to extract the knowledge used to solve special domain problems from the knowledge source with these knowledge, and transform it into a specific computer representation. Knowledge sources include knowledge and experience of human experts, textbooks, databases and lessons learned in practice. The knowledge base of collision avoidance is mainly used to store the knowledge that may be used in the process of collision avoidance obtained from various knowledge sources. A good organizational structure of knowledge base is not only conducive to the effective and fast selection and use of knowledge and reduce the search space, but also to the management and maintenance of knowledge base.

Knowledge representation is the process of symbolization and formalization of knowledge. The knowledge representation method studies the design of various data structures, through which all kinds of knowledge in the problem field are integrated into the programming process of computer system. Generally speaking, different representation methods can be used for the same knowledge. Conversely, a knowledge representation mode can represent a variety of different knowledge. However, when solving a problem, different representation methods will have completely different effects. So far, people have not found a general and perfect knowledge representation model, and there is no perfect theory to follow. A good and appropriate knowledge representation method can not only store domain knowledge in computer conveniently, but also help the system manage and use these knowledge effectively. At present, there are many knowledge representation methods, including state space representation, framework representation, process representation, and object-oriented representation.

3.2 Design of inference engine

The inference engine is actually a group of control programs that use knowledge to solve problems.
It is used to control the operation of the whole system. Whether the ship collision avoidance expert system can simulate the process of human's thinking and decision-making in the process of collision avoidance is realized by the inference engine in the process of controlling the acquisition of field knowledge and the use of knowledge. Therefore, the important role of inference engine is to determine how to effectively use and control knowledge and coordinate the role of various links.

In the ship collision avoidance expert system, according to the characteristics of the collision avoidance knowledge base, this paper establishes a forward deductive reasoning algorithm with heuristic knowledge, which is based on the idea of forward reasoning, and introduces heuristic knowledge in the reasoning process, and deduces the collision avoidance conclusion according to the existing collision avoidance information. The so-called heuristic knowledge refers to the knowledge related to the problem and can speed up the reasoning process to obtain the optimal solution of the problem. Its introduction can reduce the number of searches, speed up the search, and improve the reasoning efficiency of the system. These enlightening knowledge are contained in the rules of the knowledge base. It is not the goal of the system, such as the collision avoidance scheme, but the intermediate result of some reasoning, and plays a guiding or enlightening role in further reasoning, so it can also be called enlightening information.

4. Implementation of the system
Skeleton system and artificial intelligence language are widely used in the previous expert system. Skeleton system starts from an expert system that has been developed successfully, extracts the specialized knowledge from the system knowledge base, leaving a solid knowledge representation framework and corresponding reasoning mechanism, knowledge acquisition mechanism and interpretation mechanism. A new expert system is realized by using skeleton system only by filling in the expertise of another field and debugging it to form a new knowledge base. It can effectively establish some typical expert systems similar to skeleton system, but it has great limitations. Language is a widely used language in artificial intelligence, which can effectively express all kinds of descriptive knowledge and has strong logical reasoning ability. Using language to construct expert system directly can construct the internal form of knowledge base and reasoning machine according to the intention of system designer. It has great flexibility, but it also has the disadvantages of high transplant cost and poor expression process knowledge.

Knowledge base management includes modification and query of knowledge base. With the development of collision avoidance technology and the modification of collision avoidance rules, the system's collision avoidance knowledge base also needs to be modified and improved. In addition, in order to increase the transparency of the system, the knowledge base must also be able to query. Therefore, the function of knowledge base management must be included in the realization of the ship collision avoidance expert system.

The system setting mainly includes the setting of system working mode, automatic or manual setting and the setting of system working environment. In many cases, it is difficult to realize the automatic collision avoidance of ships without any participation. The main function of collision avoidance expert system is to help experts to make decisions on collision avoidance and conditional automatic collision avoidance, such as automatic collision avoidance in open water with simple meeting form. Therefore, the system must have two working modes, manual and automatic. The setting of system working environment refers to the setting of natural environment and static parameters of the ship.

Information Collection refers to collecting some necessary dynamic collision avoidance information through sensors, such as ship type, course and speed information, and ship distance and azimuth information by radar. Collision avoidance information is the basis of collision avoidance decision-making. When necessary collision avoidance information cannot be obtained through sensors, it can only be manually input by the driver.

Collision avoidance decision is the most important function of collision avoidance expert system. The system shall be able to make automatic collision avoidance decision based on the collected collision avoidance information, including the calculation of sum, the determination of safe passing
distance, the determination of distance in urgent situation, the calculation of ship collision risk degree, the judgment of encounter situation, the decision of collision avoidance action mode and range, etc.

Collision avoidance operation requires that the system can be connected with navigation control subsystem through appropriate interface program, so as to control the vehicle and rudder to operate the ship to avoid collision automatically according to the decision results of collision avoidance.

The following conclusions can be drawn from the simulation results of the decision-making process of system collision avoidance.

The system can dynamically determine the safe passing distance, the urgent situation distance, and the collision risk of the two ships according to the information of the ship and the environment.

The system can automatically judge the situation of two ships when they meet each other and make a decision whether to take collision avoidance action. After making decisions and taking actions, the system can also give the way, opportunity and range of collision avoidance actions to be taken, as well as the time to return to navigation after actions. It should be noted that the system does not give the opportunity to avoid collision separately, because the time of collision avoidance is determined according to the collision risk, that is to say, at that time, the system directly gives the action plan of collision avoidance.

The decision-making process of collision avoidance is simulated by computer. The simulation results of the starboard cross encounter, the ship overtaking other ships, and the encounter show that the system can well analyze and judge the situation of the encounter between the two ships, and give a reasonable and effective collision avoidance decision.

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