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# Study on Ships Safety Control System

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ABSTRACT: The proportion of main reasons of ships accidents to the whole reasons is discussed in the paper. Among these reasons, human factors are in the majority. So a method to prevent wrong orders sent by a navigator is laid emphasis on. On the basis of this, a ships safety control system is studied. The construction and control principle of the ships safety control system, as well as control strategy, implementation method and key technology are elaborated in the paper.

## 1 PREFACE

Although modern ships have been equipped with advanced facilities such as integrated bridge system, automatic navigation device, unmanned engine room, etc, fatal ships accidents still occurred from time to time. Safety has been the key issue which has restricted the development of ships. According to the analysis of ships accidents statistical data from IMO organization, there are three main kinds of reasons which have caused accidents: ① equipment failure in ship itself ② external environment( weather, oceanic condition, etc)③ human factor.

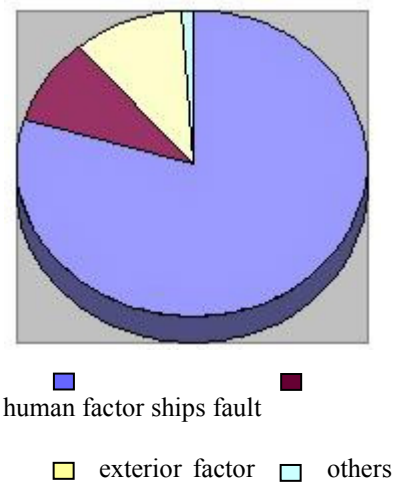


Figure 1. Proportion of reasons in ships accident

The proportion of these three reasons to the whole is shown in Fig. 1. From which it is obvious that more than eighty percent of ships accidents are caused by human factor. All the accidents caused by human factor due to wrong operation or misoperation when navigators have poor qualities, lack of watch, have poor capability in dealing with emergency, do not master marine traffic rules enough, etc. Therefore, in order to ensure safety navigating, eliminating the error of human factor is the most important issue we should deal with firstly. Except that the quality of navigator should be improved, ships safety control system should be set up, which would supervise ship's navigating condition, discover potential safety hazard in advance, and estimate the validity of operating order sent by a navigator. Especially in emergency, the system should make estimation rapidly, and then give some appropriate prompt, alarm, or orders of speeding down or blocking operations, so that safety can be ensured and accident can be avoided. The safety control system is studied in this paper. How to forecast ships accident and precaution of wrong order from navigator is the focal issue to be solved

## 2 BASIC THOUGHT OF SAFETY CONTROL SYSTEM

The ship navigation system is comprised of ship, navigation environment and navigation technology which is shown in Fig. 2.

Ship: a moving carrier which includes entity attribute of a ship (weight, size, draught, etc), running condition (course, navigational speed, etc), and motion characteristics (stowage, stability, heel, trim, swinging period, etc.).

Navigation environment: refers to exterior circumstance when ship moves. It contains water area environment, natural environment and transportation environment. Transportation environment covers obstacles in the area of navigation (fixed objects and floating objects), prescriptive lane and traffic rules, such as avoidance regulations, marine transportation safety laws, etc.

Navigation technology is referred to the technology and technique of navigating according to the moving condition of the ship.

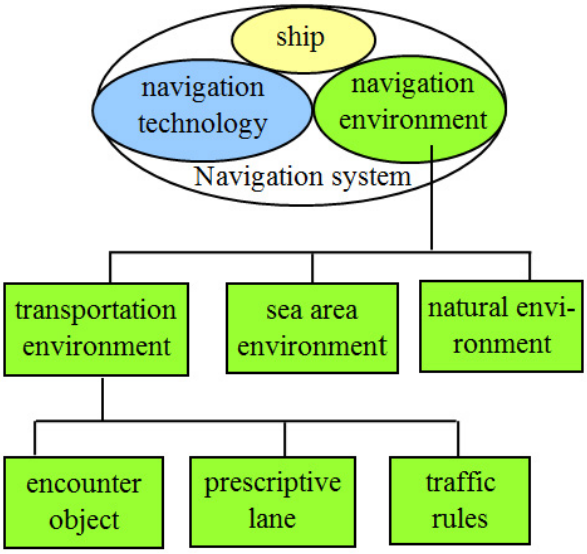


Figure 2. Construction of ship navigation system

It is obvious that among three factors of navigation system, the factor of ship is basically unchangeable, the factor of navigation environment constantly changes. The changes of environment do not lie on human beings. The factor of navigation technology is the drive technology that a navigator adopts based on the former two factors, which includes watching continuous, collecting information, comprehensive analysis, and adjusting according to changes. Thereby, in the course of navigating, navigation technology is the most decisive factor. It has been proved through the facts that most shipwrecks and collision accidents are caused by wrong operation or misoperation.

In recent years, with regard to the constituent of navigation system, great efforts have been made to improve safety of ship navigation. They mainly contain:

1 Improvement of ship: The ship size has been being bigger and bigger. Simultaneity, automation of ship has been being improved greatly. Functions of automatic navigation, supervision and control have been making perfect constantly. And hence ship manoeuvrability has becoming flexible and convenient, such as automatic navigation, location, turning, shifting, emergency shut-down, reversing, etc.
2 Improvement of navigation environment: Navigation environment is involved in transportation environment, sea area environment and natural environment. In which making transportation environment better is easy to be achieved. In recent years, masses of works have been done in scientific setting and management of lane, working out ship collision regulations, improving and perfecting transportation rules on sea, etc.
3 Improvement of navigation technology: For the sake of raising navigators' level of manoeuvre, IMO organization attaches high importance to improving the quality of navigators. They regulated WTC convention (compulsory) strictly for conforming and examining the process of training for navigators, promotion and going on duty, so that navigation technology can be improved.

All the efforts have played a great role in improving ships safety, otherwise, if we want to solve the problem of ships safety radically, a specific ships safety control system should be set up to predict accident potential and access the validity of orders sent by navigator so that human error can be eradicated completely. It is possible because the development of information technology, computer and network technology, as well as expert intelligent control technology, etc.

## 3 CONSTRUCTION OF THE SYSTEM

The core functions of the ships safety control system are forecasting accident potential and evaluating the correctness of each order sent by navigators. On the basis of equipments on board, a safety information network is established which contains a host computer, a server, the interface of data and network, control output, etc. The construction of the system is shown in Fig.3.

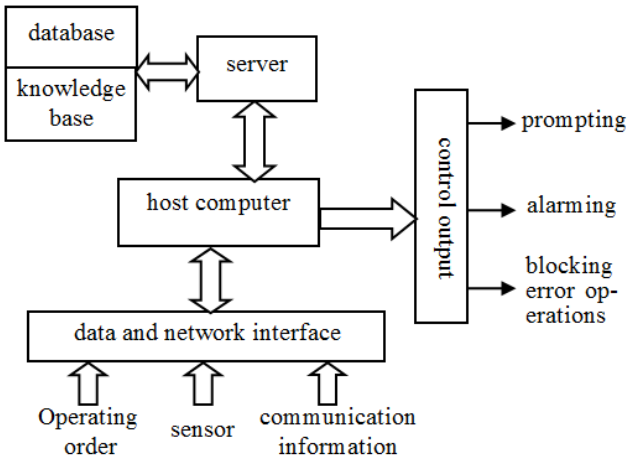


Figure 3. Construction of ships safety control system

The server is used for information integration, all data involved in ships is stored in it as a database and knowledge base. The interface of data and network is connected to sensors which are used to measure data related to safety ships, such as running parameters of main engine (velocity of a ship, etc.), running parameters of steering engine, information of ARPA, data of GPS, etc. Some data are transferred from sensors to host computer directly, otherwise most information are from network. The host computer is the nucleus of the system. All kinds of running data related to ships are collected then communicated to the host computer, and according to relevant information in the database, running conditions of the ship will be calculated in real time based on a model. Provided a potential risk is predicted, corresponding control will be outputted. The control contains three kinds of outputs: prompting, alarming, and blocking the error operations that could cause severe dangerous effect.

## 4 SAFE SPEED AND ACCIDENT PRECAUTION

Ship trajectory is determined by the course and velocity of a ship, noted as: $\sum l_i(V_i, S_i)$. Provided that in the area of a ship trajectory at a certain time, encounter objects varies in accordance with $V_n^2$ or $V_p^2$. Where, $V$ is the velocity of a ship, $n$ is the number of objects (ships, fixed objects and floating objects), $p$ is the density of objects in the specific area. The encounter rate of the ship with other objects is:

$$\lambda \propto V_n^2 \propto V / V^2 \propto 1/V \tag{1}$$

It is obvious that encounter rate is inverse proportional to velocity of the ship. Although increasing the speed could bring down the encounter rate, but the captain should also keep the ship at a safe speed in the trajectory if he wants to keep the ships safely. The concept of safe speed is put forward in IMO's new rules in 1972. It is defined as the speed relative to water that it can die away completely before the ship arrives at the collision point from anywhere. The concept of safe speed is used as the main foundation in this paper for forecasting ships accident. That is, if actual velocity exceeds the safe speed at any moment in the navigation, accident potential would exist. Based on the scanning information from ARPA radar, the object which is closest to the ship's course is regarded as a reference point at each moment, safe speed could be computed. The period of computing can be set, computing every 1 minute in normal navigation, or computing every 1/2 or 1/4 minute in the area of narrow waters or that the density of navigation object is greater.

There are many kinds of methods to calculate safe speed. In this paper one method is adopted, which is:

$$V_H = \frac{D_r - 2D_s - 2S_r}{2t_p} \tag{2}$$

where, $D_r$ is the distance from the ship to the closest object, $D_s$ is the safe distance which is not more than 1/2 of the distance that the target is in sight, $t_p$ is the time from the target in sight to that an order is sent, $S_r$ is the sliding distance from that an order is sent to that the ship stops completely.

$S_r$ is related to many kinds of factors, such as navigation velocity, braking force, etc. In order to shorten calculating time, a curve of navigation velocity which is corresponding to rev of propeller and braking distance should be stored in the host computer. The curve shows the relationship of ship's true speed $V$ (cable length/min) and rev of propeller according to the result of speed measurement every year on the measurement line, which is shown in Fig.4. Whenever calculation, firstly, the value of $D_r/2 - D_s$ (cable length/min) is got which is shown as point A in Fig.4. From the point A, a straight line is drawn parallel to x-axis, which crosses with stop line ($S_P + S_T$) at the point B ($S_T$ (cable length) is the sliding distance from that the target is in sight to that an order is sent). Then From the point B, a perpendicular line to x-axis is drawn, which crosses with ($S_P$) at the point C, the rev of propeller can be gotten as a result. Finally, from the point of C, a straight line is drawn parallel to x-axis, which crosses with y-axis at point D. The speed in point D is the safe speed.

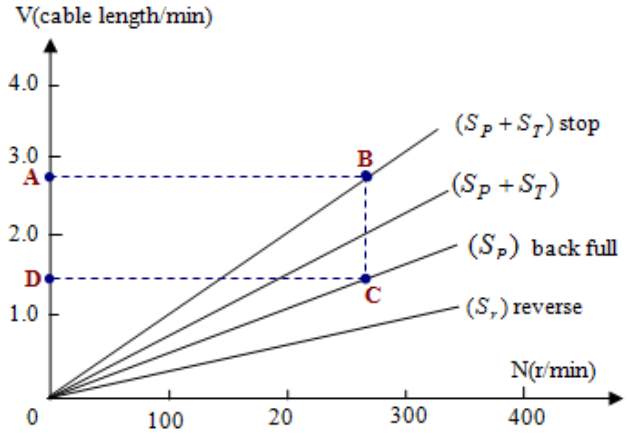


Figure 4. The schematic of computing the safe speed

## 5 STRATEGIES OF THE SYSTEM

Strategies of safety control system designed in the paper puts stress on calculating safe speed, then predicting accident according to information in database and knowledge base. The strategies can be divided into several types as follows:

1 When the ship is navigating at sea or on the broad surface of a water area, there are few targets. The safe speed calculated based on the closest distance of objects (very far generally) will be greater than the actual velocity (even greater than the top speed). Risk rate is very small.
2 When the safe speed calculated is close to the actual velocity, it means that it is near with the closest object. Risk rate is becoming greater. Potential encountering risk exists. At this time, the system should estimate that whether courses of them have the possibility of crossing. If crossing, the system should prompt the navigators.
3 When the safe speed calculated is less than the actual velocity, it means that the ship is very close to the object, risk rate is much greater. The ship is possible to collide with the object. An alarming signal will be sent immediately and slowing down or stopping the ship according to the difference between the safe speed and the actual velocity.
4 For each order sent by the navigator (rudder orders and engine orders), the system will search for the new closest object in the new course immediately and calculate the safe speed according to the change of course and velocity after the order is sent. If the safe speed calculated after the order is much less than the speed of the order, it interprets that danger will occur. The system will block the order at once so that it can not be sent to engine room.

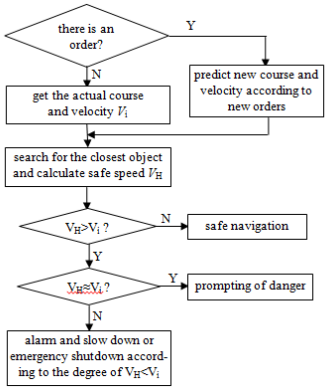


Figure 5. Strategy of safety control

For estimating the validity of an order, the system should not only base on the relationship of actual velocity and safe speed after the order is sent, but also base on the expert prior knowledge stored in database and knowledge base. Especially for emergency, it is important whether the order conforms to the emergency operation rules and collision avoidance rules. Consequently, it is one of the focal works to build a perfect safety database and knowledge base.

## 6 CONCLUSIONS

The prediction and safety control of ships accident is made a probe in this paper. The method of predicting an accident according to safe speed and estimating an order in real time is introduced. The key technology is integrating rules of safety relevant information and real-time data processing method. For the reason that there are many complex factors including in the system, many aspects have not been involve in this paper, such as processing rules after information integration, the reliability of sea scanning information, the influence of sea visibility, the real-time requirement of calculating speed, the establishment of expert judgment system, etc. But it is believed that the system of ships safety control system must play a great role in improving navigation safety by our efforts.

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