Studies on the Application of Bayesian Network in the Cause Analysis of Ship Collision

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Abstract: As an important means of logistics, shipping plays an important role in international trade. However, the growth of traffic density has increased the ship traffic accidents and collision takes up a greater portion. This paper renders the analysis of ship collision cases in recent years and summarizes the causes. By using the basic theory of Bayesian network, the paper sets up the collision cause model. The model can be used in the cause analysis in the probability of ship collision and prediction of accident probability in practice and thus effectively reduce the ship collision accidents.

Key words: Ship collision, Bayesian network, probability analysis.

1. Introduction

With the rapid development of economy, various trade activities are playing an important part. The congested sea traffic increases the chances of encounter and causes greater ratio of collision, which brings forth risks for sea transportation. For example, November 29th, 2010, the ship “Oriental Sea” collided with “Ali” in the area of Chengshantou. The collision broke the ballast tank of “Oriental Sea” and the head of “Ali.” The analysis shows that the deck officers failed to keep normal watching and took wrong actions in collision prevention. Therefore, it is necessary to find an effective means for the analysis on the causes of ship collision and take corresponding measures to improve the safety of shipping.

As a probability network, the Bayesian network [1] is based on probability theory and the Bayesian probability reasoning theorem. It demonstrates and describes the co-relationship [2] of the data in the form of network diagram. The composition of Bayesian network includes the panel points, directive line segments and the corresponding conditional

probability parameters of the panel points [3]. In order to construct the Bayesian network, it is necessary to determine the panel points and the corresponding conditional probability parameters by means of collecting and analyzing the data samples.

The studies of ship collision prevention have a long history. In the development of international shipping, the collision prevention regulations have been perfected. But little can be found in the cause studies of ship collision based on the application of Bayesian network, nor is seen the effect of the quantitative analysis on the various elements in ship collision accidents. Based on the self contained characteristics of the Bayesian network, it is extensively applied on the fields of data analysis, artificial intelligence and engineering inspection, etc., for determining the probability of the uncertainties for analysis and prediction of certain matters. This paper is applying the Bayesian network in the analysis of the ship collision accidents.

2. Cause Analysis of Ship Collision

In a broad sense, ship collision refers to one that takes place between two ships or among more ships and causes losses to one or more parties. In a narrow sense, ship collision can be understood in light

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of the definition of shipping laws. For example, Chinese shipping laws define that ship collision is one that refers to the ship contact at sea or navigable waters that are connected to the sea and that incurs losses.

The causes for ship collision can be manifold, but the relevant theories for accident analysis point at four facets that incur the accidents, man, machine, environment and management. As far as the causes for ship collision are concerned, in combination with the cases in the past years, the analysis can be based on the theories.

2.1 Human Factors

Case study shows that the ship collision accidents in navigation caused by human factors take up a greater ratio, including the wrong actions in watch keeping, collision prevention, judgment in the prevailing situations, adequate knowledge of the sailing waters, safety speed and excessive fatigue, etc[4].

2.2 Equipment Factors

They include the ship mechanical failures, such as drifting at sea on account of the main engine stop and inspection. The loss of maneuverability will surely cause the ship collision accidents.

2.3 Environmental Factors

The navigational environment refers to the natural environment in which the ship sails. The results of the adverse environment such as the maneuver difficulty caused by sailing in heavy weathers and the limited vision caused by the poor visibility, etc., will also lead to ship collisions.

2.4 Management Factors

One of the leading tasks of the shipping companies at the safety of water transportation is the routine management of the crew members. This includes the carrying out of the professional training, the

management of the competence, examination of the crew member proficiency, the management of the navigational documents, training and evaluation of the crew member safety awareness, etc.

The accident is not always caused by a single factor and it is usually the result of the interaction of various factors. The process of ship collision is shown in Fig. 1. It demonstrates that the analysis on the probability and interaction is of special importance.

3. The Ship Collision Cause Model Based on the Bayesian Network

3.1 Bayesian Network

The Bayesian network is combined with the Bayesian theory of the probability and graph theory for the use of the analysis and reasoning of the uncertain factors [5]. The probability theory includes the conditional probability, total probability, probability multiplication rule, chain rule and Bayes formula. For better understanding, here comes the brief introduction of the Bayes theorem.

Suppose the sample space of E is S, the incident A is of E, the incidents $B_1, B_2, B_3 \dots B_n$ are incompatible with each other, $B_1 \cup B_2 \cup \dots \cup B_n = S$ and $P(A) > 0$, $P(B_i) > 0$ ($i = 1, 2, \dots, n$), is then can be reasoned according to the multiplication theorem and conditional probability that:

$$P(AB_i) = P(A/B_i)P(B_i) = P(B_i/A)P(A)$$

$$P(B_i | A) = \frac{P(A | B_i)P(B_i)}{P(A)}$$

Put the formula into total probability formula:

$$P(B_i | A) = \frac{P(A | B_i)P(B_i)}{\sum_{i=1}^n P(A | B_i)P(B_i)}$$

This is the Bayes formula, in which the value of $P(B_i)$ is the prior probability and that of $P(B_i|A)$ is the posteriori probability. The process of reasoning the posteriori probability from the prior probability is achieved from the Bayes formula.

Fig. 1 Figure of collision process.

3.2 The Bayesian Network Model for Finding the Cause of Collision

In constructing the Bayesian network model for finding the cause of collision, for the accuracy of the evaluation results, there is higher requirement for the quality and quantity of the samples. In collecting the samples of the accidents, the paper selects the data samples of the collision that took place in recent years.

Now let us divide the human factors into three stages: receiving the external information, analyzing the information, judging and taking collision prevention measures. In addition, in order to extend the adaptability of the Bayesian network, the paper adds some other objective factors, mainly the mechanical and management factors, while the

environmental factors are not taken into consideration because they are not the main causes for ship collision [6]. Finally, 14 Bayesian network nodes are determined for the analysis of the factors that cause the ship collision accidents, as is shown in Table 1.

In addition, an extra node of “collision taking place” A is added to indicate that a series of factors causing the collision.

The definition of the important nodes is as follows:

3.2.1 Bad Watching D4

The COLREG regulates that all ships should use every effective means to keep the correct watching at any time. Watching is of critical importance in the duty standing of navigation and its purpose is to find the abnormal situations at an earlier time and timely collecting the external information for the final correct

Table 1 The selection of Bayesian network nodes.

Receiving the external information	Analyzing the information	Taking collision prevention measures	Mechanical failures
Improper watching D1			
Bad management D2	Failure in acquiring effective		Not using safe speed E1
Radar, AIS and navigational are not online D3	information C1	Wrong action B1	Failure in keeping the safe distance E2
Bad watching D4	Wrong judgment C2	Failure in taking collision prevention measures B2	Mechanical failures E3
Inadequate knowledge of route coming ship materials D5	Failure in timely finding the		Illegal navigation E4

Fig. 2 A Bayesian network model for the grounding of ship collision.

judgment and decision-making for collision prevention.

3.2.2 Wrong Judgment C2

The COLREG regulates that every ship should use all the effective means that suits the prevailing environment and situations to judge the danger of collision. In the practice of collision prevention, the crew members often use their experience for the judgment. Where the failure of using the effective means that suits the prevailing environment and situations to judge the danger of collision will often result in collision accidents [7].

3.2.3 Not Using Safe Speed E1

The COLREG does not contain the concrete level of the first safety speed, but requires that the speed should ensure the ship to avoid any sudden risks at any time. This requires that the deck officers should take into consideration all the prevailing situations

when determining the safety speed. In case of any change in the environmental conditions, it is necessary to adjust the speed and ensure the safety of the ship.

As there are only two situations in each node, happening and not happening, then only two values are in existence when choosing the thresholds of the Bayesian network nodes, i.e. The two values of {0,1}, 0 stand for not happening and 1 stands for happening.

There normally are three methods for constructing the Bayesian network. The first is direct determination according to the self experience, but this method is limited to the knowledge of the specialists. The second is using the data acquired to drive the generation of the Bayesian network. This method requires great amount of data as the basis, which influences the efficiency for the construction of the Bayesian network. The third is the two-stage modeling. This method integrates the privilege of the

forgoing two methods and can greatly improve the efficiency for constructing the Bayesian network with the clear relationship of the nodes. This paper adopts the third method for constructing the model [8].

Some of the Bayesian network structures are established via the analysis of the co-relation of the factors and association of the cause-effect chains of the samples. The cause chains of the samples are set up and the all the chains thus acquired are sorted out in forming the Bayesian network structure as is shown in Fig. 2.

4. Conclusion

This paper introduces the specific concepts of ship collision, cause analysis and Bayesian network and dwells upon the causes analysis and Bayesian network model. It also chooses the accident reports issued by the Maritime Administration as the sample to analyze the cause chains and establish the complete Bayesian network. It then selects some typical ship collision causes as the node variants for the Bayesian network to determine the thresholds of the nodes to construct the Bayesian network model for the cause analysis of ship collision. This model can be used for the probability analysis on ship collision and prediction

for the probability of collision in practice so as to take proper measures to prevent the accident.

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