Robust AI algorithm: a key technology to optimize ship intelligent collision avoidance system

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ABSTRACT

The current ship artificial intelligence anti-collision system is weak robust, which is characterized by displaying all detection objects, on the one hand, it will cause a load burden on the system, and on the other hand, the pilot needs to manually extract objects with collision risk and make collision avoidance decisions. In this paper, which is based on fault tree is used to calculate the collision probability in combination with industry experience in collision avoidance of innovation methods of artificial intelligence training platform, for the first time put forward to improve artificial intelligent collision avoidance system automatically choose to have strong robustness, collision danger mark makes the system automatically show key target of risk of collision, help the driver to make decision-making of collision avoidance.

1. Current research status of artificial intelligence collision avoidance system

1.1 Research advantages of artificial intelligence anti-collision system

In recent years, artificial intelligence collision avoidance system (robustness) has been widely studied and gradually practiced. Since 2021, ai collision avoidance systems have been purchased by major shipping companies. Company equipment, such as the ORCA AI integrated Marine navigation system information, and is equipped with independent thermal imaging light camera technology, the equipment can not only shown in the display radar, AIS, such as traditional navigation target, also can capture the radar is not easy to scan the goals, such as wooden fishing boat and labelled possessions integrated track shown in the display, Provide navigation environment information to pilots. The advantage of the equipment is to supplement the missing points of the traditional navigation equipment to capture objects, and enhance the awareness of the surrounding environment of the ship in the night or poor visibility environment. By improving the equipment performance and optimizing the algorithm, the visual observation assistance is enhanced to the maximum extent, and the objects around the ship are captured as much as possible. In September 2021, NYK Group announced the installation of a prototype ship Intelligent Collision avoidance and navigation system on one of its vessels to facilitate data collection and equipment testing. In early 2020, Maersk internally announced the installation of ship AI collision avoidance and navigation systems in its container fleet, and asked its crew to use the equipment as much as possible to improve the AI deep learning module. The artificial intelligence collision avoidance system equipment installed in the above two are purchased from the first-generation ship artificial intelligence collision avoidance and navigation system developed by Israel ORCA AI company. The feature of the system is that it makes up for the omission of small objects by traditional navigation equipment and makes the objects around the ship display more comprehensively.

1.2 Research on artificial intelligence anti-collision system is insufficient

However, from the observation of operation practice, the artificial intelligence anti-collision system also has obvious shortcomings at present, that is, there are too many display objects, leading to the driver can not quickly

$$P(\sum_{i=1}^{n} x_i) = 1 - \prod_{i=1}^{n} (1 - P_i)$$

retrieve the most helpful objects to avoid collision, so it is difficult to make the decision to avoid collision in the first time.

Considering that the application scenario of the system only stays in open water, once entering the narrow water with dense traffic flow, the driver still can only use the simple interface of radar and other traditional collision avoidance devices to make collision avoidance decisions. Therefore, in narrow waters with dense traffic flow, the robustness is weak: the collision avoidance data reflected by the equipment is too complex, causing excessive load to the system; Facing the overly complex object target interface, the pilot is difficult to concentrate on the object target which poses collision risk to the ship.

1.3 Methods to enhance system robustness

In order to enhance the robustness of the ship's artificial intelligence collision avoidance system, it is necessary to add the algorithm to highlight the objects constituting collision danger into the deep learning module of the artificial intelligence collision avoidance system, so that the system can broadcast the objects constituting collision danger to the ship in a centralized manner. Therefore, a collision probability model is established to calculate the collision probability of objects. Establish industry expert experience database and learn industry collision avoidance experience through AI deep learning function. Combined with the above two, a strong robust AI algorithm is obtained, which can provide drivers with simple objects with collision risk without missing dangerous objects, and can solve the key technology of the system robustness from weak to strong.

2. Explore key technologies for strengthening the robustness of intelligent ship collision avoidance system

The intelligent ship collision avoidance system should be optimized so that it not only outputs the object object information which needs to be focused on to the pilot, but also cannot omit the object object information which may cause collision, so the robustness of the system's autonomous selection of dangerous object should be enhanced. The solution is to make the system superimpose the industry experts' experience on the basis of the algorithm selection by establishing the model, and make the system automatically choose the most conducive to the output of collision avoidance information through the deep learning function of artificial intelligence.

2.1 Build collision probability algorithm model

In this paper, the method of building collision accident tree to calculate collision probability is used to help the system select objects with collision risk from probability algorithm.

Firstly, the accident tree is established according to different ship types, channel, port area, weather, fishing boats, Bridges and other underlying factors that affect ship collision. After simplification, the collision probability is calculated as follows:

When the fault tree is mutually independent events

1) : When the fault tree is a mutually independent event, the underlying obstacle is:

Failure probability: Equation 1:

.

Where: x1, x2, x3... Xn is the underlying barrier

P1, P2, P3... Pn is the accident probability of the underlying obstacle

The maximum and minimum values of faults can be calculated

2) : When the fault tree is a mutually exclusive event, the underlying obstacle is:

Failure probability: As shown in Equation 2:

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3) : When the fault tree is a compatible event, the underlying obstacle is:

Accident probability: As shown in Equation 3:

$$P(\sum_{i=1}^{n} x_i) = \sum_{i=1}^{n} P_i$$

Ship collision probability can be obtained through probability calculation of accident tree, and the value decreases from maximum to minimum. Combined with the autonomous learning algorithm of THE AI anti-collision system, a node can be selected from the probability calculated in the accident tree. The probability greater than the node accounts for a large proportion in the importance of the structure of the accident tree and has a great impact on the collision event, which should be marked in the output display of the AI anti-collision system. For the driver timely attention, make collision avoidance decision.

$x_1, x_2, x_3, x_4 \ldots\ldots x_n$

$$P(\sum_{i=1}^{n} x_i) = \sum_{i=1}^{n} P(x_i) - \sum_{i<j=2}^{n} P(x_i x_k) + \sum_{i<j<k=3}^{n} P(x_i x_i x_k) + \ldots + (-1)^{n-1} P(x_1 x_2 \ldots x_n)$$

2.2 Establish an ARTIFICIAL intelligence training platform based on the collision avoidance experience of industry experts

At present, the ship's artificial intelligence anti-collision system has the function of deep learning. For example, Artificial Intelligence and Deep Learning is one of the three functions of ORCA'S ORCA AI Platform. However, current deep learning relies on Thermal and day cameras to obtain image information and input the image information into AI intelligent deep learning module, so as to carry out deep learning of all the information included in the image. This learning module can only strengthen the capture function of all incoming ships or obstacles around the ship, but can not selectively optimize objects that pose collision danger. In order to highlight the function of capturing and displaying collision hazard objects, and even derive the function of making reasonable collision avoidance suggestions for collision hazard objects, the collision avoidance decision module with industry experts' experience should be added into the deep learning function of artificial intelligence collision avoidance system. In other words, the artificial intelligence training platform is used to increase the training content of industry experts' experience for ship intelligent collision avoidance system, so that the system has neurons based on human experience. Method: optimize the key technology of ship intelligent anti-collision system.

Industry collision avoidance experience requires a large amount of training for artificial intelligence, and collision avoidance decision-making has high requirements for ship safety. Therefore, artificial intelligence trained only by the experience of several experts obviously cannot meet the safety needs. The solution is to adopt the artificial intelligence platform based on cloud computing technology, open source the training users of artificial intelligence to all industry experts so as to increase the training samples, and adopt the AI cloud training platform based on Docker container technology and Kubernets container scheduling scheme technology to realize the construction of ship ARTIFICIAL intelligence collision avoidance system.

The training process of the system is as follows: 1) Setting up super administrator user, administrator user and general user. Among them, the super administrator user should be the ship AI anti-collision system development user, the main work content is: create training content, create administrator user; The administrator user should be the buyer of the ship AI anti-collision system, namely, the ship management company. The main work contents are as follows: assign general users to train a certain content intensively, such as image

classification that can produce collision risk factors; General users are industry experts, such as fleet drivers and captains, etc. Their main work content is: according to the assignment of management users, they complete the training of specified content through the cloud training platform, and feedback the training results to super management users for data integration. Figure 1: Schematic diagram of AI training platform.

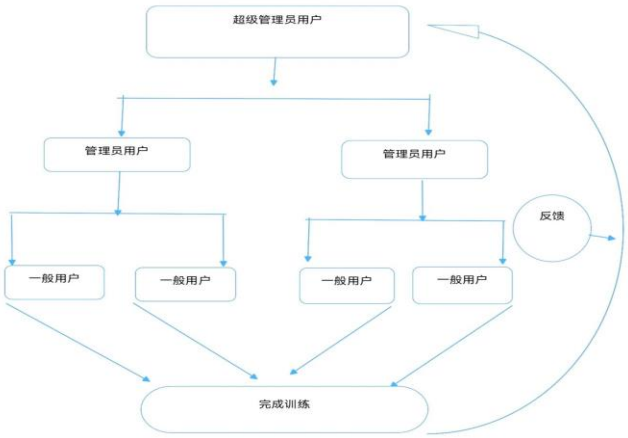

图1

Due to the complexity ar used as much as possible in the training environn and the training content according to the list and

Table 1: Grasping trainin system

The serial number	Trainir	attribute
1	The system n digit recognition c	Image recognition
2	The system is based on MNIST data set of CNN model for handwritten digital recognition of ship environment image	Image recognition
3	The system classifies the images of the ship's overall environment based on CIFAR-10 data set of CNN model	Image classification
4	The system is based on DNN model and Iris data set to identify varieties with collision risk	Characteristics of the classification
5	The system is based on the Faster R-CNN model and Pascal VOC data set for collision risk target detection	Target detection
6	Image semantic segmentation based on FCN model and Sift Flow dataset	Semantic segmentation

2.3 Evaluation of

Combined with in probability algorithm and in e underlying simplicity of have ollision - i.e., highlighting the k of the system can be tested by this paper to collect 11 ship ste ame situation as the basic data,

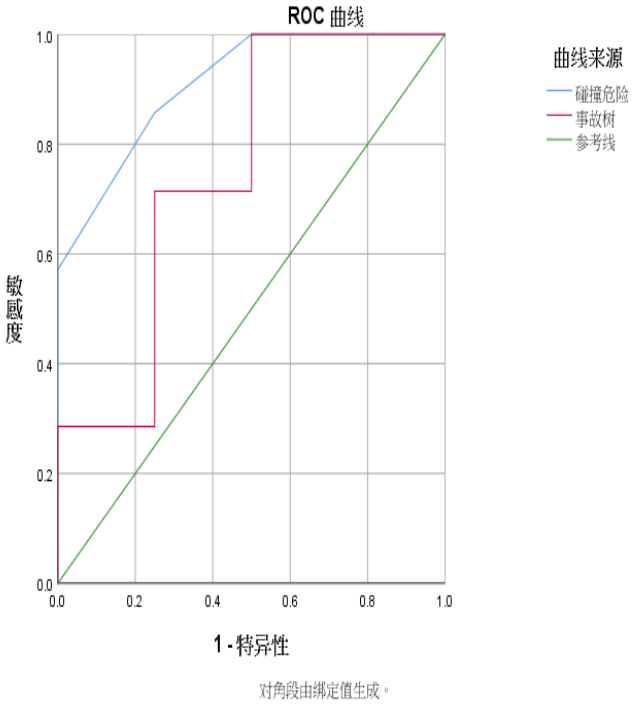

Table 2

Among them, experts' professional judgment of whether there is collision danger in this situation is 0-200; The collision risk probability of the accident tree is 0 -- 100, and the collision result is set as 1.

ROC curve drawn according to the data is shown in Figure 2: ROC curve.

	碰撞结果	碰撞危险	事故树
1	1.00	172.00	69.00
2	1.00	178.00	64.00
3	1.00	161.00	56.00
4	2.00	159.00	48.00
5	2.00	160.00	52.00
6	2.00	161.00	61.00
7	2.00	150.00	46.00
8	1.00	160.00	51.00
9	1.00	170.00	59.00
10	1.00	161.00	50.00
11	1.00	173.00	53.00

Figure 2

According to the ROC curve, the areas with collision risks are all on the reference line. Therefore, both experts

and accident tree can express the fact that collision risks exist in the same situation, which proves that the comprehensive application of human experience and accident tree analysis can enhance the robustness of the system. Based on the above analysis, this situation is shown on the output interface of AI anti-collision system with the highest priority, which can provide a reference for drivers to avoid collisions.

3. Brief assessment

Combining the establishment of ship collision probability algorithm model and the addition of AI anti-collision training content module by industry experts, the above system can improve the emphasis display of objects with collision risk in terms of probability algorithm and industry experts' experience. So that the ship pilots in the complex traffic flow environment to avoid comprehensive reading of environmental information, quickly grasp effective information, as soon as possible to make collision avoidance decision. The robustness of ship artificial intelligence anti-collision system in collision avoidance is enhanced, and the weak robustness is turned into strong robustness, which is a key technology for ship artificial intelligence anti-collision system to assist pilots to make collision avoidance decision.

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