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Intelligent Evaluation System of Ship Management

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ABSTRACT: The security of maritime traffic is a significant part of intelligent maritime traffic. It can reduce to ship maneuvering and collision avoidance by macroscopic. Eighty percents of marine accident induce by human factor from research data. So some researches about intelligent computer evaluation system to reduce the accident of human caused have emerged. Intelligent evaluation system of ship maneuvering can calculate the status of ship and getting the data of ship around, and then adopt fuzzy comprehensive evaluation method to calculate the collision risk and evaluate the operation of navigator. If it has danger of collision risk or the navigator adopts irrational operation scheme by calculating, the system will send message to the navigator. The navigator must affirm the messages, if there is not affirmance, the system will adopt collision avoidance measures or other rational operations automatically at the critical moment.

1 INSTRUCTION

The environment of navigation has great change in recent years. This make the maneuvering of ship be more difficult. At the same time, ARPA (Automatic Radar Plotting Aids), GMDSS(Global Maritime Distress &Safety System), GPS(Global Positioning System) and ECDIS(Electronic Chart Display and information System) etc. have applied in navigation, the number of crew is decreasing. This make more serious for manipulator. Eight percents of shipwreck accident were caused by human factor according to investigation.(Guedes Soares & Teixeira 2001, Gaarder et al. 1997) To decrease the accident, and increase the safety of navigation, researchers bring in automatic maneuvering to instead of human's job. This method makes up for some human's shortage, and increases work efficiency. However, they find that some accidents related to automatic equipment late years. Some person research the strand accident of "Royal Majesty" find that automation changed the style of working, and formed a new way to making mistake. So this paper proposes an intelligent evaluation system of ship maneuvering, human is the major in system, the system can calculate the status of ship and collision risk, then display it functionality. If the vessel gets into the critical area and time, the system will adopts corresponding strategy when the navigator does not adopt any measures.

2 HUMAN FACTOR

According data of Japanese Ship Safe Seminar in 1998, 84% shipwreck accident caused by human factor. Other country and region also have similar conclusion. The human's factor attaches importance to navigation safety, which has turn into people's consensus. Human have researched into human's factor indefatigably for ages, and form an academic domain "Human Factor"(Gaarder et al. 1997). With the purpose of enhancing security and efficiency, it is an extremely practical integrated subject. Human factor can bring positive impact on traffic at sea, for example human's cognitive and perceive capacity is stronger than instrument and equipment. It can bring negative impact reversely, for example making a mistake easily, forgetting memorial affair, limited analysis precision. Human's fault is one of major reason in shipwreck, and comes in for human's highly respect.

Fault is the property of human, removing the fault completely is an unpractical. Therefore, we should adopt measures to reduce the harmful consequence brought by man. To achieve a job, division of labor is an efficacious practice. BRM (Bridge Resource Management) and BTM (Bridge Team Management) at sea are discussed more by researchers of last year. VTS is a system of construct with vessels taking part in VTS and VTS organization. It has correction capability on the part of whole system. VTS attendant will correct it when ship has breach of regulation phenomenon. Another method to reduce fault is using alerting equipment. The equipment send out warning to cause human's attention when mistake occurs. For example, ARPA can send out sound and light warning when the DCPA and TCPA are smaller than a setting value. Britain, Germany and Japan develop BNWAS used to monitor steering and sailing on duty. This system used to monitor the alert of navigator, if the equipment detects that navigator cannot perform the duty of his, it will send out gradated outspread warning. At first, it will be in cage, if there is no response it will extend to caption and other sailor's room.

3 INTELLIGENT EVALUATION SYSTEM

Traditional collision avoidance is that the sailor adopts empirical collision avoidance according to self-experience. It depends on navigator's individual intuition to make decision, if the risk is large, it will be easy to make mistake. Collision avoidance expert system and decision-making support system spring up rapidly of late years. They have great auxiliary effect to vessel collision avoidance.

Human is the principal part in the evaluation system of ship maneuvering. We make use of computer and develop intelligent evaluation system of ship maneuvering. The system can gather dynamic information of vessel by AIS, ARPA, infrared and photo electricity equipments(Thomas et al. 2008). The information will be sent to the intelligent evaluation system finally, the system will enter into different model according to encounter situation and environment condition. The result of evaluation is the current situation of ship.

3.1 *The Structure of Intelligent Evaluation System*

The evaluation system consist of many models, including target ship identification, speculation and prediction of encounter status, real evaluation of operation, auto-collision avoidance strategy and risk warning model etc. We can see from Fig. 1, the evaluation system and operation of navigator form a closed-loop control system. The system will evaluate the performance of operation, and send out corresponding signals. In this way it can make up the disadvantage of none precision calculation of human, cut down the probability of human fault occurrence, and secondly make use of human's high adaptability sufficiently.

3.2 *Collision Risk Calculation*

Ship collision risk calculation is one of the most important parts in the system. The quantification of collision risk experience several stages basically(WU Zhao-lin & ZHENG Zhong-yi 2001). The first one is traffic flow theory which use ship collision rate, encounter rate, collision probability to evaluate the collision risk for special water area. The second is ship domain and arena which is based on human praxiology and psychology. (Fuji & Tanaka 1971), (Goodwin 1975) etc. who use this to calculate collision risk. In the third stage, people have considered the dCPA(Distance at Closest Point of Approach) and tCPA(Time at Closest Point of Approach) in calculation, like (Davis et al. 1980). In the fourth stage, combine dCPA and tCPA, adopt weighting method to calculate collision risk at the beginning(Kearon 1979, Imazu& koyama 1984). This method exist obvious disadvantage that dCPA and tCPA are two different variable. Then people adopt fuzzy theory to combine dCPA and tCPA. At present mostly research are based on the artificial intelligent technology as fuzzy theory, expert system, neural network to calculate the collision risk(LI Lina 2006).

This paper adopt fuzzy compressive evaluation to calculate CR(collision risk). The comprehensive evaluation result can be used as subjective evaluation, and also can be as objective one. Furthermore, system security is a progressively process. We can get perfect result through assessing the subordination of the factors. So we don't use the weighting of dCPA and tCPA to calculate collision risk, they applied fuzzy comprehensive evaluation in it. There are many factors effecting CR. We only consider the major factors here, the distance between target ship and local ship d, the position of target ship θ, $dCPA$, $tCPA$. So the target factors' discourse domain is:

$$u = \{d, \theta, dCPA, tCPA\}$$

The allocation of target factors weight is:

$$A = (w_d, w_\theta, w_{dCPA}, w_{tCPA})$$

$w_d > 0$, $w_\theta > 0$, $w_{dCPA} > 0$, $w_{tCPA} > 0$, and

$$w_d + w_\theta + w_{dCPA} + w_{tCPA} = 1$$

Expert recommend:

$$w_d = 0.12, w_\theta = 0.12, w_{dCPA} = 0.38, w_{tCPA} = 0.38$$

Target evaluation matrix is:

$$B = \begin{bmatrix} r_d \\ r_\theta \\ r_{dCPA} \\ r_{tCPA} \end{bmatrix} \tag{1}$$

$0 \le r_d \le 1; 0 \le r_\theta \le 1; 0 \le r_{dCPA} \le 1; 0 \le r_{tCPA} \le 1;$

$r_d, r_\theta, r_{dCPA}, r_{tCPA}$ are target risk membership.

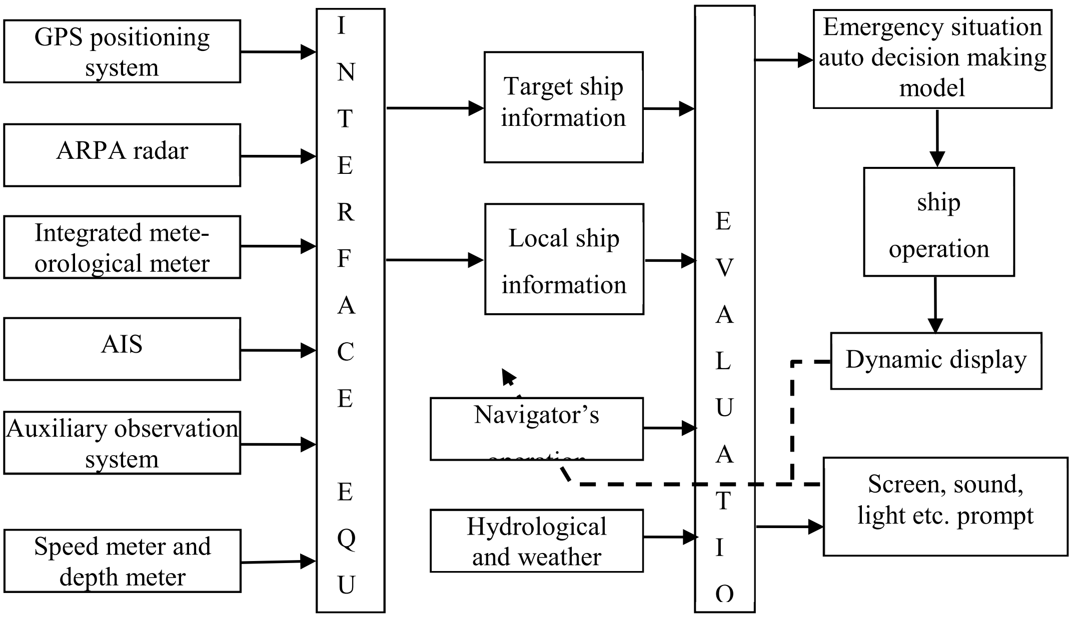

Figure1 . The diagram of evaluation system of ship maneuvering

Distance risk membership function is:

$$u(d)=\begin{cases}1 & d\le d_l\\ [(d_m-d)/(d_m-d_l)]^2 & d_l<d\le d_m\\ 0 & d>d_m\end{cases}\qquad(2)$$

d_l distance of the last minute avoidance

d_m distance of adopt avoidance action

$d_l = K_1 \cdot K_2 \cdot K_3 \cdot DLA$

$d_m = K_1 \cdot K_2 \cdot K_3 \cdot R$

K_1 decided by visibility,

K_2 decided by water area status,

K_3 decided by human factor,

DLA distance of the last minute action,

R is the radius of arena.

$$R = 1.7\cos(\theta-19^\circ)+\sqrt{4.4+2.89\cos^2(\theta-19^\circ)]},(0^\circ \le \theta < 360^\circ)\qquad(3)$$

Position of target ship membership function:

$$u(\theta)=\begin{cases}\dfrac{1}{1+(\theta/\theta_0)^2}, & 0\le\theta<180^\circ\\ \dfrac{1}{(\dfrac{360^\circ-\theta}{\theta_0})^2}, & 180^\circ\le\theta<360^\circ\end{cases}\qquad(4)$$

θ_0 is according to the velocity ratio K of local ship and target ship

$$K=\frac{v_0}{v_t}\qquad(5)$$

$$\theta_0=\begin{cases}40^\circ & K<1\\ 90^\circ & K=1\\ 180^\circ & K>1\end{cases}\qquad(6)$$

dCPA risk membership function:

$$u(dCPA)=\begin{cases}1 & ,dCPA\le\lambda\\ \frac{1}{2}-\frac{1}{2}\sin[\frac{\pi}{dCPA_0-\lambda}(dCPA-\frac{dCPA_0+\lambda}{2})], & \lambda<dCPA\le dCPA_0\\ 0 & ,dCPA>dCPA_0\end{cases}\qquad(7)$$

$\mathrm{dCPA}_0 = 1\,\mathrm{n\ mile}$,

$\lambda = 2(L_0 + L_t)$, L_0, L_t are the length of local and target ship.

tCPA risk membership function:

$$u(tCPA)=\begin{cases}1 & tCPA\le t_1\\ \dfrac{t_2-tCPA}{t_2-t_1} & t_1<tCPA\le t_2\\ 0 & tCPA>t_2\end{cases}\qquad(8)$$

$$t_1=\frac{\sqrt{(d_l^{\,2}-\lambda^2)}}{v_s}\qquad(9)$$

$$t_2=\frac{\sqrt{(d_m^{\,2}-dCPA_0^{\,2})}}{v_s}\qquad(10)$$

According to the fuzzy comprehensive evaluation method.

$$CR = A\cdot B=(w_d,w_\theta,w_{dCPA},w_{tCPA})\cdot\begin{vmatrix}r_d\\ r_\theta\\ r_{dCPA}\\ r_{tCPA}\end{vmatrix}\qquad(11)$$

Collision risk is:

$$CR = [w_d u_d + w_\theta u_\theta + w_{dCPA} u_{dCPA} + w_{tCPA} u_{tCPA}] \quad (12)$$

4 RESULTS

In a water area, local ship: course 000°, velocity 15 kn, length 75m, the visibility is better(K1=1, K2=1, K3 =1), adopt DLA=1 n mile. Get the data from ARPA, target ship: position θ=29.5°, distance d=3 n mile, relative velocity vs=26.2 kn, dCPA=0.4 n mile, tCPA= 7 min, length of target ship 110m. calculate the collision risk of target ship against local ship.

According to the data and associative formula, we can obtain:

u(dCPA) = 0.8500,

u(tCPA) = 0.3633 ,

u(θ) = 0.6477,

u(d) = 0.1624.

Divide the collision risk into 5 level:

- I—— 1.00～0.91
- II—— 0.90～0.81
- III—— 0.80～0.71
- IV—— 0.70～0.61
- V—— 0.60 ～0.51

According to this division, 0.56 belong to IV level, middle danger. At this moment, the evaluation system will display this for navigator. Navigator will adopt suitable measures according to the information and self judgment. The evaluation will calculate the encounter status of two ships in real time. The system will send an alarm to navigator for correcting it when navigator adopts irrational operation. If there is not any response at the point of last helm, the system will adopt automatic collision avoidance strategy.

5 CONCLUSION

Navigation is human's job, human factor have finality affect to navigation safety, especially human's fault, and it is one of the major reason of shipwreck. Human's fault is unforeseen and unconquerable completely, so we must adopt additional precautions to improve and make up the affect of human's fault to navigation safety. With the development of information technology, computer is an advantageous auxiliary facility. Human coordinate with computer by constructing intelligent evaluation system of ship maneuvering which makes up human weakness and also solves the problem that computer is not adaptable to environment. It makes use of the advantage of human's adaptability and computer's calculation capacity. Therefore, this is a man-machine associative method, and it is advantageous instrument in navigation.

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