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Intelligent maritime rules based on unmanned collision

Siyuan Yang, Yuhao Sun

Shipping College, Shandong Jiaotong University, Weihai 264299, China

Abstract

For unmanned boat in the process of the actual navigation situation, through the introduction of international maritime rules specific unmanned boat and the ship will meet the chase, cross meet and meet, followed in the sea based on the constraints of the collision rules, the introduction of polar coordinates derived based on maritime rules under the collision model, to the follow-up research unmanned boat collision provide a new solution.

Keywords

Maritime rules, surface unmanned boats, intelligent collision avoidance.

1. Introduction

With the surface of the unmanned craft (Unmanned Surface Vessels, USV), the rapid development in recent years, now, Unmanned craft have achieved tremendous results in a variety of military and civilian fields, However, due to the current international management organizations on the division of surface unmanned boats and traditional ships is controversial, The relative lack of research on its unmanned craft in ocean modeling, In view of the situation that unmanned boats will encounter in the actual navigation and the intelligent collision avoidance strategies in accordance with the international maritime collision avoidance rules, By derive the collision avoidance model, It provides a new solution for the continuous study of intelligent collision avoidance of unmanned craft.

2. International maritime collision avoidance rules are elaborated

The International Maritime collision avoidance Rule (International Regulations for Preventing Collisions at Sea COLREGS) is a general Marine ship operation traffic rule [1] proposed by the Maritime Consultative Organization in 1972. Since there are no special laws and regulations for the navigation code of unmanned boats, in order to ensure the navigation safety of unmanned boats as far as possible and avoid the impact with other ships to the maximum extent, unmanned boats should also abide by the COLRGEGS Convention when sailing at sea. According to the international sea The division of Chapter 2 of the collision avoidance rules makes the possible collision situations of unmanned boats in the process of sea navigation as follows [2]. Under the meeting situation, the two ships are subdivided into three situations: chase, cross encounter and opposite encounter, and their meeting encounter situation is defined as shown in Fig 1.

The International Maritime collision avoidance Rule (International Regulations for Preventing.

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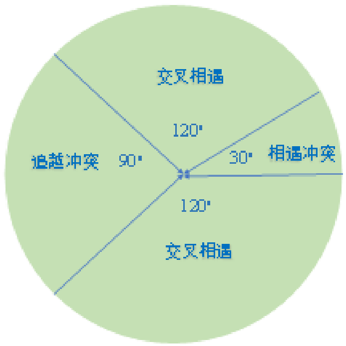

Fig 1 unmanned boats will encounter scenes when sailing at sea

Encounter situation: When the unmanned boat and the opposite ship meet their heading angle difference, it can be judged in the encounter situation $|\Delta\theta| < 30°$ [3]. It is defined as two ships traveling on opposite or near opposite courses, followed by a tendency to constitute a collision risk. As shown in Fig 2, both the drone and the drone should turn to the right, allowing the drone to pass on the left side of his ship.

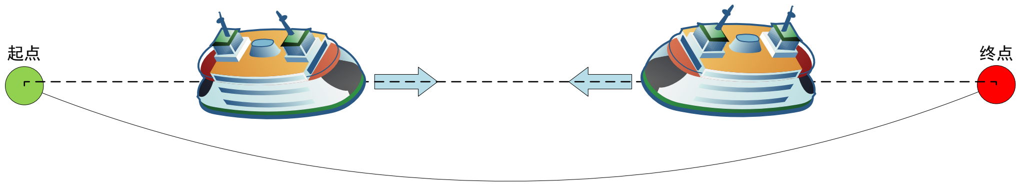

Fig 2 The encounter model

Chasing situation: When the unmanned boat is located in the rear of his ship, if the speed of the unmanned boat is higher than the overtaken ship and the heading angle is poor, it is in the pursuit situation $|\Delta\theta| < 45°$ [4]. As shown in Fig 3, the drone should turn to the port side and pass through the left side of his ship.

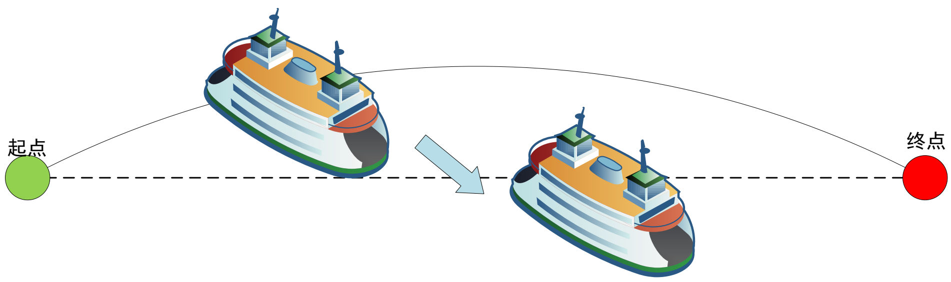

Fig 3 Recreases over the model

Cross-encounter situation: when the unmanned boat cross-meets his ship and has a trend of collision risk under the current sports situation, corresponding measures can be taken to avoid the risk[5] $45° < \theta < 165°$. If the heading Angle of the unmanned ship and the other ship is at, the right avoidance model should be adopted. As shown in Fig 4, the unmanned ship should sail to the right. If the heading Angle of the unmanned ship is at the other ship, the left avoidance model should be adopted. As shown in Fig , the unmanned ship should sail to the left. $195° < \theta < 315°$

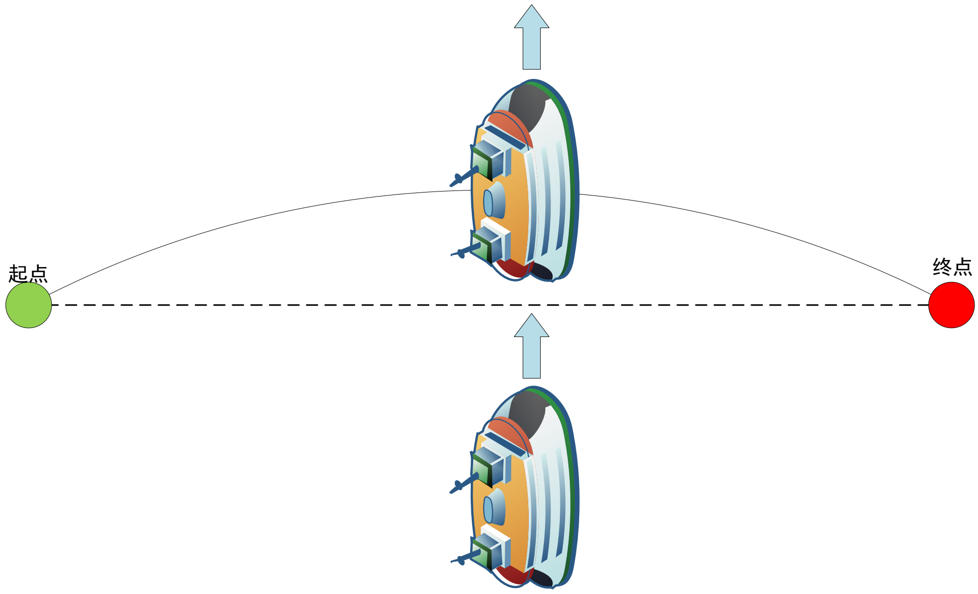

Fig 4 The starboard avoidance model

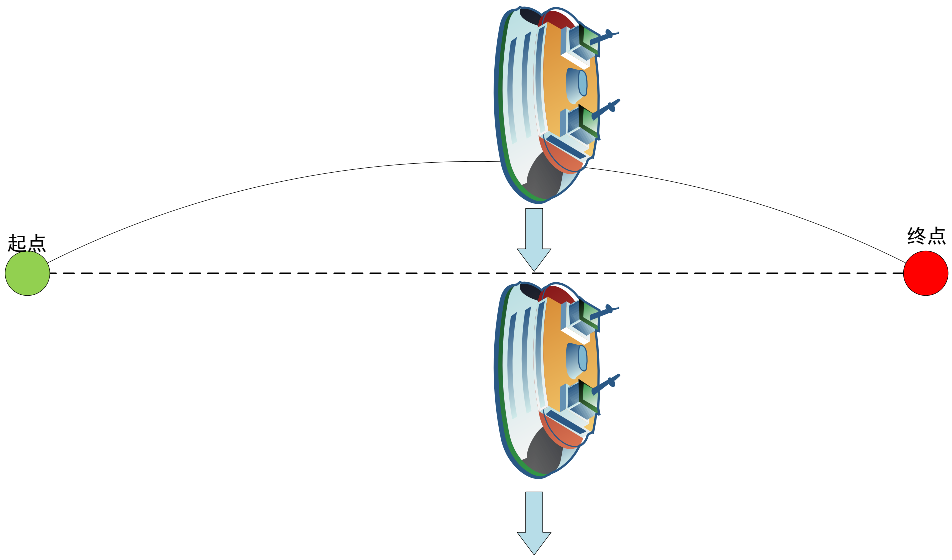

Fig 5 Port shelter model

The decision-making process of unmanned boat can be summarized as: information collection, determine whether it will happen, and determine whether there is a collision danger according to the existing information, adopt collision avoidance strategy, and resume navigation after the danger is lifted[6].

3. Establishment of collision avoidance model in line with maritime rules

The schematic diagram of the unmanned ship movement is shown in Fig . The parameters are described as follows: the polar coordinate system is established with the unmanned ship as the center and the heading direction of the unmanned ship[7] v_{usv} v_{bar} α v_{usv} $\alpha = \angle(v_{usv}, e_\chi)$ e_χ $\beta = \angle(v_{bar}, e_\chi)$ v_{bar} The motion speed of the unmanned ship is expressed as, the motion speed of the dynamic obstacle is expressed as, established from the unmanned ship as the origin and the pole axis, which can be expressed as, including the pole axis; and the angle from the pole axis. The connection between the unmanned boat and the center of the obstacle is indicated, where the angle between the pole axis to the connection is indicated; is the angle to. $\angle_{RO}$ $\theta=\angle(\angle_{RO},e_{\chi})$ $\varphi=\angle(v_{usv},e_{\chi})$ Δv v_{usv} $\gamma=\angle(\Delta v,\angle_{RO})$ $\mu=\angle(\angle_{RO},\tan\angle)$ $\tan\angle$,; Is the tangent of the obstacle circle[8].

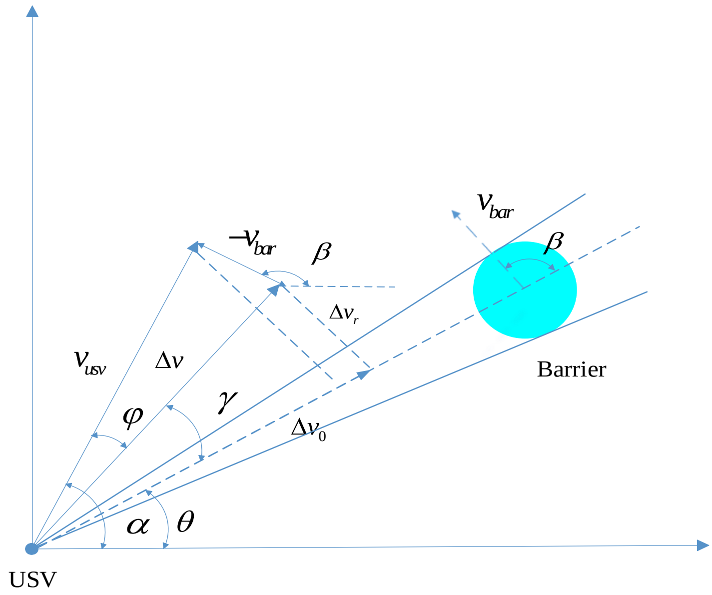

Fig 6 The obstacle avoidance model diagram

3.1. Unmanned boats meet the derivation of obstacle avoidance inequality

support Δv Decposing into the velocity component pointing to the center of the obstacle Δv_0 And the vertical velocity component Δv_{γ}, pass through V_{usv} 、 、 V_{bar} Δv It is solved by triangles Δv_r And γ 。

$$\begin{cases} \Delta v_r = v_{usv}\sin(\alpha-\theta) - v_{bar}\sin(\beta-\theta) \\ \Delta v_0 = v_{usv}\cos(\alpha-\theta) - v_{bar}\cos(\beta-\theta) \end{cases} \tag{1}$$

$$\gamma = \arctan^{-1}\left(\frac{v_{usv}\sin(\alpha-\theta) - v_{bar}\sin(\beta-\theta)}{v_{usv}\cos(\alpha-\theta) - v_{bar}(\beta-\theta)}\right) \tag{2}$$

$$f = \frac{v_{usv}\sin(\alpha-\theta) - v_{bar}\sin(\beta-\theta)}{v_{usv}\cos(\alpha-\theta) - v_{bar}(\beta-\theta)} \tag{3}$$

$$d_{\gamma} = d\{\arctan^{-1}\left(\frac{v_{usv}\sin(\alpha-\theta) - v_{bar}\sin(\beta-\theta)}{v_{usv}\cos(\alpha-\theta) - v_{bar}(\beta-\theta)}\right)\} \tag{4}$$

$$d_{\gamma} = d\{\arctan^{-1}\left(\frac{v_{usv}\sin(\alpha-\theta) - v_{bar}\sin(\beta-\theta)}{v_{usv}\cos(\alpha-\theta) - v_{bar}(\beta-\theta)}\right)\} = d(\arctan^{-1} f(v_{usv},\alpha,v_{bar},\beta)) = \frac{1}{1+f^2}df$$

$$\frac{1}{1+f^2} = \frac{(v_{usv}\cos(\alpha-\theta) - v_{bar}\cos(\beta-\theta))^2}{v_{usv}{}^2 + v_{bar}{}^2 - 2v_{usv}v_{bar}\cos(\alpha-\beta)} \tag{5}$$

$$df = df(v_{usv},\alpha,v_{bar},\beta) = \frac{\partial f}{\partial v_{usv}}dv_{usv} + \frac{\partial f}{\partial \alpha}d\alpha + \frac{\partial f}{\partial v_{bar}}dv_{bar} + \frac{\partial f}{\partial \beta}d\beta \tag{6}$$

$$\frac{\partial f}{\partial v_{usv}}dv_{usv} = \frac{v_{bar}\sin(\beta-\alpha)}{[v_{usv}\cos(\alpha-\theta) - v_{bar}\cos(\beta-\theta)]^2}dv_{usv} \tag{7}$$

$$\frac{\partial f}{\partial \alpha}d\alpha = \frac{v_{usv}^2 - v_{bar}v_{usv}\cos(\alpha-\beta)}{[v_{usv}\cos(\alpha-\theta) - v_{bar}\cos(\beta-\theta)]^2}d\alpha \tag{8}$$

$$df = \frac{\partial f}{\partial v_{usv}} dv_{usv} + \frac{\partial f}{\partial \alpha} d\alpha = \frac{v_{bar}\sin(\beta-\alpha)}{[v_{usv}\cos(\alpha-\theta)-v_{bar}\cos(\beta-\theta)]^2} dv_{usv} + \frac{v_{usv}^2 - v_{bar}v_{usv}\cos(\alpha-\beta)}{[v_{usv}\cos(\alpha-\theta)-v_{bar}\cos(\beta-\theta)]^2} d\alpha$$

$$d\gamma = \frac{v_{bar}\sin(\beta-\alpha)}{v_{usv}{}^2 + v_{bar}{}^2 - 2v_{usv}v_{bar}\cos(\alpha-\beta)} dv_{usv} + \frac{v_{usv}^2 - v_{bar}v_{usv}\cos(\alpha-\beta)}{v_{usv}{}^2 + v_{bar}{}^2 - 2v_{usv}v_{bar}\cos(\alpha-\beta)} d\alpha \quad (9)$$

$$\Delta\gamma = \frac{v_{bar}\sin(\beta-\alpha)}{v_{usv}{}^2 + v_{bar}{}^2 - 2v_{usv}v_{bar}\cos(\alpha-\beta)} \Delta v_{usv} + \frac{v_{usv}^2 - v_{bar}v_{usv}\cos(\alpha-\beta)}{v_{usv}{}^2 + v_{bar}{}^2 - 2v_{usv}v_{bar}\cos(\alpha-\beta)} \Delta\alpha$$

$$\begin{cases} v_{bar}\sin(\beta-\alpha) = \Delta v_{\sin_\varphi} \\ v_{usv} - v_{bar}\cos(\beta-\alpha) = \Delta v\cos\varphi \\ v_{usv}{}^2 + v_{bar}{}^2 - 2v_{usv}v_{bar}\cos(\beta-\alpha) = \Delta v^2 \end{cases} \quad (10)$$

$$\Delta\gamma = \frac{-\sin\varphi}{\Delta v}\Delta v_{usv} + \frac{v_{usv}\cos\varphi}{\Delta v}\Delta\alpha \quad (11)$$

The dangerous area is: $(\angle_{RO} - \mu, \angle_{RO} + \mu)$, In order to ensure that the unmanned boat can avoid obstacles, it should be met $\Delta\gamma$ The following inequality relationships are met[9].

Optimal obstacle avoidance scheme:

$$\begin{cases} \Delta\gamma \geq \mu - \gamma, \text{如}\gamma > 0 \\ \Delta\gamma \leq -(\mu+\gamma), \text{如}\gamma < 0 \end{cases} \quad (12)$$

Worst obstacle avoidance scheme:

$$\begin{cases} \Delta\gamma \leq -\mu - \gamma, \gamma \geq 0 \\ \Delta\gamma \geq \mu - \gamma, \gamma < 0 \end{cases} \quad (13)$$

$\Delta\gamma$ v_{usv} $\Delta\alpha$ Formula (11) shows that there is a correlation between the speed change and the heading change of the unmanned craft. So you can change it into speed change and heading change v_{usv} $\Delta\alpha$ [10].

4. Conclusion

This paper first discusses the actual situation of unmanned boats in the sea navigation, and by introducing the convention based on sea route rules, unmanned boats are subdivided into chase, cross encounter and three situations under the encounter with other ships[11], Second by using the sensitivity of polar axis of Angle and space, derived based on the maritime rules of collision avoidance model, elaborated the unmanned boat optimal collision avoidance strategy and the worst collision avoidance strategy, prove that the unmanned speed change and course change correlation, better for the further study of unmanned boat intelligent collision avoidance lay the foundation.

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