

# The division of action situation of collision avoidance in intelligent collision avoidance system

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**Abstract:** Based on the investigation on mariner's behaviors in collision avoidance, actuality of collision avoidance at sea and the research on the uncertainty of collision avoidance behaviors adopted by two encounter vessels, and for the purpose to reduce the no-coordination action of collision avoidance between two encounter vessels, and on the base of different encounter situation in international convention for preventing collisions at sea, the concept of action situation between two encounter vessels is proposed, and the directions for every encounter vessel to adopt course alteration to avoid collision are explained in different action situation. The mechanism of avoidance and reduction of no—coordination is established in intelligent collision avoidance system, and it is important to research on intelligent collision avoidance system.

**Key words:** intelligent system of collision avoidance; ship; acting situation

## 1 Introduction

The purpose of division of tree encountering situations is to determine the responsibility and privilege of two encountered ships in collision avoidance in good visibility in the International Regulations for Preventing Collision at Sea, 1972. One ship has the responsibility to give way and the other has the responsibility to keep her course and speed in a crossing situation. But if the stand-on ship is on the different relative bearings of the given-way ship, the given-way ship may take different actions of collision avoidance in crossing situations. In some encountering situations the given-way ship may alter course on starboard, and in the other encountering situations, she may alter course on port. Moreover, if the ratio of two encountering speeds is constant, and the relative bearings of stand-on ship are more than a certain value, the given-way ship altering course on port may be more advantageous to collision avoidance than on starboard, and the loses of deviation of course and position to the given-way ship may be smaller. Therefore, besides the division of encounter situations, there is also division of acting situations of given-way ship.

The purposes of research on the acting situation of given-way ship in intelligent system of collision avoidance are: first, have no standard of division of acting situations in the world, at the same time, the division of encountering situations is general. If the established intelligent system of collision avoidance adopted the division of encountering situations, will not fit for the actual conditions of collision avoidance and may result new risk. Second, formulize the process of collision avoidance, and regard as a part of knowledge base of intelligent system of collision

avoidance; third, make the most possible action adopted by the given-way ship in collision avoidance, so if the given-way ship does not take action to avoid collision, the stand-on ship may take proper action if necessary to avoid collision and non-coordination.

## 2 the concept and division of ship acting situation

### 2.1 The concept of ship acting situation

The ship-acting situation is defined as an encountering situation between the given-way ship and stand-on ship, the situation is determined according to the encountering situation of collision avoidance rules, the practice of seaman at sea; and considering the speeds ratio of two encountered ships, the losses of course deviation caused by course alteration of on starboard or port.

### 2.2 The division of acting situations

The ship acting situation is divided based on the three encountering situations of the Rules in good visibility. The acting situation divided shows in figure 4.

The acting situations of collision avoidance are divided into A、B、C、D、E、F six categories. In which, if a ship is in area A, the ship is stand-on ship, and the other ship should alter course on starboard to avoid collision; if a ship is in area E, she is given-way ship, the other one is stand-on ship and does not take action of collision avoidance generally. If the given-way ship does not take action and the closing situation is formed, the stand-on ship will alter her course on starboard; if a ship is in area C or D, she is given-way ship, the other one is being overtaking and should keep her course and speed. If the given-ship does not take any action, the stand-on ship will take coordinating action according to position of the given-way ship and the initial DCPA; if the a ship is in area B, she is a stand-on ship, the other one is a given-way ship and will alter her course on starboard or port based on the speeds ratio of the two encountering ships, the losses of course deviation.

The determination of the dividing-line between area C and D: through the analysis of the 236 pieces of inquiry questionnaire, if the overtaking ship is on  $210^\circ$  of the relative bearings of the being overtaken ship and  $DCPA = 0$ , the action ratios of alteration of course on starboard and on port in total is almost the same as 50%. Therefore, the dividing-line between C and D is  $210^\circ$  which is the overtaking ship on the relative bearings of the being overtaken ship.

Then, if a ship is in the area C or D and overtaking the other one so as to involve collision risk, and the overtaking ship did not take any action of collision avoidance, which side the privilege ship would turn on? or if a ship is on the area of C or D and overtaking the other one, what kind of action she will adopt? This knowledge should be contained in the knowledge base of intelligent system of collision avoidance.

Through the statistic analysis of the 236 pieces of inquiry questionnaire, shows that: if the own ship is overtaking the other one, there are 89.75% officers in charge to determine their action according to the own ship's position and the initial DCPA. If own ship situated in area D and  $DCPA \leq 0$  or own ship's course is paralleled with the other ship, own ship would alter course on port; if own ship situated in area D and  $DCPA > 0$ , own ship would alter course on starboard. If own ship situated in area C and  $DCPA \geq 0$  or own ship's course is paralleled with the other one, own ship would alter course on starboard; if own ship situated in area C and  $DCPA < 0$ , own ship would alter course on port.

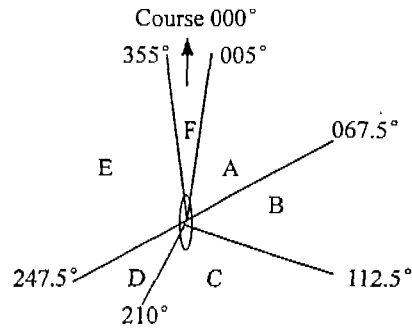


Fig.1 the division of acting situation in sight each other

Therefore, if own ship is overtaken by the other one in the area C or D, and the other ship does not take action of collision avoidance, own ship predict the other ship's most possible action of collision avoidance under the hypothesis to adopt the non-coordinated action which is believed by the most officers in charge.

There are different divisions in different researches about acting situations (or encountering type, basic encountering situation). Reference [1] divided the basic encountering situations into six categories, such as: (1) situation of the other ship is crossing from port bow to starboard bow; (2) situation of the other ship is crossing from starboard bow to port bow; (3) situation of the other ship is overtaking; (4) own ship is overtaking the other one; (5) the other ship is on reciprocal or nearly reciprocal course; (6) the other ship's engine is stopped. This division is proper for two encountering ships in normal conditions, but if own ship is stand-on ship and the other ship does not take action of collision avoidance in time, and so as to involve in close-quarters situation, it did not mention how should own ship take action to avoid collision.

Reference [2] divided the basic encountering situations into six categories. Its division is the same as reference [1] besides the overtaking situation. It divides the overtaking situation into port side and starboard overtaking two circumstances. The purpose of the division is to determine own ship's action----alteration of course on port or on starboard.

It is pointed that: notwithstanding the division of reference [1] and reference [2] for the basic encountering situation, the purpose is to determine the collision method of two encountering ships in collision avoidance.

The purposes of this paper to divide the encountering situation into acting situation are: first, to obey the international collision regulations for collision avoidance at sea; second, to supply knowledge for knowledge base of intelligent system of collision avoidance to decide own ship how to take collision avoidance action if the other ship does not take any action; third, to

summarize the practice of collision avoidance at sea.

The purposes to divide the overtaking situation into two acting situations are: (1) when the other ship is overtaking own ship and does not take action of collision avoidance, own ship adopt advantageous action to avoid non-coordination and collision avoidance based on the prediction of the other ship's action. If the other ship is in area C and  $DCPA \geq 0$ , the acting situation includes two conditions: first, the other ship will pass the head of own ship and the relative bearings in the range of  $112.5^\circ \sim 180^\circ$ , the action of the other ship will adopt is to alter course on starboard mostly; second, the other ship will pass the stern of own ship and the relative bearings in the range of  $180^\circ \sim 210^\circ$ , the action of the other ship will adopt is to alter course on starboard mostly. Therefore, if the other ship does not take action at proper distance and so as to involve in close-quarters situation, own ship should alter course on port. If the other ship is in area C and  $DCPA < 0$  also includes two acting situations: first, the other ship will pass the astern of own ship and the relative bearings in the range  $112.5^\circ \sim 180^\circ$ , the action of the other ship will adopt is to alter course on port mostly; second, the other ship will pass the head of own ship and the relative bearings in the range  $180^\circ \sim 210^\circ$ , the action of the other ship will adopt is to alter course on starboard mostly. Therefore, if the other ship does not take action at proper distance and so as to involve in close-quarters situation, own ship should alter course on starboard. If the other ship is in area D, the acting situation includes two conditions: first, if  $DCPA \leq 0$  and the other ship will pass the head of own ship, the action of the other ship will adopt is to alter course on port mostly, if the other ship does not take action at proper distance and so as to involve in close-quarters situation, own ship should alter course on starboard; second, if  $DCPA > 0$  and the other ship will pass the astern of own ship, the action of the other ship will adopt is to alter course on starboard mostly, if the other ship does not take action and so as to involve in close-quarters situation, own ship should alter course on port. (2) to determine own ship's action of collision avoidance. If own ship is in the relevant area and overtakes the other one, the action own ship adopted is the same as the other ship in the area and overtaking own ship.

The advantages of the division of acting situation in this paper are: a synthetic method of the rules, the encountering circumstance, and the collision avoidance behavior of practice and puts the method into the intelligent system of collision avoidance, so a mechanism of avoiding or reducing non-coordination is deduced to the system; the acting situation divided in the paper is corresponding with the practice of seaman, and absorbed in the researches done before.

### 3 The division of acting situations in restricted visibility

The ship's action of collision avoidance is affected by the encountering situations in good visibility in some extent. Therefore, the division of acting situations in restricted visibility should consider the affect.

#### 3.1 The requirements of COLREG 72 to ships in restricted visibility

According to the COLREG, besides ships should sound fog-signals, proceed at a safe speed,

keep proper look-out, have her engines ready for immediate maneuver, etc., the ships should take action of collision avoidance as follows:

(1) A ship which detects by radar alone the presence of another ship shall determine if a close-quarters situation is developing and /or risk of collision exists. If so, she shall take avoiding action in ample time, provided that when such action consists of an alteration of course, so far as possible the following shall be avoided:

- An alteration of course to port for a ship forward of the beam, other than for a ship being overtaken;
- An alteration of course towards a ship abeam or abaft the beam.

(2) except where it has been determined that a risk of collision does not exist, every ship which hears apparently forward of her beam the fog signal of another ship, or which can not avoid a close-quarters situation with another ship forward of her beam, shall reduce her speed to the minimum at which she can be kept on her course. She shall if necessary take all her way off and in any event navigate with extreme caution until danger of collision is over.

### 3.2 The division of acting situations in restricted visibility

There are many maneuvering diagrams used for collision avoidance at present. For the authority of division acting situations, this paper refers to the ship's maneuvering diagram made by group of Britain Navigational Institute in 1970. That diagram fit for the alteration of course only, but the ship to take action does not see another in sight and only detects the another by radar, the opinion of speed changing is also introduced in the explanation.

First, according to the encountering state between own ship and the coming target, the action of own ship is divided into alteration of course to port and to starboard, shows in figure 2. The acting situation is divided into A, B, C and D--four categories according to the relative bearings of the coming target. In which, own ship alter course to starboard, if the target is in area D; if the target is in area C, own ship alter course to port; if the target is in area A, own ship is overtaking the target and own ship is in the relative bearings of  $[210^{\circ}, 292.5^{\circ}]$  on the target,

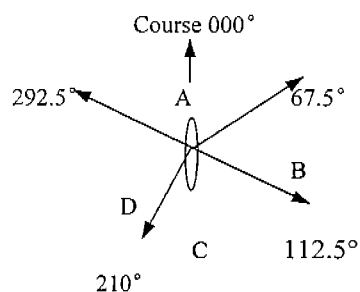


Fig.2 the division of acting situation in restricted visibility

own ship alter course to port, in the other situations, own ship alter course to starboard; if the target is in area B, own ship alter course to port.

The basis of this division is: first, it is corresponding to maneuvering diagram made by group of Britain Navigational Institute in 1970, and absorbs in the advantages of the other maneuvering diagrams. Therefore, it is better to fit for the collision avoidance in restricted visibility. Second, besides action taken by own ship aimed at target coming from area A is meet the requirements of rule 19 of COLREG, the possible action taken by the target coming from area A relative bearings  $000^{\circ} \sim 067.5^{\circ}$  and the effectiveness of action taken by own ship are also

considered. For the target coming from area B, own ship's action meet the requirement of not to alter course towards the target apparently, and own ship's action is also the as the same as that in good visibility. It can simplify the establishment of knowledge base of intelligent system of collision avoidance. For the target coming from area C or D, own ship's action also meets the requirements of rule 19 of COLREG, and also pays attention to predict the target's possible action.

In a word, the division of acting situations is reasonable and compliance with the rules of COLREG,1972.

#### 4 conclusions

It is very important to make mandatory provisions to prevent collision between ships, and the provisions should be changed if the circumstance is changed. A very important base in collision avoidance is to reduce the uncertainty of actions of the two encountering ship adopted, the purpose of all equipments, regulations, routing schemes, systems and so on adopted in collision avoidance are for that use. This research based on rules and the practice at sea:

(1) proposed the concepts of acting situation to improve the encountering situation in intelligent system of collision avoidance;

(2) divided encountering situations into acting situation, the division establishes a mechanism of avoiding non-coordination action in collision avoidance;

#### References

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