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Communication Mechanism for Automatic Identification System

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Abstract

Automatic Identification (AIS) System is becoming one of the most important information systems for navigation. How to make full use of communication power of AIS is a very important issue for navigation research. This paper proposes such a communication mechanism, if the communication system is combined with navigation mode (route searching mode), it will raises the efficiency of the ship's traffic system.

Keywords: Communication mechanism, Navigation, AIS, Complex system

1 Introduction

Since December 2004, Automatic Identification System (AIS) is compulsory to be loaded on passenger and cargo ships over 300 tonnages, which travel on international routes. After August 2008, all passenger ships and other ships that are over 500 tonnages will equip the AIS system. To make full use of the communication power of AIS, this paper proposes a communication mechanism, including communication messages, rules, protocols for two-way communication, and a message analysis method. This mechanism will help ships reach agreements smoothly through the use of AIS system and make ships to sail in cooperative. Then, it is verified by simulation.

2 Communication message and analysis state

The proposal of communication mechanism must be based on the real situation of navigation. In ordinary sailing, we always make an original route plan before departure, and in times that a collision danger is detected, ships replan their routes to avoid collision. After the collision danger is cleared, ships will take action to go back to their original route. In addition, if any emergency danger is detected, an emergency plan will be made. Therefore, replan, back plan and emergency plan are the basic processing work for navigation.

2.1 Analysis states

The communication mechanism is based on message exchange. Through message analysis, the corresponding processing is decided. According to such a flow, we make several analysis states based on the navigation practice and the need of communication. Every analysis state corresponds with a definite processing. After receiving a message, message analysis will be done, and the results will lead to a corresponding processing. We classified 6 analysis states as following:

"no talk", "waiting reply", "agreement reached", "replan", "back to original plan", "emergency plan".

"No talk" is the state that a ship is sailing in safety without receiving or sending any message.

"Waiting reply" state is that a ship has sent out a message and is waiting for the reply of others.

At "agreement reached" state, ships transfer the consulting result into broadcasting message and then take corresponding action.

"Replan" is the state that collision danger is newly detected, cooperative request from other ship is received, the ship has to replan its route and decide whether to permit or to refuse the request, and if it should ask for other ship's cooperative action.

"Back to original plan" state is that after a ship altered its route for the purpose of avoiding collision, and the alteration engenders a deviation loss, it has to make a plan to go back to its original route.

"Emergency plan" state is independent of consulting messages, that is, if a ship detects an emergency collision danger, emergency plan state

starts right away.

2.2 Communication messages

By AIS, every ship can broadcast their present information, including position, route, motion vector and so on, to all the other ships in the area. This kind of messages is to be called "broadcasting message". When a ship call others for a cooperative action, it will send message to the specified ship, such message exchange only proceeds among the talking partners. This kind of message is to be called "consulting message".

The broadcasting message is at a simple format and contents, the message exchange is mainly based on the consulting message. Just like people talk with each other, the AIS communication begins with requests sent by a ship and the replies from a receiving ship. Considering the practical situations in navigation, we propose 7 kinds of consulting messages as following:

"request", "permit", "refuse", "confirm", "cancel", "emergency plan", and "silent".

Among them, "request", "permit" and "refuse" are basic parts in consulting lines. The basic message flow of consulting message is as following:

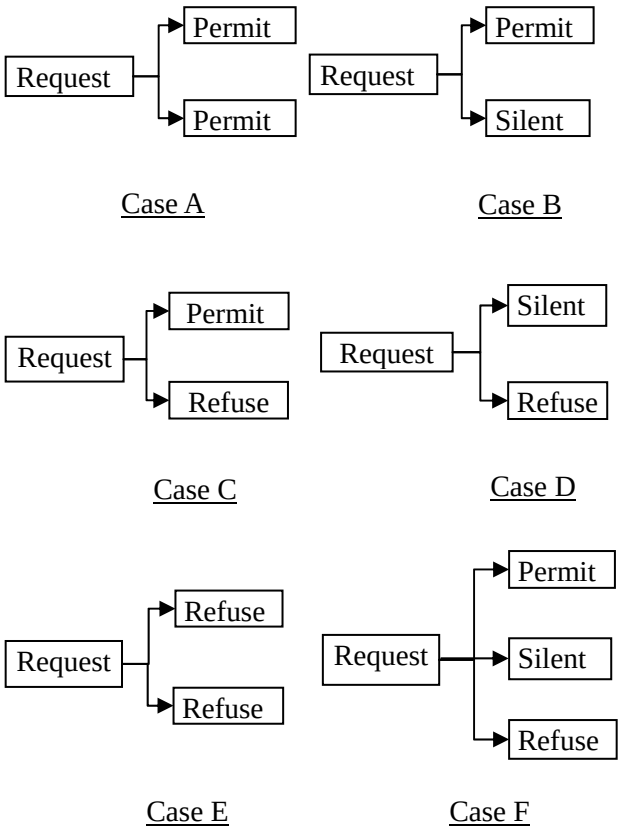


Figure 1. Possible reply combinations to a request message

Except for case A, ships do not reach agreement immediately. A "confirm" message should be sent to the requested ship to inform that an agreement has been reached.

If conditions changed, and the "request" or "permit" messages which is sent, are no longer appropriate. "cancel" or new "request" message might be sent to the talking partner.

If emergency danger is detected, the ship will enter "Emergency plan" state, emergency plan will be sent to inform its talking partners.

"Silent" is not a real message transferred between consulting ship. It just means that a consulting partner is in silent state. For the convenience of message analysis, it is regarded as a consulting message.

During the communication with the above stated message, ships must know in which of situations he should send a request message. Likewise, the receiving side must know whether or not a request should be permitted in such situation.

We propose the following decision rules as the next section.

3 Communication rules

As a common rule, we must consider about the total efficiency of an area, instead of ship A or ship B. Generally, the total efficiency can be express by the sum of lone ships. If a rule can make ships safely sailing through an area with a smaller deviation loss, we will consider it as a good one. The following rule is proposed.

- When to send a request message

When a ship detects a possible collision danger, and if avoiding solely by its own will cause a loss larger than a settled value (to be called "threshold of request"), it is necessary to ask for other ship's cooperative action. In such condition, the ship should send a request message to related ships.

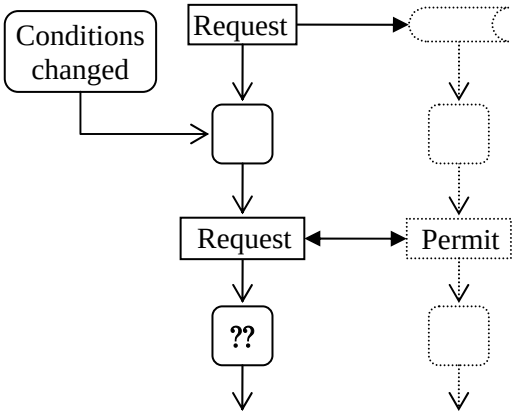
- When to permit or refuse a request

Generally, if a ship permits the request of other ships, to the requesting side, the loss will be decreased, but to the requested side the loss might be enlarged. In such situation, efficiency of both ships should be considered. That is, through cooperative action, if the loss difference (the decreased loss of the requesting ship minus the enlarged loss of requested ship) is bigger than the settled value (to be called "threshold of permit"), the request should be permitted; otherwise, it should be refused.

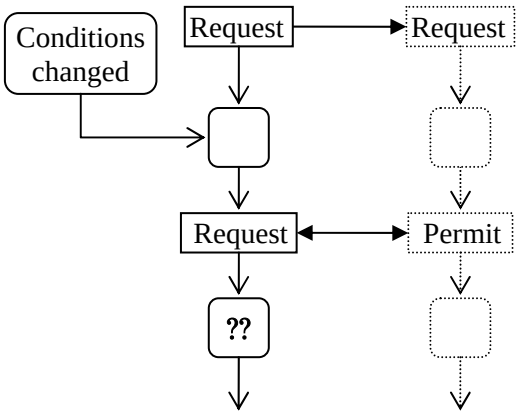
With the rule ship can make decision for communication messages.

4 Protocol for AIS communication

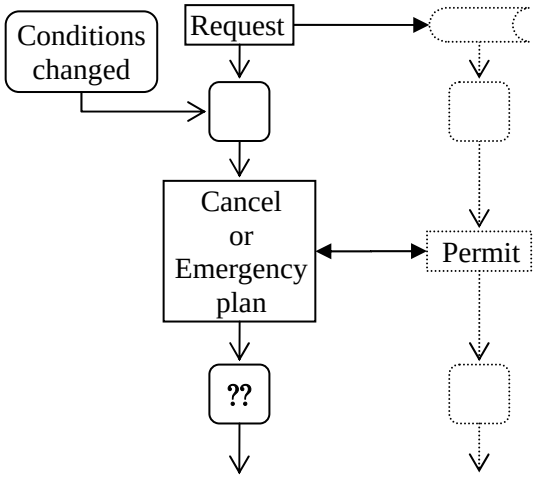
When we conduct communication with the above mentioned communication rule and messages, we have to consider the problems of two-way communications and the transition of message content. The basic message exchange route is shown in Figure 1. The consultations always begin with "request" and end with "refuse", "confirm", "cancel" or "emergency plan". Here such a message exchange route is called a message line. In the condition of two way communications, sending and receiving proceeds at the same time, there might be one or two message lines between each consulting pairs. In time of new request message is received, new collision danger is detected or other conditions changed, transition of message content might happen at such states. Some of them are listed as following:



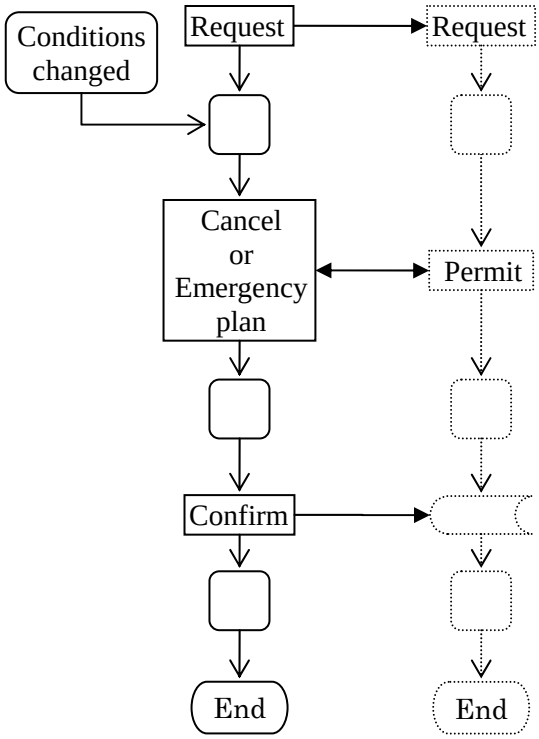
Case 1



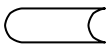
Case 2



Case 3



Case 4



: Receiving without sending

: Confusion happened during processing

: Process block

: Ship A

: Ship B

Figure 2. Transition of message content

In Figure 2, Cases 1 and 3 show the transition of message content at one message line and cases 2 and 4 show the transition at two message lines. When conditions change, in cases 1 and 3, the previous request is given up, and a new request message is sent out. At the same time permit message of the previous request message is received. In both case 1 and case 2, confusion may be caused due to lack of appropriate protocol. In cases 3 and 4, when conditions change, the previous request is given up, cancel or emergency message is sent out. Case 3 causes a confusion but case 4 goes smoothly.

Therefore, the following protocol is proposed to solve the above problem.

(1) When a request message is being sent, no consulting message except request message will be received.
(2) When talking pairs are consulting at one message line, if the end message such as "refuse", "confirm", "cancel", "emergency plan" is being sent, it will not receive consulting message except "request".

5 Message processing

Through the protocol, proper messages will be received, we will fix the present analysis state and then other processing will be run according to the analysis state and received message.

5.1 Processing the receiving message

In order to fix the analysis state with more than one receiving messages，we determine the priority of messages according to the relationship of messages and the states:

Priority 1: request, refuse, cancel, emergency plan
Priority 2: silent
Priority 3: permit
Priority 4: confirm

If message of priority 1 is received or new collision danger during the period of plan is detected, a ship should enter the "replan" state.

If none of the messages of priority 1 is received and some of the consulting partner is in "silent", and meanwhile, there is no collision danger is newly detected, a ship should enter the "wait reply" state.

If permit message is received and no higher rank message is received, a ship should enter "agreement reached" state.

If confirm message is received and no other kind of messages is received, while no collision danger during the plan time period is detected, a ship should enter the "no talk" state.

The analysis state is fixed by the processing of receiving messages. The action decision will be made according to the analysis state.

5.2 Sending message analysis

After receiving message and consulting route analysis, a ship should decide how to send message according to the messages it has received and its analysis state.

At "no talk" and "back to original route" state, no consulting message is sent; the ship will only send the broadcasting message.

At "agreement reached state", the ship sends confirming message to the ship which permits its request.

At "emergency plan", the ship will send the emergency plan message to inform its own state to all other consulting ships.

At "waiting reply", the ship will wait for reply from some of the consulting ship. Toward other consulting ships, it will keep silent.

At the "replan", we do most of the processing to decide whether to send requesting message to rule-satisfied ship, to permit or to refuse the request from other ships. Request, permit or refuse message are sent according to the result.

6 Constitution of AIS communication System

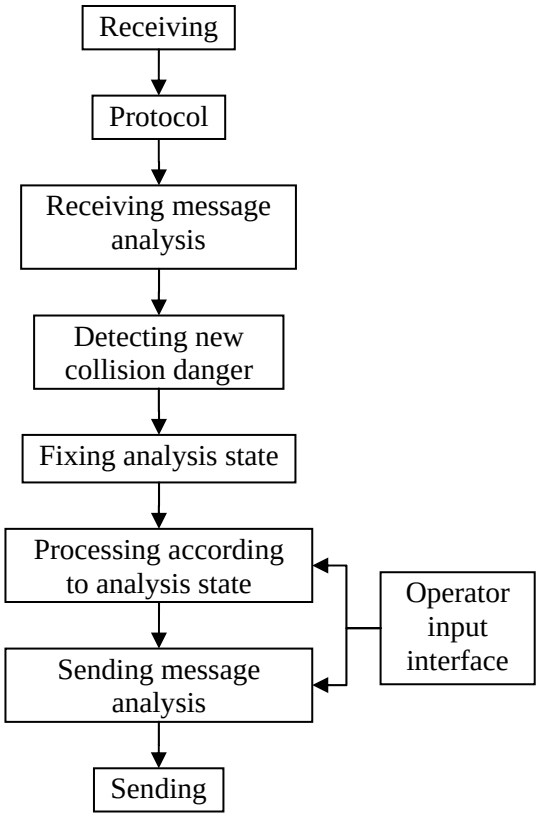


Figure 3. System constitution

The block diagram in Figure 3 summarizes the message processing system described in the above.

The system can process message exchange automatically. However navigation officer is the responsible person of the navigation. So the Operator input interface is necessary, through the interface operator can alter the control factor such as request threshold and permit threshold to influence the analysis result, or he can compulsorily change the sending message according to the actual situation.

7 Simulation based on the above navigation mode

To check the rationality and efficiency of the system, we conducted a simulation based on the communication mechanism.

(1) Simulation Area:

An area with 25 nautical miles radius from center point, with all ships inside, is considered in the simulation.

(2) Ship factors

All ships are randomly generated at the edge of the simulation area, with the frequency of 5 ships every 3 minutes.

Assume that the ships' speed follows a normal distribution, with an average of 12 knots and standard deviation of 3 Knots. Besides, the courses of ships are evenly distributed, ranging from 0 to 360 degrees. All ships are equipped with AIS system and are ready to consult with others.

(3) Basic route plan factor

Safety distance: 0.3 nautical miles
Route plan time period: 30 minutes
Emergent danger: collision danger within 6 minutes
Interval of exchanging message: 10 seconds
Simulation time: 3 hours

The permit threshold is fixed value 0.02 in the simulation.

(4) Route searching Model

Multi stages decision model (Imazu, 1985)

We run the simulation 20 times and get the average of their results. It is shown in Figure 4 to 6.

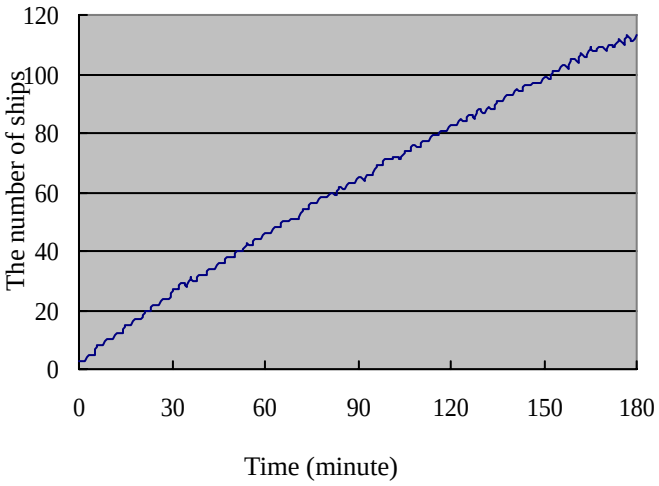


Figure 4. Number of ships per minute

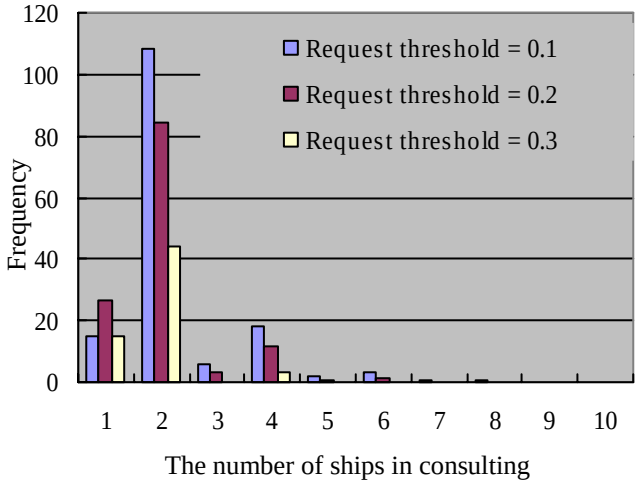


Figure 5. Frequency of the number of Ships in consulting

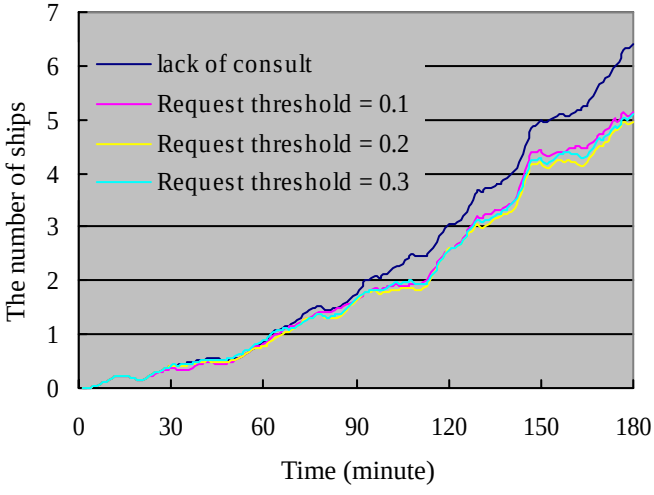


Figure 6. Number of ships per minute

8 Conclusions

In this study we presented a communication mechanism and conducted the route searching with traditional method under the communication mechanism. Then simulations were run under the above conditions. Figure 4 shows the ships number every minute in simulation. Figure 5 shows frequency of the number of ships in consulting state. From the simulation results, which are shown in Figure 6, we found that using the communication mechanism, the total deviation distance in the simulation sea area can be decreased for about 5 to 15 percent or so.

According to Casti (1995), a complex system has three characteristics: the system is constituted by medium numbers of agents; each agent has intelligence; they decide their actions based on local area information. This exactly describes ship's traffic system. By the equipment of AIS, communication is possible. With a communication mechanism, which enable ships to search for their routes in cooperation rather than to work individually, we can get entire efficiency. This also means that if agents in a complex system can communicate with each other, the communication mechanism can be used to realize navigation control. It is expected to lead to effective control over navigation systems in the future.

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