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A Study on Mariners' Standard Behavior for Collision Avoidance (1)

- A concept on modeling for collision avoidance based on human factors -

Jung-Sun Park · Hiroaki Kobayashi** · † Byeong-Deok Yea****

** Department of Ship Operation Systems Engineering, Korea Maritime University, Busan 606-791, Republic. of Korea*
*** Department of Applied Marine Environmental Studies, Tokyo University of Marine Science and Technology, Tokyo 108-8477, Japan*
**** Department of Ship Operation Systems Engineering, Korea Maritime University, Busan 606-791, Republic. of Korea*

Abstract : *Human factors have been considered the primary reason of marine accidents. Especially, the collision between vessels is mostly caused by human behavior. However, there have not been many researches to clarify the reason of marine accidents caused by human factors quantitatively. In order to understand human factors and to enhance safe navigation systematically, using a full mission ship-handling simulator, we've investigated the characteristics of avoiding behavior taken by mariners. Further in order to apply the characteristics more widely and effectively, it's necessary to formulate the standard behavior for ship-handling in the condition of collision avoidance. Is this study, therefore, we intended to propose the concept to model the mariner's standard behavior on the handling of collision avoidance as the first step. As a result, we confirmed the contents of information processing in ship-handling that mariner's generally taking to avoid collision.*

Key words : *Human factors, Mariner' standard behavior, Collision avoidance, Information processing works, Task and judgment*

1. Introduction

It is widely known that the most of marine accidents are related with mariner's behavior and among the accidents, especially, the collision between vessels is mostly caused by human behavior. However, there have not been many researches to clarify the reason of marine accidents caused by human factors quantitatively. In order to understand human factors and to maintain safe navigation, thus, we've studied human factors in the condition of collision avoidance by using a full mission ship-handling simulator and analyzed general characteristics of mariner's avoiding behavior in a previous study(Park et al., 2003; Kobayashi, 2004; 2005). As a result, we obtained that it is possible to find out main features of avoiding behavior from the majority of mariners and to define standard procedures for ship-handling of collision avoidance that they're taking in order to keep safety.

In this study, therefore, we aimed to propose the concept on modeling of mariner's behavior for collision avoidance based on human factors under navigational condition. In order to organize the mariner's behavior for collision avoidance, first of all, we defined the concept of mariner's avoiding behavior in ship-handling. And based on the concept, we categorized mariner's avoiding behavior into six processes and described each process with four kinds of components that are one mission, required information processing works to attain the given mission, necessary information and available ways. The procedure of mariners' standard behavior and structure of each process for collision avoidance based on information processing works is introduced in chapter 2.

2. Standard Avoiding Behavior

2.1 Definition of Standard Avoiding Behavior

We defined the mariner's behavior for collision avoidance as a continuous sequence of information processing works of a human to keep safe navigation and the mariner' standard behavior for collision avoidance as the behavior taken by the majority of mariners. The mariner' standard behavior for collision avoidance can be divided into six processes, which consists of detection, identification, recognition, plan, execution and return according to the given missions to attain to keep safe navigation. And each process consists of main mission, requested tasks and judgment, necessary information and available ways. The mission is defined as a certain purpose mariner has to attain in each process. The task and judgment are information processing works required in order to attain the given mission. The information requested for information

* Jung-Sun Park, goghpark@hanmail.net, 051)410-4243
** Kobayasi@e.kaiyodai.ac.jp, (03)5245-7398
† Corresponding Author : byea@hhu.ac.kr, 051)410-4243

processing works is obtained by available methods. Focused on these factors, the procedure of mariner's avoiding behavior and structure of modeling in each process is described in this study.

2.2 Procedure of Standard Avoiding Behavior

Fig. 1 shows the flow of main information processing works (task and judgment) according to each process. The procedure of information processing works of mariners for collision avoidance is explained in this section. The letters, 'D', 'I', 'R', 'P', 'E' and 'Re' means the initial of each process. In each process, 'M' is mission, 'T' is task, 'J' is judgment, 'I' is information and 'W' is way. In the flow chart, the solid and dotted arrows indicate 'Yes' and 'No' respectively.

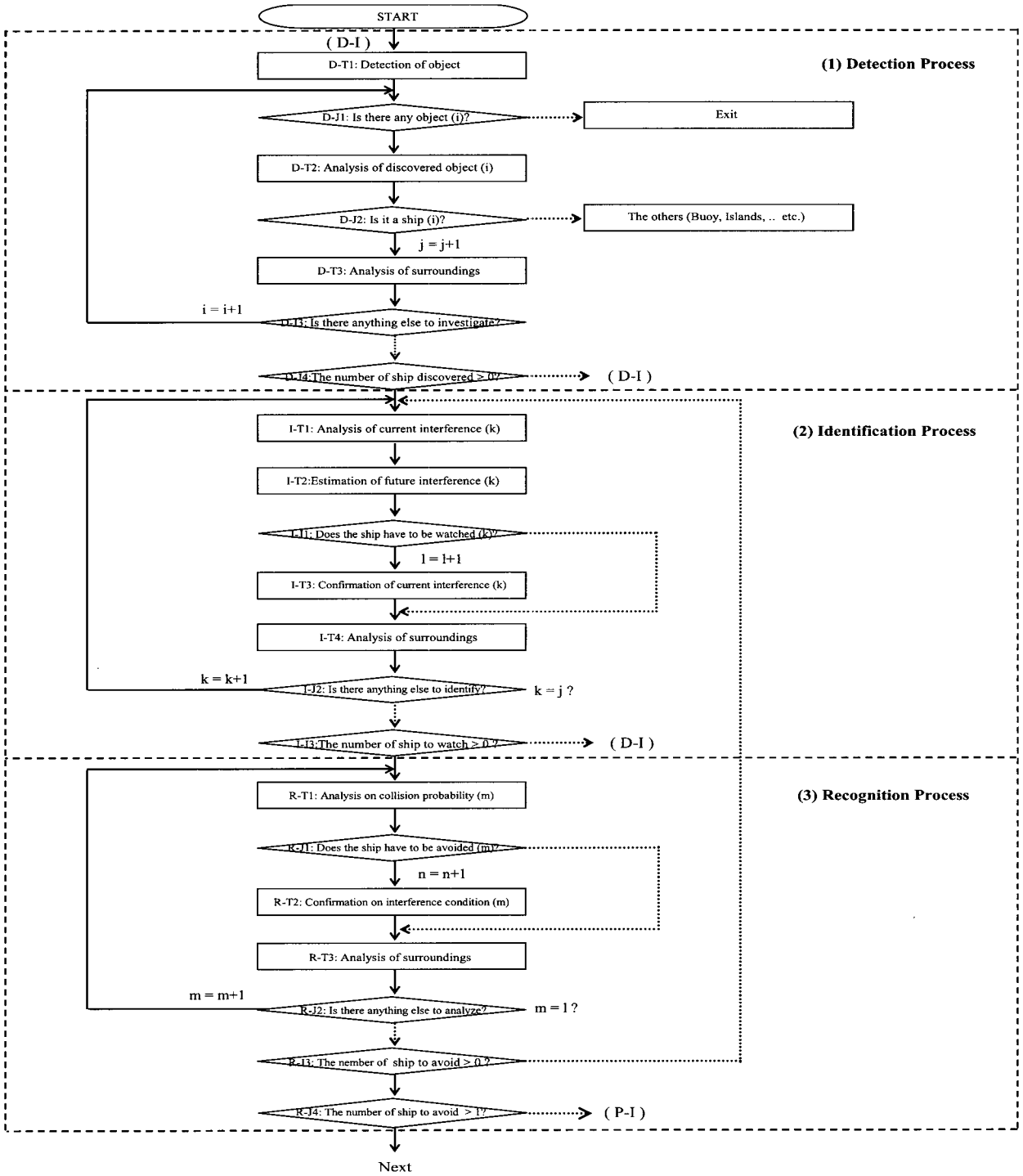

Fig. 1 Flow Chart on Standard Avoiding Process

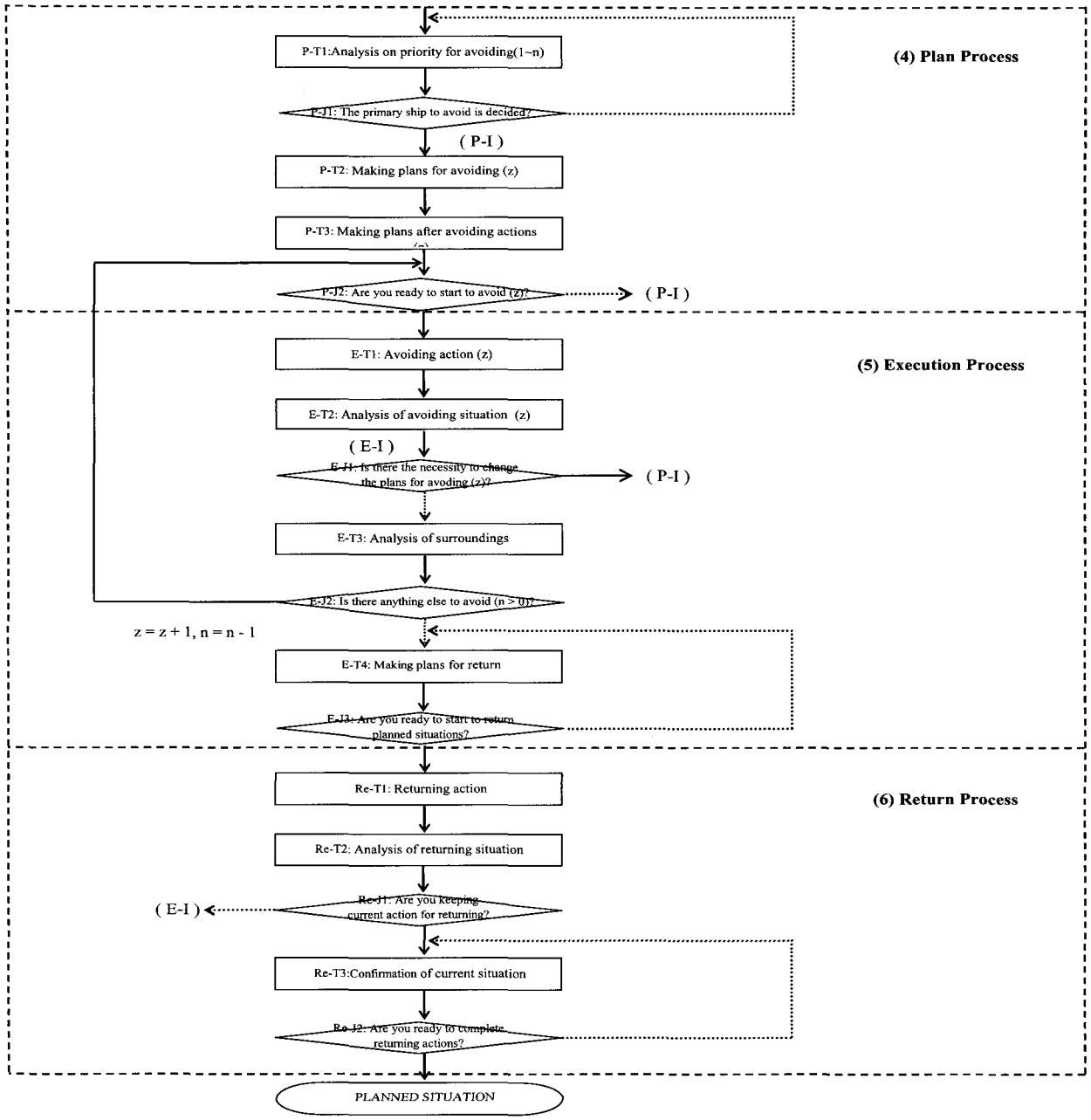

Fig. 1 Flow Chart on Standard Avoiding Process

- Start of navigation

1) Detection process

[D-T1, D-J1, D-T2, D-J2, D-T3, D-J3, D-J4]:

Mariners detect the existence of any objects around and judge the result of detection works whether any object is discovered or not. If there is any object, the discovered object is investigated and classified into two groups whether the object is a ship or not. All objects should be detected in surroundings. Mariner has to understand whether there exists any ship or not. And then they proceed to the next step if there is any ship to be identified.

2) Identification process

[I-T1, I-T2, I-J1, I-T3, I-T4, I-J2, I-J3]:

After detection process, the current and future interference condition between an own and target ships is investigated and estimated. As the result of analysis on each conditions of current and future interference, mariners decide whether the ship has continuously to be watched or not. If the ship should be kept watching, mariners confirm the current situation with the ship and keep in mind or

they proceed to next step. The condition of all ships around the own ship should be understood. Mariner has to identify the existence of ships which have continuously to be observed for the estimation of future situation. And they proceed to the next step if there is any ship to be watched.

3) Recognition process

[R-T1, R-J1, R-T2, R-T3, R-J2, R-J3, R-J4]:

After identification process, the degree of collision probability between an own and the target ship is analyzed and estimated whether the ship has to be taken an avoiding action or not. If there is the necessity of avoidance, mariners confirm the probability of collision and keep the situation in mind. The condition of all identified ships should be analyzed to estimate collision probability. Mariner judges whether there is any ship which has to be taken an avoiding action and comprehensively evaluate the number of ship to avoid. And they proceed to the next step for making plans to avoid.

4) Plan process

[P-T1, P-J1, P-T2, P-T3, P-J2]:

If the number of the ship to be avoided is more than one, the priority of ships should be decided. But, if the ship to be avoided is only one, there is unnecessary to decide the priority of avoiding. Mariner decides which one among ships to avoid in first and the avoiding methods on how and when avoiding actions should be taken according to the priority. Based on the estimation of the own and target ship's condition after the planned avoiding action, the plans for returning action and start timing or safe position in surrounding should be made properly. Mariners consider the time for avoiding actions after completing the plans and they start to take a planned action in a proper timing.

5) Execution process

[E-T1, E-T2, E-J1, E-T3, E-J2, E-T4, E-J3]:

Mariner starts to take the planned avoiding actions. The propriety of avoiding action taken by mariners is analyzed in relation to surroundings and judged whether present actions should be kept or the plans should be changed, especially if there is any change in avoiding situation or surrounding during the execution of actions after avoidance is started. The avoiding action for all ships which need to be avoided should be taken. And if the action is proper, mariner starts to prepare for planned situations and decide the plan for returning actions with considering current situations. They consider the time for returning actions after completing the plans and then they start to take the planned returning action.

6) Return process

[Re-T1, Re-T2, Re-J1, Re-T3, Re-J2]:

Mariner starts to take the planned returning actions. The propriety of returning action taken by mariners should be analyzed in relation to surroundings and judged whether the returning action should be kept or not. If the action is proper, mariners check current and planned condition, keeping the action until the own ship gets to the planned situation. In the process of being taken the returning actions, the present condition should be checked whether the own ship is on planned situations or not and then they decide the timing to finish the returning action.

- Planned situation

2.3 Structure of Standard Avoiding Behavior

The structure of each process is described in this section. Main factors to explain the contents of each process are used as followings.

- M: Mission, T: Task, J: Judgment, I: Information, W: Way
- R/A: Radar/ARPA, Gyro: Gyro compass

1) Detection process

This is the process to discover the existence of any object and detect the existence of ship. Fig. 2 shows the general structure of detection process.

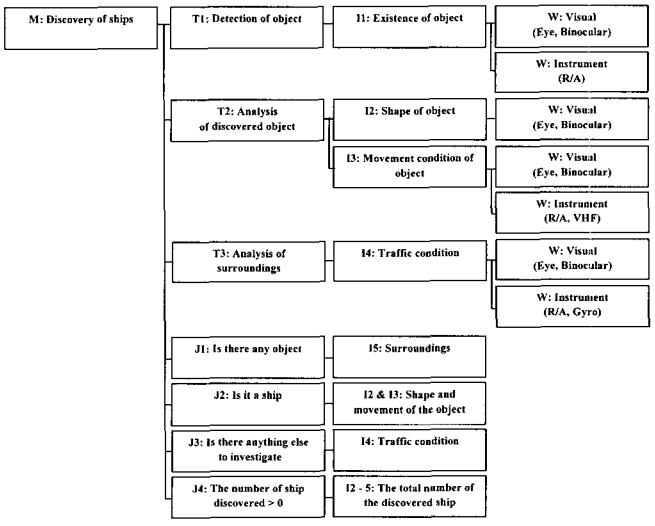

Fig. 2 Structure of Detection Process

① Mission: To detect the existence of ships.

② Task & Judgment: In order to attain the given mission, firstly, mariners observe to discover the existence of any object and judge whether there is any object. And then they analyze the existed object and judge whether it is a ship or not, if there is an object. After that, they

judge how many objects and ships there exist around.

③ Information & Way: Visual information is useful way to understand the kind of object, and Radar/ARPA is available way to obtain numerical information on the movement condition of object together with visual information using Eyes and Binocular.

2) Identification process

This is the process to identify certain ships that have to be observed among all the discovered ships. Fig. 3 shows the general structure of identification process.

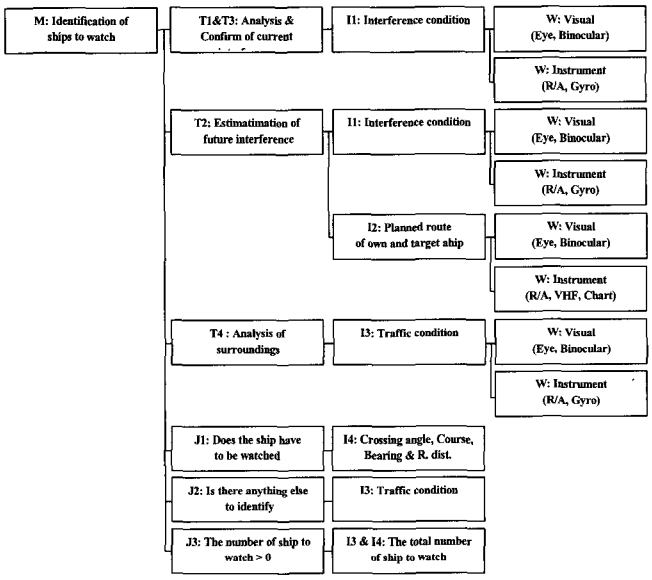

Fig. 3 Structure of Identification Process

① Mission: To identify the ship which have to be watched.

② Task & Judgment: In order to attain the given mission, firstly, mariners analyze each current interference condition between an own ship and target ships and estimate the future interference condition. And then they judge the necessity of watch for each ship and confirm current condition if necessary. After that, they analyze traffic condition in order to understand the existence of ship to identify and those already decided. Consequently, mariners judge where the ships to be watched exist and also how many ships should be watched.

③ Information & Way: The information on the position and proceeding directions of the target ship is necessary, which can be obtained using Eyes, Gyro compass and Radar/ARPA. And information on the intention of target ship helps mariner to estimate the future interference condition, which can be obtained using the ways such as Radar/ARPA, Chart and VHF.

3) Recognition process

This is the process to analyze the risk probability of collision and decide the ship to avoid. Fig. 4 shows the general structure of recognition process.

① Mission: To recognize the necessity of avoiding action.

② Task & Judgment: In order to attain the given mission, mariners analyze the degree of collision probability, considering the traffic condition and characteristics of waters. And they judge the necessity of avoiding for all ships which mariner's been watching based on the degree of collision probability.

③ Information & Way: The necessary information is the remained time to collision the closest point of approach, passing distance and direction with watching the real-time movement of target ship using Eyes, Radar/ARPA and Gyro compass.

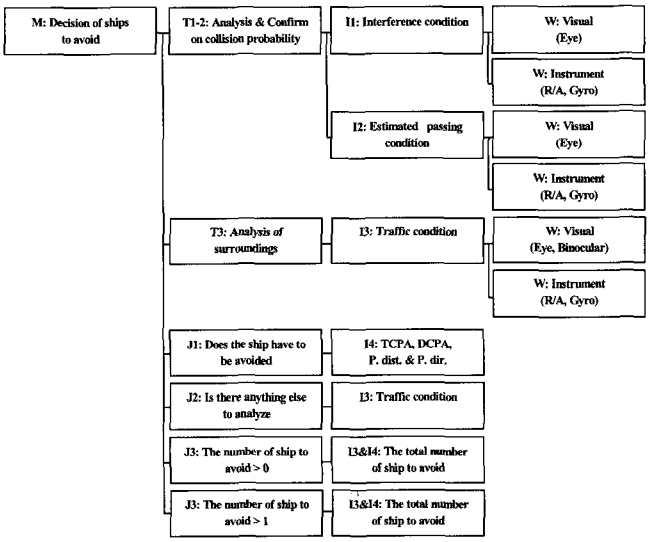

Fig. 4 Structure of Recognition Process

4) Plan process

This is the process to make plans for avoiding actions. Fig. 5 shows the general structure of plan process.

① Mission: To make proper plans for avoiding actions.

② Task & Judgment: In order to attain the given mission. firstly, the priority to take an avoiding action should be made by based on the degree of risk. And then, for the proper action and start timing for avoiding, mariners analyze the interference condition, the degree of risk, surrounding, ship maneuverability and rules. After that, the plans after taking an avoiding action should be considered based on the own ship's planned situation and estimated condition after avoiding actions. And they decide the timing to start to take avoiding action.

③ Information & Way: The necessary information is interference condition, rules, ship maneuverability and environment condition, etc.. In this process, communication between ships by using VHF is an effective method to

understand the target ship's intention and pass each other in a safe way.

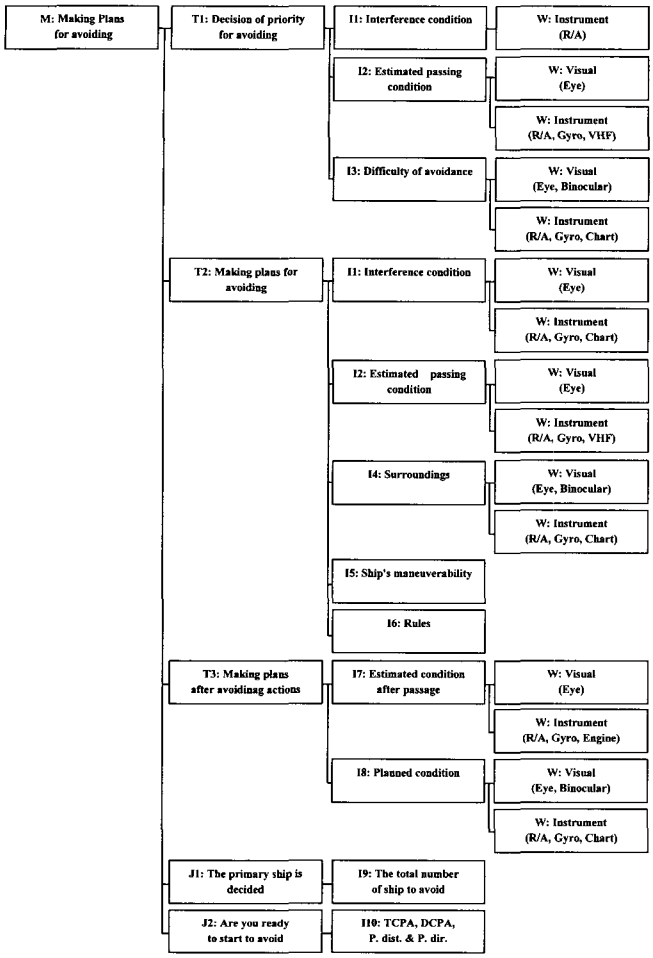

Fig. 5 Structure of Plan Process

5) Execution process

This is the process to perform planned avoiding actions. Fig. 6 shows the general structure of execution process.

① Mission: To complete taking actions to avoid collision.

② Task & Judgment: In order to attain the given mission, mariners perform the planned avoiding action and analyze real-time changing interference condition according to the action. And then, mariners evaluate the propriety of taken actions and decide the necessity of change for plans. After that, if the avoiding action is completed, they start to take an returning action after making the timing and method for return.

③ Information & Way : The necessary information is current and future interference, surroundings, ship maneuverability, rules, current and planned condition, etc.. In this process, it is important to confirm the passing condition between ships in real-time by Eyes and Radar/ARPA, to check the own changed condition such as speed, position and heading course by Eyes, Radar/ARPA, chart and Gyro compass.

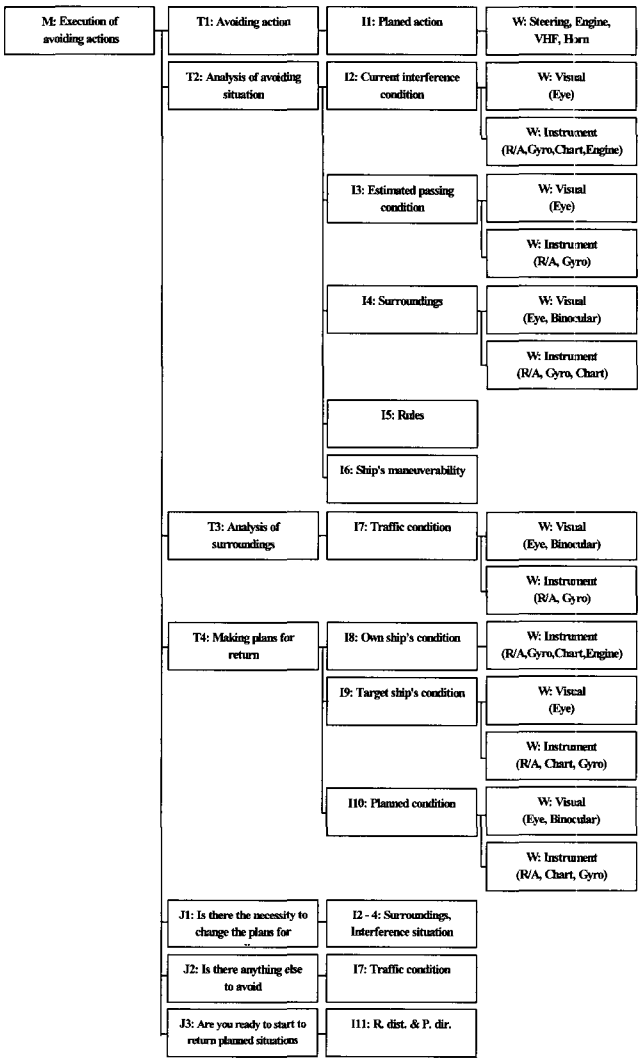

Fig. 6 Structure of Execution Process

6) Return process

This is the process to return on planned situations or destination after completing avoiding actions. Fig. 7 shows the general structure of return process.

① Mission: To return planned situations.

② Task & Judgment: In order to attain the given mission, mariners take planned actions for return. And they evaluate the propriety of the action while taking the action, and then judge whether the returning action is proper or not. After that, mariners check the own ship's condition, planned condition and surroundings.

③ Information & Way: The necessary information is the own ship's condition, interference condition, surroundings, planned condition by Eyes, Radar/ARPA, chart and Gyro compass.

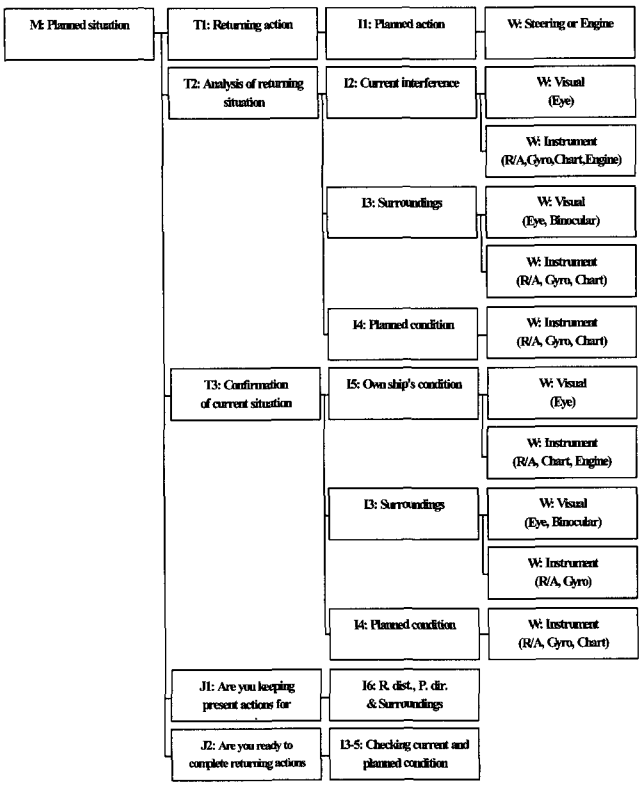

Fig. 7 Structure of Return Process

3. Conclusion

We described the contents on the standard behavior of mariner for collision avoidance based on information processing in this paper. As a result, the followings are obtained.

① Understanding the mariners' standard procedure for avoiding collision to keep safe navigation.

② Clarifying the contents of information processing works, necessary information and available way in each process.

③ Proposing the concept on modeling of mariners' standard behavior for collision avoidance based on human factors.

The detailed modeling method will be dealt in the next study. By completing the model on standard avoiding behavior, we can expect it will be good guideline for enhancement of safety navigation in following respects.

① Development of maritime education and training

② Development of navigational environment taking human characteristics into account

③ Quantitative analysis of marine accidents in human factors

④ Organization of systematic rules for safe operation

⑤ Improvement of operator supporting system

⑥ Improvement of ship's automation system

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