Intelligent Marine Traffic Simulator for Congested Waterways

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SUMMARY

The Intelligent Marine Traffic Simulator was developed for the purpose of re-organizing the traffic in congested shipping lanes. It can be used for any configuration of sea area, shipping lane or traffic conditions. Furthermore, it is an essential tool for new route planning and navigational system evaluation. Experiments using the Intelligent Traffic System (ITS) will demonstrate that the safety of any waterway will depend on the amount of traffic, its proximity to ports and the potential of having navigational hazards. The accuracy of the simulator will depend on human input and feedback from continuous testing. Marine ITS is a 5-year- project that started in 2000.

1. INTRODUCTION

Traffic safety is an everlasting problem, not only on land, but also at sea. Every time a serious accident occurs, domestic and international traffic regulations are revised and proper devices are required to be adopted according to new technologies on the market. At the moment, information and communication technology are highly developed and it seems easy to improve the safety and efficiency of the maritime transportation. Nowadays, the ITS in land transportation is fully established, laying a clear path for the improvement of safety in marine transportation by using information technology. The ITS will contribute, not only to the development of traffic safety, but also to the reinforcement of economic competitiveness. It will also contribute to the reduction of environmental damage and to the construction of the most appropriate distribution system of goods.

Since the year 2000, the Japanese Government started a project to develop Marine Intelligent Traffic Systems. The purpose of the project is listed as follows:

- To develop an automatic avoidance system for collision and stranding.
- To develop an advanced maritime traffic control system.
- To develop a supporting system for manoeuvres inside bays and harbours.

During this project, a traffic simulator for congested waterways was created by comparing virtual space between current and newly proposed shipping routes.

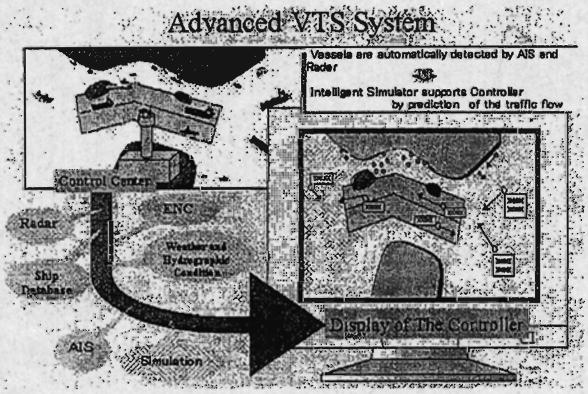

Figure 1, Advanced VTS System

2. INTELLIGENT MARINE TRAFFIC SIMULATOR

2.1 Outline and Constituents of the System

As shown in Figure 1, the system has an inference engine which decides the action of the concerned ship. The decision is based on databases such as navigation and regulation, data of seaway (water depth et al.), traffic statistics (traffic density in the area et al.), and manoeuvrability of the ship. The outcome of the simulation is then saved inside an output database. Later, a workstation will arrange this information together, and finally, client PC's will have access to this information by external means.

2.2 Development of the System

Navigational knowledge and expertise of professional mariners was used in order to create the databases for the system. In addition, the design for the output and input interfaces was planned using common procedures to build more complex systems.

2.3 Advantages of the System

The inference engine -called "G2"- is operated at a workstation but it can also be installed on a normal PC, therefore, giving a great advantage to the system.

2.4 ITS Function Settings

A. Sea Area Setting

- Inputting coastal data freely chooses the sea area.
- Input coastal data is compatible with the data published by the Waterway Department of the Japanese Coast Guard.

B. Ship Setting

- The ship type for the simulation is freely selectable by inputting coastal data.
- The ship performance can be set based upon the following parameters: velocity characteristics, turning characteristics, coasting characteristics and rudder characteristics. In addition, it can be set optionally by data input.
- Radar distance and Automatic Identification System (AIS) can be set for every ship model used in the simulation.

C. Flow of Traffic and Sailing Environmental Settings

- The place and size of the gate inside the sea area can be set optionally as the condition data for simulation.
- Vessel encounters, for each gate and each type of ship, can be set as the condition data for the simulation.
- Additionally, the point where ships veer can be set as a condition.

D. OOW (Officer of the Watch) Function Settings

If the model vessel is the stand-on or give-way vessel, the officer can select one of two options: to take evasive action or to maintain course and speed.

2.5 System Performance

The ITS has the capacity to store the following information:

- More than 30 sea areas can be stored into the database.
- More than 100 vessel models can be stored into the database.

3. SHIP AUTO NAVIGATION FUZZY EXPERT SYSTEM (SAFES)

It is the base system of the Intelligent Marine Traffic Simulator. In order to understand this complex system the following items will be explained:

- Origin of Ships
- Ship Manoeuvre Determination
- Ship Handling Processes

3.1 Origin of Ships

A ship is produced in accordance with position distribution and based upon the average arrival time interval.

3.2 Ship Manoeuvre Determination

Depending on the situation encountered at sea, the ship can perform three basic manoeuvres, in order of priority, evasive action, overtaking action and routine action.

DCPA (*Distance of Closest Point Approach*)
TCPA (*Time of Closest Point of Approach*)

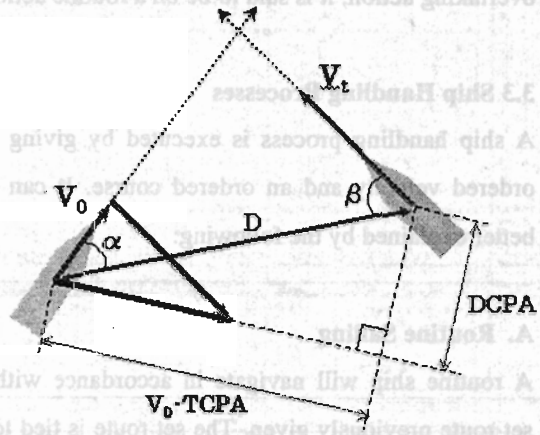

Figure 2 DCPA and TCPA

A. Evasive Action

To determine the evasive action manoeuvre the SAFES judges from two sources of information: TCPA (Time of Closest Point of Approach) and DCPA (Distance of Closest Point Approach). Figure 2 explains DCPA and TCPA which are the basic data to asses the existence of "Risk of Collision".

As an example, in case a ship encounters a situation with many possible risks of collision, the SAFES will determine the degree of the risk and will know which ships ought to be avoided.

B. Overtaking Action

The SAFES will determine if an overtaking situation is developing by analysing the position and speed of both vessels. In order to ensure safety, the give-way model ship will set a surrounding area around itself and arrange its course to keep the other vessel away from it. The surrounding -"off-limit"- area is a rectangular shape and its size is large enough to ensure safety.

C. Routine Action

When a ship is not required to take evasive action or overtaking action, it is said to be on a routine action.

3.3 Ship Handling Processes

A ship handling process is executed by giving an ordered velocity and an ordered course. It can be better explained by the following:

A. Routine Sailing

A routine ship will navigate in accordance with a set route previously given. The set route is tied to a veering point with a straight line.

B. Overtaking Sailing

A give-way vessel will overtake a stand-on vessel only if the system has determined that an overtaking situation is certain.

C. Evasive Sailing

In evasive sailing, Collision Risk (CR) determines the ship handling. Ship handling depends on the physical relationship with other ships.

D. Motion Equations of Ships

$$Tr + r = K\delta. \quad (1)$$

$$TvV + V = V_{order} \quad (2)$$

$$Te\delta + \delta = \delta_{order} \quad (3)$$

V : Ship Velocity

V_{order} : Velocity Ordered

γ : Angular Velocity

d: Rudder Angle

d_{order} :Rudder Angle Ordered

K, T: Index of Manoeuvring

T_e : Constant of Steering Gear

T_v : Constant of Ship Velocity

The rudder angle is determined by PD control judging from course fudge factor and turning angular velocity.

$$\delta_{order} = C_1\psi_e - C_2 r$$

$$C_1 = K_p$$

$$C_2 = T_d = (2\sqrt{KK_p}T\xi - 1)\frac{1}{KK_p}$$

4. OSAKA BAY SEA TRAFFIC SIMULATION

4.1 Purpose of the Simulation

- To assess the safety of the present sea-lane system in Osaka Bay.
- To compare the new sea-lane system proposal of Osaka Bay with the system used at the present time.

4.2 Outline of the Experiment

In this experiment, each ship was directed to travel from the origin to the destination automatically.

At first, the origin was determined according to statistical data of marine traffic conditions. To set the destination and parameters for the dynamic equation of each automatic ship, the following items are required:

- Origin

- Destination
- Intervals of the origin
- Routes
- Parameters of each ship

These items were determined according to statistical data.

The simulation was conducted for 12 hours, during heavy traffic, from 8:00 a.m. to 8:00 p.m. at Osaka Bay. Three possible reports can develop during a simulation, these are: “danger”, “near miss” and “accident”. A “danger” occurs when the Collision Risk (CR) exceeds 0.9. A “near miss” occurs when any ship comes closer to the minimum passing distance circle of any other ship. An “accident” occurs when two ships collide.

4.3 Conditions of the Simulation

The traffic simulation was done under the following conditions:

- There were cargo vessels and tankers that weighed 5GT and over.
- The number of vessels changed according to time zone.
- Ship motion was approximated by first order delay.
- The creation and deletion of dots (vessels) were located at the entryways of each harbour.
- It takes around 3 hours for the marine traffic to stay stationary, therefore, the simulation started at 4 a.m. but the data was collected for 8 a.m.
- The points of veering course were given by using normalized random parameter.

The following conditions were not considered:

- Passenger vessels, ferries, and fishing ships.
- Disturbance of wind or tidal current.
- Acceleration and deceleration in starting or stopping since vessels move at a constant speed in the simulator.

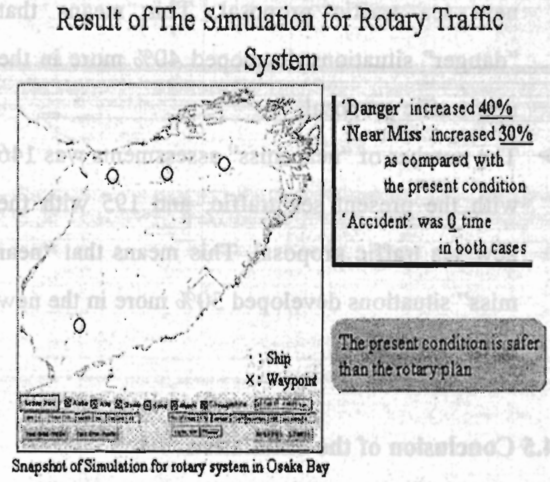

Figure 3 Result of the Simulation for Rotary Traffic

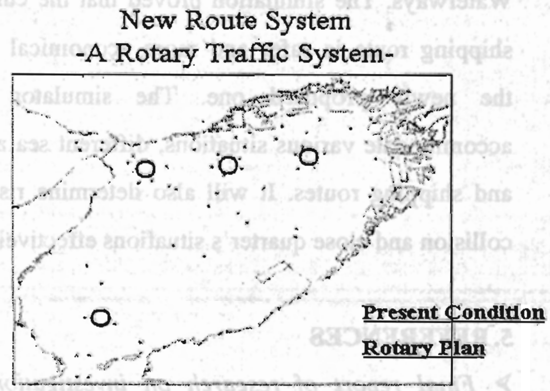

Figure 4 New Route System

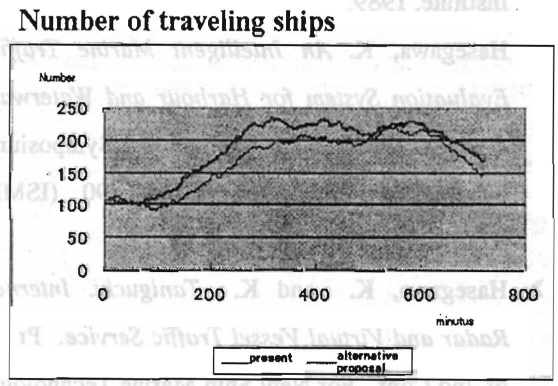

Figure 5 Result of The Simulation.

4.4 Results of the Simulation

- Figure 3 and Figure 4 show where the “near miss” cases occurred.
- The number of “danger” assessments was 973 with the present sea traffic, and 1597 with the

new sea traffic proposal. This means that "danger" situations developed 40% more in the new traffic proposal.

- The number of "near miss" assessments was 146 with the present sea traffic, and 195 with the new sea traffic proposal. This means that "near miss" situations developed 30% more in the new traffic proposal.

4.5 Conclusion of the Simulation

The traffic simulation at Osaka Bay was made by using the Maritime Traffic Simulator for Congested Waterways. The simulation proved that the current shipping route is safer and more economical than the newly proposed one. The simulator can accommodate various situations, different sea areas and shipping routes. It will also determine risk of collision and close quarter's situations effectively.

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