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A Study on Development of LCD monitor-Based Pilots' Ship-Handling Simulator

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Abstract : *This paper is to introduce the development of a LCD monitor-based pilots' ship handling simulator installed in the office of Korea Maritime Pilots Association. This simulator is composed of hardware which includes working server array, operation PC, monitor array, rudder, thruster and telegraph peripheral devices, and software which includes ship mathematical model software, ship conning software, image supporting software and so on. In this simulator, MMG mathematical model is used to create thirteen(13) ship models, which are based on sea trial data & pilots' opinion.. According to requirements of pilots, virtual scenes of different port areas are built, and some required additional functions are also developed. By using this simulator, pilots can fulfill all kinds of training exercises, design of channel approaching ports, traffic safety analysis, prevention of accident research and other tasks, so as to grasp the characteristics of different ships, and accumulate experience for piloting.*

Key words : *ship handling simulator, MMG model, mathematical model software, ship conning software, traffic safety analysis, prevention of accident research*

1. Introduction

Docking and undocking ship-handling is essential for maritime pilots and securing the safety during the handling is more important than anything else. Due to the development of a new harbor, the advent of large-sized ships, and the rapid increase in harbor traffic, the maneuvering environment in the port is changing continuously and quickly and is also getting worse. One of measures taken to cope with this situation is to improve their own maneuvering ability. Fortunately, Korea Maritime Pilots' Association determined the development project of its own ship-handling simulator, starting with November 1, 2008 and ending in April 20, 2012. This paper is to develop a LCD monitor-based ship-handling simulator for training and adapting novice or experienced pilots to a new port or a new ship in advance. The studies regarding this paper were made by Huh(1996), Jeong et al(2011) and Jeong et al(2012).

This simulator is composed of hardware which includes working server array, operation PC, monitor array, rudder, thruster and telegraph peripheral devices, and software which includes ship mathematical model software, ship conning software, image supporting software and so on. The simulation operation program and mathematical ship model was made by using 'Visual C++'(Horton, 2008; Vlissides, 2009). The image of port and geographical characteristics was created by using Vega Prime and Multi-gen (PRESAGIS, 2005; 2011). The thirteen (13) ship models such as container ships, oil tankers, VLCCs, LNG carrier etc, were developed based on real sea trial data and pilots' opinion by using MMG(Yasuo, 2005).

2. Ship motion equations & model ships

2.1 Ship motion equations

The ship fixed reference frame is a right hand frame, with the X-axis pointing forward, the Y-axis to the right and the Z-axis downward, as shown in Fig.1. And u, v, and r are the longitudinal or surge, lateral or sway, and rotational or yaw rate of the moving ship respectively. Generally speaking, the ship motion equations are given by equations (1)(Lewis, 1989). Here, m is the mass of a ship.

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X and Y are the total forces in the longitudinal direction and in the lateral direction respectively. N is the turning moment around the Z-axis. I_Z is the inertia moment of the ship about the Z-axis.

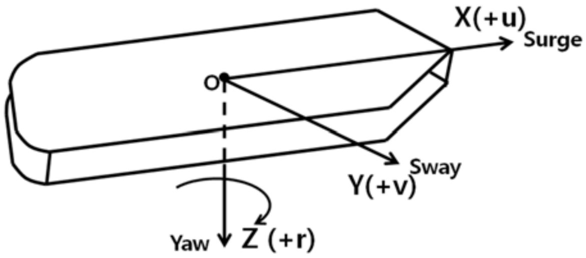


Fig. 1 Ship fixed reference frame

$$
\begin{aligned}
m(\dot{u}-vr) &= X \\
m(\dot{v}+ur) &= Y \\
I_Z\dot{r} &= N
\end{aligned}
\tag{1}
$$

And the total forces and turning moment are represented by equations (2). Here subscript H indicates the ship's hull. Subscript P means the propeller. Subscript R is the rudder. Subscript W and C are the wind and current respectively. Subscript T shows the tug including thruster.

$$
\begin{aligned}
X &= X_H+X_P+X_R+X_W+X_C+X_T \\
Y &= Y_H+Y_P+Y_R+Y_W+Y_C+Y_T \\
N &= N_H+N_P+N_R+N_W+N_C+N_T
\end{aligned}
\tag{2}
$$

In equation (2), Y_P and N_P are almost zero and disregarded. The shallow water effect by Kijima et al(2003) was applied here.

2.2 Ship models

The ship models developed in this paper are represented by Table 1. There are thirteen (13) models. The following are a LNG carrier, VLCCs of full load and half load, ore carriers of full load and ballast, a PCC, a cruise ship, container ships of more than 12,000 TEU and 9,000 TEU, oil tankers of 30,000 GT and 50,000 GT, general cargo ships of 1,000 GT and 10,000 GT. The models are based on MMG (Yasuo, 2005) and also are developed in the following procedure.

Firstly, each ship model was created on the basis of the sea trial data of real ship obtained from shipping companies. The ship models created here were checked and modified to meet the trial data such as M/E speed trial, turning test, pull out test, crash test, inertia stop test 10/10 and 20/20 zigzag test and so on.

However the sea trial tests are based on navigation full speed and each model should be modified to be suitable for pilot's handling. In fact, there are no trial data at the low speeds or very low ones which pilots use in harbor. So, the speed of each stage and the time to reach it due to engine telegraph were determined at first, which were examined by the "clutch table" we call it here. Pilots carried out simulations of model ship at various stages and recorded their points of view. By using them the ship models were tuned.

Table 1 Ship models developed

Ship's type	Size	Condition
LNG carrier	100,000 G/T, 289x44x9.3m	Full-load
VLCC	156,692G/T, 341,804M/T	Full-load
	140,661M/T	Half-load
Ore carrier	95,047G/T, 207,383M/T	Full-load
	108,001M/T	Ballast
PCC	68,701G/T, 47,977M/T	Full-load
Cruise carrier	90,000 G/T	
Container ship	12,600TEU, 366.1x48.2x15.5m	Full-load
	8,600TEU, 339.6x45.6x7.0m	Full-load
Oil tanker	50,000 G/T	Full-load
	30,000 G/T	Full-load
General cargo ship	1,000 G/T	Full-load
	10,000 G/T	Full-load

However, because the opinions are different from each other, they are averaged and used to modify each model. The work was difficult and could be done only by the help of pilots. The movement of each ship model is displayed in the LCD screen according to flow chart in Fig.2.

3. LCD monitor-based pilots' ship-handling simulator

3.1 Structure of ship-handling simulator

As shown in Fig. 3, the simulator is composed of seven(7) components. Operation software in operation PC is in charge of the process of simulation and configuration of scenarios. Conning controller means the rudder and engine telegraph to provide orders of rudder and engine. Conning server is for storing dynamic data of ships. Math model server is in charge of calculating present navigational data of ships. OPC server is for exchanging data from each part and storing the dynamic data of the own ship selected. Visual servers are for providing image signal of the process of a simulation run. Visual monitor

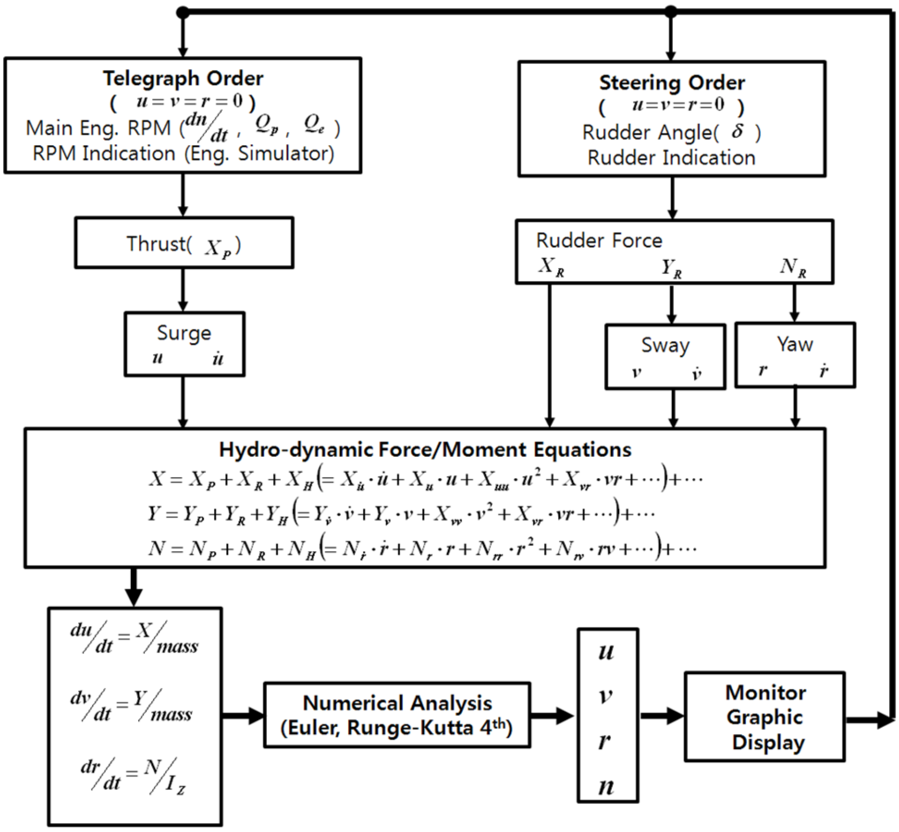


Fig. 2 Flow chart of displaying each own ship on the screen

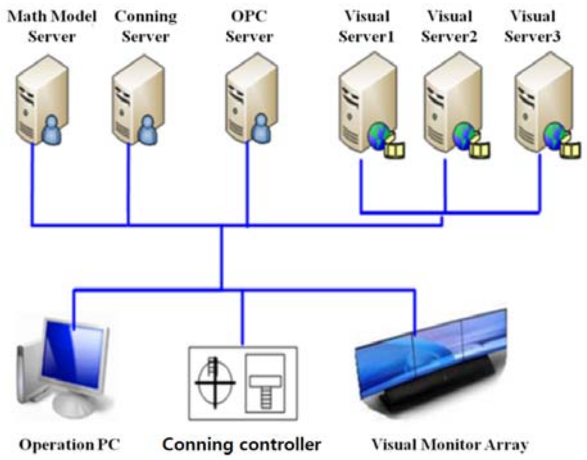


Fig. 3 Structure of Simulator

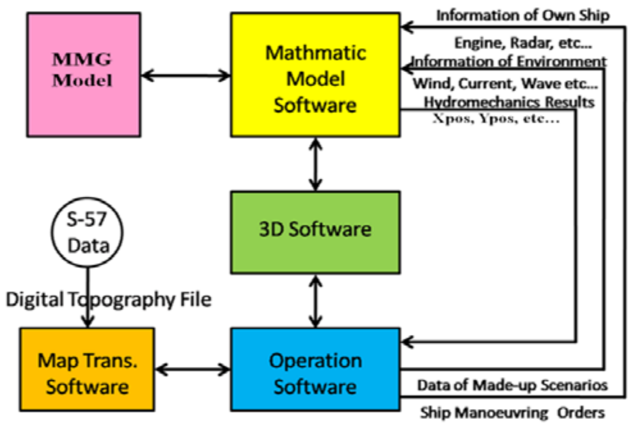


Fig. 4 Mathematic model operation concept

array is in charge of displaying the visual view of ships and environment through a simulation run.

In Fig. 4, the mathematic model operation concept used in the simulator is shown. Operation software sends data of the scenarios which was already created by a ship handler and ship handling orders to mathematic model software which can calculate variously hydro-mechanical parameters of own ships, and receives the calculated results from the model software.

3.2 Structure of image system of simulator

In Fig. 5, the structure of image system of the simulator is shown. In order to display the 3D images provided by visual servers, three 40″ Full HD supported LCD monitors are used. Each monitor is an image channel. And the display range of each channel is ±35° vertically and ±45° horizontally. And the panorama of image system of the simulator is shown in Fig. 6.

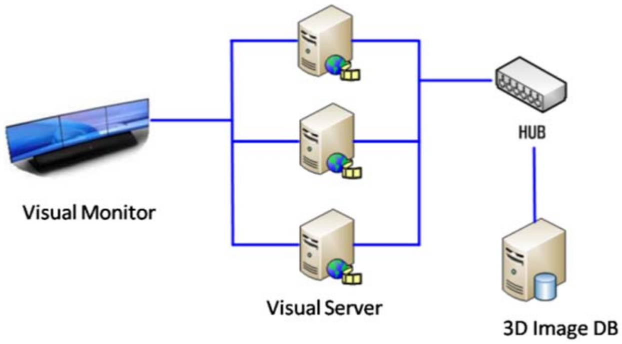


Fig. 5 Structure of 3D Image System

Fig. 6 LCD monitor, conning controller & operation server

3.3 Pilots' ship-handling simulation software

1) Composition of simulation software

As shown in Fig. 7, five(5) types of software are used in the simulator. By using operation S/W, pilots can configure or design specific scenarios, manage the process of a simulation run. Visual S/W is in charge of creating vividly realistic terrestrial and sea environment. Math model S/W is the heart of the simulator and is to calculate present navigational information of own ship. Conning S/W is for monitoring present navigational status of own ship during a simulation run. And OPC S/W is a data exchange center, receives data from operation S/W and sends proper data to conning S/W and visual S/W.

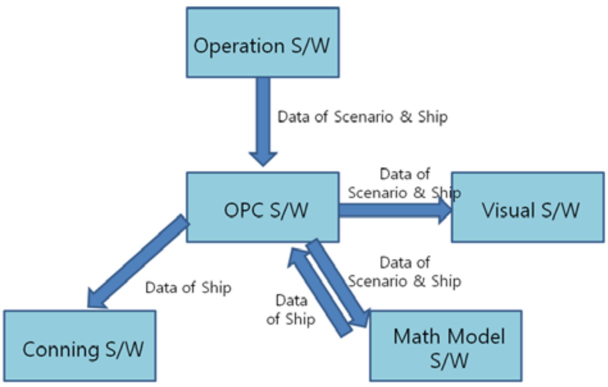


Fig. 7 Composition of simulation software

2) Operation software

Fig. 8 shows the operation S/W. And Fig. 9 represents the menus of this simulator. A pilot can use the menu of scenario to configure specific scenario which he wants. He can create new scenario, save and load it again. When he designs a scenario, he should load a 2D map (a .dxf file) and decide 'add'/'delete'/'change' models of ship and target ship. Also, a pilot can use the menu of exercise control to 'run', 'pause' and 'stop' the process of a simulation run, measure the distance/bearing between two points, adjust some properties of drawing and so on. Moreover, he can use menu of debrief to playback the finished simulation, evaluate it and so on.

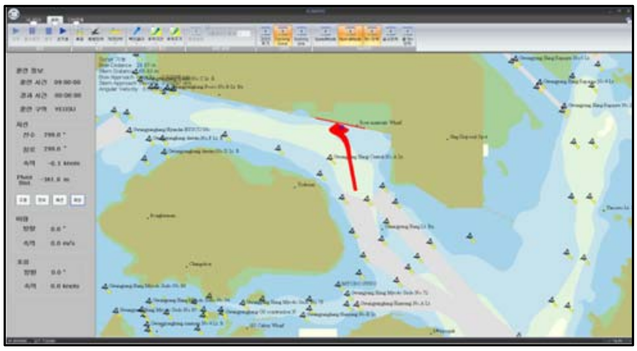
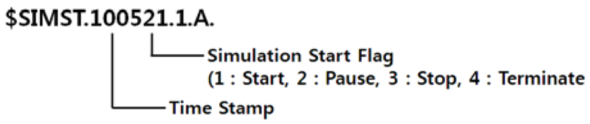


Fig. 8 Operation S/W

Fig. 9 Menus of operation S/W

3) Math model software

In Fig. 10, the math model software is shown. All protocols used here are based on TCP/IP method. Based on the environment data and initial data of the selected own ship, the math model software can calculate the present status of own ship and send the related information of own ship to OPC server by using defined protocols. For example, a protocol which includes the order information of simulation process is defined as follows.



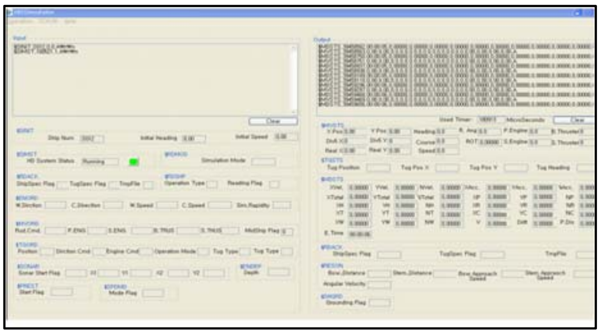


Fig. 10 Math model software

4) Conning software

In Fig.11, the conning S/W is shown. Engine telegraph, rudder angel, rate of turn, heading (degree), speed (knot), time, wind, depth, and position (latitude /longitude) of own ship can be all monitored on the conning S/W. A pilot or trainee can also monitor the necessary navigational data of own ship.

When visual S/W receives the requirements of specific scenario through the visual interface of operation S/W, it will select proper harbor or ship DB and use 3D processing S/W to produce vividly virtual reality according to these given requirements(JEONG et.al, 2011).

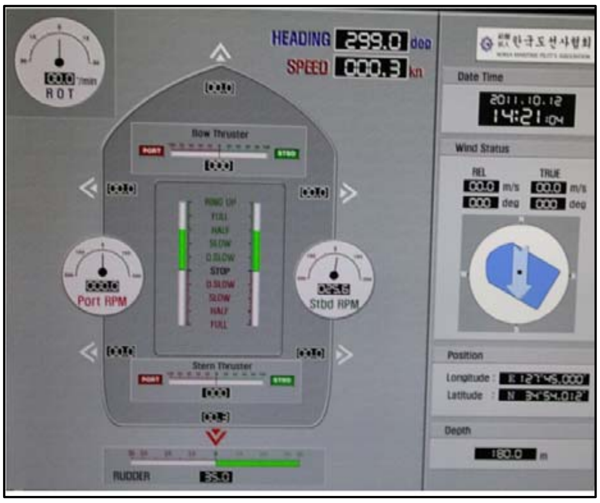


Fig. 11 Conning S/W

3.4 Construction of database of port and own ship

In the ports of compulsory pilotage 2D and 3D topographic and own ship database were developed. As an example, Fig.12 shows 2D and 3D topographic DBs of Busan harbor. These DBs include the information of topographic curve area and traffic division area. And also, Fig.13 represents 3D database of a LNG ship.

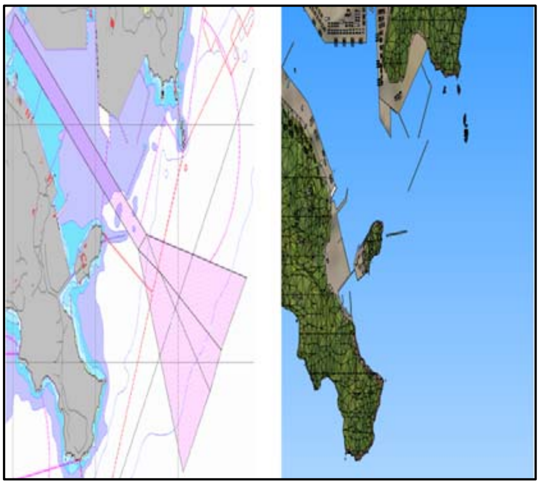


Fig. 12 2D and 3D topographic DBs of Busan Harbor

Fig. 13 DB of LNG Ship

4. Functions of pilots' ship handling Simulator

4.1 Training

Training function is a primary function of the simulator. When a pilot or trainee creates a scenario or loads a saved scenario file, he can start a simulation run and use rudder and engine telegraph to control a ship. In Fig.14, a simulation is running.

4.2 Traffic safety analysis

Using this simulator, risk of ship handling, systematization of skills, and traffic safety of a new or existing channel can be analyzed. The evaluation of port and the validation of a new ship can also be investigated.

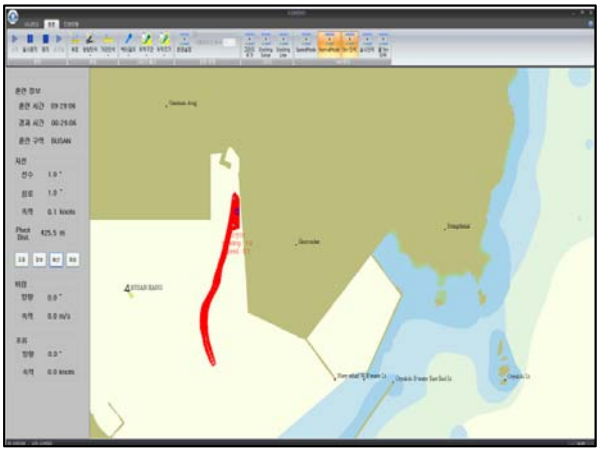


Fig. 14 Run of simulation

4.3 Prevention of accident research

Using this simulator, causes of pilot accidents can be analyzed, and accident prevention measures can be established and shared. Moreover, the difficulties of piloting areas can be analyzed.

4.4 Additional functions (dynamic data display)

According to the requirements of pilots, some additional functions are also developed in the simulator.

(1) Professional piloting to display the velocities and accelerations of surge, sway, and yaw directions and also represent the non-dimensional forces of propeller, rudder, tug, wind and current in three axial directions.

(2) Drift angle (β) and pivot point distance from the center of gravity are represented. Especially pivot point is given by a real point of rotation, not an apparent pivoting point.

(3) Prediction function and docking sonar function. Prediction function is to predict the status of ship in the near future. Docking sonar function is to provide the distances to berth from own ship's bow and stern for helping pilots to acknowledge the distances.

5. Conclusions

In order to help pilots to accumulate experience of piloting and fulfil all kinds of tasks, this paper developed a LCD monitor-based pilots' ship handling simulator. Some related conclusions can be given as follows:

(1) the simulator is composed of seven(7) components. such as operation S/W, mathematical model software, conning controller, conning server, OPC server, visual servers and visual monitor array.

(2) Five(5) types of simulation software were developed, which are operation S/W, visual S/W, math model S/W, conning S/W and OPC S/W.

(3) 2D and 3D topographic DBs of each harbor and own ship were developed.

(4) The pilots' ship-handling simulator were developed to have the following functions such as training, accident research, and additional function.

In the next studies, more research should be continuously studied and added into the simulator.

(1) Connection of engine simulator.

(2) Bank cushion/suction effects in canal transit.

(3) Ship-to-ship interaction

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