Development of Desk top Tug-barge Simulator and Evaluation Module

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Abstract : *This paper is a part of the development on the safe navigation model of tugs and barges in Korea waters. desk-top tug-barge simulator is to train the crew of tugs and barges, especially tugs' crew. It is connected with steering and engine telegraph console and winch control console, and can describe three types of operation mode for a tug-barge working unit, towing mode, side by side and push mode. It can also record and assess each simulation run. The evaluation module can confirm the result of a finished simulation run and help trainees to find and correct their faults, and it is composed of result evaluation and process evaluation.*

Key words : *desk-top tug/barge Simulator, operation mode, towing mode, side by side mode, pushing mode, evaluation module, result evaluation, process evaluation*

1. Background

In the 21st century, tugs and barges still play a key role in carrying offshore structures and plants, equipment for port development and reclamation, building materials for bridges, dredging equipment and blocks for shipbuilding. Compared with the past tugs and barges, the current tugs and barges have become larger in size and increased in number. In particular, barges have recently been specialized for cargoes carried and large-sized fast. The rapid increase and large-size of tugs and barges have caused the increase in the frequency of marine accidents related to tug/barge.

Lee et. al.(2007) shows that tug/barge accidents take 36% and is the highest next to cargo ship except for accidents of fishing boats. Collision accidents involved in tug/barge are represented by more than 40%(MOMAF, 2007). Especially, in Korea, the two(2) collision accidents of barge to the Jindo Great Bridge and the collision accident between Hebei Spirit and barge owned by Samsung Heavy Industries have caused to provide the overall measures for tugs and barges operation. Therefore a study is accomplished in order to give or suggest the overall solutions for improving the safe operation of tug-barges and includes the development of training modules and maneuvering simulator for skippers and crew, the development of wide-area control system for tugs and barges and the operation manual for operators, skippers and crew. This paper is a part of this study and is to introduce the development of a desktop tug-barge simulator and an evaluation module of simulation runs.

2. Development of Desktop Tug-barge Simulator

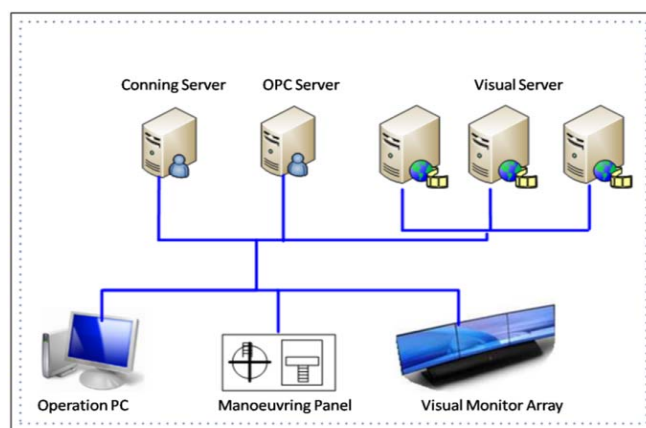### 2.1 Structure of Desktop Tug-barge Simulator

Fig. 1 Structure of simulator

As shown in Fig.1, the tug-barge simulator is composed of six(6) components. Operation software is in charge of the process of simulation and configuration of scenarios. It

is installed in Operation PC. Manoeuvring Panel is for manoeuvring a tug. It contains engine telegraph console, winch control console and steering wheel console. Conning Server is for storing dynamic data of tug/barge, OPC Server for exchanging data from each part, Visual Server for providing 3D signal for displaying 3D view of environment and vessel(tug/barges) during a simulation run and Visual Monitor Array in charge of displaying such visual 3D view.
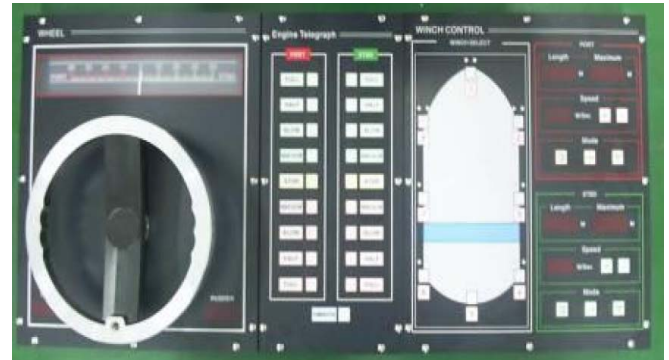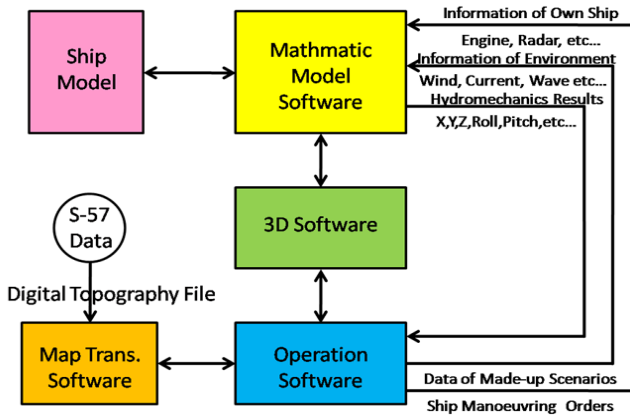

Fig. 2 Mathematic model concept

In Fig.2, mathematic model concept using in the simulator is shown. Operation software sends data of designed scenarios and manoeuvring orders of vessels to mathematic model software which can calculate variously hydrodynamic parameters of tug according to the data, and receives the calculated results from it.

2.2 Hardware of Desktop Tug-barge Simulator

2.2.1 Development of Manoeuvring Panel

In the simulator, 3 kinds of control console are developed. These are steering gear console in charge of steering, engine telegraph console giving engine orders and winch control console controlling winches. The appearances and functions of them are quite similar to the ones aboard a real towboat. They are installed in a connected case and use 220V AC as power supply.

In Fig.3, manoeuvring panel is shown. The left part is steering gear console and steering range of it is from port to starboard. The middle part is engine telegraph console which can provide nine-phase control of engine. And the right part is winch control console which can provide control of winches and display status of hawsers. The manoeuvring panel can implement three types of operation mode for tug-barge working unit, towing mode, side by

Fig. 3 Manoeuvring panel

side and push mode. Moreover, in order to communicate with the manoeuvring panel, protocols used in the simulator are designed in NAME format. For example, a protocol for sending rudder angle from PC to steering gear console for displaying is given as follows:

$IIRSA,x.x,A,x.x,A*hh<CR><LF>

2.2.2 Structure of 3D Image System of Simulator

Fig. 4 Panorama of 3D Image system

In Fig.5, the structure of 3D Image System of the Simulator is shown. In order to display the 3D images
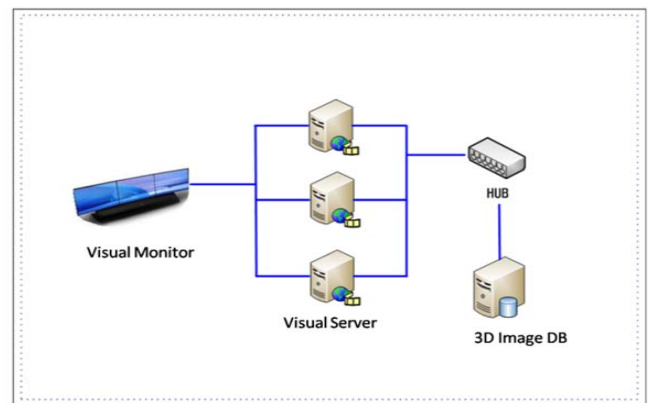

Fig. 5 Structure of 3D image system

which are provided by visual servers, three HD supported Full LCD monitors are used. Each monitor has an image channel. And the field of view range of each channel is vertical/ horizontal. And the panorama of the 3D image system of the simulator is shown in Fig.4.

2.3 Software of Desktop Tug-barge Simulator

2.3.1 Composition of Software of Desktop Tug-barge Simulator
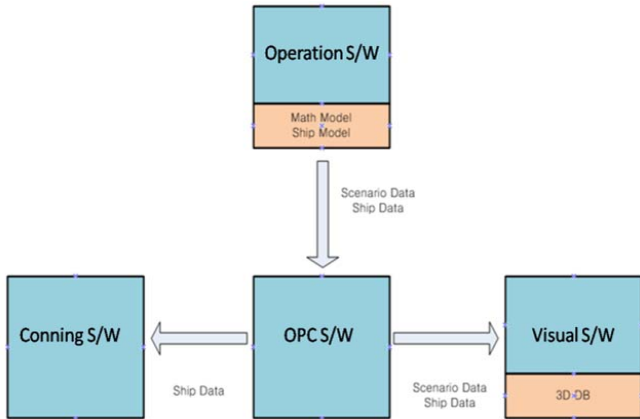

Fig. 6 Composition of Software of Desktop Tug-Barge Simulator

As shown in Fig.6, four types of software are used in the simulator. By using operation S/W, lecturer can configure or design specific scenarios, supervise the process of a simulation run and even develop ship model or 3D topography. 3D visual S/W is in charge of creating vividly realistic terrestrial and sea environment. 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 which receives data from Operation S/W and sends proper data to Conning S/W & Visual S/W.
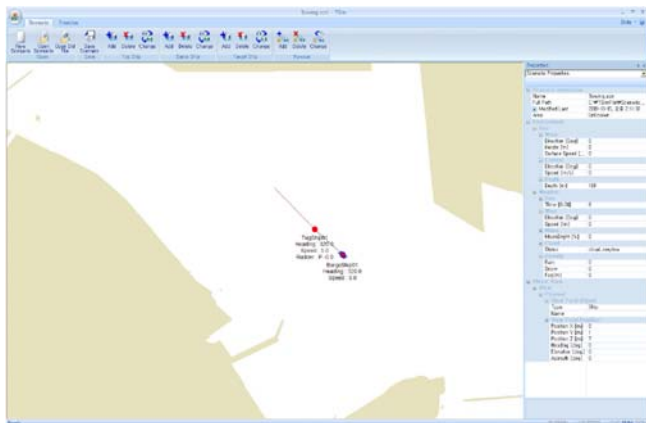
2.3.2 Operation Software

Fig. 7 Interface of operation S/W

In Fig.7, interface of Operation S/W is shown.

Fig. 8 Scenario menu of operation S/W

Fig. 9 Exercise control menu of operation S/W

And in Fig.8 and Fig.9, Operation S/W's menu of scenario and menu of exercise control are shown respectively. Lecturer can use the menu of scenario to configure the specific scenario which he wants. He can create new scenario, save and load it. When he designs a scenario, he should load a 2D map (a .dxf file) at first and decide add/delete/change specific model of tug ship, barge ship, target ship or type of hawser on it. Also, lecturer/trainee can use the menu of exercise control to control (run, pause, stop) the process of a simulation run, measure the distance/bearing between two points, adjust properties of drawing and so on.
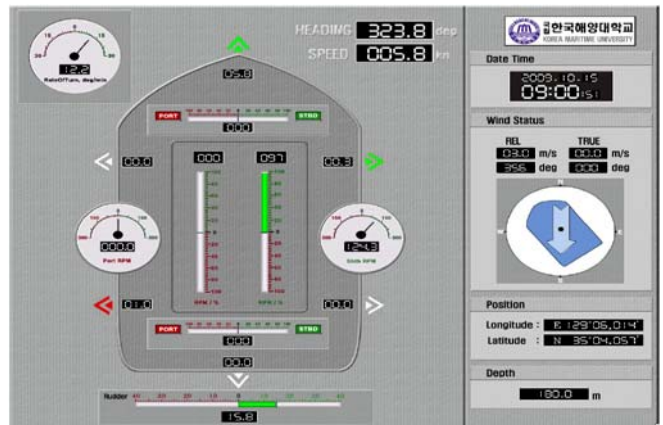
2.3.3 Conning Software

Fig. 10 Interface of conning S/W

In Fig.10, interface of Conning S/W is shown. Engine telegraph, rudder angel, rate of turn, heading (degree), speed (knot), time, wind, depth, position (latitude /longitude), bow transverse speed, stern transverse speed of own ship are all displayed in real time on the interface. So lecturer/trainee can monitor such necessary navigational

data of own ship through the interface.

When Visual S/W receives requirements of specific scenario through the visual interface of Operation S/W, it will select proper harbor DB/ship DB and use 3D processing S/W to produce vividly virtual reality 3D image according to such given requirements.

2.4 Functions of Desktop Tug-barge Simulator

2.4.1 Function of Training

Training function is the primary function of the simulator. When lecturer/trainee creates a scenario or loads a saved scenario file, he can begin a simulation run. He can use the manoeuvring panel to maneuver a tugboat, use Operation S/W to select proper type of hawser and type of operation for a tug/barge unit etc. And as shown in Fig.11, a simulation run is done.
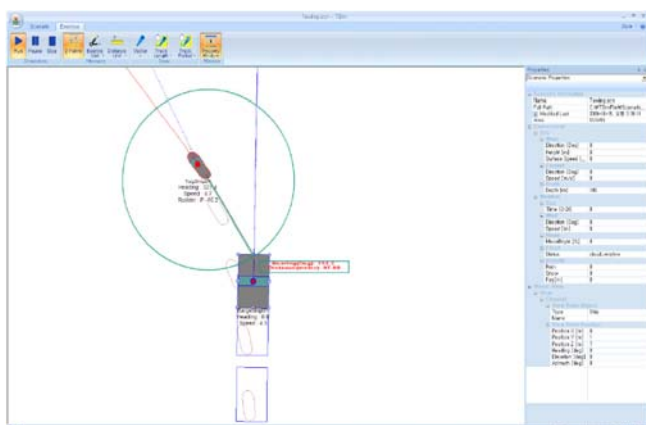

Fig. 11 A Running simulation run

2.4.2 Function of Environment Adjustment

In the simulator, during the process of a simulation run, environment can be adjusted. Lecturers and trainees only need to set proper values of variables in the environment setting area of Operation S/W just as shown in Fig.12.

Fig. 12 Environment setting area

Then the 3D image of the environment will change according to such setting values. Variables of sea condition and weather condition can be adjusted.

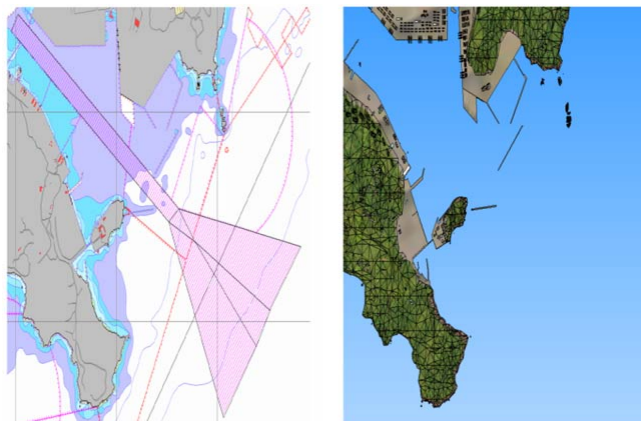## 2.5 Construction of Database of Harbor and Ship

Fig. 13 2D and 3D topographic DBs of Busan Harbor

In Fig.13, 2D and 3D topographic DBs of Busan Harbor are shown. These DBs include the information of topographic curve area and traffic division area.
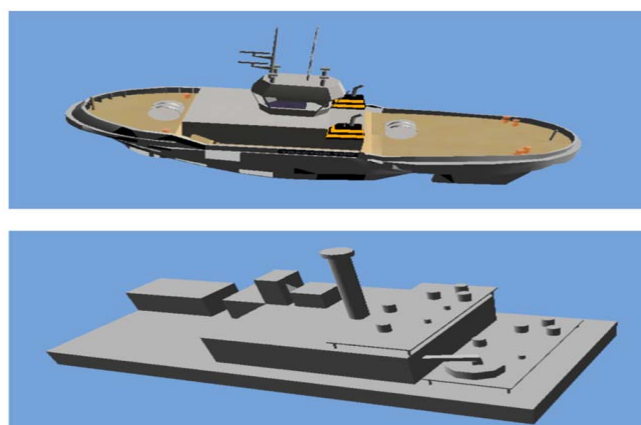

Fig.14 3D DBs of tug and barge

In Fig.14, 3D databases of tug and barge are shown.

2.6 Tug-Barge Model

In this study, the used ship model of tug-barge model is shown in Table 1. The model is developed by using "Denmark I" and "Shipyard" S/W of Force Technology.

When tug-barge working unit works in towing mode, the relationship between tug boat and barge can be demonstrated as in Fig.15, and the mathematic equations can be expressed as equation(1)~equation(5).

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Table 1 Used Tug-Barge model

Item	Tug	Barge
LOA(m)	32.9	60
LPP(m)	26.36	60
Beam(m)	10.36	30
Draught(m)	3.94(fore)	1.6
	4.94(aft)	
Displacement	710	2400
Thruster	0/2 AZ(fp)	
Propeller	ASD	
Loading State		Loading

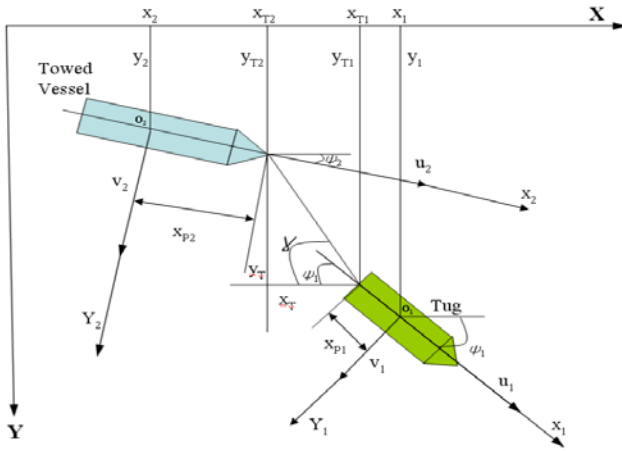Fig. 15 Relationship between Tug and Barge

$$(m_1 - X_{\dot{u}_1})\dot{u}_1 = X_1 + X_P + X_R + X_{1wind} + X_{1wave} + X_{1current} - (T + Rt)\cos(\omega_1)$$

$$(m_1 - Y_{\dot{v}_1})\dot{V}_1 - Y_{\dot{r}_1}\dot{r}_1 = Y_1 + Y_P + Y_R + Y_{1wind} + Y_{1wave} + Y_{1current} - (T + Rt)\sin(\omega_1)$$

$$-N_{\dot{v}_1}\dot{V}_1 + (I_{Z1} - N_{\dot{r}_1})\dot{r}_1 = N_1 + N_P + N_R + N_{1wind} + N_{1wave} + N_{1current} - (T + Rt)x_{p1}$$

$$(m_2 - X_{\dot{u}_2})\dot{u}_2 = X_2 + X_{2wind} + X_{2wave} + X_{2current} - (T + Rt)\cos(\omega_2)$$

$$(m_2 - Y_{\dot{v}_2})\dot{V}_2 - Y_{\dot{r}_2}\dot{r}_2 = Y_2 + Y_{2wind} + Y_{2wave} + Y_{2current} - T\sin(\omega_2)$$

$$-N_{\dot{v}_2}\dot{V}_2 + (I_{Z2} - N_{\dot{r}_2})\dot{r}_2 = N_2 + N_{2wind} + N_{2wave} + N_{2current} - T\sin(\omega_2) \quad (1)$$

$$\dot{y}_1 = v_1\cos\psi_1 + u_1\sin\psi_1$$
$$\dot{x}_1 = u_1\cos\psi_1 - v_1\sin\psi_1$$
$$\dot{r}_1 = \dot{\psi}_1$$
$$\dot{x}_2 = u_2\cos\psi_2 - v_2\sin\psi_2$$
$$\dot{y}_2 = v_2\cos\psi_2 + u_2\sin\psi_2$$
$$\dot{r}_2 = \dot{\psi}_2$$
where

$$X_i = (X_{vri} - Y_{vi} + m_i)V_i r_i + X_{0i} + X_{ui}\Delta u_i + \frac{1}{2}X_{uui}\Delta u_i^2$$

$$Y_i = Y_{vi}V_i + (Y_{ri} - X_{ui} - m_i u_i)r_i + Y_{vvvi}V_i^3 + Y_{vvri}V_i^2 r_i + Y_{vrri}V_i r_i^2 + Y_{rrri}r_i^3$$

$$N_i = N_{vi}V_i + N_{ri}r_i + N_{vvvi}V_i^3 + N_{vvri}V_i^2 r_i + N_{vrri}V_i r_i^2 + N_{rrri}r_i^3 + N_{ri}u_i r_i \quad (2)$$

$$(i = 1, 2)$$

Here, Xi, Yi, Ni are force of surge, sway and moment of yawing. Subscript 1 and 2 are tug boat and ship, and subscript P and R are effect of propeller and rudder respectively.

$$\sin\gamma = y_T / x_T$$
$$\omega_1 = \gamma + \psi_1$$
$$\omega_2 = \gamma + \psi_2$$
$$hw = \sqrt{x_T^2 + y_T^2}$$
$$x_T = x_1 - x_{p1}\cos\psi_1 - (x_2 + x_{p2}\cos\psi_2)$$
$$y_T = y_1 - x_{p1}\sin\psi_1 - (y_2 + x_{p2}\sin\psi_2) \quad (3)$$

Assuming hawser is inflexible and pendulous, using the pendulous model, tension force of different sections can be calculated.

$$H = T * (\sec\theta - 1)/w$$
$$\tan\theta = l * w / 2$$
$$lw = 2T * \sinh(\tan\theta) \quad (4)$$

Here, T is towing tension force(ton), w is weight of hawser per meter (ton/m) underwater. Resistance force of hawser can be calculated as follows.

$$R_t = \frac{0.472}{1000}V^2(\frac{d}{10})(\frac{s}{1000})[1 + \frac{1.122}{1000T}(\frac{d}{10})(\frac{s}{100})^2](ton) \quad (5)$$

Here, d is diameter(mm) of hawser, s is the effected distance of hawser as shown in Fig. 16, V is advance speed, T is tension force of hawser.

Fig. 16 Tug and Barge

Moreover, every math model of a ship is generated according to parameters of its engine and rudder by using "Denmark I" and "Shipyard" S/W of Force Technology. Therefore, expressive manoeuvring characteristics of a ship model will be different according to the difference among different type of engine and rudder.

3. Evaluation Module

In order to confirm the result of a simulation run in the

simulator of tag/barge and help trainees to correct their various faults, evaluation module which is composed of result evaluation and process evaluation is provided.

Result evaluation is a quantitative one for evaluating the result of a finished simulation run. On the other hand, process evaluation is for evaluating the process of obtaining such result.

3.1 Result Evaluation

Result evaluation does not use dependent variables to evaluate the result, and it uses a creatively comparative approach. For example, in the case of comparing deviated extent from center line of a channel, it not only compares extent with different sea routes as some normal methods but also compares the indications of navigation or achievements of different simulation runs. And therefore, it attaches importance to improvement of seafarers' seamanship and stability of the results. In fig.17, two evaluation results are shown.
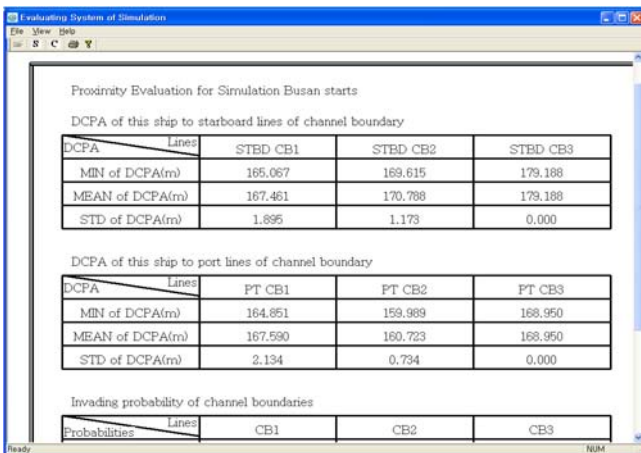

Fig. 17 Result evaluation

3.2 Process Evaluation

Process evaluation uses an inspection chart or a checklist to check the proceeding status of trainees during or after a simulation run. In order to fulfill such evaluation, instructors need to observe trainees through CCTV or visit bridge where the trainees stay, and then finish the checklist directly. Each item of such checklist occupies its corresponding points respectively. So the score of a finished checklist can be summed up in no time and show the level of performance of a trainee. Process evaluation can evaluate behavior and communication.

Behavior evaluation mainly considers several aspects as follows:

1) Focusing on motion of ship and position and observing behavior of trainees.
2) Checking lookout behaviors and specific behaviors of trainees during a simulation run.
3) Excluding the subjectivity of instructor/lecturer.
4) Items of behavior evaluation include duty shifting, preparation for port entry, collision avoidance, navigation, equipment trial & emergency, course alteration, connecting/disconnecting with large ship/bank.

Communication evaluation is to check efficiency of the communication among trainees. According to the classification of communication, the consistency of command/action of each type of communication will be checked. Usually, communication contains orders, provision of information, and request of information, etc.

4. Conclusion

In order to enhance quality of the crew of tug/barge and to ensure safe navigation of them and other ships, a desktop tug-barge simulator is developed and introduced in this paper. Some related conclusions can be given as follows:

1) The simulator is connected with the manoeuvring panel which provides steering console, engine telegraph console and winch control, and can describe three different operation modes (towing mode, side by side mode and push mode). Trainees can conveniently use the manoeuvring panel to manipulate a simulation run. Moreover, Lecturer can use operation S/W to design different scenarios for training. Each simulation run can be recorded.
2) Evaluation module can evaluate the result of simulation and the performance of trainees after/during the simulation run. And therefore, it can help trainees to find their problems on different aspects so as to further enhance the quality of them.
3) Trainees can learn to determine the suitability of a towing vessel to undertake a tow in given circumstances, evaluate the equipment fitted for a tug/barge unit.

In next study, 3D/2D database of more harbors and areas, blast/light signal training module should be continuously appended/updated. Moreover, characteristics of tugboat and tug/barge unit should be further continuously studied by fulfilling more tests and experiments.

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Acknowledgements

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