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Original article

Research on the Automatic Assessment System for the Ship Handling Simulator

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Abstract

At present, the assessment for the crew training using the ship handling simulator is completed by the assessor, which is subjective and difficult to unify the assessment criteria. Under this assessment mode, the assessor will have a great work intensity. So it is necessary to design and develop the automatic assessment system for the ship handling simulator. This paper introduces the automatic assessment system developed by Dalian Maritime University (shorted for DMU), which includes the assessment method, system architecture and implementation. A selected example of applications is described.

Keywords: Automatic Assessment Model , Ship Handling , Assessment Indices , Simulator

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1. Introduction

The assessment for pilot, captain or other ship offi cer's competency in ship manoeuvring using Full M ission Ship Handling Simulator is completed by the assessor. In this way, it is more subjective and d ifficult to unify the assessment criteria. By the end of 2013, there are more than 650,000 crews in Chin a. Under this assessment mode, the assessor will h ave a great work intensity. So it is necessary to des ign and develop an automatic assessment system.

At present, ship handling simulator can meet the re quirements of STCW convention and STCW code i ncluding 2010 manila amendments, most of simulato rs already have an automatic assessment function, b ut which need to be further improved. Knud et al.(2 006) has created Software tools and implemented at the Maritime Simulation Centre in Warnemünde: th e "Surveillance Tool", allows for a monitoring durin g the run and the "Evaluation Tool" enables a detai led evaluation by the instructor after the run. It allo ws for in-depth search within the replay data and at the same time facilitates the calculation of the final score for the student's performance based on meas urement factors as penalties for exceeding quality li mits. Kongsberg (2015) also has evaluation functions in their simulator, the evaluation system enables th e instructor to make the structured and objective ass essment of the trainee's performance. Transas (2014) has developed evaluation system named Transas Ev aluation and Assessment System (TEAS). Memorial University also has done some researches in the eva luation system.

Liu (2002) built an assessment system to evaluate t he radar operation in radar simulator. The assessmen t obtained from this system is objective and depend able. Shi and Jia (1997) established a mathematic m odel of the comprehensive assessment to evaluate th e safety of the ship manoe-uvring.

Hong and Jia (2002) established evaluation indices for ship manoeuvrability, and then ranked the ship manoeuvrability by using the Analytical Hierarchy P rocess (AHP). Qiu, et al.(2005) constructed a mathe ma-tical model of comprehensive fuzzy assessment a ccording to the model of Formal Safety Assessment (FSA).

Ma(2011) established an evaluation system for the bridge resource management.

Zhang et al.(2022) initially screened the evaluation indicators, and the final evaluation index system is c onstructed according to the four stages of berthing a rea identification, path planning, inshore manipulatio n and unberthing manipulation.

Murai et al.(2022) proposed a quantitative evaluatio n based on saliva, and applied it in a simulator-base d experiment.

Koji et al.(2022) quantify the skills related ship op eration, particularly skilled operator-level recognition of maneuvering environments and determination of s hip maneuvers.

Fang et al.(2021) Established an evaluation model of Berthing behavior. Liu et al.(2022) proposed a n ovel ship collision risk evaluation model.

This paper introduces an automatic assessment system developed by Dalian Maritime University. Chapter 2 intro-duces the assessment method and system architecture. Chapter 3 introduces the design and implementation of three main modules. And an example is shown in Chapter 4.

2. System architecture

The automatic assessment system for ship manoeuv ring based on Dalian Maritime University's ship han dling simulator, includes five functional modules--qu estion edition module, data management module, ass essment module, question transmission module, and answer module. The first three modules are in the c oach station, the others in the own ship station. The specific system architecture is shown in Figure1(Ch en et al. 2011, Wang 2013).

The system operation procedure is that, firstly, edit the question; secondly, transmit to the own ship station; thirdly, start the own ship program after initializing the ship parameters and navigational environment; fourthly, the trainee does the exercise in the own ship station; finally, transmit the manipulate data and system parameters to the coach station, start the assessment program to give the assessment results.

3. Design and Implementation of three modules

3.1. The question edition

There are three main parts in the assessment sectio ns, including the ship manoeuvring (berthing and de -berthing, anchoring and sailing in the fairways etc.), the collision avoidance (in sight of each other, in p oor visibility, in the special water area etc.) and the bridge resource management (BRM). The ship man oeuvring and collision avoidance assessment models have been established. The BRM contains many hu man factors, so the BRM assessment model has not been established completely.

3.1.1 The Type of Question Selection

In this part, divide the evaluation content into three categories, the ship manoeuvring, collision avoidanc e and BRM based on the theory and practice of the navigation.(shown in figure 2)

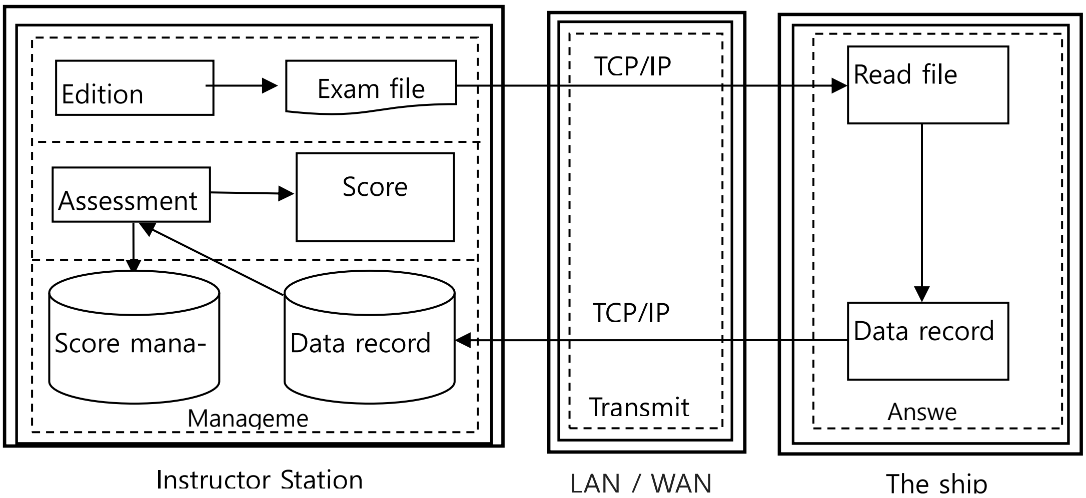


Figure 1: System architecture

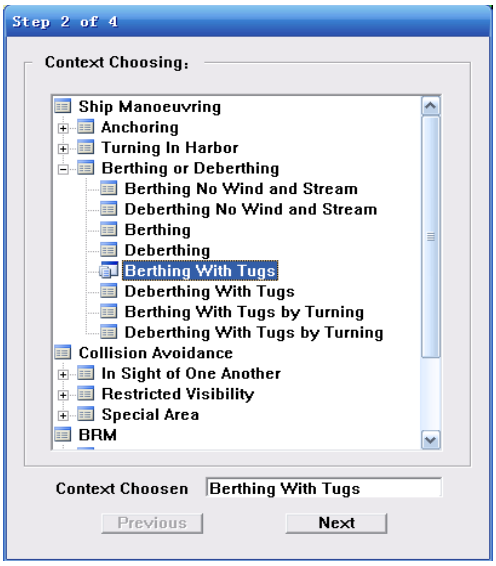


Figure 2: Select the type of questions

The ship manoeuvring includes "anchoring", "turnin g in harbour", "berthing" and "de-berthing". A more detailed classification can be given by considering different environments for each category. Take the "Berthing or De-berthing" for example, it can be di vided into 8 categories, includes "Berthing with no wind and stream", "De-berthing with no wind and s tream", "Berthing", "De-berthing", "Berthing with tu gs", "De-berthing with tugs", "Berthing with tugs by turning" and "De-berthing with tugs by turning".

The framework of automatic assessment model is a s follows: firstly, establish an evaluation index syste m for each category based on the theory and practic e of the navigation; secondly, calculate the weight o f each index in this system by using the expert inv estigation method and analytic hierarchy process; thir dly, get the standard value or standard handling for each index; fourthly, choose membership function (mostly an exponential function or a piecewise funct ion) based on the characteristics of the index; fifthly, give the acceptable range of the difference between the operation result and the standard result for each index; finally, get the automatic assessment model.

3.1.2 The Ship Navigational Environment Setting

Let the assessment model know the content to be evaluated before evaluating the candidate's ability. T herefore, an exam file should be set in advance. Th e exam file should contain the environment, own sh ip and target ships information which can be set by using the platform shown in figure 3.

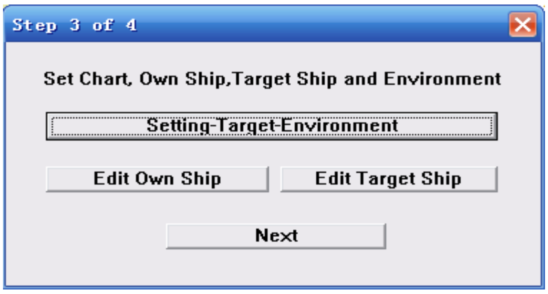


Figure 3: Setting the ship navigational environment

3.1.3 The Assessment Indices Edition

The assessment index system has been built before the assessment model was built based on the theor y and practice of the navigation. The function of ed iting the assessment indices is designed especially fo r the examination, because the emphasis and criteria of assessment for the specific examination are different from others. The examiner can adjust the assessment indices by using the interface shown in figure 4, and then make the assessment indices meet the requirements of the specific examination.

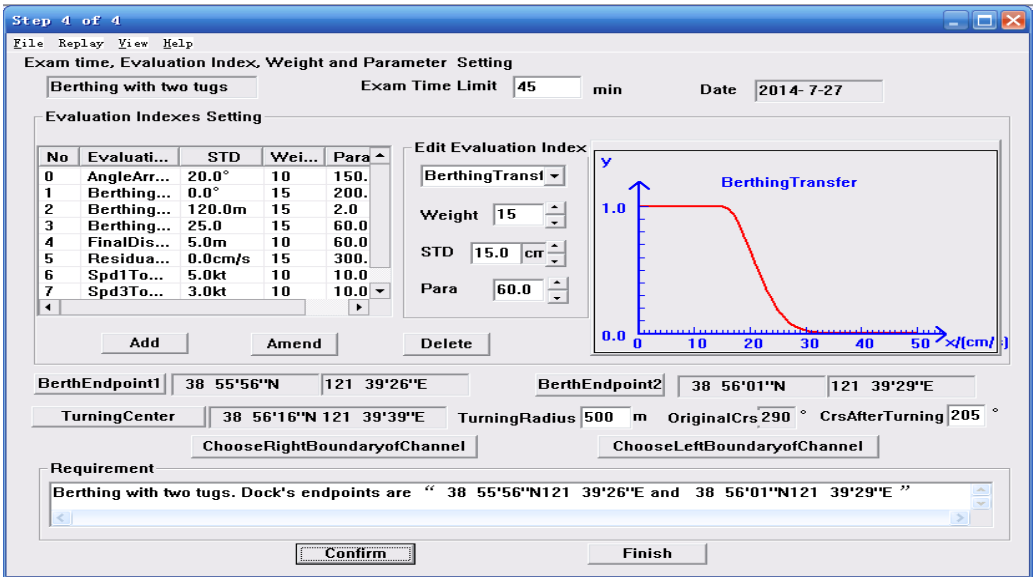


Figure 4: Question edition interface

The contents, which can be modified on the basis of the assessment index system given by default at the beginning of the question edition, are as follows: adding or deleting one assessment index or more, changing the standard values (or operation), weights and parameters of an assessment index.

3.1.4 The Question Confirmation

After finished all settings above, the examiner should check whether the settings are correct by himself or using program. The confirmation should contain the following information: the total weights of the assessment indices, whether the modifications meet the requirements of the specific examination or not. If there is no problem, save the exam file.

3.2 The Assessment

3.2.1 The Assessment Method and Assessment Index System

The criterion for ship manoeuvring sometimes is tentative and ambiguous. It is very hard to find a precise quantifiable criterion. So, it is suitable for establishing a fuzzy membership function for each assessment index, and calculating the weight by using expert assessment method and analytical hierarchy process.

The assessment indices are established for each type of questions shown in figure 2. For each assessment index, set a standard value or operation, then establish a membership function. The trainee's score can be gotten after completing the exercise. Take berthing assessment for example, the assessment indices are shown in Tab.1.

In this assessment indices system, there are 12 indices, the details of which are as follows:

(1) Ship Speed Control (1~3 n mile from the berth)

v_1 is the average speed in the area of 1 to 3 n miles from the berth.

v_{1S} is the standard speed in the area of 1 to 3 n miles away from the berth, and it can be obtained from the theory of the ship handling.

k_8 is the parameter of the membership function for this index.

(2) Ship Speed Control (3~5 times LOA from the Berth).

v_2 is the average speed in the area of 3 to 5 times length overall (LOA) away from the berth.

v_{2S} is the standard speed in the area of 3 to 5 times (LOA) from the berth, and it can be obtained from the theory of the ship handling.

k_9 is the parameter of the membership function for this index.

(3) Trail keeping.

t_K is the average value. Add up the distances from each ship position to the nearest point in the centre of the channel, and then divide the total of the sh ip positions in the channel to get the average value.

Table 1: Berthing assessment indices

Assessment Index	Weight	Membership Function
Inertial Speed	15	$\mu(v)=e^{-(v-v_s)^2/k_1}$
Transfer Distance on Arrival of the Berth	15	$\mu(d)=e^{-(d-d_s)^2/k_2}$
Angle Arrived	10	$\mu(a_A)=\begin{cases}1 & a_A\le a_{AS}\\ e^{-(a_A-a_{AS})^2/k_3} & a_A>a_{AS}\end{cases}$
Berthing Angle	10	$\mu(a)=e^{-(a-a_s)^2/k_4}$
Berthing Speed	15	$\mu(v_T)=\begin{cases}1 & v_T\le v_{TS}\\ e^{-(v_T-v_{TS})^2/k_5} & v_T>v_{TS}\end{cases}$
Final Distance to the Berth	5	$\mu(d_F)=\begin{cases}1 & d_F\le d_{FS}\\ e^{-(d_F-d_{FS})^2/k_6} & d_F>d_{FS}\end{cases}$
Minimum distance to t he Channel boundary	5	$\mu(d_C)=\begin{cases}1 & d_C\ge d_{CS}\\ e^{-(d_C-d_{CS})^2/k_7} & d_C<d_{CS}\end{cases}$
Ship Speed Control (1 ~3 n mile from the be rth)	5	$\mu(v_1)=\begin{cases}1 & v_{1S}-1\le v_1\le v_{1S}+1\\ e^{-(v_1-v_{1S})^2/k_8} & v_1<v_{1S}-1 or v_1>v_{1S}+1\end{cases}$
Ship Speed Control (3 ~5 times LOA from the berth)	5	$\mu(v_2)=e^{-(v_2-v_{2S})^2/k_9}$
Trail keeping	5	$\mu(t_K)=\begin{cases}1 & t_K\le t_{KS}\\ e^{-(t_K-t_{KS})^2/k_{10}} & t_{KS}<t_K<1\\ 0 & t_K\ge 1\end{cases}$
Lines Order	5	$\mu(L)=\begin{cases}1 & OperationOK\\ 0 & Otherwise\end{cases}$
Tug Assistance	5	$\mu(T)=\begin{cases}1 & OperationOK\\ 0 & Otherwise\end{cases}$

t_{KS} is the standard value, and it can be obtained fr om the theory of the ship handling.

k_{10} is the parameter of the membership function for this index.

(4) Minimum distance to the Channel boundary.

d_C is the average value. Add up the distances from each ship position to the nearest point in the boun dary of the channel, and then divide the total of the ship positions in the channel to get the average val ue.

d_{CS} is the standard value, and it can be obtained fr om the theory of the ship handling.

k_7 is the parameter of the membership function for this index.

(5) Inertial Speed.

v is the longitudinal residual speed at the time the ship bow arrives at the front area of the berth firstl y.

v_S is the standard value, and it can be obtained fro m the theory of the ship handling.

k_1 is the parameter of the membership function for this index.

(6) Transfer Distance on Arrival of the Berth.

v is the vertical distance from the ship to the berth when the ship bow arrives at the front area of the berth firstly.

d_s is the standard value, and it can be obtained fro m the theory of the ship handling.

k_2 is the parameter of the membership function for this index.

(7) Angle Arrived.

a_A is the angle from the direction of the ship track s to the direction of the berth when the ship bow a rrives at the front area of the berth firstly.

a_{AS} is the standard value, and it can be obtained fr om the theory of the ship handling.

k_3 is the adjustment parameter of the membership f unction for this index.

(8) Berthing Angle.

a is the angle from the ship heading to the shoreli ne of the berth when the ship begins to berth at the berth.

a_S is the standard value, and it can be obtained fro m the theory of the ship handling.

k_4 is the parameter of the membership function for this index.

(9) Berthing Speed.

v_T is the vertical speed to the berth when the ship begins to berth at the berth.

v_{TS} is the standard value, and it can be obtained fr om the theory of the ship handling.

k_5 is the parameter of the membership function for this index.

(10) Final Distance to the Berth.

d_F is the vertical distance from the final ship posit ion to the berth.

d_{FS} is the standard value, and it can obtained from the theory of the ship handling.

k_6 is the parameter of the membership function for this index.

(11) Lines order. If the trainee’s operation meets the pre-set standard operation, the score for this index is 1, otherwise, is 0.

(12) Tug assistance. If the trainee’s operation meets the pre-set standard operation, the score for this ind ex is 1, otherwise, is 0.

3.2.2 The Assessment Process

The assessment process mainly has 9 steps shown i n Figure 5:

(The trainee manoeuvres the own ship, then the syst em records the data.)

(1) Judge whether the own ship is in the channel. I f so, evaluate “minimum distance to the channel bo undary”. The purpose is to judge whether the ship i s sailing in the safe area.

(2) Evaluate “trail keeping”. Distinguish to different legs.

(3) There are three main reasons, if the trainee chan ges course. The first one is that the ship is nearby or at the way point; the second one is that he is ta king the collision avoidance operation; the third one is mistaken. For the first reason, evaluate “the man oeuvre of altering course”, which includes the efficie ncy of altering course and the steady operation; for the second reason, call the collision avoidance modu le; for the third reason, return to step 1.

(4) Evaluate “ship speed control”, when the ship is sailing in the area of 1 to 3nm away from the bert h.

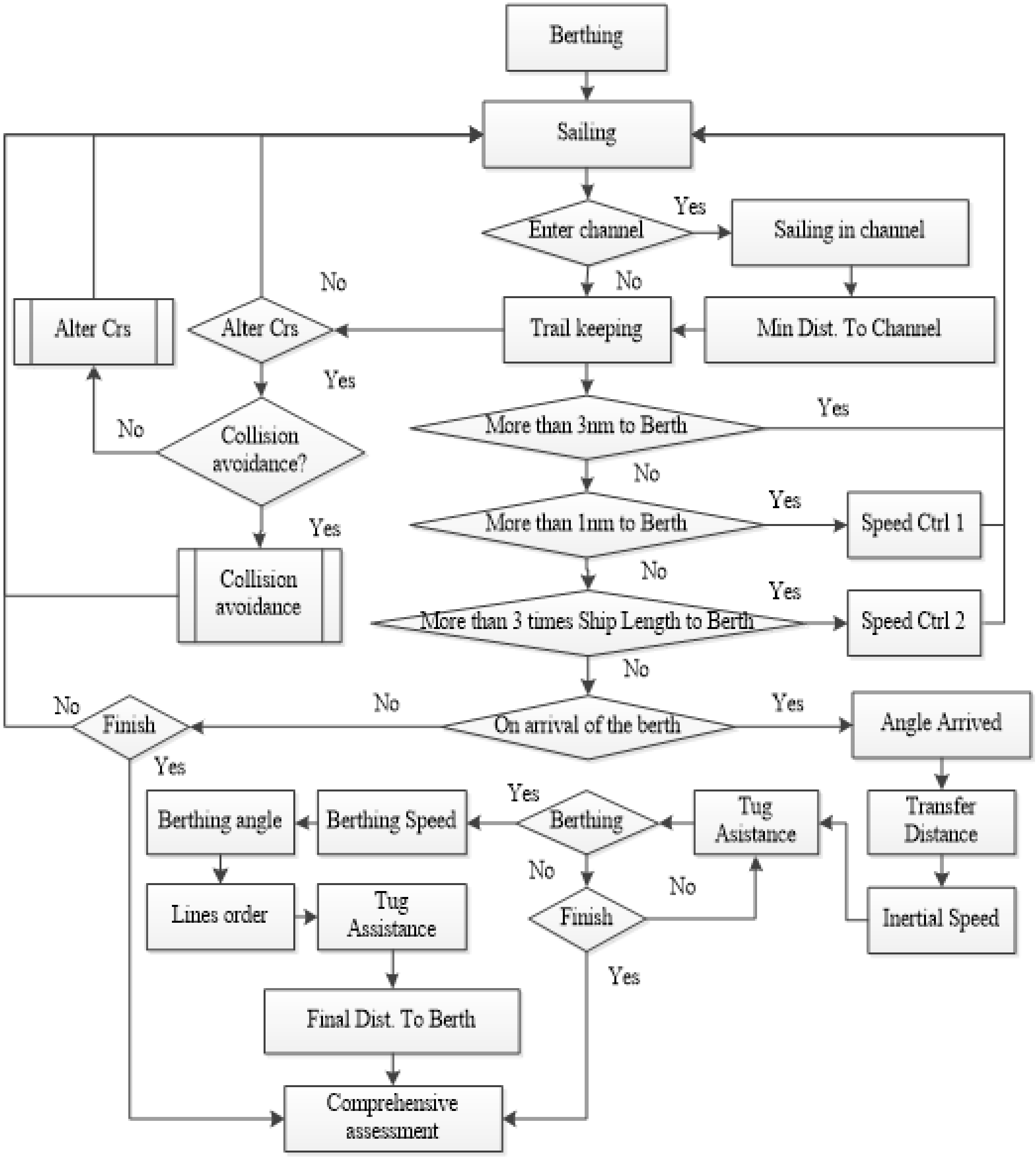


Figure 5: Assessment process

(5) Evaluate “ship speed control”, when the ship is sailing in the area of 3 to 5 times of ship length away from the berth.

(6) There are four main assessment indices to be evaluated, when the ship arrives at the berth, such as “angle arrived”, “transfer distance”, “inertial speed” and “tugs use before arrived at the berth”.

(7) There are also four main assessment indices to be evaluated, when the ship begins to berth, such as “berthing angle”, “berthing speed”, “lines order” and “tug assistance”.

(8) The final assessment index is “final distance to the berth”.

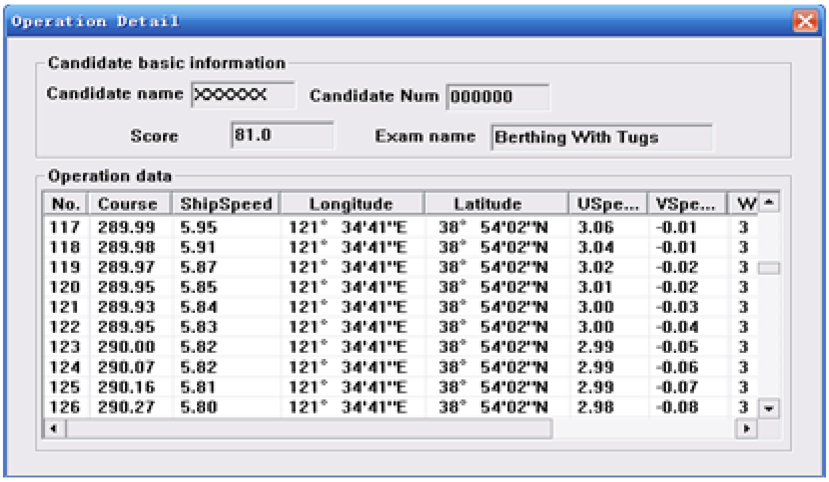
(9) Comprehensive assessment. Give the total score and the assessment details of each assessment index.

In this study, there is a specific assessment index system for each type of the exercise. In the exercise edition module, the relation factors have been set. When the trainee does the exercise, the trainer needs to do nothing about the assessment system.

3.3 The Data Management

The system uses Microsoft Access database to manage the data including the question edition information, ship handling data and assessment details; ADO technology is used to access the database (Yan 2007); TCP/IP file transmission protocol is used to transmit the data between the exam terminal and the server (Fan 2003).

There are two databases in this automatic assessment system, including the data record database and the score management database. The data of ship handling process are stored in the data record database, including the course, the ship speed, the V speed, the U speed, theship position, the wind direction, the wind speed and so on (shown in Figure 6).


Operation Detail

Candidate basic information

Candidate name XXXXXX Candidate Num 000000

Score 81.0 Exam name Berthing With Tugs

Operation data

No.	Course	ShipSpeed	Longitude	Latitude	USpe...	VSpe...	W
117	289.99	5.95	121° 34'41"E	38° 54'02"N	3.06	-0.01	3
118	289.98	5.91	121° 34'41"E	38° 54'02"N	3.04	-0.01	3
119	289.97	5.87	121° 34'41"E	38° 54'02"N	3.02	-0.02	3
120	289.95	5.85	121° 34'41"E	38° 54'02"N	3.01	-0.02	3
121	289.93	5.84	121° 34'41"E	38° 54'02"N	3.00	-0.03	3
122	289.95	5.83	121° 34'41"E	38° 54'02"N	3.00	-0.04	3
123	290.00	5.82	121° 34'41"E	38° 54'02"N	2.99	-0.05	3
124	290.07	5.82	121° 34'41"E	38° 54'02"N	2.99	-0.06	3
125	290.16	5.81	121° 34'41"E	38° 54'02"N	2.99	-0.07	3
126	290.27	5.80	121° 34'41"E	38° 54'02"N	2.98	-0.08	3

Figure 6: Operation details display

4 Example

Let's take an example to confirm the stability and reliability of the automatic assessment system. The exam file is edited as mentioned previously. The own ship's basic information is: Bulk carrier, Belnor (ship name), Ballast, 290°(original course), 6 kt (original speed), 5 m (draft), 190 m (ship length), 30.4 m (ship width). The two endpoints of the berth are 38°55′56″N 121°39′26″E and 38°56′01″N 121°39′29″E.Use two tugs, sailing to No.1 berth, port side alongside the berth.

After the trainee completes the exercise, the assessment process is as follows:

Firstly, calculate the average speed in the area of 1 to 3 n miles away from the berth, then get the membership value ($\mu(v_1)$); Secondly, calculate the average speed in the area of 3 to 5 times of the ship length away from the berth, then get the membership value ($\mu(v_2)$); Thirdly, judge whether the ship bow arrives at the front area of the berth, if so, get the longitudinal residual speed and the ship position at this moment, at the same time, and then, calculate the vertical distance from this ship position to the berth and the angle from the direction of the ship tracks to the direction of the berth, after that, get the membership values, $\mu(v)$, $\mu(d)$ and $\mu(a_A)$; Fourthly, judge whether the ship begins to berth at the berth, if so, get the ship heading and speed at this moment, and calculate the angle from this ship heading to the direction of the berth and the vertical speed to the berth, after that, get the membership values, $\mu(a)$ and $\mu(v_T)$;

Fifthly, calculate the membership values, $\mu(d_F)$, $\mu(d_C)$ and $\mu(t_K)$(the method for calculation is shown in chapter 3.2.1); Finally, get the total score by weighting the values of the membership functions.

The details of the ship's track and assessment score are shown in Figure 7 and 8.

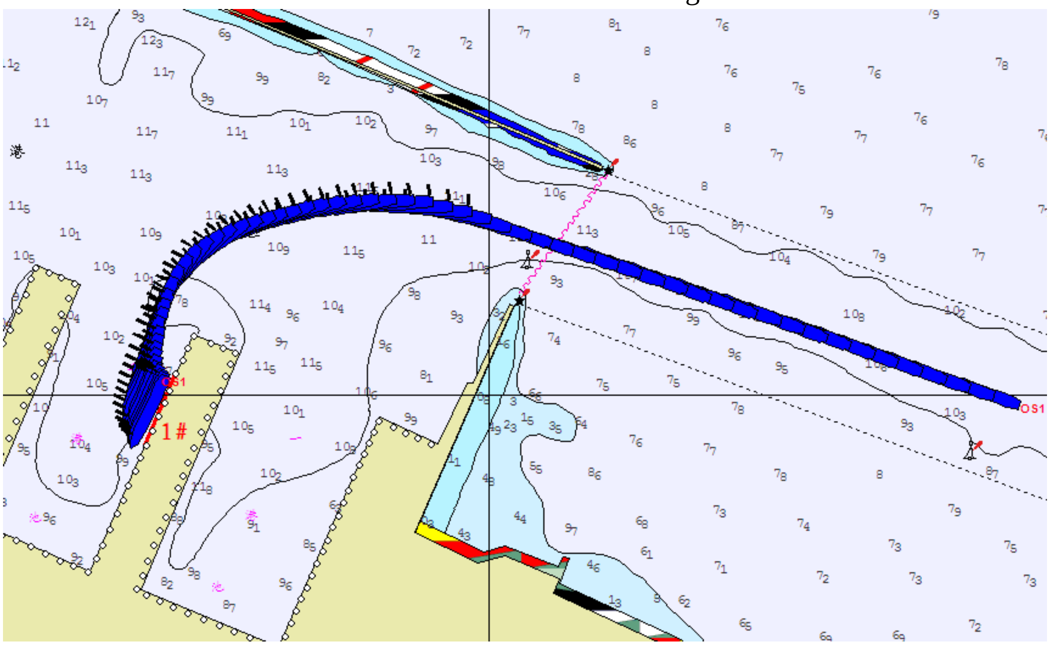
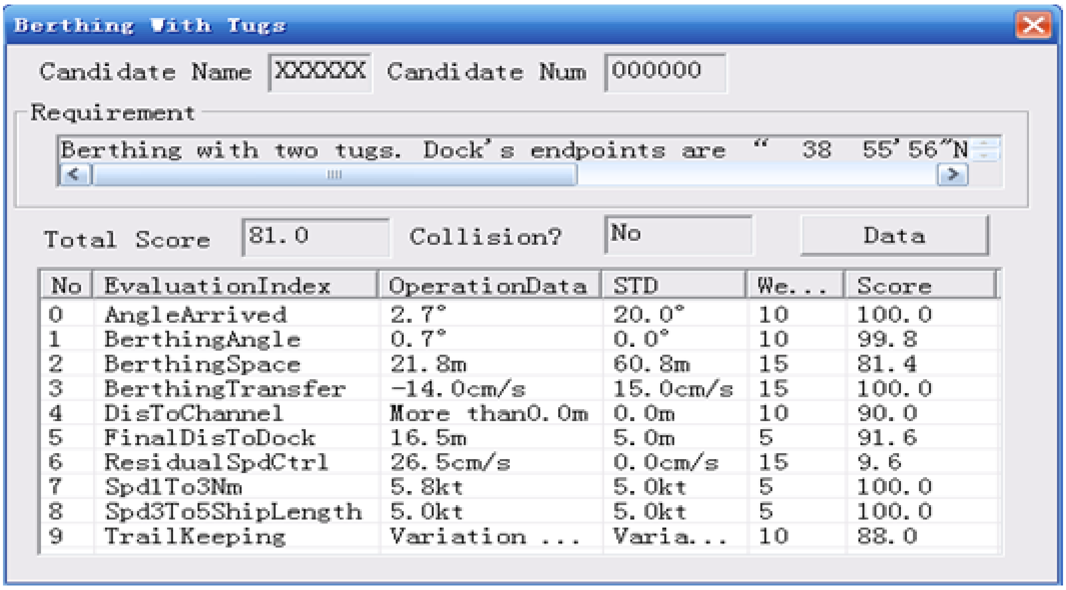


Figure 7: Ship trails


Berthing With Tugs

Candidate Name XXXXXX Candidate Num 000000

Requirement

Berthing with two tugs. Dock's endpoints are " 38 55'56"N

Total Score 81.0 Collision? No Data

No	EvaluationIndex	OperationData	STD	We...	Score
0	AngleArrived	2.7°	20.0°	10	100.0
1	BerthingAngle	0.7°	0.0°	10	99.8
2	BerthingSpace	21.8m	60.8m	15	81.4
3	BerthingTransfer	-14.0cm/s	15.0cm/s	15	100.0
4	DisToChannel	More than0.0m	0.0m	10	90.0
5	FinalDisToDock	16.5m	5.0m	5	91.6
6	ResidualSpdCtrl	26.5cm/s	0.0cm/s	15	9.6
7	Spd1To3Nm	5.8kt	5.0kt	5	100.0
8	Spd3To5ShipLength	5.0kt	5.0kt	5	100.0
9	TrailKeeping	Variation ...	Varia...	10	88.0

Figure 8: Score details display

The ship's track is smooth, and almost coinciding with the centre of the channel, but at the entrance of the harbour, the ship is nearer to the light buoy. In the assessment system, the score of "Tail keeping" is 88, and the score of "Minimum distance to channel" is 90.

The inertial speed is 26.5cm/s, which cannot meet the requirements of the theory of ship handling. So, the score of "inertial speed" is 9.6.

The angle arrived is 2.7 °, and the berthing angle is 0.9 °. Usually, the berthing angle is smaller than the angle arrived. So, both of them can meet the requirements of the theory of ship handling, and the trainee gets good results for both of this two indices.

5. Conclusions

This paper introduces an automatic assessment system developed by Dalian Maritime University. The assessment method, system architecture and implementation have been introduced. The framework of automatic assessment system has been built completely. After initial testing, the system is relatively stable.

At present, there are two parts in the evaluation system. One part is used to edit the evaluation indices, and the other is the evaluation model.

For Kongsberg Simulator Exercise Assessment (SEA), the assessment sheets must be created in advance and stored with the exercise. For Transas Evaluation and Assessment System (TEAS), evaluation indices can be edit in advance or when the exercise is being done. In this research, the evaluation indices must be edited in advance and stored with the exercise. In this part, it is quite different from SEA and TEAS. We divide the evaluation contents into many types (sea chapter 3.1.1) based on the theory and practice of the navigation, and establish an evaluation index system for each type, and then, give the weight, the standard value or handling for each index in particular evaluation index system. When the trainer edits the evaluation indices, he could change the default values or do nothing.

In the part of assessment, count how many times the assessment criteria have been violated, and then give the final score, for TEAS and SEA. In this research, calculate the operation data for each index, and then, use membership function to calculate the membership value, finally, weight the indices to get the final score. The former is to demonstrate what cannot do, the latter is to judge the similar level between the trainee's handling and the standard handling.

In the further research, the focus is to improve and perfect the evaluation model, which includes the assessment indices, the selection of the membership function and the evaluation process. In addition, the BRM assessment model needs to be established completely.

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