TRANSNAV
http://www.transnav.eu

the International Journal on Marine Navigation and Safety of Sea Transportation

Volume 8
Number 1
March 2014

DOI: 10.12716/1001.08.01.15

Simulation Augmented Manoeuvring Design and Monitoring – a New Method for Advanced Ship Handling

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ABSTRACT: A fast time simulation tool box is under development to simulate the ships motion with complex dynamic models and to display the ships track immediately for the intended or actual rudder or engine manoeuvre. Based on this approach the innovative "Simulation Augmented Manoeuvring Design and Monitoring" - SAMMON tool box will allow for (a) a new type of design of a manoeuvring plan as enhancement exceeding the common pure way point planning (b) an unmatched monitoring of ship handling processes to follow the underlying manoeuvring plan. During the manoeuvring process the planned manoeuvres can be constantly displayed together with the actual ship motion and the predicted future track which is based on actual input data from the ship's sensors and manoeuvring handle positions. This SAMMON tool box is intended be used on board of real ships but it is in parallel an effective tool for training in ship handling simulators: (a) in the briefing for preparing a manoeuvring plan for the whole exercise in some minutes, (b) during the exercise run to see the consequences of the use of manoeuvring equipment even before the ship has changed her motion and (c) in debriefing sessions to discuss potential alternatives of the students decisions by simulating fast variations of their choices during the exercises. Examples will be given for results from test trials on board and in the full mission ship handling simulator of the Maritime Simulation Centre Warnemuende.

1 INTRODUCTION

Within this paper investigations into the feasibility and user acceptance of the new layout of navigation display will be introduced and selected results of simulation studies testing the influence on manoeuvre performance dependent on different kind of prediction functions will be discussed. Examples will be given for results from test trials in the full mission ship handling simulator of the Maritime Simulation Centre Warnemuende.

Normally ship officers have to steer the ships based on their mental model of the ships motion characteristics only. This mental model has been developed during the education, training in ship handling simulator in real time simulation and most important during their sea time practice. Up to now there was nearly no electronic tool to demonstrate manoeuvring characteristics efficiently or moreover to design a manoeuvring plan effectively - even in briefing procedures for ship handling training the potential manoeuvres will be explained and drafted on paper or described by sketches and short explanations. To overcome these shortcomings a fast time simulation tool box was developed to simulate the ships motion with complex dynamic models and to display the ships track immediately for the intended or actual rudder or engine manoeuvre. These "Simulation Augmented Manoeuvring Design and Monitoring" - SAMMON tool box will allow for a new type of design of a manoeuvring plan as enhancement exceeding the common pure way point planning. The principles and advantages were described at MARSIM 2012 (Benedict et al., 2012) specifically for the potential on board application for manoeuvring real ships. This holistic approach goes beyond the prediction tool mentioned e.g. in Källström et al. 1999 and Wilske & Lexell 2011.

This paper presents the potential of the new method to be used on board and for the teaching and learning process at maritime training institutions.

Manoeuvring of ships is a human centred process. Most important elements of this process are the human itself and the technical equipment to support its task (see Figure 1).

However, most of the work is to be done manually because even today nearly no automation support is available for complex manoeuvres. Even worse, the conventional manoeuvring information for the ship officer is still available on paper only: the ship manoeuvring documents are mainly based on the initial ship yard trials or on some other selective manoeuvring trails for specific ship / environmental conditions - with only very little chance to be commonly used in the overall ship handling process situations effectively.

Ship Handling Simulation for simulator training has a proven high effect for the qualification, however, it is based on real time simulation, i.e. 1s calculation time by the computers represents 1s manoeuvring time as in real world. This means despite all other advantages of full mission ship handling simulation that collecting/gathering of manoeuvring experiences remains an utmost time consuming process.

For increasing the effectiveness of training and also the safety and efficiency for manoeuvring real ships the method of Fast Time Simulation will be used in future – Even with standard computers it can be achieved to simulate in 1 second computing time manoeuvres lasting about to 20 min using innovative simulation methods. This allows substantial support in both, the training process and the real manoeuvring process on board ships. A comparison is given in Figure 2 for some essential elements of the real manoeuvring process on ships and in training within the ship handling simulators as well. Additionally, in the right column of Figure 2 some of the Fast Time Simulation (FTS) tools are mentioned and their roles to support each element of the manoeuvring process are indicated: These tools were initiated in research activities at the Maritime Simulation Centre Warnemuende which is a part of the Department of Maritime Studies of Hochschule Wismar, University of Applied Sciences - Technology, Business & Design in Germany. It has been further developed by the start-up company Innovative Ship Simulation and Maritime Systems (ISSIMS GmbH 2012).

2 DESCRIPTION OF THE CONCEPT

2.1 *Fast Time Simulation Modules*

A brief overview is given for the modules of the FTS tools and its potential application:

- SAMMON is the brand name of the innovative system for "Simulation Augmented Manoeuvring – Design, Monitoring & Control", consisting of software modules for Manoeuvring Design & Planning, Monitoring & Control based on Multiple Dynamic Prediction and Trial & Training. It is made for both:
  - application in maritime education and training to support lecturing for ship handling to demonstrate and explain more easily manoeuvring technology details and to prepare more specifically manoeuvring training in SHS environment, i.e. for developing manoeuvring plans in briefing sessions, to support manoeuvring during the exercise run and to help in debriefing sessions the analysis of replays and discussions of quick demonstration of alternative manoeuvres and
  - application on-board to assist manoeuvring of real ships e.g. to prepare manoeuvring plans for challenging harbour approaches with complex manoeuvres up to the final berthing / unberthing of ships, to assist the steering by multiple prediction during the manoeuvring process and even to give support for analysing the result and for on board training with the Simulation & Trial module.
- SIMOPT is a Simulation Optimiser software module based on FTS for optimising Standard Manoeuvres and modifying ship math model parameters both for simulator ships and FTS Simulation Training Systems and for on board application of the SAMMON System.
- The Advantage and Capabilities of this software is: The Math Model reveals same quality for simulation results as the Ship handling simulators SHS, but it is remarkably faster than real time simulation, the ratio is more than 1/1000, the steering of simulator vessels is done by specific manoeuvre-control settings / commands for standard procedures and individual manoeuvres dedicated for calculation standard ship manoeuvring elements (basic manoeuvres) but moreover for the estimation of optimal manoeuvring sequences of some characteristic manoeuvres as for instance person over board manoeuvres.
- SIMDAT is a software module for analysing simulation results both from simulations in SHS or SIMOPT and from real ship trials: the data for manoeuvring characteristics can be automatically retrieved and comfortable graphic tools are available for displaying, comparing and assessing the results.

The SIMOPT and SIMDAT modules were described in earlier papers (Benedict et al. 2006) for tuning of simulator ship model parameters and also the modules for Multiple Dynamic Prediction & Control (Benedict et al. 2009) for the on board use as steering assistance tool.

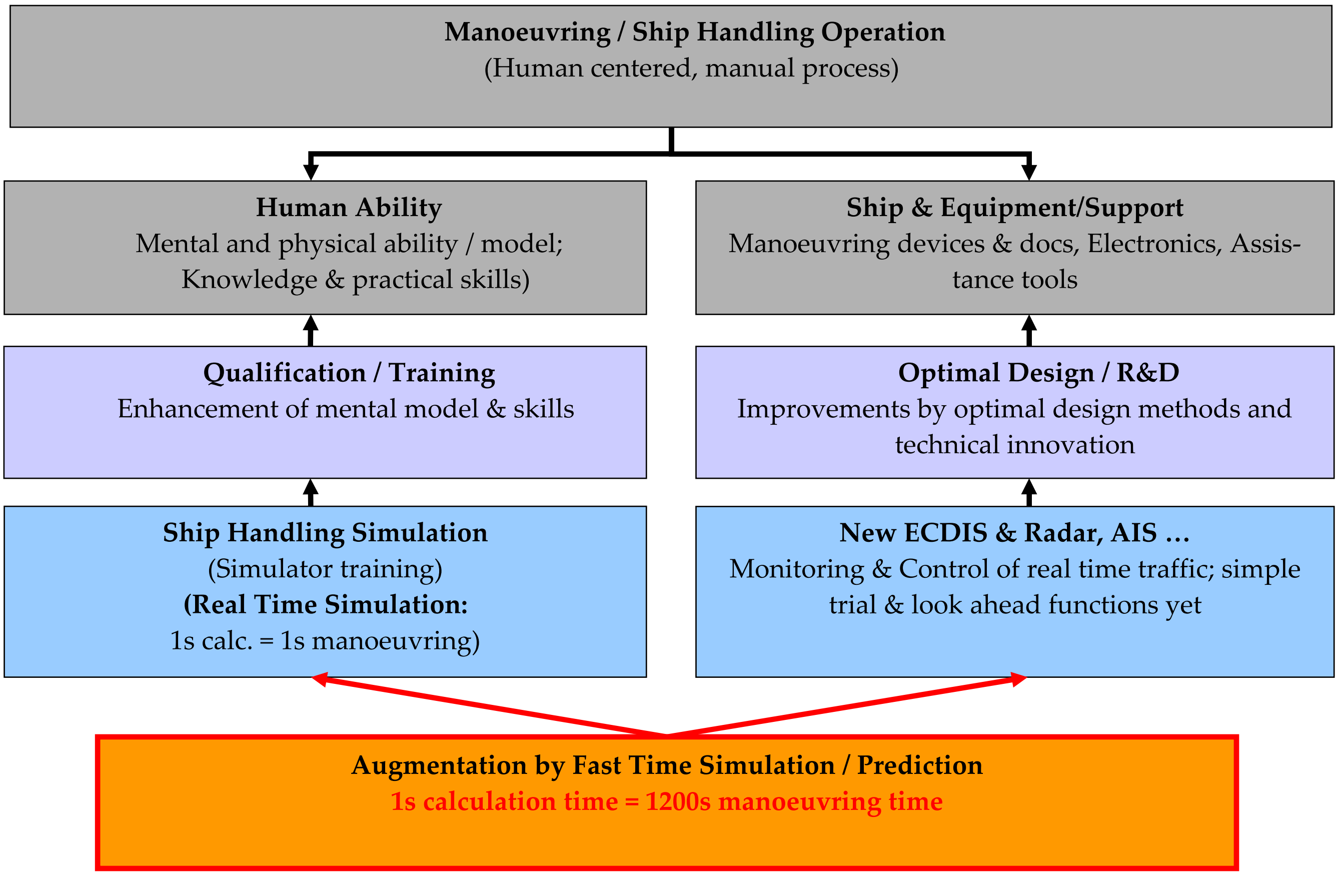

Figure 1. Elements of the manoeuvring process and potential for enhancement by new Simulation / Augmentation methods

Elements of Manoeuvring Process on Ships & in Education/Training and support by Fast Time Simulation Modules / Tools		
Real World/ Ship Operation	**Ship Handling Simulator Training**	**Fast Time Simulation Tools**
Real ship / Familiarisation runs	Math model of the ship for simulation Familiarisation Exercises	SIMOPT & SIMDAT tool for developing & tuning of parameters of math models MANOEUVRING TRIAL & TRAINING tool for Demonstration / Lecturing / Familiarisation
Mission / Planning	Scenario / Briefing	MANOEUVRING DESIGN & PLANNING tool to generate and edit a manoeuvring plan
Manoeuvring Operation	Execution of exercise	MANOEUVRING MONITORING & MULTIPLE DYNAMIC PREDICTION tool to monitor and control the vessels motion
Recording (VDR, ECDIS)	Recording by simulator	SIMDAT tool to display and assess recordings
Evaluation of success	Debriefing	MANOEUVRING TRIAL& TRAINING tool for verification of results by simulation & prediction

Figure 2. Elements of Manoeuvring Process on Ships & in Training and support by Fast Time Simulation Tools for Simulation / Augmentation

In this paper the focus will be laid on the potential of the SAMMON software as an integrated system for planning and monitoring of manoeuvres as well as a tool to be used on board and for supporting the teaching and learning process.

2.2 *Fast Time Manoeuvring Simulation for Manoeuvring Support in ECDIS environment*

The core modules of the fast time simulation tools can be used for the calculation of manoeuvres up to the design of complete manoeuvring plans in ECDIS environment. Some basic functions are shown in the next figures.

Figure 3 explains the operational interface in a sea chart environment which combines the electronic navigational chart ENC window (centre), the status of the current actual ship manoeuvring controls (left) and the interface window for the steering panel of the ship (right).

The ship was positioned in a certain place to demonstrate the ships motion for a very simple manoeuvre kick turn from zero speed. The ships motion can be controlled by the settings in the control panel window where any manoeuvre can be generated to be immediately displayed in the ENC in one second with full length. The length of the track corresponds to the settings in the prediction window (left top corner): the range value represents the duration of the manoeuvre; the interval value controls the number of displayed ship contours on that manoeuvre track. The sample represents a kick turn from zero speed to full ahead with full rudder to Port.

3 FAST TIME SIMULATION FOR DESIGNING MANOEUVRING PLANS

3.1 *Principle of fast time simulation of manoeuvres in ECDIS and sample data*

The fast time simulation method is used to find out efficient manoeuvres and even more for the design of manoeuvring plans within the briefing for Ship Handling Simulator exercises and practically for route planning process on board (Benedict et al. 2012). The use of this tool will be explained by some sample scenarios:

The sample ship is the RO-PAX Ferry "Mecklenburg-Vorpommern" with Loa=200m, Boa=28.95m, Draft=6.2m, Displacement=22720t and Speed=22kn. She has two pitch propellers and two rudders located behind the propellers and additionally one bow thruster.

The test area is the Rostock Sea Port. The RO-PAX ferry is entering the fairway from north to be steered through the fairway and to be turned at the turning area followed by astern motion to the berth at west pier (as in in the sample Figure 7).

For purposes of demonstration of a complex manoeuvre procedure the ship is initially positioned in the fairway (black contour) and is going to enter the turning area as objective for the first manoeuvring segment. For the planning procedure the ship's motion can be controlled by the settings in the control panel window on the right side. Any manoeuvre can be generated and will be immediately displayed in the ENC in less than one second with full length. In this case the rudders are set 10° to STB to achieve a small turning rate ROT=4.5°/min to port. The length of the simulated track corresponds to the settings in the prediction window (left top corner): the range value represents the duration of the simulated manoeuvre and that means the track length of that manoeuvring segment; the interval value controls the number of displayed ship contours on that predicted manoeuvre track. The selected end position of the manoeuvring segment is indicated by the red ship's contour. Its position can be shifted and adjusted using the slider at the bottom line which is adjusted to 165 seconds after the beginning of the manoeuvre at initial Manoeuvring Point MP 0. If this position is accepted it will be acknowledged as the next manoeuvring point MP 1.

This planning process guarantees the full involvement of the navigating officer: The best version of the manoeuvres can be found by trial and error but it is possible to bring in one's full knowledge and to take advantage of one's skills – it is possible to see and to verify immediately the results of the own ideas and to make sure that the intentions will work. This is import for safety and efficiency, but also for gaining experience for future manoeuvres.

3.2 *Sample of designing a full manoeuvring sequence as training concept*

The planning procedure for a complete manoeuvring plan follows the principles as described for a single segment in Figure 4 as follows: Figure 5 presents the situation after accepting the manoeuvre previously planned – now the next segment is to be planned from MP 1 to MP 2: the ship is going to enter the turning area and to slow down. Both engines are set to STOP (EOT 0). In Figure 6 the complex turning manoeuvre is to be seen: the ship is using in parallel engines, rudders and the bow thruster to turn as fast as possible. Afterwards the engines have to be reversed and the ship controls are adjusted to go astern to the berth. In Figure 7 the result for the full manoeuvring plan is to be seen with the whole set of Manoeuvring Points (MP) for the complete approach and the berthing manoeuvre.

The different settings of the controls and the track of the planned manoeuvre sequences are stored in a manoeuvre planning file to be displayed in the ENC.

For the execution of the manoeuvre this plan can be activated later to be superimposed in the ECDIS together with the actual position of the ship and, most important, with the prediction of manoeuvring capabilities for effective steering under the actual manoeuvring and environmental conditions.

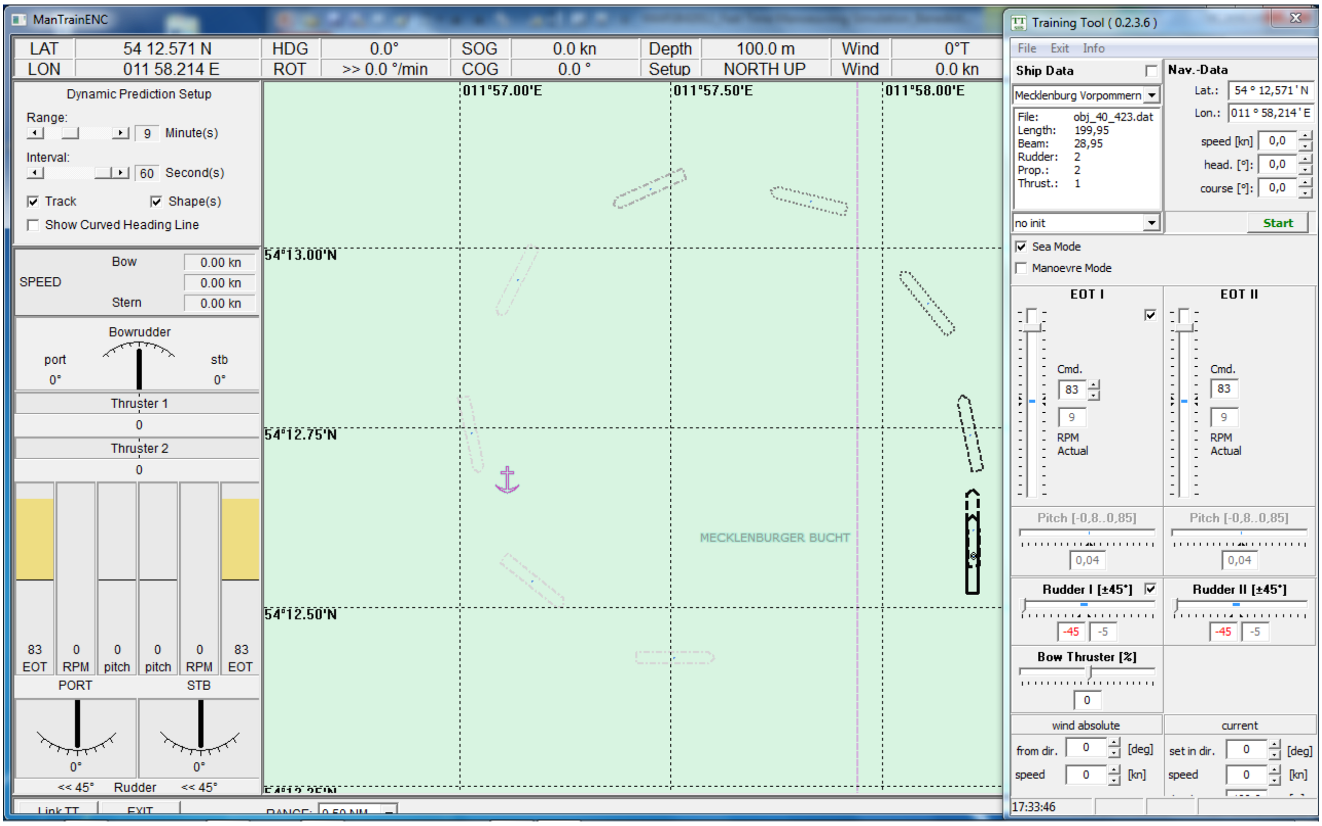

Figure 3. SAMMON Trial & Training Tool Interface with sample for Kick turn with rudder Hard PT from zero speed to EOT Full Ahead port as sample for potential ships manoeuvring capabilities

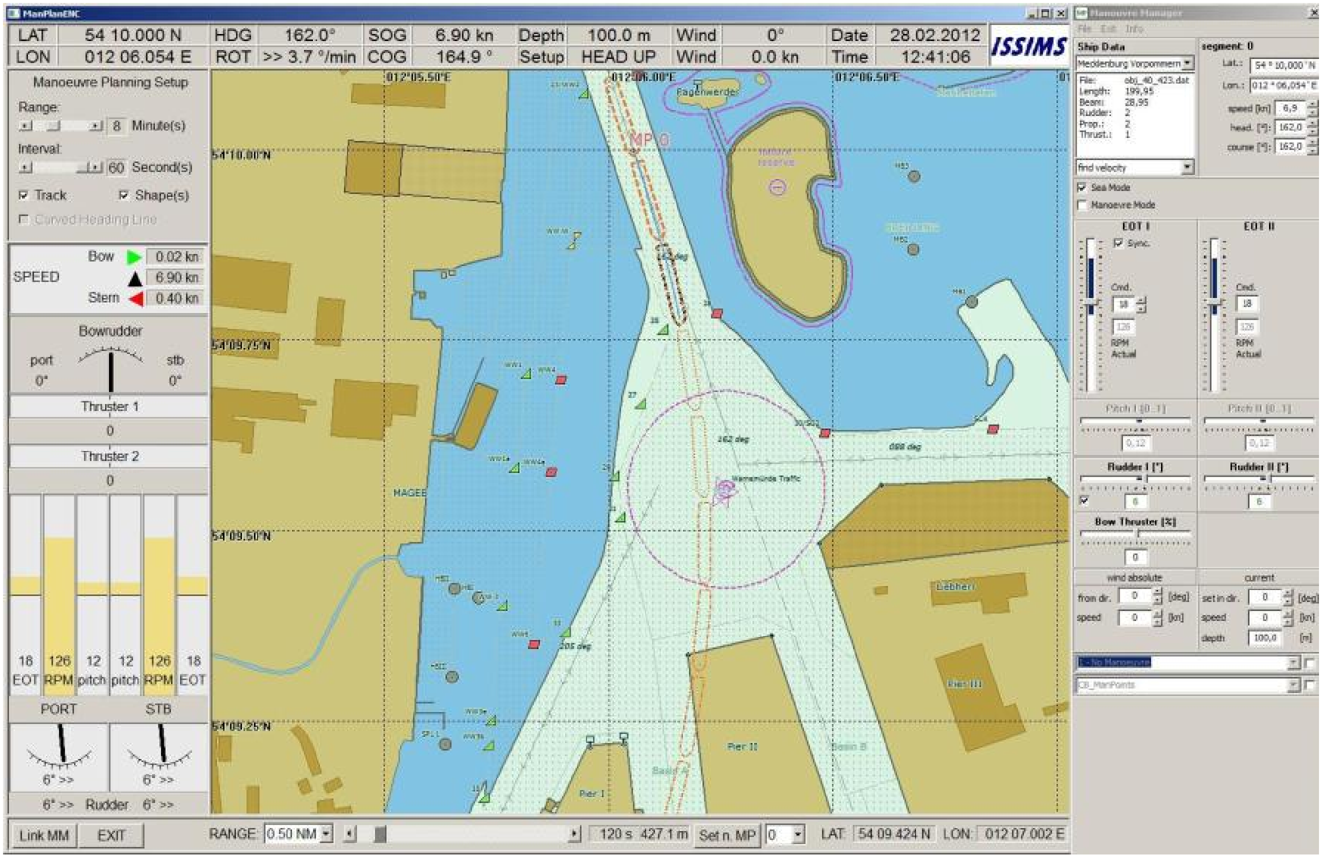

Figure 4. Display for Manoeuvring Design by Fast Time Simulation for immediate presentation of manoeuvring results: Sample for entering the turning area with slight turning to STB from initial conditions in a fairway at initial Manoeuvring Point MP 0

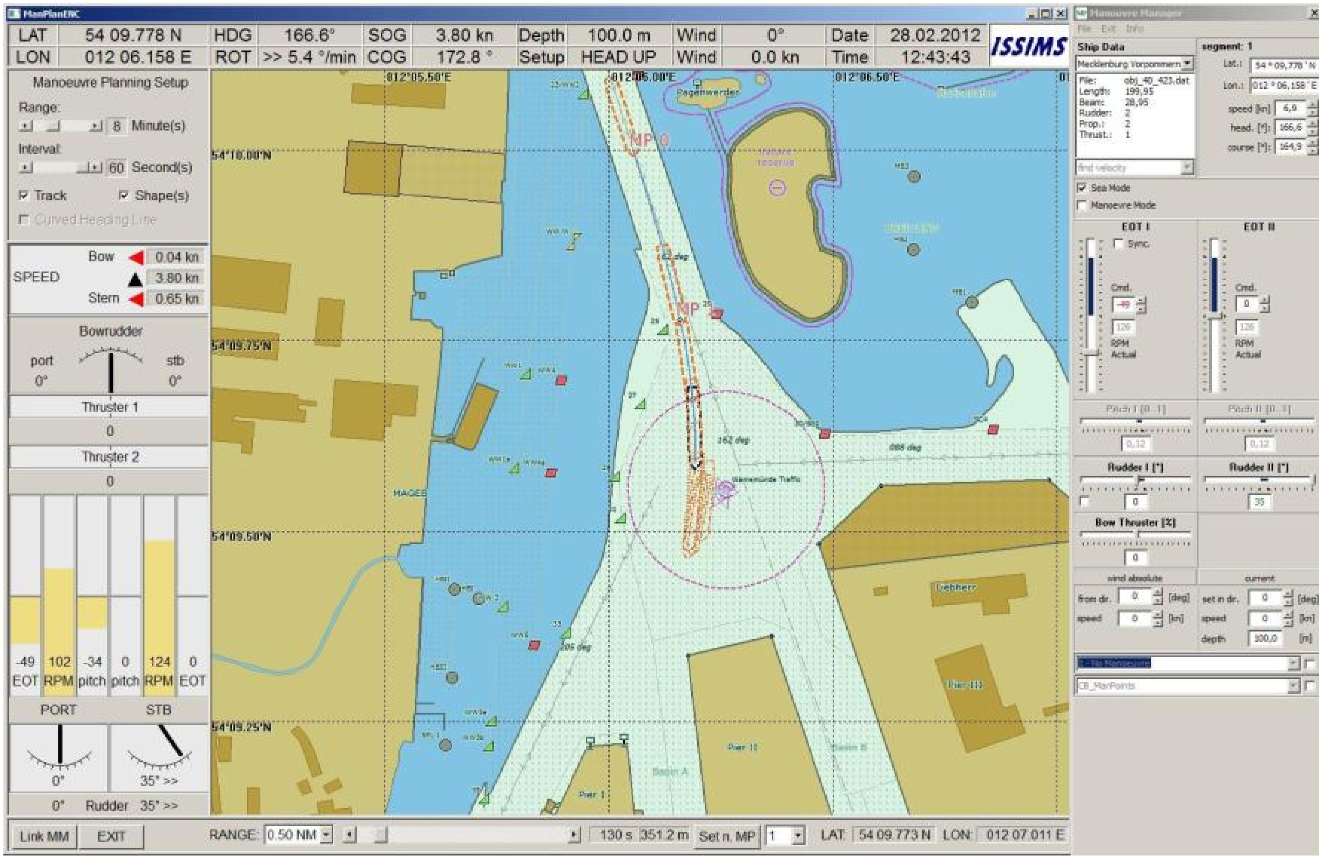

Figure 5. Planning of the next segment from MP 1 to MP 2 – speed reduction

Figure 6. Planning of the next segment from MP 2 to MP 3 – complex turning and stopping with engines, rudders and thruster

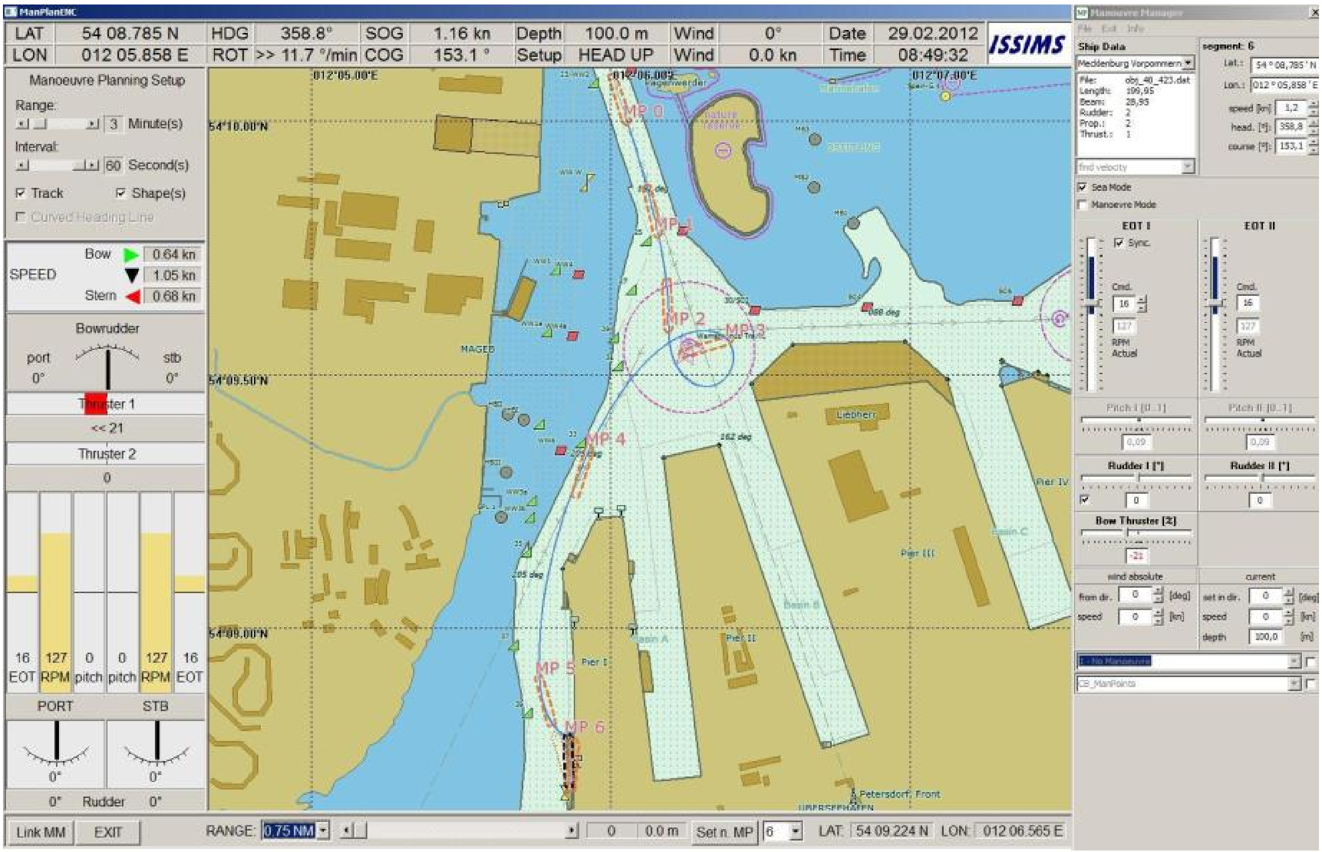

Figure 7. Complete manoeuvring plan for the route segment for passing the turning area and approaching the berth in astern motion

4 MANOEUVRING MONITORING AND MULTIPLE DYNAMIC PREDICTION MODULE - OVERLAID PREDICTION FOR ON-LINE MANOEUVRING DECISION SUPPORT USING MANOEUVRING PLANS

4.1 *Presentation of dynamic predictions in ECDIS environment*

For a compact presentation of information to the captain, pilot and responsible navigating officer respectively a new layout of a conning display was designed and implemented into the equipment installed on an integrated navigation system. For the purpose of testing the technical feasibility and user acceptance the new conning display with the integrated MULTIPLE MANOEUVRING PREDICTION MODULE was implemented in the INS equipment of the large full mission simulator bridge of the ship handling simulator of MSCW. The sample ship is again the RO-PAX Ferry "Mecklenburg-Vorpommern", the test area is the Rostock Sea Port. The RO-PAX ferry is leaving the berth to be steered through the fairway and to leave the port.

The layout of a dedicated prediction display integrated into an ECDIS is shown in Figure 8. It contains conning information together with the prediction and the planned manoeuvring track. The centre window shows the ENC in Head up Mode together with motion parameter for longitudinal speed and transverse speed as well as a circle segment with the rate of turn is shown. The ships position is displayed in the centre of the ENC as ship's contour where also the track prediction can be indicated as curved track or as chain of contours for the selected prediction time. The prediction parameters as range or interval of presentation can be set in the control window at the upper left side.

The Dynamic Path Prediction with the sophisticated simulation model is shown as chain of ships contours based on full math model (ship contours every 60 sec for 4 min with turning to STB). This dynamic prediction reflects already the effect of the setting of rudder and propeller control parameters shown in the left bottom window: In this sample the two rudders of the ferry used are set to 15° Starboard and the Engine Order Telegraph for the two controllable pitch propellers are set to 19% representing 127 rpm of the propeller. The actual pitch status is 13. This interface allows a presentation of dynamic predictions of steering and stopping characteristics as an immediate response according to the current steering handle or engine order telegraph position. It can be perfectly compared with the planned manoeuvring track as a reference line or curve, shown as blue line in the ENC window along the chain of manoeuvring points MP.

The predicted track for the simplified static path prediction based on of current constant motion parameters (implemented as add-on in some ECDIS solutions) are shown as magenta curve: According to the actual/present small rate of turn to Port the predicted track is presented as a circle segment to the left side.

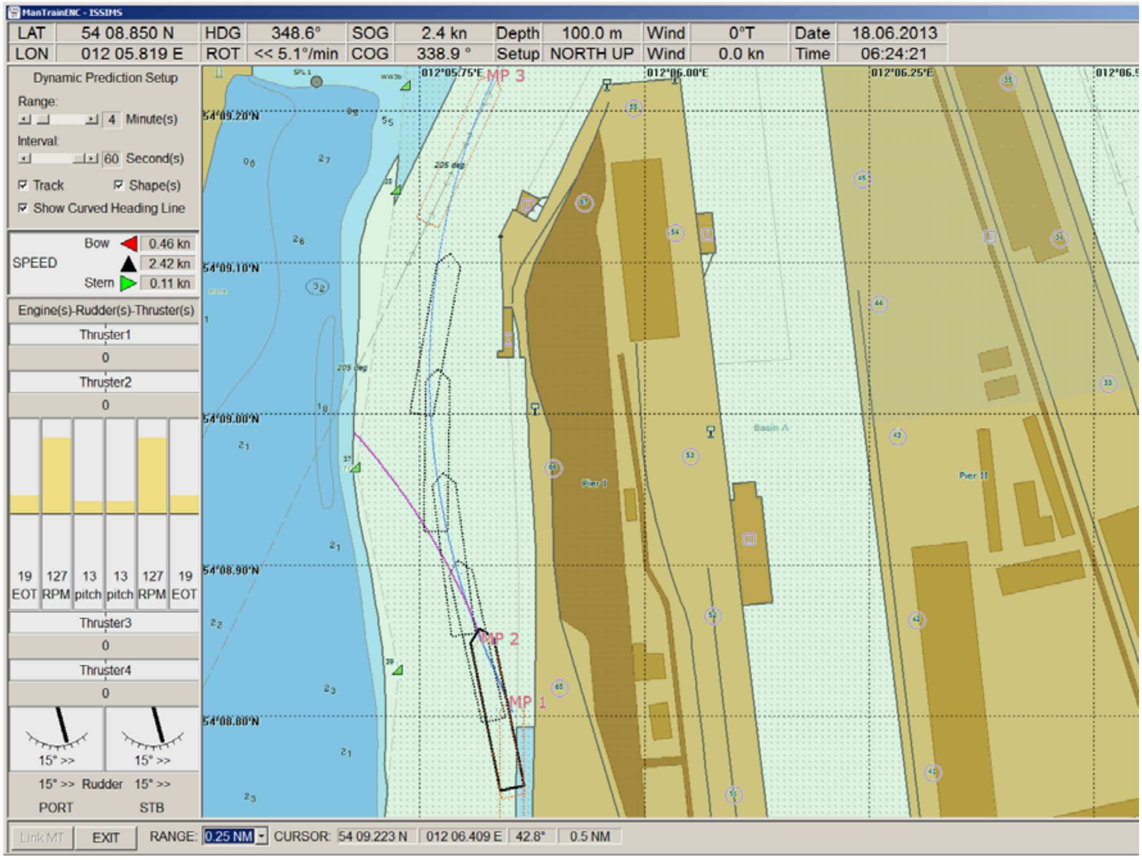

Figure 8 Layout for Manoeuvring Prediction integrated into ECDIS and comparison of static and dynamic predictions together with planned manoeuvring track (blue line) - - Scenario after leaving the berth and turning into the fairway

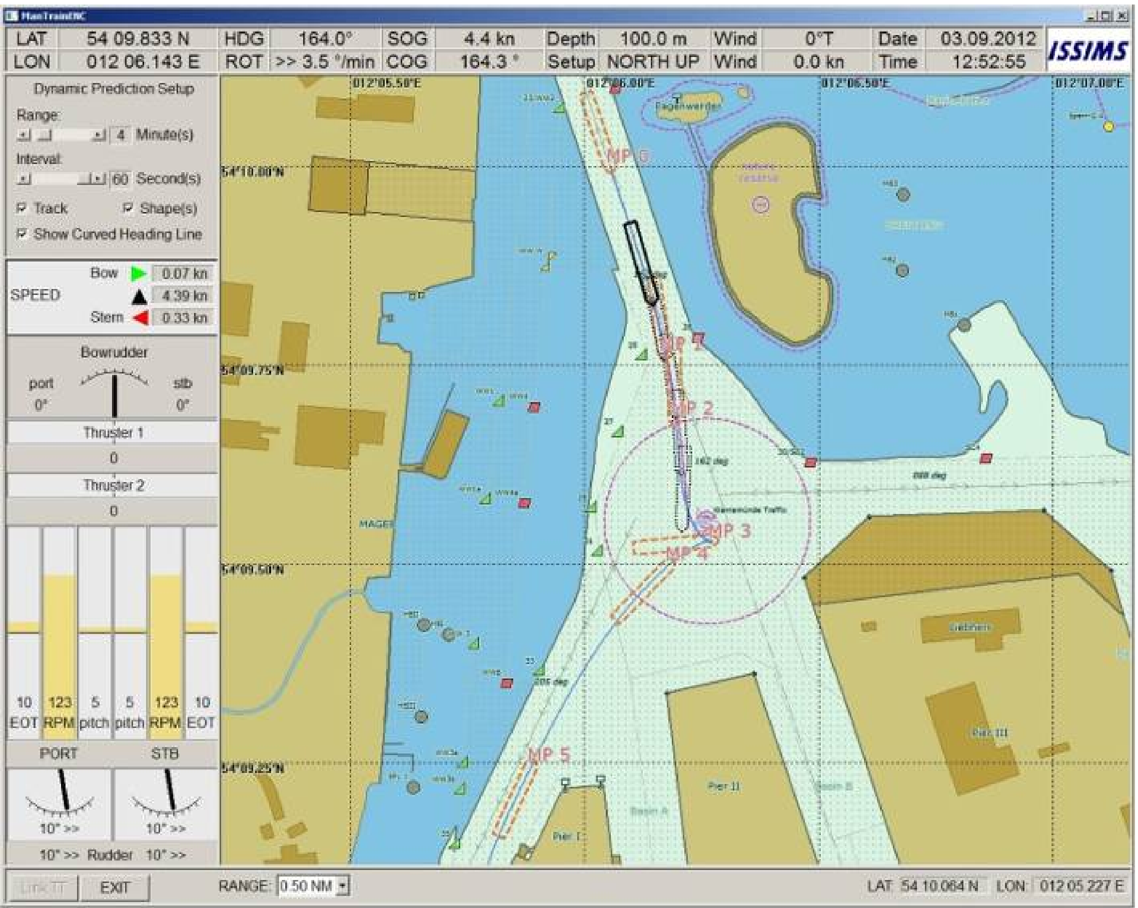

Figure 9. Manoeuvring Prediction integrated into ECDIS and comparison of static and dynamic predictions together with planned manoeuvring track (blue line) and contours at manoeuvring points - Scenario when entering the port and reducing the speed before turning the ship on the turning area

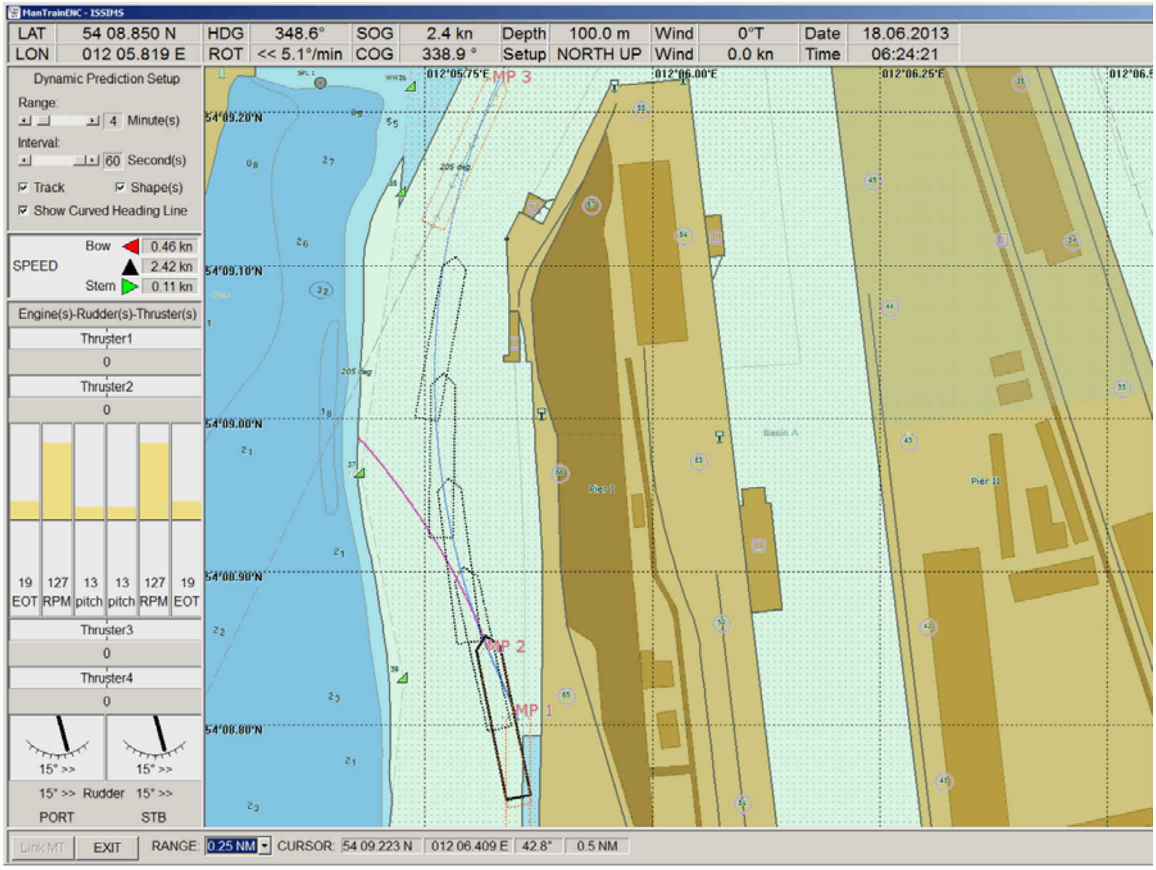

Figure 10. Layout for Manoeuvring Prediction integrated into ECDIS and comparison of static and dynamic predictions together with planned manoeuvring track (blue line) - - Scenario after leaving the berth and turning into the fairway

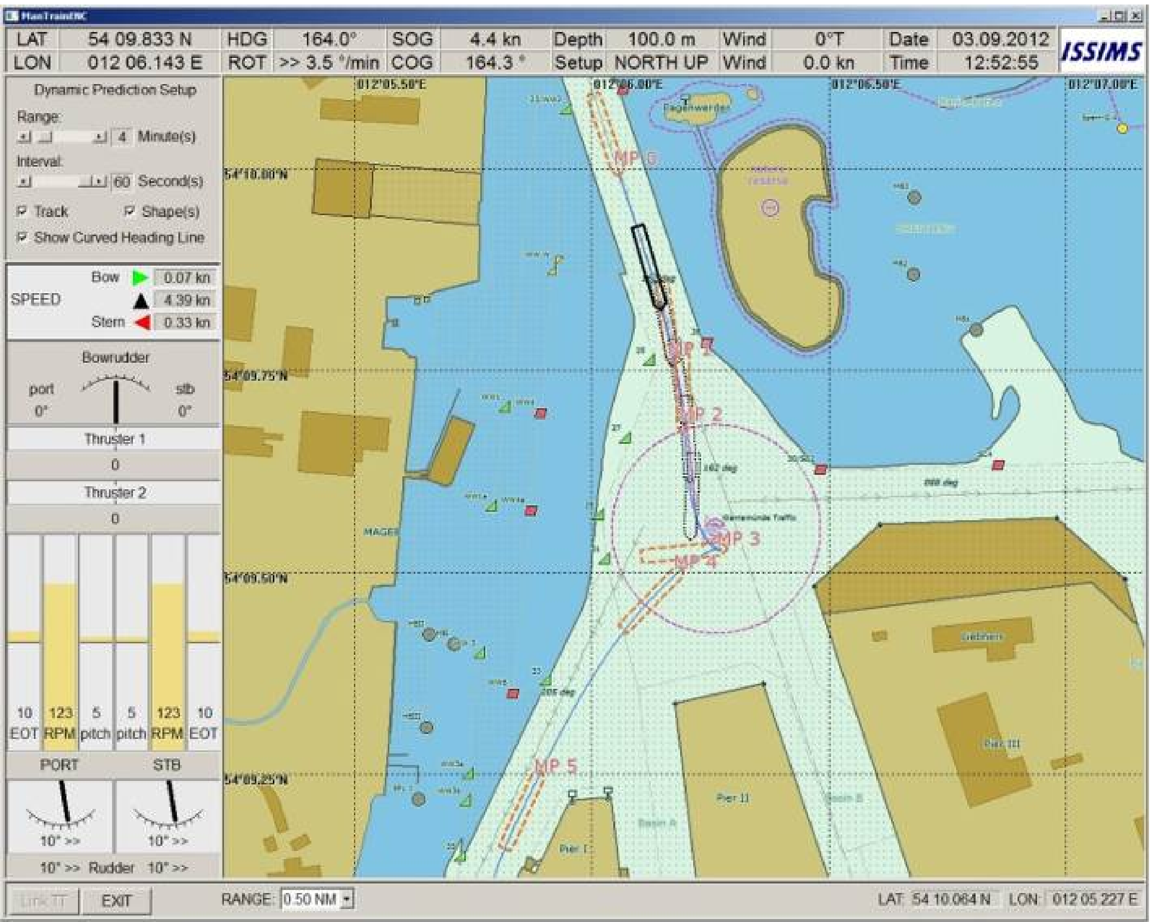

Figure 11. Manoeuvring Prediction integrated into ECDIS and comparison of static and dynamic predictions together with planned manoeuvring track (blue line) and contours at manoeuvring points - Scenario when entering the port and reducing the speed before turning the ship on the turning area

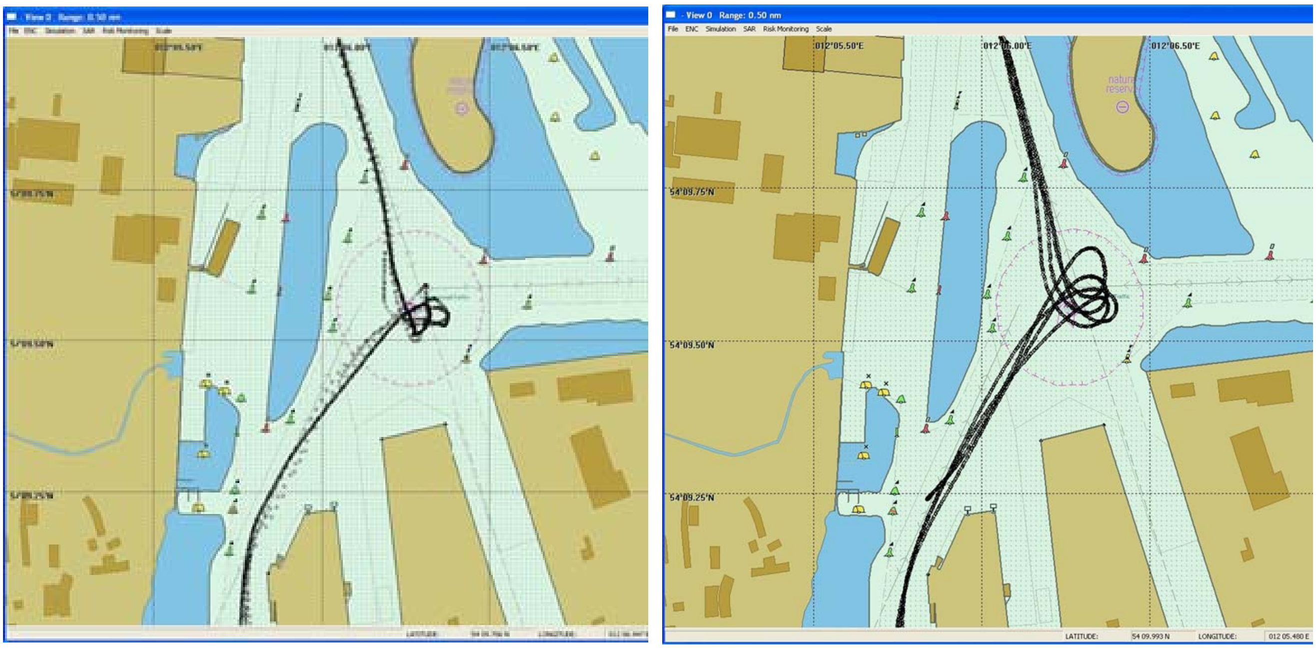

Figure 12 Comparison of manoeuvring performance- Left: Analysing recorded data from VDR of real ship: Ferry MV entering port and manoeuvring on turning area by stopping until V=0, turning, accelerating and backing to berth (total time 18 min)
Right: Alternative manoeuvring strategies using FTS developed in simulator: Combining stopping and turning on turning area, non-interrupted turning and backing to berth: Result - Saving 3 to 5 min!

The use of path prediction with simplified models was already mentioned in previous papers, however, the use of this new multiple predictions based on the full dynamic model including the propulsion / engine process together with the result of preceding manoeuvring design is a great innovation and advantage. It was found that for the application of this dynamic prediction technology new strategies were developed to save some minutes in this area (see Figure 12) which is very important in tight time schedules (Fischer & Benedict 2009).

4.2 *SAMMON Manoeuvring Trial & Training Tool*

This module combines a full simulation module for the ship manoeuvring process with all the modules above for planning and monitoring in order to test and try out manoeuvring plans and strategies, to be used both:

- as training tool in maritime education
  - in briefing / debriefing sessions for ship handling simulator training,
  - as well as in lectures on ships manoeuvring in classes and
- as training tool on board ships.

In order to control the virtual ship during the simulation process a manoeuvring panel on the screen allows steering the ship in real time along the planned route supported by the Multiple Predictor.

5 INTEGRATION OF SAMMON SYSTEM INTO EDUCATION FOR LECTURING & TRAINING SIMULATION

For training & education the SAMMON System is available as a portable version based on Tablet PCs for Planning of Manoeuvres in Briefing, Instructor stations and use on Simulator bridges Figure 13. The SAMMON system is interfaced to the Rheinmetall Defence Electronics ANS 5000 Ship Handling Simulator (SHS) at the Maritime Simulation Centre Warnemünde by WLAN connection. All ships which are available for the SHS are also ready for use in the SAMMON system for the following Concept of Application for Ship handling simulation:

<u>Briefing:</u>

- Demonstrating ships manoeuvring characteristics by using SIMOPT for familiarisation
- Drafting Manoeuvring Concept as Manoeuvring Plan (using MANOEUVRING DESIGN & PLANNING tool) according to the training objectives
- Optimisation of the concept by several trials of the trainee (using MANOEUVRING TRIAL & TRAINING tool)

<u>Execution of simulator Exercise:</u>

- Training of conventional ship handling procedures and by using the by means of new FTS technology with underlying manoeuvring plan and dynamic prediction (MANOEUVRING MONITORING & MULTIPLE DYNAMIC PREDICTION tool)

<u>Debriefing:</u>

Assessment of the exercise results from full mission SHS by comparison of exercise recordings with trainees own concept or optimised manoeuvring plan by using SIMDAT tool for displaying and assessing the results of the exercise, e.g. comparing the result with the initial concept developed by the student in the briefing session and additionally to discuss alternative manoeuvring solutions by using the MANOEUVRING DESIGN & PLANNING tool).

Figure 13. SAMMON System set up based on Tablet PCs within Ship Handling Simulator environment: as Bridge Version (top), Lecturer System (left) and Instructor Version (right)

ACKNOWLEDGEMENTS

The research results presented in this paper were partly achieved in a number of research projects, among those “Integrative simulation-based Manoeuvre Planning and Monitoring System” (IMMoS-ISMAP), “Multi Media for Improvement of MET” (MultiSimMan), Satellite-based Maritime Safety (SAMARIS), “Accessibility for Shipping, Efficiency Advantages and Sustainability” (ACCSEAS), as well as "Simulation-based training module to promote green energy-efficient ship operation" (ProGreenShip) funded by EU, by Nippon Foundation as well as by the German Federal Ministry of Economics and Technology (BMWi), Education and Research (BMBF) and the Ministry of Education and Research of Mecklenburg-Pomerania, surveyed by Research Centre Juelich PTJ and DLR. Additionally it has to be mentioned that the professional version of the SAMMON software tools has been further developed by the start-up company Innovative Ship Simulation and Maritime Systems GmbH (ISSIMS GmbH; www.issims-gmbh.com).

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