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Manoeuvring Prediction for Safe and Efficient Ship Handling in Training & Ship Operation – Status Quo and Outlook

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ABSTRACT: Prediction methods and forecast of future developments and trends as well as related decisions or actions and reactions have been playing a vital role in human live and evolution. Human intelligence allowed for a dominating role in the development of our planet using our brains and more and more computers and merging artificial intelligence in the future. In the maritime domain, among others, the forecast of ships motion has been developed: from simple straight forward voyage planning in paper charts based only on rough measurement of estimated positions and ship motions, up to the latest developments using electronic navigation, ECDIS, communication technologies and high sophisticated Fast Time Simulation (FTS) methods. In the paper the already known technologies for supporting the ship handling process will be compared with potential new methods from single prediction up to multiple prediction and even step ahead prediction with unrivalled extension of the decision horizon. It reflects new requirements for preplanning of manoeuvres as part of berth-to-berth voyage planning specifically for arrival and departure segments - and increasing demands for safety and efficiency for the execution of manoeuvres in the conning process. Computer-based systems have been developed for "Simulation Augmented Manoeuvring Design, Monitoring & Conning" and are used to analyse and demonstrate the different prediction methods. Complex models of ship manoeuvring dynamics are implemented in order to forecast the immediate response on commanded control settings or even external effects as wind and shallow water for a suitable time period of the future motion. The paper provides insights into the potential benefits of various prediction methods based on FTS, discussed both for long term preplanning and short-term prediction for real-time support during the manoeuvring process. The benefits for increasing the effectiveness of lecturing and simulator training using these methods are obvious specifically for complex manoeuvring systems and will be demonstrated in this paper. It is a break-through in lecturing and training for immediate knowledge generation and checking ideas, it works perfectly for self-study individual learning and is excellent for the preparation of trainees for Full Mission simulator training, covering not only aspects of safe but also energy efficient and emission-minimized manoeuvres. Finally, potential future applications for wider navigation areas will be addressed.

1 INTRODUCTION

In ship handling practice several manoeuvring prediction technologies are used to have a better insight into the development of ships motion. There is a historic development from very simple methods based only on the measurement of current ship motions up to high-tech innovative technologies where complex models of ship manoeuvring dynamics are used to forecast the response on commanded ruder, engine or thruster application or even external effects as wind and shallow water immediately for a suitable time period of the future motion. In the following the already know technologies will be compared with potential new methods from single up to multiple prediction and step ahead prediction with unrivalled extension of the decision horizon:

- The simplest prediction is the speed vector giving only information about the momentary speed and the direction of motion.
- The (static) path prediction reflects the momentary speed but also the turning motion of the vessel - therefore it can be seen as a speed vector with a curvature according to the amount of rate of turn
- The dynamic prediction shows the real path according to the steering commands provided by a simulation model
- The new step ahead prediction allows not only for on but at least for two or more manoeuvring segments

Parallel prediction can be used to display and compare some of the previous prediction methods in parallel to give a better understanding of the motion and the precision of the prediction.

The SAMMON software system for "Simulation Augmented Manoeuvring Design, Monitoring & Conning" will be used to demonstrate and analyse the different prediction methods. This system has been developed and matured over years, and promising experiences were made at the Maritime Simulation Centre Warnemuende MSCW (e.g. [1]).The software is based on the innovative "Rapid Advanced Prediction & Interface Technology" (RAPIT) to simulate the ships motion with complex dynamic math models and to display the ships track immediately based on Fast Time Simulation in an Electronic Sea Chart. Using this technology provides insights into the potential benefits of the prediction methods discussed both for simulator training and future on-board application.

The SAMMON system represents the full information from Ships' manoeuvring documentation and additional trial measurements, which have been condensed in a complex ship dynamic simulation model, capable of simulating environmental effects. Even with standard computers it simulates 1000 times faster than real time: in 1 second computing time it simulates a manoeuvre taking up to 20 minutes. This technology was initiated in research activities of the "Institute for Innovative Ship Simulation and Maritime Systems" ISSIMS at the Maritime Simulation Centre Warnemuende MSCW, which is a part of Hochschule Wismar, University of Applied Sciences - Technology, Business & Design in Germany, specifically in its Department of Maritime Studies, Systems Engineering and Logistics. The technology has been further developed and is maintained by the company ISSIMS GmbH (see website).

There are several modules of the fast time simulation system (FTS): The centre element SAMMON is the innovative system for "Simulation Augmented Manoeuvring – Design, Monitoring & Conning". It comprises several software modules, the two most important are (a) the Manoeuvring Design & Planning Module and (b) the Manoeuvring Monitoring & Conning Module with Multiple Dynamic Manoeuvring Prediction. These modules are made for both for lecturing and simulator training for ship handling and also to assist manoeuvring of real ships on-board, e.g. to pre-pare manoeuvring plans for challenging harbour approaches / departures. Important tools are made to support SAMMON, e.g. the SIMOPT software for modifying ship math model parameters both for simulator ships in Ship Handling Simulators (SHS) and for on board application of the SAMMON System and the SIMDAT software module for analysing / displaying simulation results both from simulations in SHS or SIMOPT /SAMMON and from real ship trials [6].

The benefits for increasing the effectiveness of lecturing and simulator training using these methods are obvious specifically for complex manoeuvring systems and will be made visible in this paper by using ships both with twin screw and azimuth propulsion for discussion of the manoeuvring effects.

2 OVERVIEW ON EXISTING AND NEW INNOVATIVE MANOEUVRING PREDICTION METHODS

2.1 *Speed Vector as Simple Prediction and Use for Stopping Distance Indication*

The speed vector is an indication for the momentary speed of the vessel and also for the direction of motion: (a) The vector is pointing into the momentary direction of motion of the vessel. That means when moving in a turning circle the speed vector is a tangent to the circular track. (b) Normally the length of the vector can be adjusted in its length e.g. from 1 to 6 min. This means, the vector shows the distance along the ship is moving in this time period.

The length of this vector can be used as a reference length for manoeuvring characteristics which are depending on the speed of the vessel, e.g. for comparison with the stopping distance from a certain initial speed, specifically when the ship is moving on a straight track. One of the elements during the lectures in simulator training courses is the familiarisation with the ship manoeuvring characteristics and its effective application – and SAMMON is a very smart tool to do this in a short time and with high success. The following example addresses the ships stopping capability. Specifically, for the samples in this paper a mathematical model of the cruise ship "AIDAblu" is used. This ship has the following dimensions: length LPP= 244.6m, beam B=32.2m, mean draft Tm= 7.00 m. The ship is equipped with two pitch propellers, two rudders and two thrusters each at the bow and at the stern.

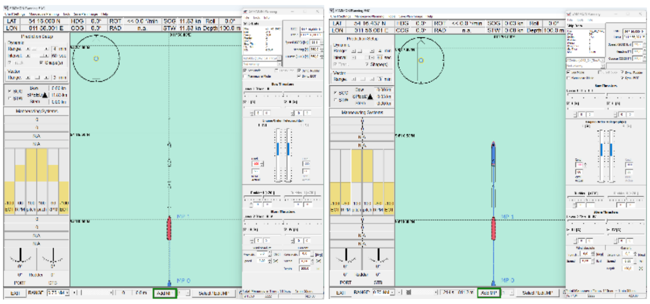

Figure 1. Display of the Manoeuvring Design & Planning Module: Stopping manoeuvre for Cruise ship from Half Ahead (EOT=+50% for 11.8 kt) at MP1 to Full Astern (EOT=-100%)

To get an overview on the ships stopping distances from several speeds and with various astern power, some test trails could be done either with the Design & Planning tool (Fig. 1) or with the SIMOPT and SIMDAT program. By means of the Planning tool the ship can be set in the chart window on an initial position MP0 (Fig. 1, bottom) where the initial speed can be adjusted using the handles in the right window. Then the ship is moved by the time slider at the bottom of the chart window, e.g. to a position after 1 min or more, and there the MP 1 is set by pressing "Add MP". Then the handles are active at this MP1 and are used to reverse the engine to EOT=-100% and immediately the stopping position can be seen on the chart window.

As long as such a sophisticated dynamic prediction tool is not available on the bridge or in the simulator yet, it is helpful to use the speed vector as alternative, because it shows the distance the ship runs in the vector time set. The basic idea is to adjust the speed vectors' length to the stopping distance: The required speed vector length can be easily calculated from the well-known relation speed=distance/time, which can be changed to time = distance / speed. From this equation, we can calculate the vector time: t_vector=Stop way / Starting speed.

2.2 *Static Path Prediction as Indication of Current Motion Status and Dynamic Manoeuvring Prediction as Description of Future Motion of Ship*

Path Prediction is a well-known feature in various bridge navigation or pilotage systems to be used in ENC or Radar image environment. It is based on a simple method to use the momentary values of ship speed and rate of turn as constant for the future and integrate these values over time. The result is a track in form of a circle segment with constant curvature and the positions of the ship are shown as equidistant ship shapes on that circle. This means for an intended turning manoeuvre as for the podded cruise ship in Fig. 2 in the first moment after rudder action (when the ship is not turning yet), the predicted path is a straight line, positions over time are presented by the magenta shapes, which are lined up in a straight line – same as the speed vector. When the ship starts turning then the predicted track is bending according to the momentary increasing rate of turn. This means the information of the future track is not very informative in the first phase of a turning manoeuvre. The predicted track is always changing, allowing only for information on the tendency of the turning direction and the change in rate of turning. Only when the rate of turn and the ship speed has reached its constant, steady state motion status then the predicted track is equal to the future ships motion.

In contrast to the static prediction, the dynamic prediction immediately shows the future track following the command input given, even if the pod has not changed its position. In Fig. 2. both static and dynamic prediction methods can be compared: at the beginning of the turning manoeuvre when the rate of turn is still zero (left) both predictions are totally different because only the dynamic prediction shows the future track. The more the ship starts turning (right), the static prediction changes and the track and the distances of the shapes becomes more and more identical with the dynamic prediction and are equal when the steady state condition are reached with constant speed and turning rate. In case the rudder will be reduced then the dynamic prediction immediately would show the reaction and the future track: e.g. due a azimuth TOE-IN 15° position, the dynamic prediction indicates immediately the decrease of turning whereas the static prediction remains a circle for a certain time, according to the existing rate of turn.

The SAMMON Planning tool allows with its dynamic predictions an unrivalled opportunity for demonstrating ship dynamics during lecturing and also individual student training on laptops using the on-screen manoeuvring handles. It is unique in providing more predictions at the same time and with this functionality to build up a full manoeuvring plan for arrival / departure manoeuvre for the approach and in ports as in the following chapter.

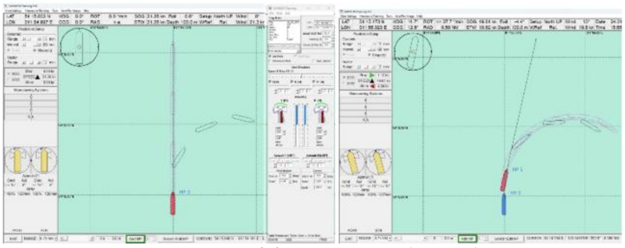

Figure 2. Comparison of for Static Path Prediction (magenta ship shapes) and dynamic prediction (black shapes) in SAMMON Planning for a turning manoeuvre of a ship with Azimuth Propellers 15° PT (Top: Situation at the beginning of the turning manoeuvre right after the initial rudder command; Bottom: Situation after 30s (left) after initiating the manoeuvre at MP0)

2.3 *Extended Prediction for wider Horizon in Manoeuvring Processes*

The predictions discussed above are providing the look ahead for the next manoeuvre only. However, it happens quiet often that the previous manoeuvre was not sufficient and therefore the next manoeuvre ahead cannot be performed successfully. Therefore, the so called "Edit Mode" was developed as feature of the Planning tool in order to allow to jump back on previous MPs to correct the commands there sufficiently. A great support can be given by presenting the prediction for not only one but at least two manoeuvring segments ahead as shown in Fig. 3 .

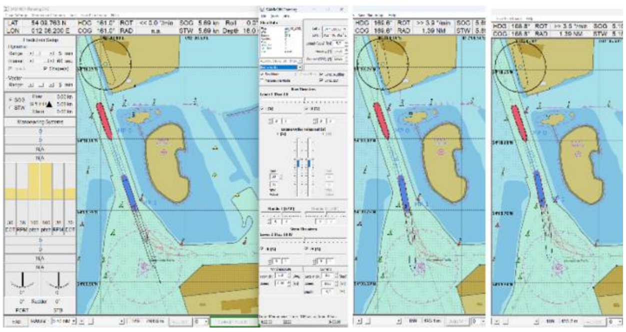

Figure 3. Sample for Intelligent prediction with two simulated steps ahead for a turning manoeuvre into the side arm at Rostock Port (Black shapes: first prediction at current position; Red shapes: second prediction from the blue shape reference position). Left: Approach to the turning area and Rudder Midships at MP0, next manoeuvre is the turning manoeuvre at MP1 prepared with commands to achieve the track ahead with red shapes. Centre: control action at MP0 - Change of Rudder to 3°SB. Right: additional control action at MP0 - EOT 28% was reduced on top of Rudder to 3°SB.

It shows the approach to the turning area of Rostock Port. In the left figure the black shapes represent the prediction from the current position MP 0 with command settings shown in the manoeuvring panel on the right side set to Rudder Midships and both engines EOT +30%. The red shapes represent the prediction for the next manoeuvre, planned from the blue shape to turn in the side arm which is pre-planned with split engines and rudders 20° PT. Both predictions are calculated in parallel, therefore the whole manoeuvre can be controlled at MP0: for instance, by changing the rudder (centre) the whole prediction chain will turn, or by changing the engine then the starting position of the next manoeuvre will be moved and comes closer for reducing the EOT (right). This is a good opportunity to adjust commands at the actual position, for instance when wind or other forces are coming into the scenario. This samples show how easy it is to prepare a full manoeuvring plan and the benefits to get information and learn about the manoeuvring behaviour of the ship. The operational interface on the screen allows for comfortable use on a laptop, both for lecturers and for trainees, in simulators or on board.

2.4 *Prediction for Efficiency Consideration during Manoeuvres*

In research projects an extension of the SAMMON system is under preparation for adding energy consumption into the fast time simulation. Previous research has shown that an efficient ship operation is not only depending on the provided technical equipment, but also on the efficient handling. Measurement on board of a real vessel showed a variety of required energy for the same port approach but with different manoeuvring concepts [4]. Measurements under controlled conditions in a simulated environment showed that proper assistance tools could lead to an effective manoeuvring while reducing the amount of engine orders and rudder commands given and using alternative manoeuvring concepts (see e.g. [9], [4]). In these publications and in the following example the energy reduction regarding the simulations was only determined by the calculation of the propeller energy - without taking into account the drive train yet. In Fig. 4 an example is given for two initial manoeuvring conditions with different variations of propulsion for a double-end ferry with four azimuth propellers. The required power in kW at MP0 (red ship contour) can be seen in the new manoeuvring handle interface on the right side with the green bar display: for the propulsion condition by using the two pairs of azimuth propellers at front and aft with equal EOT 40% the power is equally distributed indicated with bars of same length and an initial speed of 6.5kn can be observed. For the condition where the aft propellers are used (bottom) with EOT 50% a speed of 7.6 kn can be seen and a smaller power requirement at the front propellers, obviously the propeller load is reduced at these azimuth propellers.

In future it is planned to consider the drive train energy into the simulation in the same way as in the on-board measurements where the total energy has been directly calculated by integrating the power of installed azimuthal drives (see [4]). Therefore, the project SimpleShip was initiated by various institutions and funded by the German government [5]. Considering that one of the largest consumers on a passenger ship is the propulsion, the main target is to give the nautical crew innovative assistance for navigating with higher safety and efficiency, to calculate and predict the total energy consumption within the manoeuvring time.

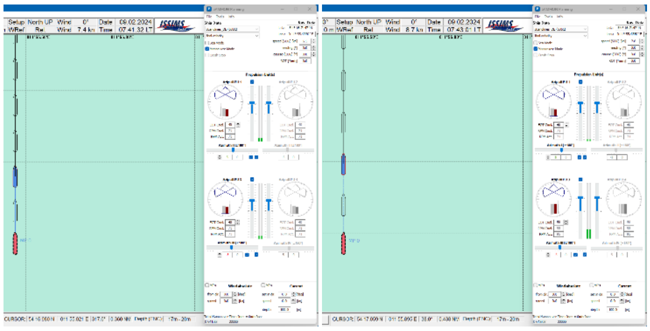

Figure 4. Examples of prediction of power requirement (green bar display, in kW) for a double-end ferry with four azimuth propellers (left: both pairs of azimuth propellers are active with EOT 40%, right: aft propellers increased to EOT 50%)

In the next Figure 5 two different manoeuvres are shown to discuss the different turning strategies starting at position MP3: In the left figure it is done in conventional way by stopping the port engine and turning the ship with the SB POD IN100° with transverse thrust like a rudder; In the right figure the pods are used in a tandem position: PT POD IN120° and SB pod OUT60°

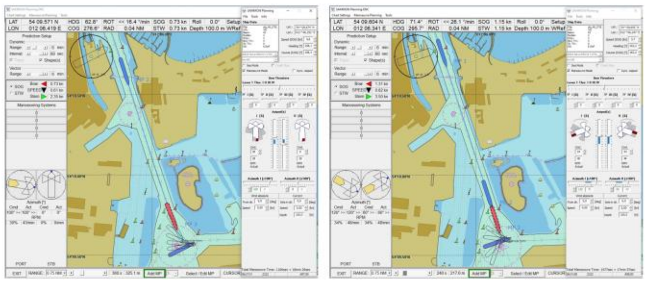

Figure 5. Two manoeuvres for different turning strategies starting at position MP3: left: conventional way by stopping the port engine PT POD EOT 0% and turning the ship with the SB POD to IN100° with EOT 30%; right: the pods are used in a tandem position: PT POD to IN120° and SB POD to OUT60°, both with EOT 34%

In the final phase of the manoeuvring plan the ship will be stopped short before the berth: also here the pods can be used in conventional way of stopping by reversing the pods to direct the thrust in astern direction or to be used inward to create maximum resistance and on the same time adjusting the EOTs so that the ship is moving in the direction of the berth, together with the bow thrusters.

The question is now to decide which of the two strategies are better? For this reason, the fuel consumption was estimated for both versions by means of the SIMOPT [6] / SIMDAT software programs. The benefit is shown in Figure 6 comparing the consumption for both manoeuvring strategies for each manoeuvre separate (left) and as a cumulative sum of all the manoeuvres (right). It can be analysed with respect to consumption:

– Conventional POD- strategy: consumption ca. 3x106 g, i.e. ca 3 t

– New POD-Inward strategy: ca. 9x106 g consumption, i.e. ca 9 t

Therefore, the following conclusion can be made:

– The conventional operation of PODs like for a normal Twin Screw ship has only 30% fuel consumption (and in analogy about 30% emission of CO_2), compared to the New operation: Operating the PODs against each other is a waste of energy and damage to the environment!
– It is without any doubt that the Inward strategy has a lot of advantages because the ship is much easier to control due to the immediately available steering forces when turning the pods for higher revolutions. But this should only be used if these high forces are really needed, e.g. for challenging external forces or complicated manoeuvres.

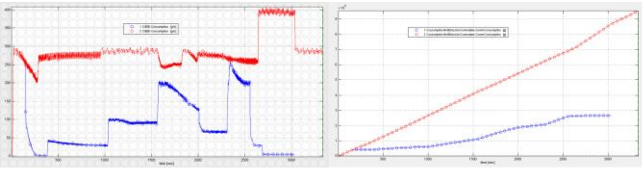

Figure 6. Comparison of consumption for both manoeuvring strategies: Left: Plot of consumption of separate manoeuvres; right: Plot of cumulative consumption (Blue: Conventional POD strategy, speed changes by reducing POD revolutions - Red: New POD strategy, speed changes by turning both PODs inward)

2.5 *Parallel Prediction for Direct Steering with Handles on Bridge*

For hands-on experiences it is of advantage to use the SAMMON Monitoring and Conning tool because it allows the input to the prediction using the bridge handles – both in simulators or on- board ships. In Fig. 7 the handles on the bridge console represent a typical configuration for Azimuth Propeller steering. Because of the complexity of the response of the vessel as result of the 360° azimuth thrusters in combination with bow and stern thrusters there is a big variety of options. The prediction can be used either in freeze mode when the simulator exercise is stopped (left) to familiarise with different manoeuvring strategies and also during the run of the exercise where the predictions are shown during the run (right).

Using the Monitoring & Conning tool, several predictions can be shown in parallel for steering the ship: Display of Manoeuvring Plan, together with current position and Predicted Manoeuvres in parallel, i.e. with the new Multiple Dynamic Prediction tracks for Dynamic Prediction, based on full ship dynamic simulation for future ships motion due to the input from actual bridges handle settings together with the “Path Prediction”. This feature allows for more safe and efficient manoeuvring which has been proven in several tests (see e.g.[3])

Figure 7. SAMMON Monitoring & Conning Tool with Multiple predictions used in Ship Handling Simulator for Training used in familiarisation exercise for Podded Ships (Full Dynamic Predictions: black dotted ship contours; Static Path Prediction: Magenta ship contours). Left: Exercise in Freeze Mode for TOE IN method for Stopping Manoeuvre with dynamic prediction. Right: Turning manoeuvre during simulator run using static and dynamic prediction in parallel

In Figure 8 a sample for the screen is shown with Display of Manoeuvring Plan and Predicted Manoeuvres Multiple Dynamic Prediction in parallel for tracks for full ship dynamic Simulation for future ships motion and “Path Prediction” Presentation simply taking the current rate of turn and speed as constant for the prediction time period.

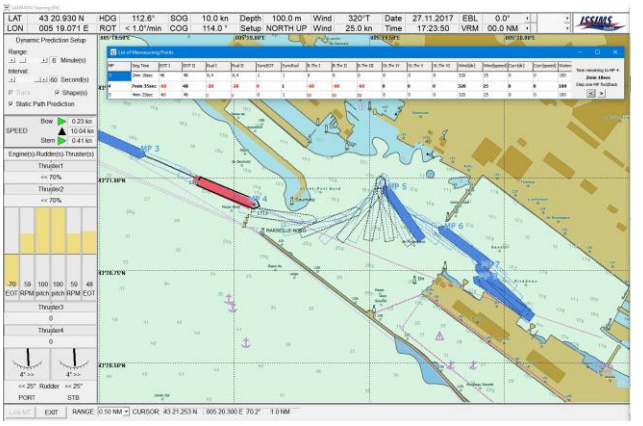

Figure 8. Display for Multiple predictions: Real time simulation and Manoeuvring Prediction integrated into ECDIS with comparison of Full Dynamic Predictions (black dotted ship contours) and the simple static prediction (magenta curve, no shapes) together with planned manoeuvring track (blue line and ship shapes) for a Cruise ship arrival at Marseille and berthing at Pier 163

3 PREDICTION FOR ASSISTANCE IN COLLISION AVOIDANCE

Moreover, predictions help the Officer of the Watch (OOW) make decisions during potential collision situations. There are three main applications: determining when to initiate maximum rudder angle for safe passage, identifying the "Last Line of Defence" for collision avoidance, and visualizing manoeuvring zones for steering control options. Besides providing information about latest time for initiating an avoidance manoeuvre for safe passage, new features support situational awareness by displaying navigable space and predicting paths with maximum rudder angles. This is valuable for simulation training, demonstrating risk models and collision avoidance strategies to cadets.

Additionally, visualizing the escalated risk of collision based on the ship's own manoeuvring capabilities at the prevailing circumstances enhances maritime education and training.

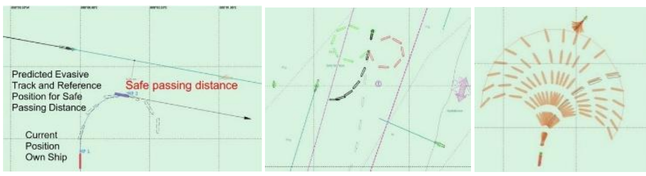

Figure 9. Visualising lower action limit for "Stand on Vessel" (left), multiple prediction of maximum manoeuvres (centre) and manoeuvring zones with all potential manoeuvres (right)

Figure 9 (left) shows an encounter situation in an electronic chart environment. The own ship (red shape) is on a north-easterly course, approaching another vessel on a south-easterly course, crossing the bow at a short distance. The prediction highlights the closest approach when the own ship's heading equals the target ship's course over ground. To ensure a minimum passing distance of 0.25 nm at the CPA, the hard wheel over command must be initiated at MP 1, reaching MP 2 ([2]; [6]). An extended version is to be seen in the centre as a sample for presentation of four dynamic-manoeuvring predictions: of actual manoeuvring track (black-dotted contours) and additional manoeuvring tracks for hard-to-STB (green) and PT (red) as well as for crash stop (black) from actual motion parameters - the ship has applied rudder amidships the contours of actual control are ahead of the ships position. From the figure it is to be seen that a stopping manoeuvre would not help anymore but a turning circle to starboard would help.

An alternative concept for situation assessment and decision-making is to use multiple predictions to visualize all potential positions of a manoeuvring ship within a given timeframe (Figure 3 (right)).

Manoeuvring zones can be calculated and displayed, representing areas a ship may cover using various control settings for the exact situation. This concept may enhance situation assessment for collision avoidance on board ([9]) as well as monitoring from a VTS ([11]).

4 APPLICATION OF FAST TIME SIMULATION FOR PREDICTION IN A NEW MASTER DEGREE COURSE FOR MARITIME PILOTAGE - MODULE MANOEUVRING

Traditionally, seafarers in Germany had to be vessel masters for an extended period before allowed applying to become a pilot. However, declining applicant numbers with that experience level led to considerations how to cope with lowered entrance experience and therefore to be balanced by increased training needs. Today, pilot training in Germany follows three paths (named LA1, LA2 and LA3) depending on participant experience levels:

– Career Path LA3: For those with a master’s license and 24 months sea experience in the last 5 years. It requires 12 months of in-house training and an exam.
– Career Path LA2: For those with a master’s license but lacking sea experience. Participants undergo an additional 6 months training before starting LA3.
– Career Path LA1: For those without a master’s license, a selection process and a new, dedicated degree program "Master of Maritime Pilotage" in Warnemünde is required, covering content and training also for the foregoing steps.

To bridge experience gaps, extensive simulation exercises are used, including conventional ship handling simulators, virtual reality (VR) headset simulations, and remote operated model ships. Model ships for practical training are used for demonstrating hydrodynamic effects and allowing practice of berthing manoeuvres under varying conditions. Especially the problem of students’ heterogeneity level of experiences in regards to their sea times and the variety of the experienced ship types is very crucial. The overall aim is to improve and to make individual knowledge accessible to all participants. According to constructivist learning theory, effective learning should be active and individual. In heterogeneous groups, this is achieved through project work, where participants solve problems together, utilizing their strengths. Fast Time Simulation tools are perfect for this approach.

One element of the Manoeuvring Module in the new course is to apply knowledge of different propulsion and manoeuvring aids to create and prepare a detailed manoeuvring plan. Participants were divided into four groups, each tasked with developing a departure manoeuvre for their vessel type:

– Group 1: Right-handed fixed propeller, no thruster
– Group 2: Left-handed pitch propeller, bow thruster
– Group 3: Inward turning double propeller, bow thruster
– Group 4: Podded propulsion, bow thruster

All vessels were defined to be 200m in length, with no current or wind conditions, and operated in a wide manoeuvring area with a simple pier. Each group had to depart from the same berth but with different vessels. The goal was to focus on the propulsion and thruster performance, allowing participants to present and discuss their detailed manoeuvre plans.

The discussion within the groups fostered a rich exchange of knowledge and experience. When presenting their results, participants detailed their manoeuvres, and the lecturer used the SAMMON Planning tool to illustrate the outcomes Figure 5. This had three key effects:

– Participants took the manoeuvre descriptions seriously.
– Incorrect assumptions were quickly corrected through simulation of alternatives.
– Other groups benefited from moderate exchanges and knowledge specific to each propulsion setup.

Afterwards, reshuffled groups planned a departure from same pier under same conditions, focusing on accurate detailing and identifying limits. The Fast Time Simulation tool demonstrated several advantages:

– Enhanced knowledge of propulsion setups, particularly double propeller and podded propulsion.
– Quick correction of wrong assumptions through immediate simulation feedback.
– Efficient demonstration of well-prepared plans versus reactive manoeuvring.
– Focused manoeuvre planning without distractions like handling errors or visuals.

Final discussions revealed the existing great potential of the software and suggestions for future software feature extensions were made.

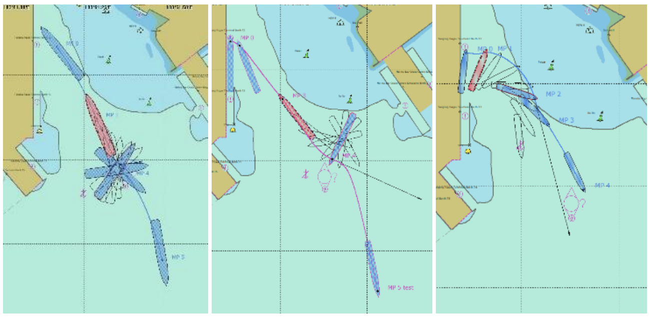

Figure 10 Three different departure Manoeuvres created by groups of participants. Left: departure with right-handed fixed propeller and bow thruster, Middle: shows departure with two inward turning propellers and bow thruster, Right: shows vessel with two podded propulsion and bow thruster.

5 CONCLUSIONS

Prediction of ship motions is an essential part of safety of navigation in general, for manoeuvring in coastal or narrow waters - and particularly when approaching terminals and ports for berthing. In this paper a survey of historic developments and recent achievements of simulation-based manoeuvring predictions is provided.

Digitalization and modern information and communication technologies are main prerequisites for advancements of predictions. The invention of Fast Time Simulation and its implementation for more exact and reliable manoeuvre planning is a big advantage - not only for simple course changes but very complex manoeuvring for berthing operations in narrow harbour basins. A powerful and reliable prediction tool for manoeuvring operation including energy and fuel consumption is a path to include the crew and provide them with proper information. Moreover, situation assessment and decision making for manoeuvring with purposes of collision avoidance can be supported much more comprehensively and easily than just 5 or 10 years ago. It is possible to provide situation-dependent limit values for triggering collision warnings precisely - considering the manoeuvring behaviour for determination of the latest moment to take action. The developments and technical implementations focussing on the support of the Officer of the watch on a ship's navigational bridge, are very beneficial for training purposes in maritime education and training of navigating officers. In this way manoeuvring predictions improve simulation training and shall be integrated accordingly as for the new Master Course for Maritime Pilotage at Hochschule Wismar.

ACKNOWLEDGEMENTS

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