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Full-state Manoeuvre Planning System for Marine Vehicles

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Abstract: Nowadays vessels are often equipped with modern steering devices like thrusters and podded drives. Such modern steering concepts substantially increase the manoeuvring capability of the vessels. Special manoeuvres, such as berthing and cast off manoeuvres, can be performed by controlling all available aggregates without using tug boats, lines and anchors. Furthermore, the reliability of the position information especially in ports and other safety critical areas has been improved by auxiliary systems. The user gets warranted position data, so that control tasks with high safety requirements can be realised automatically, especially in case of decreased visibility. The deficit of today's track control systems is the path planning method to generate the input values of the specific track control systems by the navigating officer, especially in low speed modes. In order to face this lack, new manoeuvre planning algorithms have been developed and embedded in a simulation and test environment. The feasibility of the developed manoeuvre planning methods is demonstrated with one of the most challenging nautical tasks - the berthing manoeuvre.

Keywords: manoeuvre planning, track control systems, guidance systems, berthing manoeuvre

1. INTRODUCTION

In the last years a rapid development could be observed in and around shipbuilding. Maritime vehicles are equipped with a wide range of different propulsion and steering devices such as podded drives, Voith-Schneider propellers, waterjets and transverse thrusters. These manoeuvring geers increase the manoeuvrability of the vessels substantially and modern control systems completely consider these aggregates within the feedback control process. Thus, it becomes possible to realise special manoeuvres automatically, especially in low speed mode and with only small manoeuvring space.

A deficit of commercial guidance systems for path following exist in planning exact paths to generate the input values of the specific track control systems by the navigating officer. All the substantial degrees of freedom of the vessel have to be addressed actively considering the manoeuvring characteristics of the specific vessel. This is the only way to plan special manoeuvres and to prepare them for the control system, especially in low speed modes.

The traditional way to minimize the disadvantages of the planning methods is to develop smart path following controllers and motion guidance algorithms, e.g. Breivik and Fossen (2004) and Breivik and Fossen (2008) or Zizzari et al. (2010). But, the problem could be addressed already within the planning phase. This approach is described by the paper.

Beyond that, there are raised ambitions to increase the quality and the reliability of position data in safety critical areas like ports and limited waterways with auxiliary systems. Thereby, the quality of the position information can be improved essentially by so-called Ground Based Augmentation Systems (GBAS). For example a system called seaGATE was developed in the port of Rostock as maritime Galileo test and development environment. This GBAS provides the user with different correction and integrity information in real time and fuses data from other systems. seaGATE broadcasts Galileo-compliant signals with the help of so-called *pseudolites*, which are distributed in the area of the port since 2008. A monitor and a control segment permits the test of Galileo receiver engineering. Furthermore, two reference stations permit applications with high position requirements in the port of Rostock, Kurowski and Lampe (2011).

As an example of a safety relevant manoeuvre, Fig. 1 shows a replay of a manual berthing manoeuvre of the ferry *M/V Mecklenburg-Vorpommern* in the port of Rostock. It was extracted from given motion and position data of the voyage data recorder of the ferry. Such manoeuvres are challenging tasks for the nautical staff and have the highest safety requirements.

2. STATE OF THE ART

Presently, in the area of path planning for maritime vehicles, there are differences between the nautical-oriented path planning methods to use with standard ship guidance system and the (automatic) trajectory planning algorithms used for open sea applications as well as high-dynamic vehicles, like Unmanned Surface Vehicles (USV) and smaller boats. Within the commercial shipping, the

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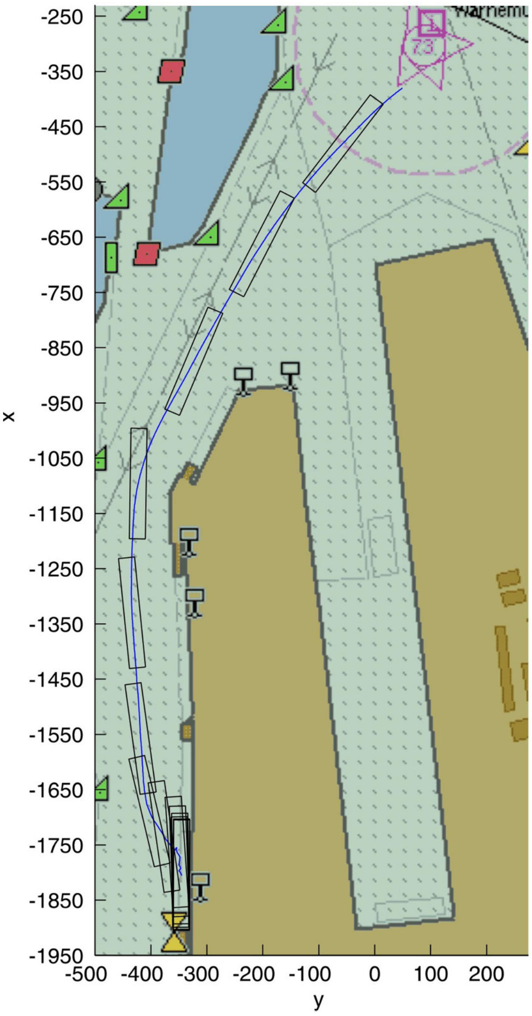

Fig. 1. Replay of a manual berthing manoeuvre of the ferry *M/V Mecklenburg-Vorpommern* in the port of Rostock

generation of reference paths is executed by the responsible navigating officer. Thereby, identical path planning methods are used for a wide range of vehicles from slow-acting large ships up to more agile multi-purpose vessels with their special manoeuvre requirements. For this reason, only very conservative planning methods can be used, which have to be adapted with only few parameters to the respective vessel. In spite of the cautious algorithms, it is possible to produce trajectories, which are not retractable by the vehicle. In case of guidance system for path following this leads to larger actuating variables or endangerments for the vessel. Hence, these planning methods are only applicable to generate paths in open sea areas with sufficient manoeuvre space. This kind of track planning method bases on the current valid European Standard EN 62065:2002, CENELEC (2002).

2.1 Commercial path planning technologies

Planning methods used with industrial standard guidance systems for path following are considering the standard already mentioned. This procedure refers to field of waypoint planning method. Therefore a finite number of waypoints is indicated and connected with straight lines. Circular

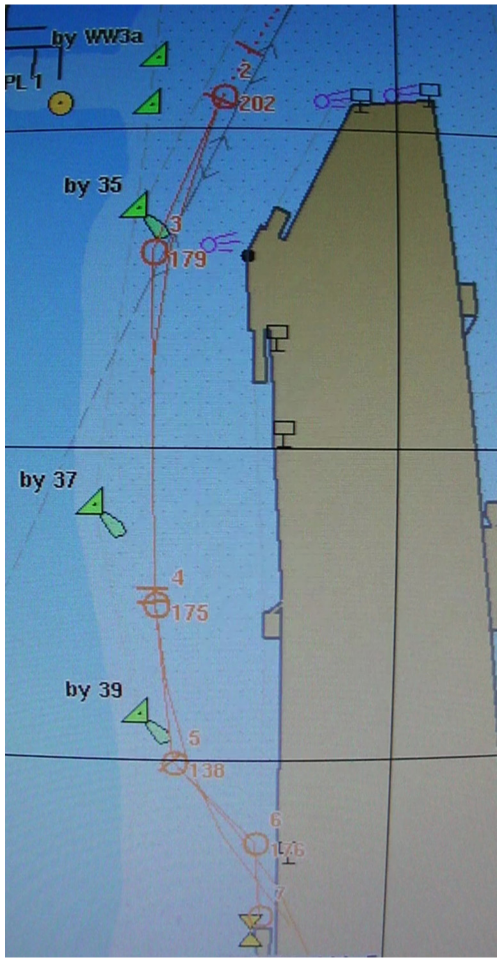

Fig. 2. Planning a berthing manoeuvre in the port of Rostock with an industrial standard guidance system for path following

arc elements are integrated automatically by the additional definition of turning circles for each waypoint. The minimum possible radius is selected for the given ship and has to reflect its manoeuvrability. This can succeed due to the multiplicity of most different ships only very conditionally. Besides, the manoeuvrability of maritime vehicles changes significantly over the speed range. An entire parameter set would be necessary to map these effects to the manoeuvrability of the vessel.

For this reason problems occur when planning tracks in narrow waters or special manoeuvres with low vehicle speed. For clarification, a route was planned with an industrial standard guidance system for path following. The planned track shows a routine manoeuvre to approach the ferry terminal in the port of Rostock. Fig. 2 shows the generated route. The minimal radius was not sufficient to calculate the curvature of the path, especially in the final part of the approach. Therefore the route can not be activated by the operator for track control application. An analysis whether the manoeuvrability of the vessel is sufficient to follow this reference path with the planned speed and the equipped propulsion and steering devices, as well as the track control system cannot be accomplished.

Dynamic Positioning (DP) Systems offer more distinguished planning methods due to the operational modes of