Application of recent GNC Approaches for Automation in Shipping

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The use of assistance systems for inland vessels has shown to improve operational safety while reducing the skipper's workload at the same time. Currently available assistance systems mainly focus on supporting the human operator. Most common examples are the autopilot and the Electronic Chart Display and Information System.

However, increasing economic competition and personnel shortage in the last decade are driving the demand towards modern assistance systems with a much higher degree of automation. In order to succeed, such an automation system must fulfill three core tasks that are currently performed by the human operator. First, a guidance system bridging the gap between environmental perception and ship maneuvering is required. Second, a navigation module has to estimate the state information. Third, a control system executing the guidance command based on the current state information is needed.

Recent research at the Institute of Automatic Control at RWTH Aachen University addresses various aspects of the guidance, navigation and control (GNC) of surface vessel. This presentation gives an overview about recent research work within the research projects *GALILEOnautic 2*, *AKOON* and *FernBin* and shows the related developments, similarities and differences in the concrete implementations for each individual application.

When maneuvering in dynamic environments, the guidance systems needs to perceive the evolving surrounding in order to plan safely. The perception task is even more challenging in unstructured port environments, where different types of objects and vessels have to be tracked at the same time. Lin et al. (2021)[1] have addressed this problem by pairing LiDAR point clouds with adaptive shape fitting techniques to detect close objects. The extracted objects are then tracked using an adaptive extended Kalman filter. The method has been experimentally validated in *GALILEOnautic 2* using an equipped unmanned surface vessel and a rubber dinghy in the harbor of Rostock.

After receiving information of surrounding obstacles and the topographic map, the guidance system of an automated vessel is also responsible to plan a safe and fuel-efficient trajectory from the current position to the target position. Recent simulation results in *AKOON* have shown that in case of a fixed area and an overactuated ferry, a discretization of the state space into a graph-based problem may lead to a nearly optimal real-time solution for the trajectory planning problem.

Exemplary for the navigation module, a tightly coupled navigation filter from the Institute of Automatic control is presented in the context of *FernBin*. Satellite signal losses due to shore-side structures leads to design adjustments. Additionally, the integration and fusion with other sensor information such as from visual odometry are explored.

The control system afterwards allocates required steering forces based on a desired trajectory and state estimation. Exemplary results from simulator test of the automated river ferry in AKOON using nonlinear-model predictive control and linear-quadratic integral control are presented.

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[1] Lin, J.; Campa, G.; Framing, C. E.; Gehrt, J. J.; Zweigel, R.; Abel, D. (2021). Adaptive shape fitting for LiDAR object detection and tracking in maritime applications. *International Journal of Transport Development and Integration*, *5*(2), pp. 105-117.