Marine Robotics - Seminar 2

Dynamic Positioning and Acoustic Localization

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Introductory remarks

- **Goal of the seminar**
  The goal of Seminar 2 is to evaluate controllers designed and simulated during Seminar 1 using a real autonomous surface vehicle (ASV) in the pool. The topics of sensors, acoustic communication and mathematical modeling covered during the first part of the semester are going to be demonstrated in practice during hands-on exercises. After testing the heading control and dynamic positioning implementations on an actual vehicle, the vehicle position is going to be recorded using a variety of available sensors. During two-hour lab sessions the vehicle is going to log IMU measurements as well as a short-baseline (SBL) acoustic positioning signal which are going to be used for visualization of the achieved trajectories.

- **Preparation:**
  - Seminar 1 (prerequisite)
  - Lecture 3 & 4: Mathematical Modelling of Marine Vehicles
  - Lecture 5 & 6: Control and Guidance of Marine Vehicles

  The practical part of this exercise is done in the Laboratory for Underwater Systems and Technologies (LABUST) in the prearranged time-slots. Gain coefficients for controllers designed in Seminar 1 for the ASV model in Matlab should be applied to the equivalent controllers on the actual ASV. The post processing and data analysis is done in Matlab.

- **Instructions on report submission:**
  Upload your submissions through the course Moodle page that can be accessed from:
  `https://www.fer.unizg.hr/predmet/podrob`
  The submissions should include the assignment PDF form complete with answers and required graphs. Fill in your simulation parameters, comments and conclusions in the respective fields provided. The system response and trajectory images should be in .bmp, .jpg or .png format and they can be attached using Adobe Acrobat to this PDF as follows: `Tools` → `Comment & Markup` → `Attach a File as a Comment` and choose the picture of the related simulation, which makes the picture a part of your submission PDF document. Adjust the duration of the plots and the axes scale in a way that the vehicle trajectory or the desired effects can be clearly seen, all transients have taken place and outputs stabilized. All the axis in the plots should be labeled accordingly and correct units of measurement indicated. For any questions or assistance you can contact the e-mail address `luka.mandic@fer.hr`.

Seminar 2

The process of designing the controllers described in the lectures and Seminar 1 through a practical Matlab simulation is going to be evaluated on the H2Omni surface platform. The platform is equipped with four thrusters in an X-configuration enabling it to move omnidirectionally. This kind of surface vessel and the thruster configuration allocation matrix was previously discussed in the lecture Mathematical Modelling of Marine Vehicles. The simulation and control algorithms used in this seminar are designed during Seminar 1 and the resulting controllers should be ready when coming to the laboratory.. The H2Omni USV can be seen in a lab setup on figure 1.

Fig. 1: Image of the USV H2Omni and the laboratory setup used for the seminar

Inside the carbon hull of the platform is a Linux based PC running Robot Operating System (ROS). All the controllers necessary to operate the platform are running in ROS and are already implemented and should be tuned based on the initial parameters given in Seminar 1. Additionally, the platform can also be controlled manually using a remote joystick. The goal of this seminar is to test the behaviour of the regulators designed in simulation for heading and surge/sway velocities. After a successful demonstration of velocity regulators, you will use the two regulators cascaded in a dynamic positioning controller with which you will be able to control the vehicle position. Dynamic positioning is going to be used to drive the vehicle through the given trajectory points and record the localization sensor logs.

Task 1 : Testing and evaluation of the I-PD Heading controller

The first task in Seminar 1 was to design a yaw-rate controller for the H2Omni USV model in Matlab/Simulink. The controller discussed in the lectures was the I–PD heading controller whose functionality was demonstrated in Matlab simulation during Seminar 1. Another task was to implement an anti-windup mechanism on the controller using a saturation block. The resulting controller parameters Ki, Kp and Kd obtained in Seminar 1 are going to be applied to the equivalent controller running on the actual platform. A set of reference values is going to be set to the controllers and the responses recorded using on board sensors.

Heading controller evaluation	
• Enter the heading controller parameters from Seminar 1 in the H2Omni user interface. Familiarize yourself with GUI controls, setting control references and turning on/off individual controllers. Using the manual joystick control position the surface platform in the center of the pool, away from the edges. Turn on the heading controller and set the reference to 0. Take a photo of the USV in the pool setup and attach here →	
• Change the heading reference from 0 to 90 degrees and record the platform sensor topics. Find the heading vector response of the corresponding reference and plot the graphs ψ and ψ_{ref} vs. t on the same image →	
• Change the heading reference from 0 to 270 degrees and record the platform sensor topics. Find the heading vector response of the corresponding reference and plot the graphs ψ and ψ_{ref} vs. t on the same image →	

Task 2 : Testing and evaluation of dynamic position control

The second task in Seminar 1 was to design a PI velocity controller for the surface platform model. Since the USV is symmetric in surge and sway directions, the same controller is used for both degrees. Test your design implementation of dynamic position control on the actual surface platform by entering the control parameters obtained in the simulation to the actual controllers on the platform.

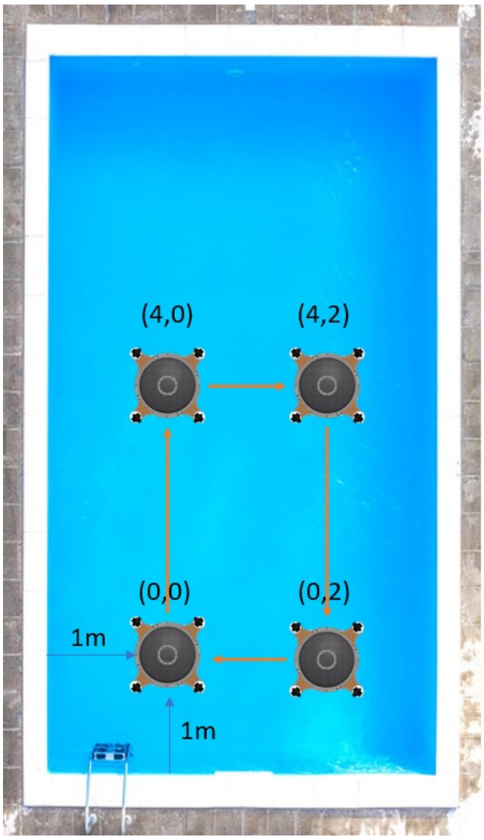

Fig. 2: Planned trajectory using dynamic positioning, starting from the bottom left corner

To test the dynamic positioning control you are going to drive the platform to a series of waypoints and record the trajectories in x-y plane. The trajectory positions (relative to the starting position) are going to be:

X	Y
0	0
4	0
4	2
0	2
0	0

Table 1: x-y waypoints of the vehicle trajectory

Surge/sway velocity simulation images	
• Using manual control, position the platform in the corner about 1m from both edges. This is going to be your origin position (0,0). Take a picture of the starting position and attach it here →	
• Follow the four trajectory points given in Table 1 (relative to the starting position). Close the loop and return to the starting position (0,0). Record the platform sensor topics from the both the IMU measurements and the UWB positioning system. Plot the x-y trajectories from both measurements on the same graph and attach here →	

Task 3 : Acoustic dataset collection

Repeat the steps from Task 2, this time recording acoustic localization data. The localization data is logged from the WaterLinked acoustic positioning system with four receivers sounding acoustical data from each corner of the pool and a locator transmitting from the ASV. Using known baseline dimensions between the receivers and time difference of arrival of the periodic acoustic signals, a position estimate of the locator can be obtained.

Acoustic localization evaluation	
• Use the dynamic positioning from Task 2 to follow the same trajectory pattern from Table 1 and record vehicle navigation data, acoustic localization data and the UWB position data. On the same graph, plot the position trajectory obtained with acoustic localization and the UWB localization system as ground truth →	
• Comment on the results you obtained. What are the advantages and disadvantages of each of the two methods? Which measurements can we trust more? What methods could be applied to improve the acoustic localization? Metoda upravljanja vozila iz drugog zadatka pokazala se uspješnijom i preciznijom kada je riječ o kretanju plovila na površini vode dok bi akustika iz trećeg zadatka bila pogodnija za kontrolu plovila ispod površine vode. Iz grafova je vidljivo da UWB daje preciznije i točnije rezultate za razliku od akustike u čijim rezultatima se očituju nagli skokovi i promjene. Neki od razloga koji mogu utjecati na šum prisutan kod akustike jesu zagađenost vode	