Marine robotics - Seminar 1

Dynamic positioning

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Introductory remarks

- **Goal of the seminar**
  Introduction to processes of modeling, planning, guidance and control of marine vehicles. Introduction to kinematic and dynamic modeling and actuator allocation. Heading control implementation. Dynamic positioning. Anti-windup methods for regulator synthesis.
- **Preparation:**
  Study the following course lectures:
  - Lecture 3 & 4: Mathematical Modelling of Marine Vehicles
  - Lecture 5 & 6: Control and Guidance of Marine Vehicles

  This exercise is done in Matlab and Simulink.
- **Instructions on report submission:**
  Send filled PDF form to luka.mandic@fer.hr with subject [POMORSKA] S1. The same PDF form has to have required images attached in the appropriate places in the document. The images must be in .bmp, .jpg or .png format and they can be attached using Adobe Acrobat as follows: `Tools` → `Comment & Markup` → `Attach a File as a Comment`.

Seminar 1

All the files required for completing this seminar can be found on the link above which includes incomplete Simulink models and Matlab scripts with initial parameter settings. In case of any difficulties using the scripts or questions regarded to the seminar you can contact the e-mail address above. The goal of this seminar is to go through the process of designing the controllers described in the lectures through a practical Matlab simulation. It is thus necessary to go through those lectures first. The simulation and control algorithms in the seminar are designed for a surface marine vehicle equipped with four thrusters like the one covered in the lectures. The USV is shown in figure 1.

The goal of this seminar is first to design the regulators for heading and surge/sway velocities. After successful velocity regulator synthesis, you will put them in cascade and design the dynamic positioning controller with which you will be able to control the vehicle position. In the end, you will drive the vehicle through the given trajectory and plot the drive results.

First, in script *parameters.m* enter simulation parameters that are assigned to you and then run the script to load model parameters. Open the *platform_dp.slx* Simulink scheme. Navigate around the model and inspect the different parts until you are comfortable with it.

Task 1 : Design and Implementation of the I-PD Heading controller

Navigate to *Regulator/Yaw Controller* subsystem of the model. Design the I–PD heading controller. For the implementation of the controller you can use the closed loop transfer function discussed in the lectures (Control of Marine Vehicles). Implement an anti-windup mechanism on the controller. For anti-windup demonstration put a saturation block on the output of the controller. You will set the appropriate saturation N limit value for multiple cases from table bellow . Enter the controller parameters here:

Controller parameter values: Ki = 11.0975 Kd = 27.9450 Kp = 33.2925 Kt

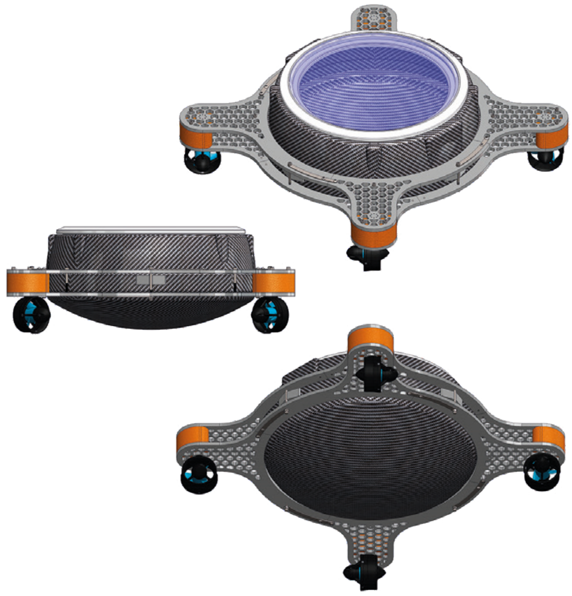

Fig. 1: Image of the USV used for the seminar

HEADING CONTROLLER SIMULATION IMAGES	
• adjust simulation parameters - control value N limit in a way that windup <u>does not</u> happen, and capture the system responses ψ vs. t and N vs t on the same image $\rightarrow$	
• adjust simulation parameters - control value N limit in a way that windup <u>does</u> happen, and capture the system responses ψ vs. t and N vs t on the same image $\rightarrow$	
• adjust simulation parameters - control value N limit in a way that windup <u>does</u> happen, and capture the system responses ψ vs t and N vs t with the anti-windup block on the same image. $\rightarrow$ $\rightarrow$	

TASK 2 : Design and Implementation of the PI Surge/sway velocity controller

Navigate to *Regulator/Velocity Controller* subsystem of the model. Design the PI controller for both surge and sway velocities. Since the USV is symmetric in surge/sway, the same controller can be used for both. For the implementation of the controller you can use the closed loop transfer function discussed in the lectures (Control of Marine Vehicles). You can test your implementation by setting the manual switch before the regulator to the constant value.
Note: anti-windup for surge/sway velocity controller is not necessary.

Tune the controller parameters to get the satisfactory response from the USV surge and sway velocities. Note: Be careful when setting the reference velocity, because max velocity of the vehicle is around 2.2 m/s. Enter controller parameters here:

Controller parameter values: Ki_surge = 50.4725 Kp_surge = 100.945 Ki_s

SURGE/SWAY VELOCITY SIMULATION IMAGES	
• Set the reference value for the surge velocity and capture the system responses u vs t and u_{ref} vs t →	
• Set the reference value for the sway velocity and capture the system responses v vs t and v_{ref} vs t →	
• Set the reference value for both surge and sway velocities. Capture the angular velocities of all 4 thrusters on the same plot (input to Platform subsystem called n). Comment on the results. → Na grafu su prikazane kutne brzine četiri thrustera. Sve brzine dolaze u stacionarno stanje nakon otprilike 15ak sekundi. Kutna brzina četvrtog thrustera brže dolazi do stacionarnog stanja nego npr. kutne brzine	

TASK 3 : Dynamic position control

Navigate to *Regulator/Position Controller* subsystem of the model. Design the PI controller for surge/sway control.

Set the manual switch in front of the velocity regulator to the input from the position controller output. From the outside you can set the reference values for dynamic positioning. Enter controller parameters here:

Controller parameter values: Kp_surge = 0.05 Kd_surge = 0.1 Kp_sway = (

SURGE/SWAY VELOCITY SIMULATION IMAGES	
• Set the reference value for the x position and capture the system responses x vs t and x_{ref} vs t →	
• Set the reference value for the y position and capture the system responses y vs t and y_{ref} vs t →	
• Set the reference value for both surge and sway. Capture the angular velocities of all 4 thrusters on the same plot (input to Platform subsystem called n). Comment on the results. → Na grafu su prikazane kutne brzine sva četiri thrustera plovila. Očito je da se u početku sve vrijednosti kutnih brzina razlikuju te su te vrijednosti također maksimalne. S vremenom se vrijednosti zakreta smanjuju kako bi se	

Task 4 : Driving trajectories using dynamic positioning

Set the manual switch after references to the DP control subsystem output. Inside, there is a matlab function block where you can set waypoints for the vehicle to go through. Set the *references* variable for the vehicle and start simulation.

Example of the *references* variable: $\begin{bmatrix} 10 & 0 & 0 \\ 10 & 10 & 90 \\ 0 & 10 & 180 \\ 0 & 0 & 360 \end{bmatrix}$

Fill the table bellow with the model responses.

Surge/sway velocity simulation images	
• Capture the system responses during the whole trajectory ψ vs t and x_{ref} vs t $\rightarrow$	
• Capture the system responses during whole trajectory x and y vs t and x_{ref} and y_{ref} vs t $\rightarrow$	