NATIONAL UNIVERSITY OF SINGAPORE

CEG5303: Intelligent Autonomous Robotic Systems

Lab: Dynamic Modelling and Control of IARs (20%)

Instructions

1. The main content of this Lab is to realize the dynamic modeling and control of autonomous vehicles, marine surface vessels or drones in MATLAB. The control tasks include the tracking of the desired trajectory and reducing the tracking error to a certain interval at the steady state. Note that this Lab consists of both **group** tasks and **individual** tasks.
2. This Lab should be finished by a group of three. For the autonomous model, you can directly choose one from autonomous vehicle, marine surface vessel or drone. A detailed guideline will be given for the system you choose. If you would like to choose a different type of model, you need to initiate a conversation with us about the specific work that needs to be done.
3. Mention your group number, matriculation numbers, and the module code on the cover page; each group is required to submit the assignment independently.
4. The report length should not exceed a maximum of 10 pages; 1.5 line spacing; 12-point font; 1-inch margins; upload in PDF. Include proper citations and references.
5. Submit the zip file including your codes, reports, etc., in Canvas by 23:59 PM on 20th March 2025. Follow the file name convention as: Lab_Group#.zip
6. Feel free to contact Teaching Assistant Aoqian Zhang (e1144122@u.nus.edu) or Prof. Sam Ge (samge@nus.edu.sg) should you have any queries.

Objective:

Understand the contents of Chapter 2 in the class, build a better understanding of the process of dynamics modelling of common IARs (autonomous vehicles, marine surface vessels or drones), and implement some typical control methods for IARs, like PID, MPC, Backstepping, etc.

Note:

If you choose any of the three systems below and would like to have some guidance/starter file, download the corresponding .zip file on canvas.

Option #1: Autonomous Vehicle Control: Using Model Predictive Control

Task-I: System Establishment and Modeling of the Autonomous Vehicle

- Familiar with the model types of autonomous vehicles, establish any one of the vehicle models, i.e., basic 2-DOF, 3DOF considering yawing moment, etc. In addition, explain the model that you have established.
- Establish the simulation model/environment using MATLAB/Simulink, which should clearly show the plant model part, controller part and input/output channel.

Task-II: Optimization-based Model Predictive Control for Autonomous Vehicle

- Realize the provided MPC control algorithm on motion planning for ground vehicle and choose the suitable control parameters.
- Take different autonomous vehicle structures into consideration in your dynamic modeling and optimize the control performance.
- Realize different driving functions or implement other kind of controllers of your choice.

Lab Assessment

Lab assessment		Score Distribution
i)	Basic Realization: The successful implementation of the tasks that includes building the basic dynamic model of the autonomous vehicles you choose and realizing the position tracking task for specific input signal in MATLAB or Simulink.	60% (Group)
ii)	Optimized and More Accurate Dynamic Model: Take different autonomous vehicle structures into consideration in your dynamic modeling and optimize the control performance.	20% (Group)
iii)	You can either (a) Realize different driving function: Consider more complex driving environment (e.g. multiple vehicles or intersection left/right turn) and implement your design. or (b) Your preferred controller: Implement any other kind of controller of your own preference: such as PID, Learning Based Control, Model-based Adaptive Control, NN Based Adaptive, etc.	20% (Individual)

Option #2: Marine Surface Vessels: Using Backstepping Control

Task-I: Modeling of the Marine Surface Vessels

- Select a specific type of marine surface vessel, collect relevant information from internet, describe the structure features of it in your report, and build its 3-DOF dynamic model.
- If you want to take the challenge of modeling of six degrees of freedom marine vessel, you are welcome to choose other underwater intelligent robotic systems like ROV and AUV.

Task-II: Backstepping for the Control of Marine Surface Vessels

- Implement the backstepping to control the marine surface vessel, so that it can track the desired input trajectory and reduce the tracking error to a certain interval at the stable steady state (≤1% of the peak value of the desired trajectory).
- Implement any other control methods of your choice.

Lab Assessment

Lab assessment		Score Distribution
i)	Basic Realization: The successful implementation of the tasks that includes building the basic dynamic model of the surface vessel you choose and realizing the position tracking task for specific input signal in MATLAB or Simulink (tacking error at stable state ≤ 1% of the peak value of the desired trajectory)	60% (Group)
ii)	Optimized and More Accurate Dynamic Model: Take various underwater environment factors into consideration in dynamic modeling and try to design special structure of dynamics to make your surface vessels work better.	20% (Group)
iii)	Your preferred controller: Implement any other kind of controller of your own preference: such as PID Control, Learning Based Control, Model-based Adaptive Control, NN Based Adaptive, etc.	20% (Individual)

Option #3: Aerial drone: Using Proportional-Integral-Derivative Control

Task-I: System modeling of the drone system

- Familiar with the dynamics and kinematics of aerial drone systems, establish any one of the drone models, i.e., quadcopter, helicopter, multirotor drone, etc. In addition, explain the model that you have established.
- Establish the simulation model/environment using MATLAB/Simulink, which should clearly show the plant model part, controller part and input/output channel.

Task-II: PID control implementation

- Implement a PID control on the model you built. Show the control part in Simulink/MATLAB. Show the controller's effectiveness in a trajectory following task. Explain how you tuned the PID parameters and discuss your observations.
- Modify anything in the system or controller. For example, use another control method, make a more complicated trajectory, change the dynamics, or add disturbances. Explain your observations.

Lab Assessment

Lab assessment	Score Distribution
iv) Basic Realization: the successful implementation of the tasks that includes building the basic dynamic model of the aerial drone you choose and realizing the position tracking task for specific input signal in MATLAB or Simulink.	60% (Group)
v) Optimized and More Accurate Dynamic Model: take different aspects of aerial environment into consideration in your dynamic modeling and observe how change in dynamics impact controller performance.	20% (Group)
vi) You can either (c) Realize different flying functions: Consider more complex flying tasks: such as more complex trajectories, multi-drones, or (d) Your preferred controller: Implement any other kind of controller of your own preference: such as Optimal, Learning Based Control, Model-based Adaptive Control, NN Based Adaptive, etc.	20% (Individual)