University of Westminster
Department of Computer Science & Engineering

5ELEN018W - Robotic Principles Coursework (Semester 1)

Module leader	Dr D. Dracopoulos
Unit	Coursework
Weighting:	50%
Qualifying mark	30%
Description	
Learning Outcomes Covered in this Assignment:	- L02. Use mathematical and software tools to model basic systems relevant to robotics; - L03. Analyse simple control feedback systems; - L04. Implement and code simple control systems using a high-level development platform;
Handed Out:	December 2024
Due Date	6/1/2025 13:00
Expected deliverables	1. Matlab Simulink files for modelling and control (*.slx files) 2. Report in PDF format
Method of Submission:	Online via Blackboard
Type of Feedback and Due Date:	Individual feedback via Blackboard within 3 weeks of submission **All marks will remain provisional until formally agreed by an Assessment Board.**

Assessment regulations

Refer to section 4 of the “How you study” guide for undergraduate students for a clarification of how you are assessed, penalties and late submissions, what constitutes plagiarism etc.

Penalty for Late Submission

If you submit your coursework late but within 24 hours or one working day of the specified deadline, 10 marks will be deducted from the final mark, as a penalty for late submission, except for work which obtains a mark in the range 40 – 49%, in which case the mark will be capped at the pass mark (40%). If you submit your coursework more than 24 hours or more than one working day after the specified deadline you will be given a mark of zero for the work in question unless a claim of Mitigating Circumstances has been submitted and accepted as valid.

It is recognised that on occasion, illness or a personal crisis can mean that you fail to submit a piece of work on time. In such cases you must inform the Campus Office in writing on a mitigating circumstances form, giving the reason for your late or non-submission. You must provide relevant documentary evidence with the form. This information will be reported to the relevant Assessment Board that will decide whether the mark of zero shall stand. For more detailed information regarding University Assessment Regulations, please refer to the following website :http://www.westminster.ac.uk/study/current-students/resources/academic-regulations

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5ELEN018W Robotic Principles - Assignment
Deadline 6/1/2025, 13:00

Dr Dimitris C. Dracopoulos
Email: `d.dracopoulos@westminster.ac.uk`

Description

Your task for this coursework is to model a robot which controls the liquid level contained in two tanks which are connected to each other. The modelling and control of the system will be done using Simulink.

You will be assessed for 3 parts (the details of which are described in the following sections of this specification):

1. Model the dynamic system of the two tank system using Simulink.
2. Control the system (PID control) using Simulink.
3. Write a short report (no more than 5 pages) discussing your results with the inclusion of appropriate diagrams.

The Problem

A robot tries to control the level of the liquid contained in 2 tanks which are connected to each other. The system is shown in Figure 1. The robot controls the inflow Q_{in} for tank 1 by turning a valve. It is assumed that the time to turn the valve is negligible therefore the robot controls the inflow Q_{in} instantaneously.

Tank 1 receives an inflow $Q_{in}(t)$. Tank 2 receives an outflow from Tank 1 and drains liquid from its own outlet. Both tanks have outlets through which liquid exits at a rate proportional to the height of liquid in each tank. The objective for the robot is to control the liquid (e.g. water) levels in both tanks using a PID controller, by adjusting $Q_{in}(t)$ at every time step.

The dynamic system is described by the following coupled system of differential equations derived from the principle of mass conservation (rate of change of volume = inflow - outflow):

$$\begin{aligned} A_1 \frac{\mathrm{d}h_1(t)}{\mathrm{d}t} &= Q_{in}(t) - Q_{out,1}(t) \qquad (1) \\ A_2 \frac{\mathrm{d}h_2(t)}{\mathrm{d}t} &= Q_{out,1}(t) - Q_{out,2}(t) \end{aligned}$$

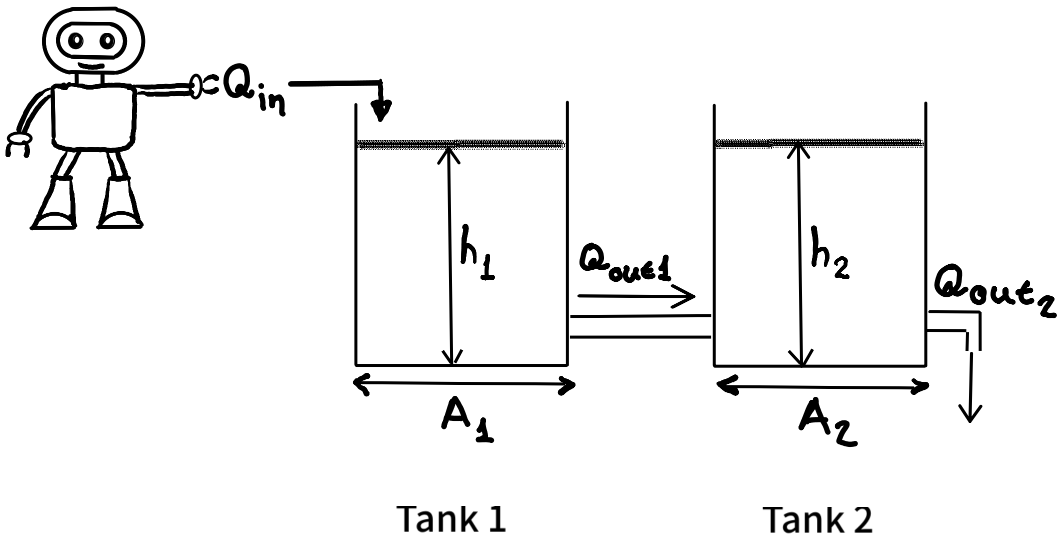

Figure 1: The 2 tank system controlled by the robot.

where the outflow from Tank 1 $Q_{out,1}(t)$ is proportional to its height h_1:

$$Q_{out,1}(t) = k_1\sqrt{h_1(t)} \tag{2}$$

and the outflow from Tank 2 $Q_{out,2}(t)$ is proportional to its height h_2:

$$Q_{out2,1}(t) = k_2\sqrt{h_2(t)} \tag{3}$$

In the above equations, the following variables are used:

- $h_1(t)$ is the liquid level in Tank 1 (m units)
- $h_2(t)$ is the liquid level in Tank 2 (m)
- Q_{in} is the inflow to Tank 1 (m^3/s), i.e. the control variable
- $Q_{out,1}(t)$ is the outflow from Tank 1 to Tank 2 (m^3/s)
- $Q_{out,2}(t)$ is the outflow from Tank 2 (m^3/s)
- A_1 is the cross-sectional area of Tank 1 (m^2)
- A_2 is the cross-sectional area of Tank 2 (m^2)
- k_1 is the valve constant for outflow from Tank 1 (m^2/s)
- k_2 is the valve constant for outflow from Tank 2 (m^2/s)

For the purposes of all simulations in this problem, the following constant values should be used:

- $A_1 = 2\ m^2$ (Tank 1 cross-sectional area)
- $A_2 = 1.5\ m^2$ (Tank 2 cross-sectional area)
- $k_1 = 0.4\ m^2/s$ (Tank 1 outflow constant)
- $k_2 = 0.3\ m^2/s$ (Tank 2 outflow constant)

1 Simulink Model

Implement a Simulink block diagram model of the 2-tank system without controlling the level of liquid in the two tanks. The dynamic system is described in equations (1).

2 Control of the Simulink Model

Extend the Simulink model you developed in Section 1 with a PID controller which the robot applies.

The goal of the robot equipped with a PID controller is to maintain the liquid levels in both tanks at desired levels $h_1^{desired}$ and $h_2^{desired}$:

- $h_1^{desired} = 1.5m$
- $h_2^{desired} = 1.0m$

The total simulation time is 1000 secs.

3 Report with Analysis of your Solution

You are expected to write a short report **in PDF format (no more than 5 pages)** which you discuss both your modelling and your controller implementation of the plant. You should discuss how you chose the PID controller parameters and how these choices affect the performance of your controller. You should include and discuss step response and Bode diagrams among others. A description of the stability of the overall system should also be included.

Marking Scheme:

In addition to the marks below, higher marks will be awarded for a better organised block diagram, a controller which is precisely tuned and an analysis that considers more than just the suggested plots.

1. **Simulink Model**
   - Clear and consistent labelling of signals and blocks: *5 marks*
   - Modelling of the dynamic system: *20 marks*
     - 20 marks for a totally correct diagram
     - 15–19 marks for minor omissions
     - 10–14 marks for some major blocks missing
     - 5–9 marks for a very incomplete diagram.
     - 0–4 marks for a diagram not corresponding to the actual dynamic system.
   - Appropriate inputs and outputs and correct values of parameters for the modelling as given by the specification: *5 marks*
2. **Controller**
   - Implementation of the PID controller: *10 marks*
     - 4 marks for correct input connectivity
     - 4 marks for correct output connectivity
     - 2 marks for a correct block of the controller and relative placement within the diagram.
   - Initialisation of the PID controller parameters and appropriate reference signal: *10 marks*
     - 2 marks for the initialisation of the parameters
     - 8 marks for a totally correct reference signal
     - 5–7 marks for minor omissions in the reference signal
     - 0–4 marks for major omissions or a totally incorrect reference signal.
   - Fine tuning of the controller: *10 marks*
     - precise tuning: 10 marks
     - good but no precise tuning 5–9 marks
     - 0–4 marks for a poor or no tuning at all.
3. **Analysis Report**
   - Response diagrams (step, Bode, etc.): *15 marks*

    - Bode diagram: 5 marks
    - step response diagram: 5 marks
    - additional diagrams: 5 marks.
    - For each of the above, higher marks will be given depending on the correctness and accuracy of the diagrams as well as their clarity.
- Analysis of response diagrams: *15 marks*
    - Excellent description of the diagrams: 12–15 marks
    - Sufficient description of the diagrams with some omissions: 8–11 marks
    - rather incomplete description or with some mistakes: 5–7 marks
    - poor or very incomplete or incorrect description: 0–4 marks.
- Analysis of stability and suitability of the choices made for the controller: *10 marks*
    - 5 marks for the description of system stability
    - 5 marks for the justification of the suitability of the choices made.
    - For each of the above:
        * Excellent description/analysis/justification: 4–5 marks
        * Sufficient but with some minor omissions discussion: 2–3 marks
        * Poor or incorrect description: 0–1 mark

Submission of assignments using a different method other than Blackboard will not be accepted and zero (0) marks will be awarded in such cases.

Deadline: Monday 6th of January 2025, 13:00.

Submission Instructions

Files to submit: The Simulink model of the system (`slx` file), the controlled system (`slx` file) and the report in PDF format. All 3 files should be submitted in a single zip file.

You should submit via BlackBoard's Assignment functionality (do NOT use email, as email submissions will be ignored.), all the files described above. A single zip file with the name `wNNNNNNNN` (where `wNNNNNNN` is your university ID login name) containing all the above files should be submitted.

Note that Blackboard will allow to make a submission multiple times. Make sure before submitting (i.e. before pressing the `Submit` button), that all the files you want to submit are contained there (or in the zip file you submit).

In the case of more than one submissions, only your last submission before the deadline given to you will be marked, so make sure that all the files are included in the last submission attempt and the last attempt is before the coursework deadline.

Request to mark submissions which are earlier than the last submission before the given deadline will be ignored as it is your responsibility to make sure everything is included in your last submission.

The following describes how to submit your work via BlackBoard:

1. Access `https://learning.westminster.ac.uk` and login using your username and password (if either of those is not known to you, contact the Service Desk, tel: +44 (0) 207 915 5488 or log a call via `https://servicedesk.westminster.ac.uk`.).

2. Click on the module's name, `MODULE: 5ELEN018W.2024 ROBOTIC PRINCIPLES` found under `My Modules & Courses`.

3. Click on the `Assessment->Submit Coursework->Coursework`.

4. Click on `View Assignment`.

5. Attach your zip file containing all of the required files, by using the `Browse` button.

6. Create a Word or PDF file with the following information:

   - *Comments*: Type your full name and your registration number, followed by:
     "I confirm that I understand what plagiarism is and have read and understood the section on Assessment Offences in the Essential Information for Students. The work that I have submitted is entirely my own. Any work from other authors is duly referenced and acknowledged."

7. Attach the file with the statement above.

8. Check that you have attached both the zip and the statement file.

9. Click the `Submit` button.

If Blackboard is unavailable before the deadline you must email the Registry at `studentcentre@westminster.ac.uk` with **cc:** to myself and your personal tutor before the deadline with a copy of the assignment, following the naming, title and comments conventions as given above and stating the time that you tried to access Blackboard. You are still expected to submit your assignment via Blackboard. Please keep checking Blackboard's availability at regular intervals up to and after the deadline for submission. You must submit your coursework through Blackboard as soon as you can after Blackboard becomes available again even if you have also emailed the coursework to the above recipients.