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:	November 2022
Due Date	9/1/2023 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

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**

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**

5ELEN018W Robotic Principles - Assignment
Deadline 9/1/2023, 13:00

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

Description

Your task for this coursework is to model and control a car towing a trailer 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 car-trailer system using Simulink.
2. Control the system (PID control) using Simulink.
3. Write a short report (no more than 3 pages) discussing your results with the inclusion of appropriate diagrams.

The Problem

A car is towing a trailer. It is assumed that the car travels along in one dimension x pulling the trailer along the same dimension.

The engine of the car applies a force E to the car making it moving ahead and pulling the trailer. The trailer is connected to the car with a tow-bar with stiffness k. The mass of the car is M_c and the mass of the trailer is M_t. The rolling friction coefficient is λ.

Newton's second law states that "The change of motion of an object is proportional to the force impressed; and is made in the direction of the straight line in which the force is impressed".

The forces acting on the car are rolling resistance, the force due to the tow-bar and the engine's generated force.

Assuming that the toe-bar force is proportional to its deformation $xc - xt$, where xc and xt are the displacements of the car and the trailer respectively, then the application of Newton's second law gives the following equations for the car-trailer dynamic system:

$$\begin{aligned} \ddot{x}_c &= \frac{1}{M_C}(E - k(x_c - x_t) - \lambda M_c g \dot{x}_c) \qquad (1) \\ \ddot{x}_t &= \frac{1}{M_t}(k(x_c - x_t) - \lambda M_t g \dot{x}_t) \end{aligned}$$

where $g = 9.81 m/s^2$ is the gravity. For the purposes of the simulation of the system here, use $M_c = 2, M_t = 1, k = 1, \lambda = 0.03, E = 1$.

1 Simulink Model

Implement a Simulink block diagram model of the car-trailer dynamic system described in equations (1) based on Simulink blocks.

2 Control of the Simulink Model

Extend the Simulink model you developed in Section 1 with a PID controller, so that the speed of the car follows the desired speed shown in Figure 1. The total simulation time is 500 secs and the car starts with a speed of 0, increasing its speed to 1 after 50 secs and keeping this speed for 150 secs before coming to a rest (speed equals to 0) at time $t = 200$ secs.

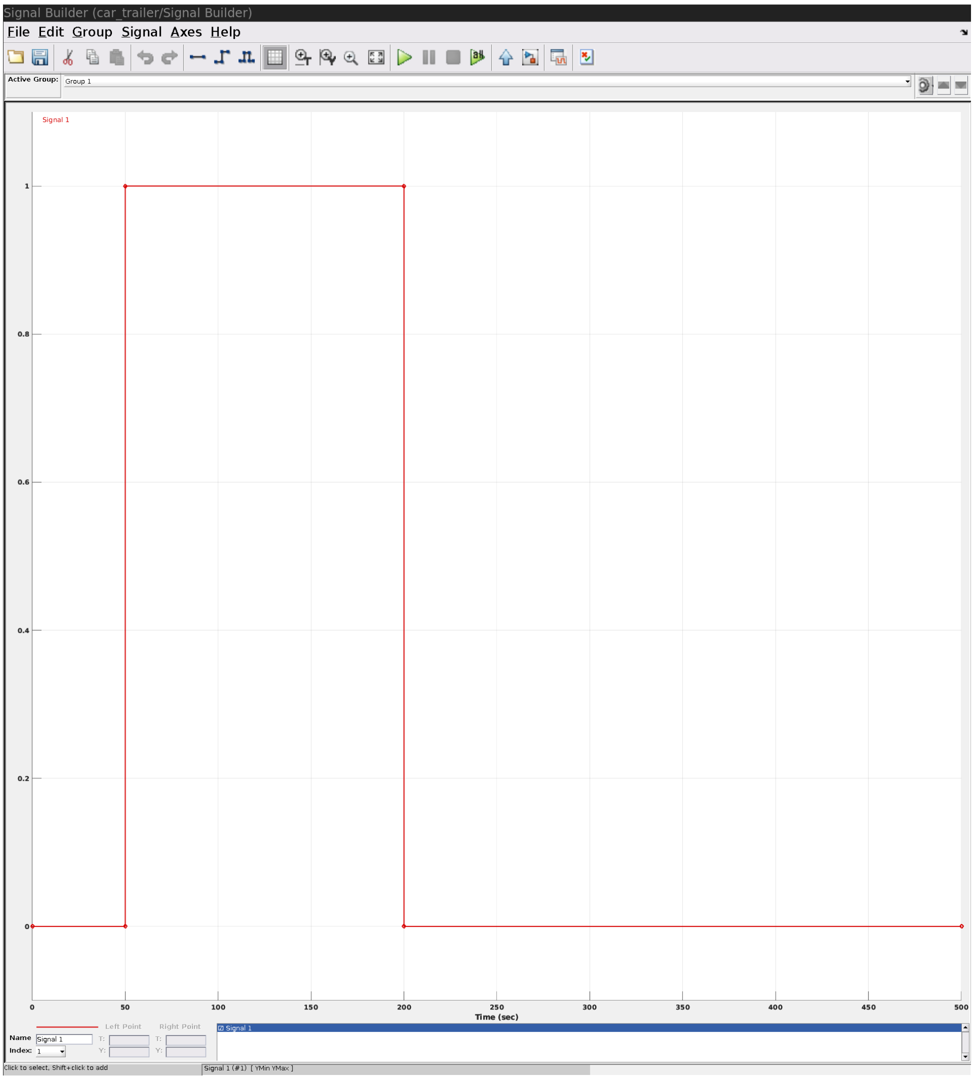

Figure 1: The desired speed $\dot{x}_c$ of the car-trailer system. The controller should try to drive the system to this response.

To generate the signal shown in Figure 1 which is the desired speed (response) of the dynamic system, you should use the *Signal Builder* Simulink block found under the *Sources* library of blocks. From the *Axes-¿Change Time Range* menu change the max time to 500 secs.

3 Report with Analysis of your Solution

You are expected to write a short report **in PDF format (no more than 3 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*
   - 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*
   - Initialisation of the PID controller parameters and appropriate reference signal: *10 marks*
   - Fine tuning of the controller: *10 marks*
3. **Analysis Report**
   - Response diagrams (step, Bode, etc.): *15 marks*
   - Analysis of response diagrams: *15 marks*
   - Analysis of stability and suitability of the choices made for the controller: *10 marks*

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 9th of January 2023, 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.2022 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.

Coursework 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.

The Coursework will be marked based on the following marking criteria:

Criteria	Mark per component	Mark provided	Comments
Simulink Model			
Clear and consistent labelling of signals and block	5		Part 1
Modelling of the dynamic system	20		
Appropriate inputs and outputs and correct values of parameters for the modelling as given by the specification	5		
Simulink Model with Controller			
Implementation of the PID controller	10		Part 2
Initialisation of the PID controller parameters and appropriate reference signal	10		
Fine tuning of the controller	10		
Analysis Report			
Response diagrams (step, Bode, etc.)	15		Part 3
Analysis of response diagrams	15		
Analysis of stability and suitability of the choices made for the controller	10		
Total	**100**		