MECHATRONICS II: MECN4029A - PROJECT ASSIGNMENT - MAY 2024

MECHATRONIC SYSTEMS DESIGN: ANALYSIS AND CONTROL

PROJECT B: SOLAR TRACKER

1. INTRODUCTION

- Each student registered for this course is required to perform a mechatronic systems design assignment; the objective of which is to gain better understanding of the principles covered in the syllabus.
- This will be accomplished by means of computer simulations of an actual mechatronic system design, via which the ideas presented in the coursework can be validated.
- Students are to divide themselves into groups of a maximum of 4 members. Assignment groups have been set up on the course website, students can add themselves into available groups. https://ulwazi.wits.ac.za/courses/55030/groups#tab-13789
- All students will be given access to MathWorks products (MATLAB, Simulink, and 100+ Toolboxes) in the SWE PC Pool. The bonus will be on each student to familiarize herself/himself with the operation of the package, and the plotting and printing of its outputs. The course site includes a MODULE where students can find links to MathWorks resources such as MATLAB Academy where training certifications can be accomplished: (https://ulwazi.wits.ac.za/courses/55030/modules).

REMINDER: This assignment accounts for 25% of each student's total course mark for Mechatronics II.

2. ASSIGNMENT TOPIC & PARTNERSHIP WITH MATHWORKS

The 2024 Mechatronics II assignment is a joint endeavor between MathWorks and the School. Students will need to visit GitHub to access the assignment webpages:

- https://github.com/mathworks/MATLAB-Simulink-Challenge-Project-Hub

Student groups will need to select one of two possible projects. This document addresses PROJECT B.

Project	Weblink
B. Solar Tracker Control Simulation	https://github.com/mathworks/MATLAB-Simulink-Challenge-Project-Hub/tree/main/projects/Solar%20Tracker%20Control%20Simulation

MathWorks has collated resources for these projects which can be found when accessing the GitHub page weblink given above.

You will also have access to discussion forums where you can interact with students across the world who are also working on the same projects. The forums are moderated by MathWorks engineers, who will answer any questions posted in the forum.

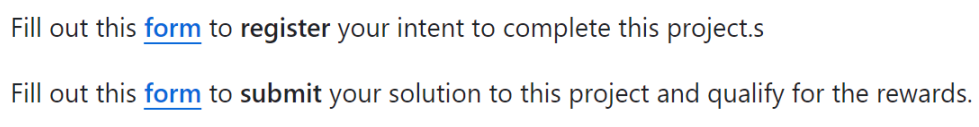
Project	Forum link
B. Solar Tracker Control Simulation	https://github.com/mathworks/MATLAB-Simulink-Challenge-Project-Hub/discussions/99

Students who successfully complete the assignment in the course Mechatronics II will be awarded with a certificate issued by MathWorks. The best project will receive a LinkedIn endorsement by a MathWorks engineer. Both the certificate and the LinkedIn endorsement are unique to the Mechatronics II course assignment.

Moreover, as the selected projects are part of the official MathWorks program called "MATLAB and Simulink Project Challenge", students will have the possibility to gain an international recognition for official internship at MathWorks. Remember to sign up for the project and, upon completion, submit your solution to gather your additional certification. The program will entitle you of other benefits too:

https://github.com/mathworks/MATLAB-Simulink-Challenge-Project-Hub/wiki#rewards

You can find the necessary links at the top of the project webpage (as in the screenshot below). Please, designate a single point of contact within your team who will be responsible for registering for the project and submitting the team's solution.



As this is your final year, this will count positively towards your employment journey once you have completed your degree.

3. ASSIGNMENT TASKS

- Develop a controller for the single-axis solar tracker
- The control system should be designed to optimize the tracking of the sun's path, ensuring the solar panel maintains the best possible angle for energy absorption throughout the day
- Bonus marks will be assigned if you design controls for more than one axis
- Based on the (virtual) geographic installation of the solar tracker system, decide which will be the primary axis (Azimuth or Elevation) appropriately.
- Figure 1 shows the daily solar path, whereas in Figure 2 & Figure 3 you can see the position of the sun in the sky changes as the year progresses.
- Figure 4 and Figure 5 show the orientation / axes for the solar panels.
- For the bonus scenario, the motions of the solar panel around the axes can be independent or combined.
- There are databases from which you can obtain information regarding the position of the sun in the sky throughout the year.

SYSTEM PARAMETERS & MODELLING

3.1. Develop a scenario for the solar tracker which will be the basis for your assignment, e.g., solar power for a corporate office block in city XYZ. This scenario will form the basis from which you will draw performance specifications for your controller[s].

3.2. Develop a realistic, complete (nonlinear) physical and mathematical model of the system. All assumptions and necessary approximations used must be stated. Document fully the modelling process as well as any design-related decisions that you made.
3.3. Linearize the plant model around [a] suitable operating point[s].
3.4. Make use of Matlab &/or Simulink to model your developed system.

SYSTEM ANALYSIS

3.5. Analyze the basic performance of the uncontrolled system both in time and frequency domains. Compare the time-responses of the linear and nonlinear models of the given system to a variety of realistic input signals.
3.6. Conduct full stability analysis for both the linear and nonlinear uncontrolled plant.
3.7. At this stage, discuss the implications for control, i.e., can control be made unnecessary through improved plant design? If yes, how can this be achieved? If no, also provide a rationale.

CONTROLLER IMPLEMENTATION

3.8. Under the assumption that feedback control is required, design closed-loop controllers using:
  3.8.1. Root-locus technique
  3.8.2. Proportional-Integral-Derivative (PID) control technique
3.9. Apply the obtained controller gains to both the linear and nonlinear plant. Apply the controller to solar data for summer and winter, for your single axis controller.
3.10. Evaluate the controlled system analytically and by simulation.
3.11. Discuss the controller performance in achieving the required performance specifications, including any limitations and notable results.
3.12. Discuss the instrumentation needed to implement your controller fully. Also discuss what may be necessary if one of the states is not measurable via a standard instrument.

ASSIGNMENT REPORT

3.13. Each group is to submit a report addressing the above-mentioned tasks. Groups will be expected to show a high degree of individuality in their reports as well as a good understanding of the subject matter investigated. The layout of the report and its effectiveness as a technical document will also be taken into account in the awarding of marks. Please remember that this is a group submission, i.e., only one report per group.
3.14. Each group is expected to submit the MATLAB &/or Simulink codes developed for the assignment together with the report.
3.15. Each group is to submit a report video demonstration of their system including explanations of the modelling process and showcasing the system performance, capabilities, and limitations. A full system specification should be presented. While this is a technical demonstration, effort should be put into making the video interesting and engaging.

BONUS POINTS – OPTIONAL – NOT COMPULSORY!

3.16. As outlined on the GitHub webpage: Develop a multi-axis solar tracker with appropriate control for each and every motor.

3.17. Analyze the efficiency of the solar panel system with and without the solar tracker using MATLAB, employing tools such as the Solar Position Algorithms for solar radiation.

For the bonus scenario, the motions of the solar panel around the axes can be independent or combined. If you intend to submit for bonus marks, you can simply consider independent axes. However, if for whatever design reason you required combined axes, it might be easier to develop the system model as dual-axis right from the beginning.

Please make sure that as you execute your assignment, you demonstrate your skills in the required modelling, analysis and implementation BEFORE bringing in the bonus scenario.

FIGURES MENTIONED EARLIER

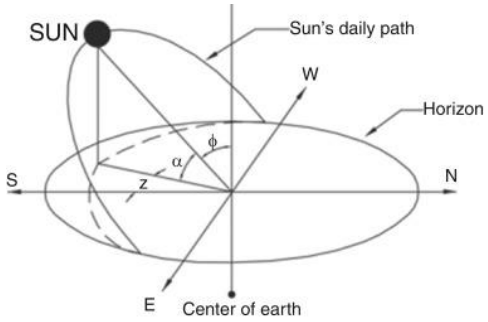


Figure 1: Daily movement of the sun East to West

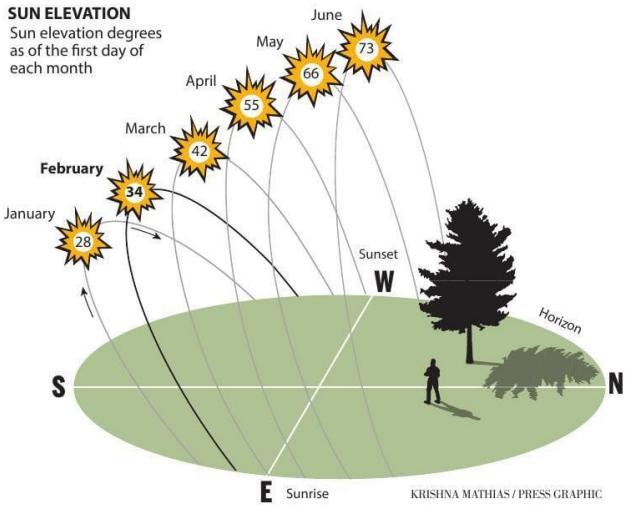


Figure 2: Monthly & daily movement of the sun East to West

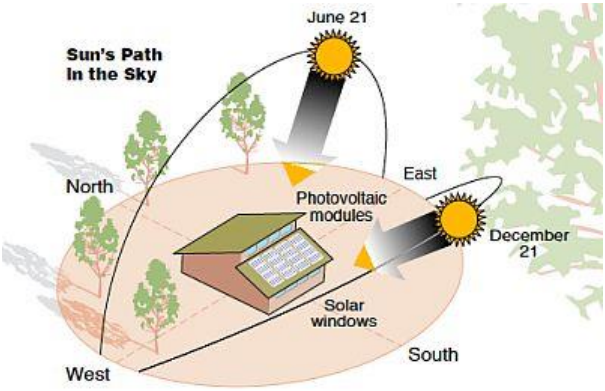


Figure 3: Monthly & daily movement of the sun East to West

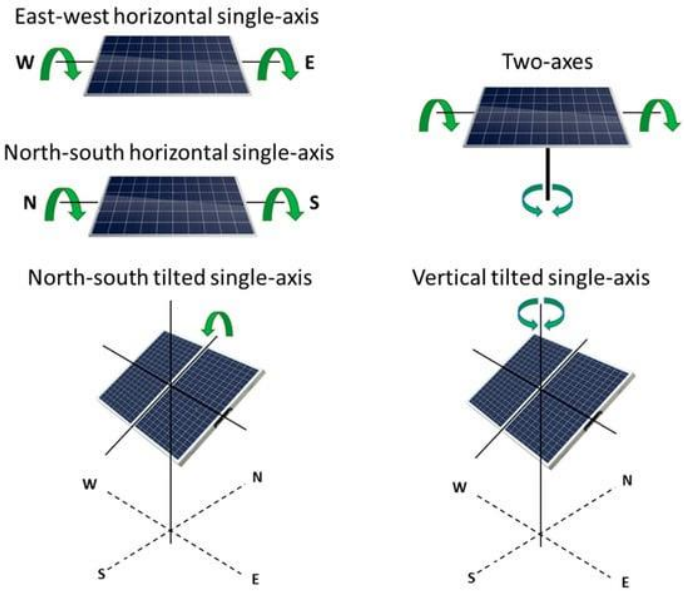


Figure 4: Single- & dual-axis solar panel configurations

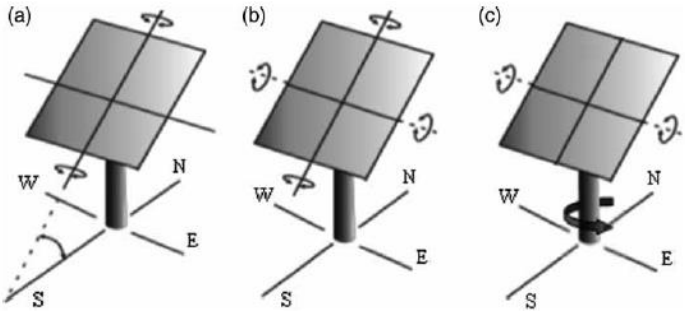


Figure 5: Dual-axis solar panel configurations – polar & azimuthal axes/orientations (Bonus scenario)

4. SUBMISSION

The final submission date for the assignment is Monday 13 May 10:00 am. Take note that submission will be on-line at the MECN4029A Ulwazi Website

https://ulwazi.wits.ac.za/courses/55030/assignments

Late assignments' submissions will be penalised as follows:

- 10% for the first 24 hours or part thereof.
- An additional 10% penalty will then apply on the second day and any assignment handed in on the third day will not be able to obtain a mark greater than 50%.
- Any submission after the third day (weekend included) will be deemed to be Failed Absent and may result in withdrawal of permission to write the final examination.

Once you have submitted on Ulwazi, you can upload your submissions on the GitHub site as explained in Section 2 above. Please, be aware that the GitHub submission will entitle you to participate in the worldwide program "MATLAB and Simulink Challenge Projects" and obtain the official MathWorks internship certification.

5. MARK BREAKDOWN

Assessment Area	Description	Max Marks
Application of theoretical knowledge	Effective and accurate application of relevant theories and concepts learned during the academic career	30
Tools proficiency	Demonstrated skill and understanding in using the tools effectively	10
Effectiveness and depth of solution	Extent of meeting objectives and how well it addresses the problem.	20
Quality of implementation	Robustness, reliability, and performance of the technical solution	20
Real-world applicability	Feasibility and scalability of the solution for real-world implementation)	5
Quality of documentation	Comprehensive and clear project documentation	15
	TOTAL	**100**
	BONUS POINTS	**10**

6. PLAIGIRISM

- The 2024 assignment format allows you to interact with other students around the world who are also working on the same project.
- Additionally Mathworks has made resources available for students who have selected these projects.
- You are reminded that you will need to provide citations to all work that is not your own.
- If you intend to make use of AI-based tools, you will need to explain their use in your

project report, along with providing citations to the tool[s] that you have used.

7. PROCESSING AND PRESENTATION OF RESULTS IN THE REPORT

- As stated in the Course Outline and as indicated earlier, this assignment will also be assessed on the effectiveness of communication in the written answers.
- Neat, legible, clear and clearly labelled diagrams will help here.
- **Simulink screenshots without any processing will obtain 0 (zero) marks. (See screenshot below)**
- Students will be provided with a guide that shows how data from Simulink can be exported to the Matlab workspace for further processing and plotting, where figures can be exported in images for insertion into the report.
- It is important when performing computer-based assignments that students do not invest excessive time in producing and processing of results: **do not present vast numbers of unnecessary simulation outputs in your reports.**
    - Instead, you are encouraged to make use of subplots to condense multiple related plots into 2X2, or 3X1 or whatever format is most efficient.
    - You are also encouraged to overlay results where applicable, e.g., step response of the linear and nonlinear plant can be overlayed and labelled. The linear plant for example, can have a straight line, whereas the nonlinear plant can have a dashed-line or they can be in different colours.

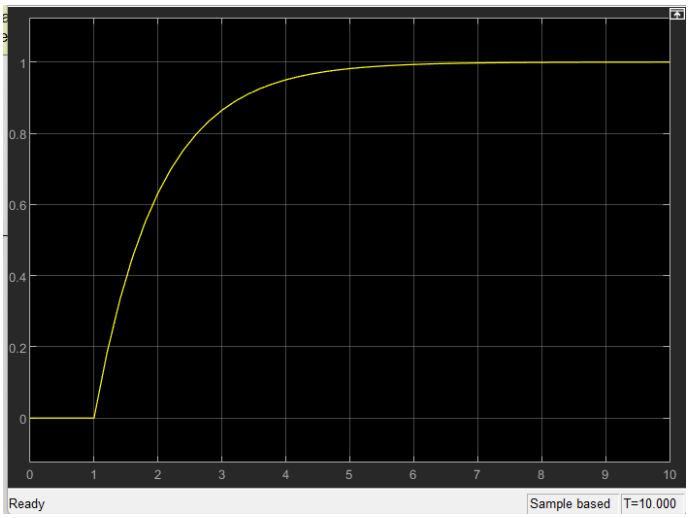


Figure 6: Unacceptable Simulink figure, which WILL EARN YOU 0 MARKS

8. PROJECT PLANNING & COORDINATION

- You are expected to manage your own time and create your own workplan with your group (this need not be submitted in the report).
- Please ensure that tasks are shared amongst group members.
- You may make use of consultation sessions with me should you have any questions regarding the assignment.