EEE3061W/EEE3099S Design Project 2019: Maze Solver

1 INTRODUCTION

Welcome to the EEE3061W/EEE3099S Mechatronics Design Course. Students are strongly encouraged to begin the course by thoroughly reading this document which contains all the required information for the project and course.

In this course, students will be assigned a project relevant to the Mechatonics (Electrical and Mechanical) discipline where they will need to design, build and test a system against a set of specifications.

The purpose of the project is to provide insight to understand the intricacies of the design of systems, including sub-system design and testing. Students are expected to approach the development process in a systematic way using principles that were learnt in EEE3061W /EEE3088F.

The learning outcomes of the EEE3061W/EEE3099S course are listed below:

- Knowledge
    - Understanding of the development process; and
    - Awareness and understanding of various design processes.
- Skills
    - Identification of the user requirements of the system to be developed;
    - Identification of required sub-systems to meet the user requirements;
    - Identification of technical requirements of the system and sub-systems based on the theoretical calculations and simulations.
    - Description of the system and sub-systems using a modelling tool such as a SPICE, Solidworks, etc.
    - Identification of multiple approaches to solve specific problems in the project;
    - Selection of one approach from multiple design approaches/alternatives based on the constraints of the project, sub-system requirements and the performance metrics of the system that need to be optimised;
    - Identification of component alternatives;
    - Selection of components with reasons such that the sub-system technical requirements are met;
    - Logical and systematic integration of working sub-systems and relating testing to realise the system;
    - Use of system level testing or system acceptance testing to ensure that the user and system requirements are met; and
    - Documentation of the system development process in a clear and concise written report for engineering audiences and the community at large.
- Values and Attitude
    - Understanding and demonstration of the importance of a quality design approach in the system development process;
    - Understanding and demonstration of the importance of documentation;

- Appreciation of the need of effective teamwork and project management in engineering problem solving.

Students will be divided into teams of 4 requiring team and individual work equivalent to 8 credits for each team member. This results in a project equivalent to 32 credits relating to roughly 320 hours' worth of work. Please ensure the load is shared evenly among the team members and document individual work done.

2 PROJECT DESCRIPTION

Students are divided into groups of 4 and are required to develop an autonomous multi-wheeled platform to participate in a line maze race where the maze is previously unknown. The race is composed of two parts.

First part is the learning of the maze where the robot needs to follow a black line (track) to learn the maze and find the shortest path from the start to the end of the maze. Second part is a timed event where the robot needs to race through the same maze on the shortest path that it learnt.

In the first part, the robot must start at the push of an easily accessible button and stop once it has learnt the maze and found the shortest path to the finish. The robot is then required to indicate by blinking an LED that it has found and learnt the shortest path from the start to the end of the maze.

In the second part, the robot is required to participate in a timed event where it races through the maze on the shortest part that the robot has learnt from Part 1. The race starts at the push of an easily accessible button and ends once the robot has located itself on the black circular patch.

Students will be given limited time for both parts. Therefore, students may not be able to participate in the second part if it fails to complete the first part in time. Further, students may attempt second part multiple times as long as they have spare time.

The project has been divided into three milestones, each requiring a very concise and short report. Each Milestone is described in greater detail below, along with the marking rubric for each.

3 AIMS AND OBJECTIVES

The aim of the project is to design an autonomous multi-wheeled robotic platform capable of starting at the push of an easily accessible button; following a black line (track); solving a line maze; finding and learning the shortest path from the start to the end of the maze. The robot is further required to indicate that it has found the shortest path by stopping and blinking an LED.

Once it has learnt the shortest path from the start and end of the maze, the robot is required to take part in a timed event where it must race through the line maze on the shortest path (black line) it has learnt. The robot is required to start the race at the push of an easily accessible button and end the race by stopping and locating itself on the black circular path with diameter of 150 mm.

In the final demo, the robot must be capable of meeting above-mentioned aims and objectives on a previously unknown line maze completely autonomously (except the pushing of a button) and within a limited time.

4 SPECIFICATIONS

The robot must meet following requirements:

- Part 1 (Learning the maze):
    - The robot must start at the push of an easily accessible button (the robot therefore does not need to sense the start of the race);
    - The robot must sense and follow a line (sensor);
    - The robot must solve the maze (algorithm);
    - The robot must detect the end of the maze by sensing a black circular patch with a diameter of 150 mm (sensor);
    - The robot must find the shortest path (black line) from the start to the end of the maze (algorithm); and
    - The robot must stop and blink an LED once it has completed solving and learning the shortest path from the start to the end of the maze.
- Part 2 (Race through the maze):
    - The robot must start at the push of an easily accessible button (the robot therefore does not need to sense the start of the race);
    - The robot must race through the maze on the shortest path (black line) it has learnt from Part 1 (sensor);
    - The robot must detect the end of the maze by sensing a black circular patch with a diameter of 150 mm (sensor);
    - The robot must stop and locate itself on the black circular patch with a diameter of 150 mm (sensor);
- The robot must fit in a volume of 150 mm x 150 mm x 100 mm (width, length, height);
- The robot must be self-powered and autonomous (using the supplied battery and STM32F0).

Sensor: a line sensor

Algorithm: a maze solver algorithm

5 PROJECT CONSTRAINTS

- You will be supplied with a battery: 2 cell Lipo, 800mAh:
    - (https://flyingrobot.co/collections/batteries/products/xpower-800mah-2s-20c);
- You will be supplied with only 1 x A4 sheet of 3mm Perspex and 1 x A4 sheet of 3mm hardboard;
- You will be supplied with only two motors that must be used: https://www.mantech.co.za/ProductInfo.aspx?Item=72M0687
- You will be supplied with only R600 budget (*including any white-lab stock you acquire*) for components such as motor-drivers, wheels, photo-transistor, voltage-regulators etc. only from RS Components Ltd (https://za.rs-online.com/).
    - ***Do not place your own orders! You will not be reimbursed!***
    - One large order for the entire class will be placed.
    - If you fail to submit a .csv file of required components by the deadline, you will not be given components. Refer to section 6 below for more details.

    - If you fail to submit a .csv file of required components in a requested format, your order will not be placed, and you will not be given components.
    - If you submit a table of required components over the given budget, your order will not be placed, and you will not be given components.
- You can obtain components from the White lab store. Refer to section 7 below for more details.
- No 3D printing parts may be used.
- No alternative processor may be used other than the STM32F0.
- A max "out of pocket" budget of R100 is allowed.

Failure to meet above-mentioned project constraints will result in disqualified for demonstration.

Please check with the lecturer/TA before purchasing items as robots with prohibited components will be disqualified for demonstration.

For any other material you are unsure of, please speak to the lecturer/TA and ask.

6 ORDERING COMPONENTS

Students need to submit their required components with the report required for Milestone 1. A bulk order will then be placed. Students may not place their own orders! You will not be reimbursed! Only components from RS Components Ltd (https://za.rs-online.com/) will be accepted.

We cannot ensure the availability of components therefore three sets of component choices need to be submitted, if one component is not available, your second or third sets will be ordered. Orders will be placed as soon as possible to ensure that the components arrive in time for the final demo.

Things you may purchase:

- Motor drivers
- Wheels
- Photo-transistors
- Photo-diode
- Voltage regulators

Things you may not purchase:

- Fully working sensors (these need to be designed and built)
- Motor
- Gearbox
- Chassis
- Batteries

Components that are not related to the course and/or that were previously supplied by previous courses will not be ordered.

If you are unsure if something is allowed or not, please email the lecturer or TA and ASK!

7 WHITE LAB COMPONENT STORE

Students must fill in the form to request components from White lab component store. The form is available at the store. Without filling the form, you will not be given any components from the White lab component store.

The budget available for each group will be updated weekly based on your RS Components Ltd (https://za.rs-online.com/)order and white lab store component requests.

Students will not be supplied with any components if the students have no budget left.

8 MILESTONES

The design project is broken into three milestones as follows:

8.1 DELIVERABLES FOR MILESTONE 1:

Concept design report: A detailed report with three unique concept designs of the robot chassis needs to be submitted. For each concept design, you need to include details and labels such as component placement/layout and drive mechanism. The concepts need to be compared in a table according to a design metric and the best design must be selected with justification. Calculations need to be performed on this design to see if it is feasible. Calculations must include a mass budget, torque and velocity estimate as well as a detailed layout of all the components such as battery placement, sensor placement, etc.

The report must be submitted on VULA in PDF form with filename:

Group <group number>_Milestone1.pdf

In addition to three unique concept designs of the robot chassis, you also need to submit three sets of component choices from RS Components Ltd (https://za.rs-online.com/). If stock is not available for one of your components, then the second set of components will be ordered etc. If there is only enough stock for some of the groups, then groups who submitted earlier will be given preference. See rubrics for further details.

The component request must be submitted on VULA in .csv form with filename:

Group <group number>_Milestone1_BOM_Order.csv

Concept design demo: Each group is required to meet with the tutors, TA and/or lecturer to briefly discuss the concept designs and the selected components that need to be ordered. This is purely to help the students and is not for marks. The purpose is to prevent the purchasing of infeasible components.

The tutors, TA and lecturer may refuse to discuss and sign off if students do not have component layout diagram, datasheets and summary of component characteristics available for them.

Mechanical drawing: Each group is required to submit their mechanical drawing for laser cutting as a scale 1:1 PDF with filename:

Group <group number>_<Hardboard/Perspex>.pdf

It is not advised to cut any structure that is smaller than 20 mm in diameter the laser cutting is done on a grid where any small parts can get lost. The tutors, TA and lecturer will not be liable for any part(s) that is smaller than 20 mm in diameter if they get lost in the laser cutter. Refer to *EEE3099S_Laser_Cutting.PDF* for details.

If you fail to submit the mechanical drawing by the deadline, your parts will not be cut.

8.2 DELIVERABLES FOR MILESTONE 2:

Sensor and Algorithm report: A report documenting the following: sub-system (sensor I) development consisting of theoretical calculations, simulations (SPICE), circuit diagrams, bill of materials, cost, building and testing procedures that took place need to be submitted. In addition to the documentation related to sensor I, you also need to include documentation on algorithm I development consisting of theoretical algorithm for maze solver and shortest path finder and flow-chart of the algorithm. See rubrics for further details.

The report must be submitted on VULA in PDF form with filename:

Group <group number>_Milestone2.pdf

Sensor demo: demonstrate the testing of the sub-system (sensor I) according to the specifications. You only need to demonstrate a single black line sensor. The circuit diagram and working of the sensor will also need to be explained to the lecturer/TA. See rubrics for further details.

8.3 DELIVERABLES FOR MILESTONE 3:

Final demo: demonstrate the testing of the complete system and results of these tests should either confirm if the system's technical specifications were met. The second part (race) is a timed event and marks will be awarded for speed. See rubrics for further details. Students will be given 10 minutes for both Part 1 and Part 2 of the demonstration.

Final report: A report documenting the following: logical integration of the sub-systems and testing that the integration was successful; system level testing to ensure that the system requirements and the user requirements are met. Refined versions of the work done for milestone 1 and milestone 2 and integrated into report. This is an "as built" report. See rubrics for further details.

The report must be submitted on VULA in PDF form with filename:

Group <group number>_Milestone3.pdf

9 TIMELINE

9.1 VULA SUBMISSION & DEMONSTRATION

Milestone	Deadline
Concept design demo	01 August 2019 (compulsory but not for mark)
Concept design report	08 August 2019
Mechanical drawing for laser cutting	12 August 2019
Sensor demo	22 August 2019
Sensor and Algorithm report	22 August 2019
Final demo	19 September 2019
Final report	26 September 2019

Above deadlines are hard deadlines and will not be changed.

9.2 SUPPORT SESSIONS

Milestone	Deadline
Introductory lecture (compulsory)	18 July 2019
Introductory practical (compulsory)	25 July 2019
Mechanical drawing submission preparation	08 August 2019
Sensor demo preparation	15 August 2019
Final demo preparation	05 September 2019
Final demo preparation	12 September 2019

These sessions are not for marks and nothing needs to be submitted, however it is compulsory for each group to show progress on their project and get signed off by the TA/lecturer.

10 DP

DP will be granted to groups that submit reports and attend demonstration for all three milestones.

11 RECOMMENDATIONS

Groups are strongly encouraged to develop the project plan for their project with the milestones in mind. A plan helps to focus what the teams need to achieve. It is critically important to start early and work consistently throughout the semester.

It is a recipe for disaster to wait until a day or two before a milestone to only start working towards the deliverables. The 1-2 days before the milestone submission should be focused on refining the quality of the report and preparation for a demonstration

Each member must contribute an equivalent of 8 credits work towards the project. Groups will typically have 4 members resulting in a project equivalent to 32 credits or 320 total hours. This accounts for the group work and individual work. Group complaints will not be dealt with 1 week prior to any hand-in or after the due date for a hand-in.

12 RULES

- Report:
  - With each hand-in, you need to submit a 1-page report detailing which members were responsible for each aspect of the hand-in and what each member did.
  - All reports should be submitted on Vula in PDF format only, unless otherwise stated.
  - No handwritten reports and hand drawn diagrams will be accepted in the report submission.
- Demonstration:
  - For demonstrations, at least one member needs to be present for the time slot that they signed up for. Members that are not present need to have a valid excuse otherwise marks will be deducted from their individual demo mark.
  - Demonstrations can only occur during the time slot signed up for by the group. (no swapping or longer demonstrations)
- Component ordering:
  - Students may not purchase a fully working sensor. These need to be designed and built as part of the project.
  - Refer to section 6 and 7 for more details.
- Team work:
  - The lecturer may use the team's summary of contribution by each member to distribute marks unequally amongst the team members in the case of a dispute.
  - Group complaints will not be dealt with 1 week prior to or any time after any hand-in is due.
- The tutors, TA and lecturer may refuse:
  - to assist the students if the students have put no effort in the solving of the problem.
  - to assist the students if the students have conducted no or insufficient research in the solving of the problem.
  - to assist the students with debugging if the students have no schematics, flow chart, datasheets etc. for the tutors, TA and lecturer.
- General liability and responsibility:
  - Students are fully liable for:
    - The consequence of not submitting required component table in the specified format. Refer to section 8 for details. The tutors, TA and lecturer will not run after the component table from each group.
    - The consequence of breaking the component(s). The tutors, TA and lecturer will not provide the students with alternative if any component is damaged.
    - The consequence of breaking/losing the robot. The tutors, TA and lecturer will not provide the students with extra components and materials if the robot is damaged or lost.

        - The consequence of not considering the budget. The tutors, TA, lecturer and white lab store will not provide a group with any components the moment there is no budget available for the group.
    - It is students' responsibility to:
        - submit the requested hand-ins in time in a specified format.
        - sign up for a timeslot for the demonstrations.
        - appear on time for the demonstrations.
        - ask questions.
        - inform the TA and lecturer of any valid reasons for late hand-ins and conflict in the group at least a week prior to any hand-ins.

13 MARK

Calculation of the final mark for EEE3099S

- Hand-in 1: 25%
- Hand-in 2: 25%
- Hand-in 3: 50%

14 RUBRIC

14.1 MILESTONE 1

Group Number			Mark	Subtotal
Comparison (Josh)	Design 1	Drawings (Digital)		5
		Clarity of design		5
		Feasibility/uniqueness of design		5
	Design 2	Drawings (Digital)		5
		Clarity of design		5
		Feasibility/uniqueness of design		5
	Design 3	Drawings (Digital)		5
		Clarity of design		5
		Feasibility/uniqueness of design		5
	Design Comparison (a table with weighted categories)			20
Calculation (Josh)	Mass budget			5
	Component layout			5
	Velocity/Torque + Motor Torque			5
Component	RS Component Ltd Component Selection (3 sets)			20
Penalty				
Total				**100**
Note	• 10 marks will be deducted if one-page report of group members' contribution to the assignment is not attached. • 10% will be deducted if a report is not less than 13 pages including one-page report of group members' contribution to the assignment, diagram, drawings and reference. • 10% will be deducted if a report includes any hand-drawn diagram or diagram that is not visible if printed. • Component CSV file is not to be included in the report and does not count towards page limit.			

14.2 MILESTONE 2

Group Number		Mark	Subtotal
Report (Sensor I)	Circuit diagram		5
	SPICE simulation and explanation		5
	BOM with cost		5
Report (Algorithm I)	Algorithm explanation		10
	Flowchart		10
Demo	Neatness (must fit in 30 mm x 30 mm veroboard, 3 pin molex connector for VCC, GND and digital output signal: high for line detection and low for no line detection)		5
	Works off a wide range of input voltage [7: 12] V		5
	Single trigger event with digital output. High: [2.8: 3.3] V. Low: [0.0: 0.5] V.		15
	Successful line sensing, 5mm above the line		10
	Successful line sensing, 30 mm above the line		10
	Accuracy and repeatability		10
	Operates in different light conditions		10
Penalty			Penalty
Total			**100**
Note	• 10 marks will be deducted if one-page report of group members' contribution to the assignment is not attached. • 10% will be deducted if a report is not less than 7 pages including one-page report of group members' contribution to the assignment, diagram, drawings and reference. • 10% will be deducted if a report includes any hand-drawn diagram or diagram that is not visible if printed.		

14.3 MILESTONE 3

Group Number		Mark	Subtotal
Demo	Starts with a button press		5
	Follows a line		10
	Find the end and stop (line maze solver)		20
	Timed event (shortest path finder)		25
Note	• 1 mark will be deducted each time robot diverges from line and must be re-placed onto the line • 5 mark will be deducted if not stopped above black circular patch • Timed event marks are according to class ranking • 10 marks will be deducted if the robot does not meet the size constraints. • 5 marks will be deducted for messy robot.		
Report	Introduction (200 words)		5
	Sub-system descriptions (500 words)		5
	Logical testing of sub-systems and system level testing (500 words)		5
	Commentary on the mechanical design: What worked and what did not? What did you learn in the post-design work? What design modifications were required to get the result? (500 words)		5
	Commentary on the electrical design (hardware only): What did you learn in the post-design work? What design modifications were required to get the result? (500 words)		5
	Commentary on the maze solver and shortest path finder algorithm: What did you learn in the post-design work? What design modifications were required to get the result? (500 words)		5
	Results and conclusions (500 words)		5
	References and Layout		5
	Compulsory appendices: • Test results • Schematic of the final design (1 sheet) • Final mechanical drawings (2 sheets) Compulsory archive (.zip only) hand-in: • Code of the final design		

Penalty		Penalty	
Total		**100**	
Note	• 10 marks will be deducted if one-page report of group members' contribution to the assignment is not attached. • 10% will be deducted if a report is not less than 10 pages including one-page report of group members' contribution to the assignment, diagram, drawings reference and compulsory appendices. • 10% will be deducted if a report includes any hand-drawn diagram or diagram that is not visible if printed. • 5 marks will be deducted if compulsory appendices are not attached. • 5 marks will be deducted if compulsory archive hand-in is not submitted.		

15 GROUP

Students will be assigned to a group randomly. The group list will be announced on 24th July 2019.

16 PENALTIES (ON TOP OF WHAT IS SPECIFIED IN THE RUBRICS)

Groups and individual team members should be aware of the following penalties:

- Report submission
  - Each day of late submission translates to a penalty of 5% (max 3 days).
  - A penalty of 5% will be deducted for messy and unstructured work.
  - See rubrics for more penalties.
- Demonstrations
  - If all team members are absent from the group's demonstration time-slot, the entire group will be given 0% for their demonstration mark.
  - Team members who are absent from the demonstration without a valid reason and supporting evidence, will get marks deducted from their individual demonstration mark.
  - You may only demo during your timeslot. You must arrive on time for your time slot; the TA and lecturer will not come looking for you. If you arrive late, you will not be granted full time slot for demonstration.
  - If technical work was not spread approximately evenly amongst team members, marks will be deducted from *all* group members.
- Course support
  - Support for the EEE3099S course is offered by the lecturer, TA and tutors during the Thursday demo/tutorial sessions throughout the semester. Ad-hoc sessions can only be arranged via email to TA. (see course hand out for TA's email address).