DEPARTMENT OF ELECTRONIC AND
ELECTRICAL ENGINEERING

BEng Project
Final Report

Dynamic Modelling of a Continuum Robotic Snake-arm and its Performance Evaluation by Analysing Robustness

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Submission Date: 13th of December 2019

DECLARATION

I have read and understood the College and Department's statements and guidelines concerning plagiarism.

I declare that all material described in this report is all my own work except where explicitly and individually indicated in the text. This includes ideas described in the text, figures and computer programs.

Name: Arundathi Shaji Shanthini

Signature: Arundhti

Date: 13.04.2020

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Appendix A

Project Gantt Chart (as submitted with proposal)

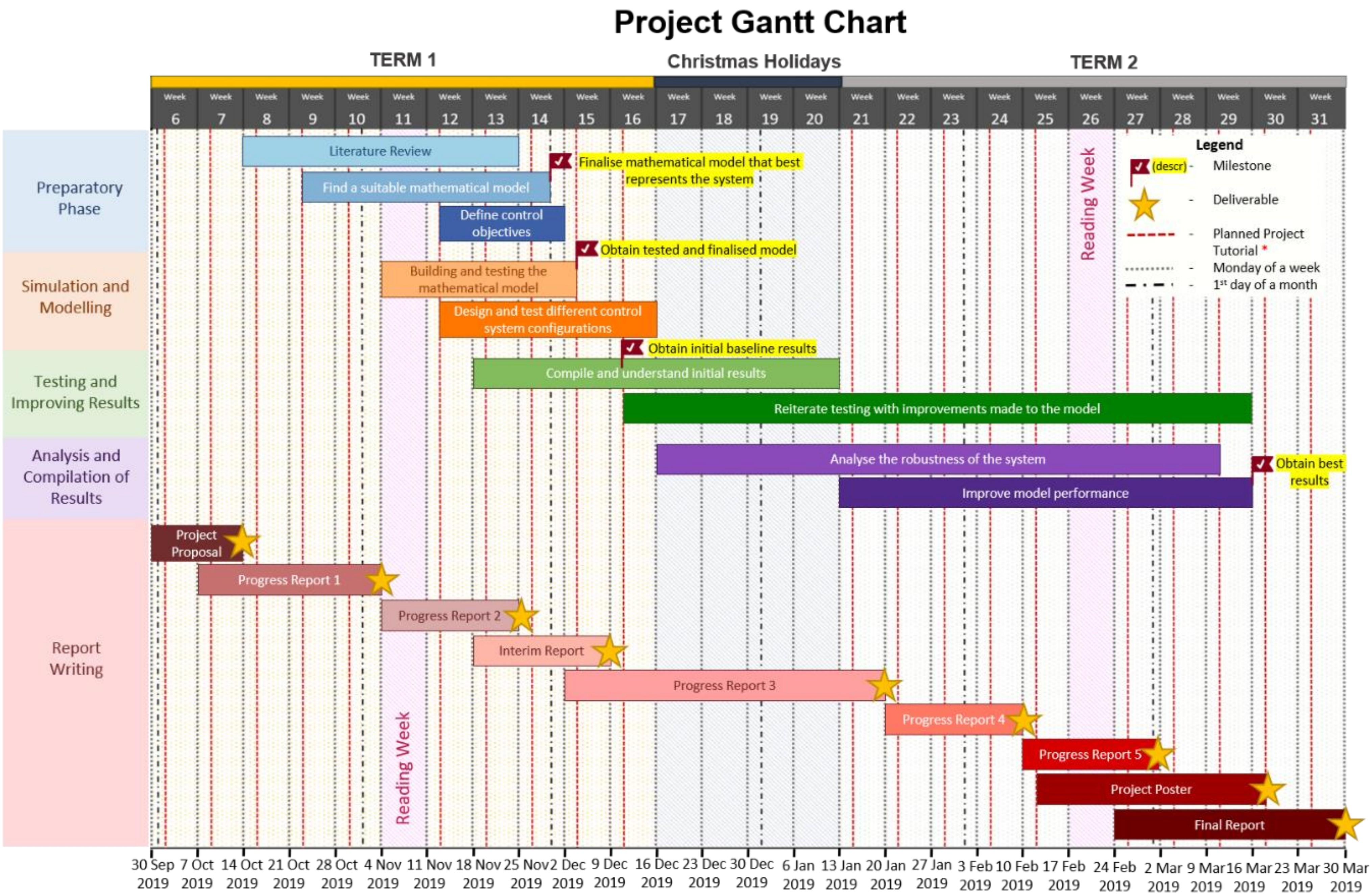
This appendix discusses the Project work plan and Gantt Chart as submitted in the project proposal. The project will mainly have four phases - *Preparatory phase, Simulation and Modelling, Testing and Improving results* and *Analysis and Compilation of Results*

- **Preparatory Phase:** The first month and a half will involve preparatory phase during which through literature review several suitable mathematical models will be identified and the model that best represents the physical snake-arm will be implemented. During this phase the control objectives of the snake arm will also be clearly investigated and will be defined mathematically. Work undertaken over summer proved that the approach of mimicking a biological snakebot to improve reach and span of the robot will not be suitable, as controlling such a snakebot poses a lot of challenges. Even though extensive research over the years have led to improved results, the level of accuracy of the tracking of the controlled variable is lower than what is required for a task like air wing inspection. The risk of a snake-arm making contact with the structures due to incorrect path following can be very unsuitable for this scenario. Also, given that the OC Robotics snake-arm is more like a tethered continuum robot moving in free space, the viscous friction model adopted by most authors to describe the dynamic model of a wheel-less ground-hugging robot snakebot won't be suitable. Therefore, the initial approach when modelling the snake-arm the concept of continuum robots may be used the most.

- **Simulation and Modelling:** The next phase of the project will then involve implementing the mathematical model, simulating the control system on Simulink and obtaining the initial results. The tracking error of the parameters (specially speed, position and orientation) will be analysed and efforts will be made to improve these results. It is expected that at this stage, an iterative testing method would be adopted to improve the model until desired tracking accuracy is obtained.

- **Testing and Improving Results:** From the start of the second phase to the end of the project, results will be improved and tested iteratively until desired results are achieved. Although this has been specified as a separate phase it represents the steps that are part of the second and the last phase.

- **Analysis and Compilation of Results:** Once satisfactory results are obtained; the final phase of the project will focus on testing the robustness of the system in varied conditions. It is expected that the payload attached to the head will change depending on the optical metrology technique for which it is being used. Further, it might be performing measurements in environments where external disturbances are no longer negligible. So, for these scenarios, tests will be performed to analyse the robustness of the system to these disturbances. Results obtained will be reported systematically and periodically through progress reports that are roughly due once in every three weeks since the start of the project.



* - Planned tutorials are subject to change based on supervisors availability

Appendix B

Risk Assessment

The following hazards were identified through the risk assessment:

- Eyestrain
- Poor posture
- Repetitive movements involved with working on a computer
- Tripping over objects
- Poor lighting conditions
- Lone working
- Fire
- Contact with electricity
- General Welfare

The following pages includes a summary of the approved risk assessment generated using RiskNET.

Risk Assessment

Summary

Reference: RA030578/1 **Sign-off Status:** Authorised

Date Created:	05/10/2019	**Confidential?**	No
Assessment Title:	ELEC0036: Third Year Project - Arundathi Shaji Shanthini		
Assessment Outline:	This risk assessment is being carried out prior to the third year individual project (Module code: ELEC0036) undertaken as part of my undergraduate course.		

Area Responsible (for management of risks)

Division, School, Faculty, Institute:	Faculty of Engineering Science
Department:	Dept of Electronic & Electrical Eng
Group/Unit:	All Groups/Units

Location of Risks On-Site

Building:	Roberts Building
Area:	Ground and Above
Sub Area:	Laboratory

Further Location Information:

RISK_HE_FORMA_COUNTRYLABEL:

RISK_HE_FORMA_COUNTRY_HEADER
UNITED KINGDOM

Assessment Start Date:	05/10/2019	**Review or End Date:**	05/10/2020

Relevant Attachments:

Description of attachments:

Location of non-electronic documents:

Assessor(s):	SHAJI SHANTHINI, ARUNDATHI
Approver(s):	SARAH SPURGEON
Signed Off:	SARAH SPURGEON (16/10/2019 12:07)
Distribution List:	

PEOPLE AT RISK (from the Activities covered by this Risk Assessment)

1. Working in Computer Lab / Study Spaces

Description of Activity:	The project undertaken mainly involves working on a computer and the following are the risks associated to working in computer labs or study spaces.

Hazard 1. Eyestrain

Long continuous hours of looking at the screen, poor DSE workstation and lack of suitable corrective eyewear can lead to eyestrain.	**Existing Control Measures** Ensure the screen colours are easy to look at, and that the characters are sharp and legible. Ensure that the contrast and brightness settings are suitable for the room lighting conditions. Reposition the screen to avoid glare/bright intrusive light from lights or windows. Look away from the screen into the distance for a few moments to relax your eyes; focus on something 30 metres away for 30 seconds every 30 minutes. Keep the screen clean and use a desk lamp to make it easier to see. Zoom into the text file being read such that the text is large enough to read easily on screen when sitting in a normal comfortable working position. Utilise eye test provisions (if required)

Hazard 2. Poor posture

Postural issues may give rise to discomfort or injury and can arise through a poor or inadequate workstation set up.	**Existing Control Measures** Ensure that sit upright with your back positioned comfortably on the backrest of the chair. Sit close to the desk to prevent leaning forward uncomfortably. Ensure that your eyes are at the same height as the top of the screen. Take short and frequent breaks and change position if possible.

Hazard 3. Repetitive movements involved with working on a computer

Poorly designed workstations or uncomfortable working postures might cause repetitive strain injuries or problems like carpal tunnel syndrome

Existing Control Measures

Sit upright and close to the desk to reduce working with the mouse with your arm stretched.

When typing stretch use the space in front of the keyboard can help you rest your hands and wrists when
not keying.

Position the mouse within easy reach, so it can be used with a straight wrist. Sit upright and close to the desk to reduce working with the mouse arm stretched.

Stretch and change position. Take short, frequent breaks. Look into the distance from time to time, and blink often.

Do not overstrain muscles by overstretching fingers when typing or holding onto the mouse with a tight grip.

Make sure there is space under the desk to move legs.

Hazard 4. Tripping over objects

Congested layout of room, temporary obstructions, trailing wires near printing equipment etc. can be reasons that can cause tripping over objects and cause injury

Existing Control Measures

Be mindful and careful of obstructions on the floor/walkways even in rooms that you are used to working in. Avoid walking around looking into the screen of the computer.

Report the responsible management if any major obstruction with potential risk is noticed. This may include damaged floors, trailing cables, inadequate housekeeping, incorrect lighting levels etc.

Hazard 5. Poor lighting conditons

This refers to both insufficient lighting as well as excessive lighting of a room. Poor lighting conditions may cause headaches or sore eyes.

Existing Control Measures

Control the lighting in the room suitably.

Adjust the blinds to control natural light levels or to avoid glare on screens.

Inform responsible management of insufficient lighting or broken lights in the room .

Hazard 6. Lone working

When working alone in the office there is risk of injuries, emergencies etc. with inadequate provision of help.

Existing Control Measures

Avoid non-routine working.

Be aware of the risks and precaution associated to the work undertaken especially when working alone.

Have the information and knowledge of how to deal with emergencies

Hazard 7. Fire

If trapped in the event of a fire, one could suffer fatal injury from smoke inhalation or burns.	**Existing Control Measures** Make sure that when working in a room you are aware of the nearest emergency exit and assembly point. Be aware of the instructions on the notices or information boards in the room installed by the management for such events. Inform the responsible management if any obstructions are noticed near emergency exits.

Hazard 8. Contact with electricity

Exposed electrical conductors in general office / computer lab equipment can cause electric shocks, burns and injuries.	**Existing Control Measures** Be mindful and careful of exposed electrical conductors which may be live on the floor/walkways even in rooms that you are used to working in. Avoid walking around looking into the screen of the computer. Report any exposed electrical conductors or damaged equipment that can cause electric shock.

Hazard 9. General Welfare

Inadequate facilities or unplanned work can affect the general welfare of a person.	**Existing Control Measures** Report any problems with basic facilities in the building like lack of source for potable water, toilet and hygiene facilities, heating and lighting provision etc. In case of unlikely extreme situations like stress, bullying or disturbances from another student/staff, use university services provided like Student Support and Wellbeing to report and to receive help. To avoid stress ensure that a plan for the work is in place and avoid working long hours. Ensure that the regular discussions take place with the supervisor and raise any issues with him/her.

Risk Level

With Existing Controls:

Risk Level	**A - Very Low / Trivial**

Appendix C

MATLAB Code

References

[1] W. Xu, T. Liu, and Y. Li, "Kinematics, dynamics, and control of a cable-driven hyper-redundant manipulator," *IEEE/ASME Transactions on Mechatronics*, vol. 23, no. 4, pp. 1693–1704, 2018. [Online]. Available: https://dx.doi.org/10.1109/TMECH.2018.2842141

[2] Z. Mu, T. Liu, W. Xu, Y. Lou, and B. Liang, "Dynamic feedforward control of spatial cable-driven hyper-redundant manipulators for on-orbit servicing," *Robotica*, pp. 1–21, 2018. [Online]. Available: https://dx.doi.org/10.1017/S026357471800084X

[3] ——, "Dynamic feedforward control of spatial cable-driven hyper-redundant manipulators for on-orbit servicing," *Robotica*, vol. 37, no. 1, p. 18–38, 2019.