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THE FEEDBACK CONTROL OF A SWINGING ROBOTIC GYMNAST

Mechatronic Project 488 Proposal

Henry Kotzé

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Faculty of Engineering
Fakulteit Ingenieurswese

Department of Mechanical and Mechatronic Engineering
Departement Meganiese en Megatroniese Ingenieurswese

Privaat Sak / Private Bag X1, Matieland, 7602, Suid-Afrika / South Africa · Banghoek Weg / Road, Stellenbosch, 7600, Suid-Afrika / South Africa
Tel: +27 21 808 4376 · Epos / Email: mmchair@sun.ac.za

Supervisor: Dr. J.A.A. Engelbrecht

2018

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Date: 4 March 2018

Executive Summary

Executive Summary
Title of Project
Feedback Control of Swinging Robotic Gymnast
Objectives
Implementing the swinging robotics gymnast as a rotating double pendulum, using 2 separate controllers for the swing-up sequence and the balancing.
Which aspects of the project are new/unique?
Implementing the robotic gymnast as a rotating double pendulum.
What are the expected findings?
The different ways in which a underactuated robot can be controlled.
What value do the results have?
Better understanding of the control of underactuated robotics.
If more than one student is involved, what is each one's contribution?
Not Applicable
Which aspects of the project will carry on after completion?
None
What are the expected advantages of continuation?
Implementation of control where rotating double pendulum is applicable.
What arrangements have been made to expedite continuation?
None

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1 Introduction

The field of underactuated robotics have increasingly become more important due to technology growing in areas where control is crucial. Areas include: air drones, underwater inspection vehicles, space exploration and the aeroplane industry.

Underactuated robotics is an interesting and open field in control, with many design options to approach these types of problems. The most interesting examples of underactuated control problems are legged, swimming and flying robots that has been mentioned in the previous paragraph. This results in underactuated robotics being relevant in many fields.

The project is proposed to investigate the full feedback control of a robotic gymnast that contains two parts: the ability to balance the double inverted pendulum and the swing up sequence from the stable equilibrium position. The primary focus of the study is to investigate the multiple approaches of control theory to apply to the two parts of the project and then to design the system. This project, which is undertaken by Mr. Henry Kotzé as part of his Mechatronic Project 488, originates from Dr. JAA Engelbrecht as his supervisor.

This document will describe the project objectives, motivation, planned activities, academic consideration and risk that the project entails.

2 Motivation

The feedback control of a swinging robotic gymnast can be modelled as a first approximation of a double pendulum with a torque input at the link between the two pendulums. This model is categorised in the field of underactuated robotics, since there are no instantaneous control over one or more of the state variables describing the system.

The double pendulum tests various problems such as the highly non-linear problem in the swing-up sequence and the well-defined linearised balancing model of the system, where both are common practical problems in today’s products.

With technology growing in a greater variety of fields, as mentioned in the introduction, these problems are a stepping stone to the understanding of many of today’s control challenges.

3 Project Objectives

Stated in the introduction, the focus of the project is the control system implementation during the two parts of the gymnast, namely the swing-up and balancing of the double pendulum. To achieve these, the objectives of the project are:

1. Simulation of swing-up sequences- and balancing control of double inverted pendulum in the unstable vertical position.
2. Electronic and mechanical design of system.
3. Implementation and verification of control system against simulation.

4 Planned Activities

4.1 Literature Study

Research the control system design approaches in the field of underactuated robotics with the focus on the double inverted pendulum.

4.2 Simulation implementation

Deriving the model that explains the dynamics of the double inverted pendulum on various approaches to find the optimal equations to use for simulation. Implement these equations in Simulink.

4.3 Testing various control systems implementation from literature in simulation.

Implement the swing-up - and balancing control systems in Simulink found during the literature study. Test each control system and find the requirements needed for the design of the system based on simulation results.

4.4 Mechanical Design of System

Design the mechanical system based on requirements for the model describing the system and results found in simulation. Verify design by external input and iterate design as necessary.

4.5 Electronic Design of System

Determine the correct sensors to use and design the electronic system according to requirements based on control theory, specification of sensors and simulation. Verify design by external input and iterate design as necessary.

4.6 Manufacturing of System

Manufacture the electronic and mechanical design and build the complete mechatronic system for first experiments.

4.7 Implementation and verification of system against simulation results

Run various experiments on the mechatronic system, comparing the results found during simulation to test the legitimacy of the simulation.

4.8 Optimization based experiments of systems

Based on experimental results, optimize the system

4.9 Final Report

Document the entire process that every activity went through, in order to create an accurate result in the field of underactuated robotics.

5 Academic Consideration

As seen in the planned activities section, all the ECSA outcomes will be achieved by this project.

5.1 Problem Solving

To approach a well-researched problem in control systems, but implementing it in a way that is uncommon. This will cause many problems that will need to be identified, assess and solved innovatively.

5.2 Application of scientific and engineering knowledge

The project requires the solving of engineering problems from first principles.

5.3 Engineering design

As seen in the activities section, the project will consist of mechanical and electronic design that will require synthesis of components, systems and non-procedural design.

5.4 Engineering methods, skills and tools including Information Technology

Tools such as MatLab Simulink will be used to formulate requirements for the design of the system. Engineering methods will be demonstrated throughout the project.

5.5 Professional and technical communication

The final report which will document the entire process of each activity. This will demonstrate the competence to communicate effectivity in writing, and a final oral exam to test the individual's communication skills.

5.6 Individual, team and multidisciplinary working

The project entails work with a supervisor who will give critical feedback on the student's individual work. This co-working will enhance the success of the project.

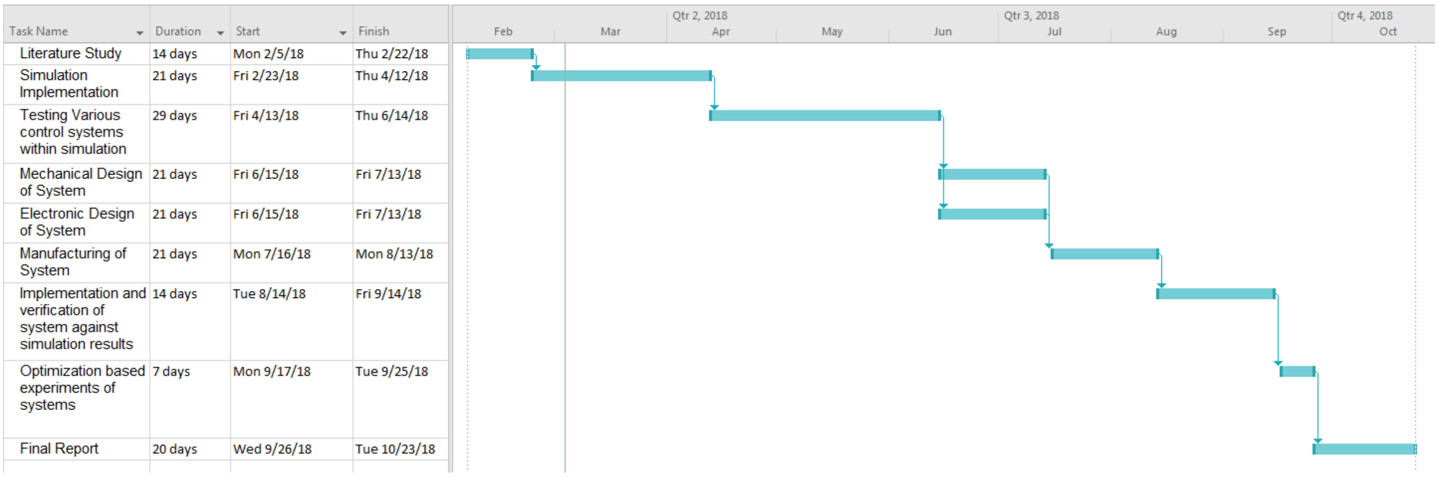
5.7 Independent learning ability

The project insists for a mechatronic student to learn the principles of digital control, non-linear control design approaches and electronic design.

6 Risk Assessment

From a safety perspective, the risks involved in the project entails the rotating double pendulum, rotating shaft and motor. This rotation of the pendulums will be supplied by the motor that will be mounted on one of the pendulums.

These risks will only surface during experimental tests and for presentations. Thus, these risks will be minimised using stickers on the hardware indicating that there are rotating parts and a certain distance is required from the model. A visible restricted area around the experimental test will be used to keep individuals safe from harm, with a kill switch for the operator to stop the tests for any reasons.



Task Name	Duration	Start	Finish
Literature Study	14 days	Mon 2/5/18	Thu 2/22/18
Simulation Implementation	21 days	Fri 2/23/18	Thu 4/12/18
Testing Various control systems within simulation	29 days	Fri 4/13/18	Thu 6/14/18
Mechanical Design of System	21 days	Fri 6/15/18	Fri 7/13/18
Electronic Design of System	21 days	Fri 6/15/18	Fri 7/13/18
Manufacturing of System	21 days	Mon 7/16/18	Mon 8/13/18
Implementation and verification of system against simulation results	14 days	Tue 8/14/18	Fri 9/14/18
Optimization based experiments of systems	7 days	Mon 9/17/18	Tue 9/25/18
Final Report	20 days	Wed 9/26/18	Tue 10/23/18

Figure 1: Gantt Chart for Feedback Control for Swinging Robotic Gymnast

7 Conclusions

Underactuated robotics are increasingly gaining importance in consumer products and in areas where technology is branching into. Understanding the challenges and design philosophies in underactuated robotics are important to solving many industry needs. The proposed project will investigate the various control approaches to a underactuated control problem, determination of the best control system method, and the implementation of the control system on a physical system by designing the mechanical and electronic parts.

The project team is capable to successfully complete the project with the expertise of Dr. J.A.A Engelbrecht and mechatronic student Mr. Henry Kotzé. The planned duration of the project is 9 months.

8 References

Basson, A.H. & Coetzee, C.J., 2013, Guidelines for Project Proposals, viewed 4 March 2018 from https://www.sun.ac.za/english/faculty/eng/mechanical-mechatronic/Documents/Undergraduate/Current%20UG/MM%20Procedures%20for%20Final%20Year%20Projects/2013cguidelines%20for%20project%20proposals2014.pdf