Design, model and build a USAR robot platform

Mechatronic Project 478
Final Report

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I know that a mark of zero may be awarded to assignments with plagiarism and also that no opportunity be given to submit an improved assignment.

Signature: ....

Name: .... Student no: ....

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Executive summary

Title of Project
Design, model and build a USAR robot platform
Objectives
Create a model to describe the kinematics of a Load Intuitive Module (LIM). Build a prototype Urban Search and Rescue (USAR) device which uses LIMs to climb stairs. Validate the model using the prototype.
What is current practice and what are its limitations?
The current practice for USAR platform ranges widely, but the most successful platforms use tracks with paddles for locomotion. These devices are effective but very expensive, so there is a need for low cost expendable USAR robots.
What is new in this project?
This project will introduce a model to describe a less expensive stair climbing robot platform using LIMs.
If the project is successful, how will it make a difference?
The model developed in this project can be used to inform future USAR designs.
What are the risks to the project being a success? Why is it expected to be successful?
The main risk to this project is that it does not build a working prototype in time. This risk will be mitigated through careful planning and consideration of previous pitfalls.
What contributions have/will other students made/make?
In 2013, Matthew Wilson developed the LIM system as a masters project at the University of Cape Town (UCT). Further development on the system was done in final year projects at UCT by students Jordan Haskel, Murray Buchanan, and Richard Daniel Powrie in 2017, 2018, and 2019 respectively.
Which aspects of the project will carry on after completion and why?
USAR devices using LIMs as a platform can be designed, built and tested.
What arrangements have been/will be made to expedite continuation?
All calculations, designs, and code will be made available to future students.

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Chapter 1

Introduction

1.1 Background

During disasters such as earthquakes, Urban Search And Rescue (USAR) robots are used to detect victims in hazardous environments where first responders would otherwise be put at risk. Advanced USAR robots can explore and map the environment while overcoming obstacles, and deliver supplies to victims who cannot be immediately evacuated. USAR robots were first used in the aftermath of the September 11 attacks on the World Trade Centre, where they had limited success as they would frequently get stuck or damaged. Since then, designs for USAR robots with many different locomotion methods have been considered and compared in competitions such as the RoboCup Rescue Robot League and the DARPA Robotics Challenge. At present, USAR robots are typically only successful at surveillance; due to the extreme conditions in disaster zones and the urgency of rescue operations, first responders will rarely consider using USAR robots.

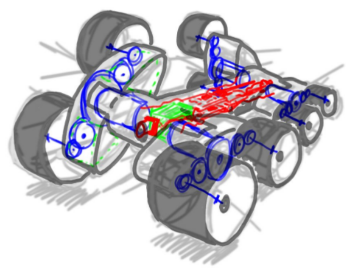

Figure 1.1: Systems layout of Wilson's LIM device (Wilson, 2013)

Another problem limiting the use of USAR robots is cost; USAR robots are prohibitively expensive so rescue organisations use them sparingly. There is a need for low-cost, expendable USAR robots. In 2013, Matthew Wilson proposed an automatically-shape-shifting platform that uses a Load Intuitive Module (LIM) in the place of regular wheels, shown in Figure 1.1 (Wilson, 2013). The LIM system uses a two outer "minor wheels" placed on a central hub that can be rotated as a "major wheel". The minor wheels are geared to the central hub such that they drive the vehicle, however if they experience high resistance, for example from hitting an obstacle, the torque will cause the major wheel to rotate instead, flipping one of the minor wheels over the obstacle to automatically climb it. This is a strong concept for an inexpensive stair-climbing robot as it only uses a single motor for both normal driving and climbing obstacles.

"LIMed" robot platforms (platforms using LIMs for locomotion) were built individually by four final year students at UCT (Wilson, 2013), (Haskel, 2017), (Buchanan, 2018), and (Powrie, 2019). One of these robots is shown in Figure 1.2. These platforms show some success in climbing a single step, albeit inconsistently. Powrie noted that a mathematical model that accurately describes the kinematics of the system could be developed to optimise the design of LIMed robots. This project is a continuation of these students' work.

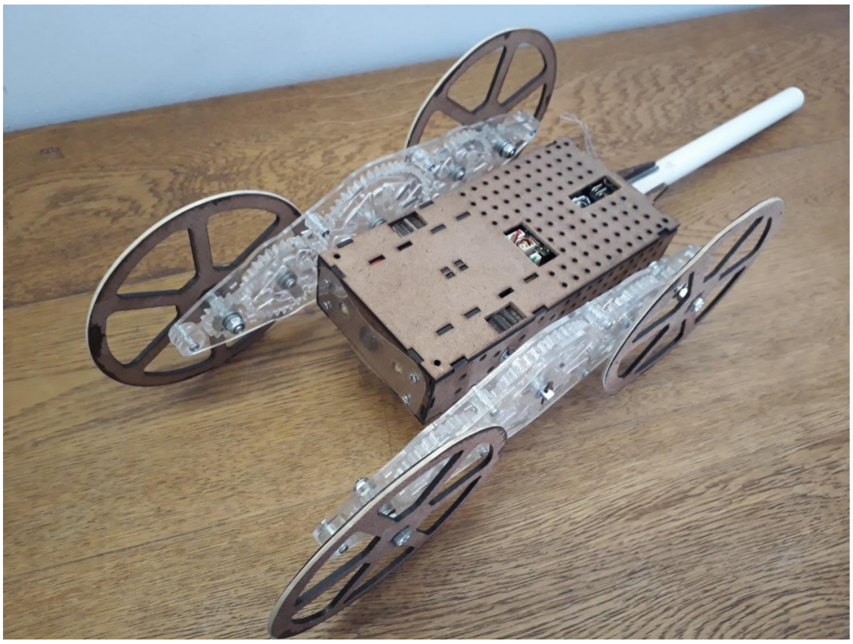

Figure 1.2: Powrie's "Di-Wheel" robot (Powrie, 2019)

1.2 Objectives

The aim of this project is to create a model that can be used to inform future USAR designs. The following objectives were identified to meet this aim:

1. Create a model to describe the kinematics of a LIM.
2. Build a prototype USAR device which uses LIMs to climb stairs.
3. Validate the model using the prototype.

This project does not intend to create a fully functioning USAR robot, but rather a prototype of the platform that a USAR robot may use.

1.3 Motivation

Many designs for USAR locomotion exist, however highly capable devices are prohibitively expensive. There remains a need for USAR devices that are both affordable and effective, and LIMed USAR robots could fill that role in the near future. Designers will be able to use the model produced in this report to design and optimise LIMed USAR robots. These robots use fewer actuators so could be cheaper than existing USAR robots. Lowering the cost of USAR robots is a priority as it makes them more accessible to rescue organisations.

Chapter 2

Literature review

2.1 USAR

2.2 USAR Robots

2.3 Load-Intuitive Modules

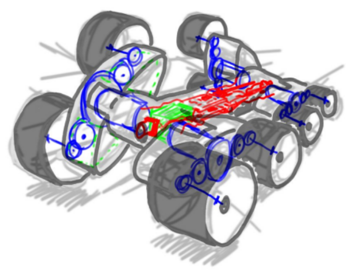

Figure 2.1: Systems layout of Wilson's LIM device (Wilson, 2013)

A Load-Intuitive Module (LIM) refers to a wheel system proposed by Matthew Wilson, shown in Figure 2.1 (Wilson, 2013). The LIM system uses a two outer "minor wheels" placed on a central hub that can be rotated as a "major wheel". The minor wheels are geared to the central hub such that they drive the vehicle, however if they experience high resistance, for example from hitting an obstacle, the torque will cause the major wheel to rotate instead, flipping one of the minor wheels over the obstacle to automatically climb it. The system is referred to as "Load-Intuitive" because it will intuitively climb over obstacles in response to increased load on the wheels. LIMs are designed to be used in low cost USAR robots, allowing them to climb over objects without the need for many actuators. "LIMed" robot platforms (platforms using LIMs for locomotion) were built individually by four final year students at UCT (Wilson, 2013), (Haskel, 2017), (Buchanan, 2018), and (**?**). One of these robots is shown in Figure 1.2. These platforms show some success in climbing a single step, albeit inconsistently. None of the previous students were able to build a full system such that they can perform extensive tests on the system.

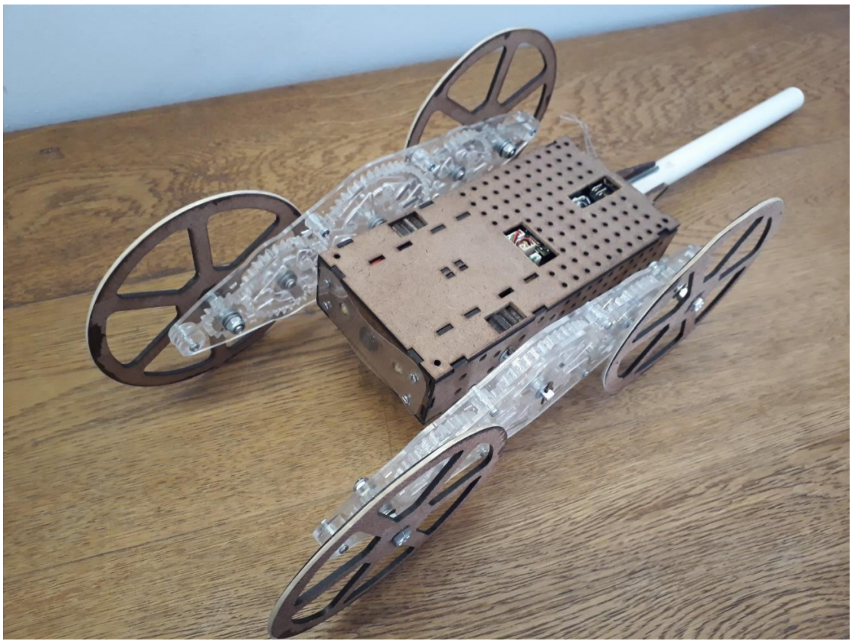

Figure 2.2: Powrie's "Di-Wheel" robot (Powrie, 2019)

Chapter 3

Content chapter

Unless the chapter heading already makes it clear, an introductory paragraph that explains how this chapter contributes to the objectives of the report/project.

3.1 Heading level 2

3.1.1 Heading level 3

3.1.1.1 Deepest heading, only if you cannot do without it

Equations: An equation must read like part of the text. The solution of the quadratic equation $ax^2 + bx + c = 0$ given by the following expression (note the full stop after the equation to indicate the end of the sentence):

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2b}. \tag{3.1}$$

In other cases the equation is in the middle of the sentence. Then the paragraph following the equation should start with a small letter. Euler's identity is

$$e^{i\pi} + 1 = 0, \tag{3.2}$$

where e is Euler's number, the base of natural logarithms.

The `amsmath` has a wealth of structure and information on formatting of mathematical equations.

Symbols and numbers: Symbols that represent values of properties should be printed in italics, but SI units and names of functions (e.g. sin, cos and tan) must not be printed in italics. There must be a small hard space between a number and its unit, e.g. 120 km. Use the `siunitx` package to typeset numbers, angles and quantities with units:

`\num{1.23e3}`	→	1.23×10^3
`\ang{30}`	→	$30°$
`\qty{20}{N.m}`	→	$20\,\mathrm{N \cdot m}$

Figures and tables: The `graphicx` package can import `PDF`, `PNG` and `JPG` graphic files.

Table 3.1: Standard ISO paper sizes

Paper	Sizes	
	W [mm]	H [mm]
A0	841	1189
A1	594	841
A2	420	594
A3	297	420
A4	210	297
A5	148	210

Figure 3.1: Water plants

Chapter 4

Conclusions

Appendix A

ECSA Outcome Self Assessment

Table A.1: ECSA outcome self assessment

ECSA outcome	Application
Demonstrate competence to identify, assess, formulate and solve convergent and divergent engineering problems creatively and innovatively.	The design aspect of this project will require creative solutions to overcome the limitations of previous designs.
Application of scientific and engineering knowledge: Demonstrate competence to apply knowledge of mathematics, basic science and engineering sciences from first principles to solve engineering problems.	Producing the mathematical model will require kinematic calculations.
Engineering Design: Demonstrate competence to perform creative, procedural and non-procedural design and synthesis of components, systems, engineering works, products or processes.	A prototype of a USAR platform will be designed and produced.
Engineering methods, skills and tools, including Information Technology: Demonstrate competence to use appropriate engineering methods, skills and tools, including those based on information technology.	The project involves a CAD drawing and simulation of the platform, which will be based on information technology.
Professional and technical communication: Demonstrate competence to communicate effectively, both orally and in writing, with engineering audiences and the community at large.	All deliverables, including the proposal, progress report, final report, and presentation will demonstrate competent and effective communication.
Individual, Team and Multidisciplinary Working: Demonstrate competence to work effectively as an individual, in teams and in multi-disciplinary environments.	This project is done individually, with some input from the project supervisor.
Independent Learning Ability: Demonstrate competence to engage in independent learning through well-developed learning skills.	Research will be done in the literature review.

Appendix B

Mathematical proofs

B.1 Euler's equation

B.2 Navier Stokes equation

Appendix C

Experimental results

List of references

Buchanan, M. (2018). Ascender.

Haskel, J. (2017). A cost effective, tele-operated observation search and rescue robot.

Powrie, R. (2019). Di-wheel robot.

Wilson, M. (2013). Development of a low-cost, mid-sized, tele-operated, wheeled robot for rescue reconnaissance.