Patrick Leung
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, BC. V5A 1S6
Date 2/18/08

Re: ENSC 440 Functional Specification for the Wall Climbing Robot

Dear Mr. Leung,

I have attached the functional specification document from WallyBot Robotics for the Mattoid wall climber. We are designing and implementing a climbing robot that can navigate a vertical surface and also transition between horizontal and vertical surfaces. The WallyBot Mattoid will provide a basis for further research in the field of wall-climbers, and establish an entry point into a virgin market.

The functional specification provides our mechanical and electronic development teams with a guide for development of Mattoid. Specific requirements are outlined in order to create a proof of concept and a production model for the wall climbing system.

Wallybot Robotics consists of four motivated, innovative, and talented fifth-year engineering students: Curtis Gittens, Daniel Goundar, Daniel Law, Johannes Minor. If you have any questions or concerns about our functional specifications, please feel free to contact me by phone at (778) 882-7223 or by e-mail at ensc440-spring08-a-team@sfu.ca.

Sincerely yours,

Daniel Goundar
CEO
Wallybot Robotics

Enclosure: Functional Specification: Wall Climbing Robot

Functional Specification: Wall Climbing Robot

Prepared for: Patrick Leung – ENSC 440
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Executive Summary

To date, there are no wall-climbing robots on the commercial market, but new research explores cutting edge climbing robot technology [1]. Competitions in North America [2] and Europe [3] highlight the fast-paced, international growth of this field. The race is on to meet the growing demand for robots that can perform critical tasks in places that are traditionally difficult to reach, or environments that are too hazardous for direct human contact. These robots can have many diverse applications, such as nuclear power plant inspection, space research, and maintenance on tall structures. Plans for Mattoid, a first prototype in the Wallybot line of reliable, practical, and inexpensive commercial wall-climbers, are now in motion.

Development of our wall-climbing robot begins with a single prototype: Mattoid. This original prototype will include the following key features:

- development costs under $525.00
- small, durable, and lightweight structure
- autonomous control

Functionally Mattoid should:

- navigate two-dimensional horizontal and vertical surfaces
- transition between horizontal and vertical surfaces at an angle of 90°

The Mattoid prototype development is slated to be completed for April 15th 2008. The major enhancements of the production model over the prototype are:

- the ability for obstacle avoidance
- near unlimited expandability due to universal nature of modules
- minimal environmental footprint by adherence to green standards (RoHS), and environmentally sound production methods

This document describes the functional requirements met by a production ready Mattoid climbing robot, and reduced requirements for a first prototype. Mattoid is the first step towards market penetration.

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Glossary

Minimal slip	The least loss of traction
MTTF	Mean Time to Failure
RoHS	Restriction of Hazardous Substances Directive
Turning radius	The radius of the smallest circular turn possible

Wall Climbing Robot

1 Introduction

Wallybot Robotics is a research based organization that works towards creating technology for use in industry-ready robots that solve a battery of real world problems. Our goal is to develop small robots that can navigate man made environments, without being impeded by walls and corners.

1.1 Scope

This document outlines the requirements met by the Mattoid wall climbing robot prototype. It also describes those requirements satisfied by potential production variations of Mattoid.

1.2 Intended Audience

The target audience includes the project manager and the development team at Wallybot robotics, and potential Wallybot customers. Management and developers should consult this document to assess development progress and to ensure functional requirements are met. Sponsors and potential investors may also use this document for a detailed functional description of Mattoid, and as a market exploration tool.

1.3 Classification

The following convention will be used to classify functional requirements:

[Rn-p]
Where **n** is the functional requirement number and **p** is the category designator. **p** has three possible values:

p = I Functional requirement of the Mattoid prototype.
p = II Functional requirement of both prototype and production Matttoid models.
p = III Functional requirement of the Mattoid production model.

2 System Requirements

A fully functional wall climbing robot must be capable of movement in two dimensions on horizontal and vertical surfaces, and must be able to transition between perpendicular surfaces. The aforementioned general functions are broken down into specific requirements for each subsystem.

2.1 System Overview

Figure 1 shows conceptual diagrams to illustrate the various general requirements of a wall-climbing system. The labels correspond to the requirement descriptions in the General Requirements section.

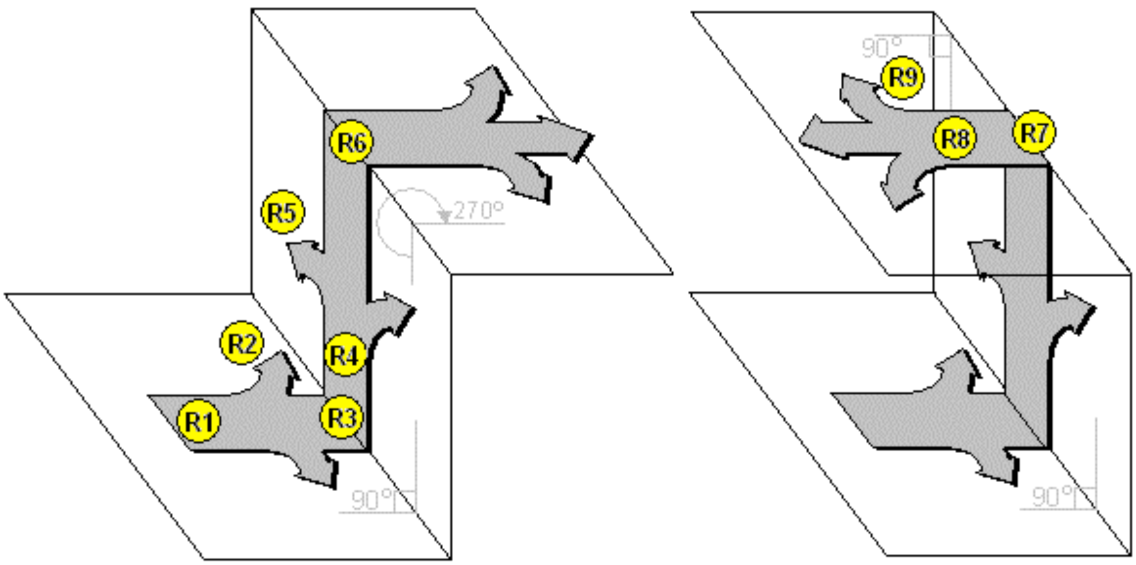

Figure 1: Overview of System Operation

2.2 General Requirements

[R1-II] The climber must move in a straight line on a horizontal surface
[R2-II] The climber must turn left and right on a horizontal surface
[R3-II] The climber must navigate a 90^o inside corner from a horizontal to a vertical surface
[R4-II] The climber must ascend a vertical surface in a straight line, perpendicular to the horizontal
[R5-II] The climber must turn left and right on a vertical surface
[R6-III] The climber must navigate a 270^o outside corner
[R7-III] The climber must navigate a 90^o inside corner from a vertical to a horizontal surface, upright or inverted
[R8-III] The climber must move in a straight line on an inverted horizontal surface
[R9-III] The climber must turn left and right on an inverted horizontal surface
[R10-II] Relevant functionality must be consistent over a variety of smooth surfaces
[R11-III] The climber system must be modular and expandable to arbitrary, application specific size

2.3 Physical Requirements

2.3.1 Individual Module

[R12-I] The contact area on a single module must be sufficient to support the weight of the module on a vertical surface
[R13-III] The contact surface dimensions must be optimized for minimal slip, given the desired turning radius
[R14-III] The contact area on a single module must be sufficient to support three times the weight of the module on a vertical surface

2.3.2 Robot Assembly

[R16-III] The climber assembly must be expandable to any n-row and m-column configuration of modules, as per Figure 2
[R17-II] The climber must support the weight of a control platform on a vertical surface
[R18-III] The climber must support the weight of a power supply on a vertical surface
[R19-III] Modules must be individually replaceable in the event of a failure

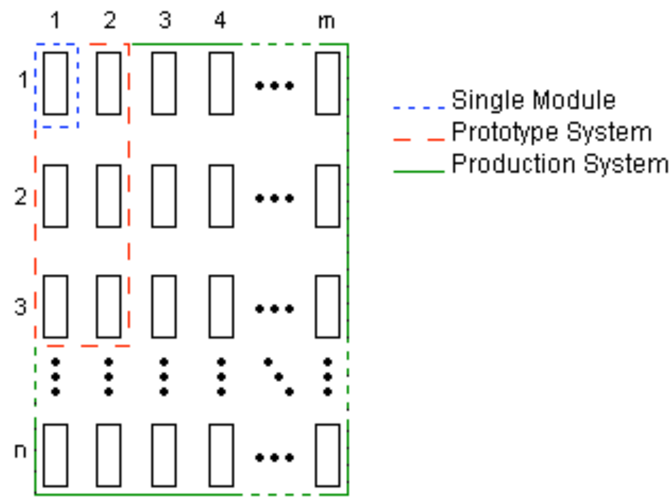

Figure 2: Modularity of the Climber

2.4 Mechanical Requirements

[R20-I] Individual modules must be independently capable of meeting requirements **[R1]**, **[R3]** and **[R4]**

[R21-III] Individual modules must be independently capable of meeting requirements **[R1,…,9]**

[R22-II] Modules must provide mounting points for a supporting structure

[R23-II] Supporting structure must be lightweight and rigid

[R24-II] Supporting structure must afford turning and corner transitions as described in **[R1,2,…,9]**

[R25-I] Actuators must provide sufficient force to propel a single module up a vertical surface

[R26-III] Combined actuators must provide sufficient force to propel the climber assembly, control platform, and power supply up a vertical surface

2.5 Control Requirements

[R27-II] Modules must be individually controllable

[R28-I] The climber must accomplish all applicable forward movement, turning and corner transitions as described in **[R1,…,5]** by coordination of individual modules, without additional actuation in the supporting structure

[R29-III] The climber must accomplish forward movement, turning and corner transitions as described in **[R1,…,9]** by coordination of individual modules, without additional actuation in the supporting structure

[R30-III] The climber must function autonomously after navigation goals are assigned

[R31-III] The climber must implement self protection strategies in the event of loss of contact with the vertical surface

[R32-III] The climber must have an emergency shut-off control input

[R33-III] A user interface must allow for user assignment of navigation goals

2.6 Power Requirements

[R34-I] Sufficient power must be supplied to the assembly to allow all necessary mechanical and electronic components in the system to function simultaneously

[R35-III] Power source(s) must be attached for ready access and maintenance

[R36-III] Upon power loss, the assembly must remain stationary

[R37-III] The climber assembly must acquire power from a portable power supply

2.7 Performance

[R38-III] The climber must carry enough charge for 1 hour of continuous use or 6 hours of standby

[R39-I] The climber must have a MTTF of 2 minutes

[R40-III] The climber must have a MTTF of 50 hours

[R41-I] The climber must have a maximum speed of no less than 1 cm/s

[R42-III] The climber must have a maximum speed of no less than 15 cm/s

[R43-I] The climber must achieve a turning radius, r, of 75 cm, illustrated in Figure 3

[R44-III] The climber must achieve a turning radius, r, of 10 cm, illustrated in Figure 3

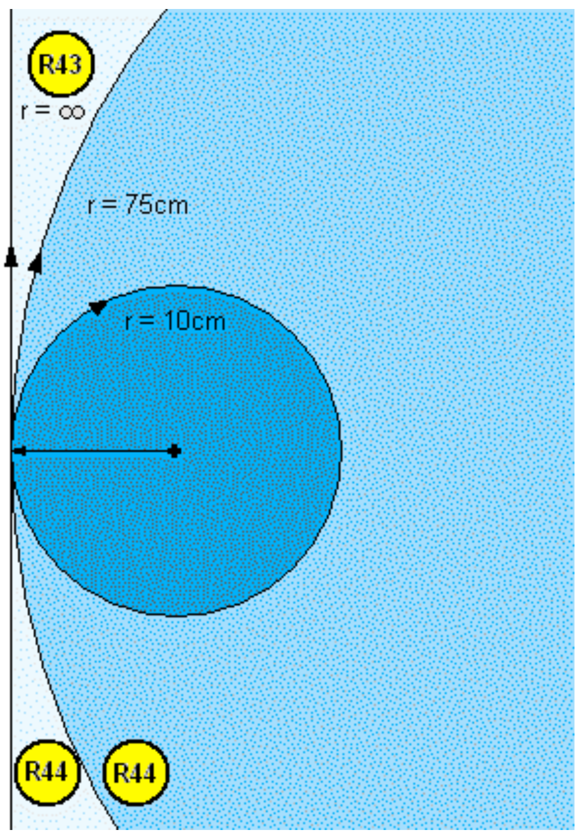

Figure 3: Set of possible clockwise turns

3 Standards & User Documentation Requirements

3.1 Standards

We are working on a research project; therefore, all standards and regulations will apply to our production model only. These standards will vary according to the country in which our climber is being operated and/or sold.

[R45-III] The climber must not cause any harmful interference to other devices as defined by the CRTC [4] (or equivalent standards body)

[R46-III] The climber must accept any interference received and continue to function normally as defined by the CRTC [4] (or equivalent standards body)

[R47-III] The climber must be powered by an approved source as defined by the CSA [5] (or equivalent standards body)

[R48-III] The climber must be built with environmentally friendly components that satisfy RoHS [6] (or equivalent) requirements.

3.2 User Documentation

[R49-I] Documentation will be written in English

[R50-III] A manual will be created for users of the Mattoid production model. It will explain, in common language, the features, functionality, and capabilities of Mattoid

[R51-III] The user documentation must provide instruction on the user interface specified in **[R33]**

[R52-III] Operation of the Mattoid production model must require no on-site training

[R53-III] The user manual must be written for users with minimal knowledge of Mattoid or robotics

4 System Test Plan

The Mattoid prototype system will undergo a battery of tests to evaluate the functionality of each iteration in the climber development process. The performance of three basic motor tasks will be assessed for each completed iteration. Three test cases are outlined below.

4.1 Test Case I: Basic Climb

Design Iteration: Two modules [1x2]

Desired Procedure:

The most basic test case involves attaching a Mattoid climber, consisting of two modules, to a vertical surface. The climber will begin in a neutral state and will be expected to:

1. Activate and move upward, perpendicular to the ground
2. Move 0.5m in a vertical line
3. Stop at 0.5m, with the two modules aligned within some tolerance

Figure 4 shows a conceptual two module system in a 1x2 configuration.

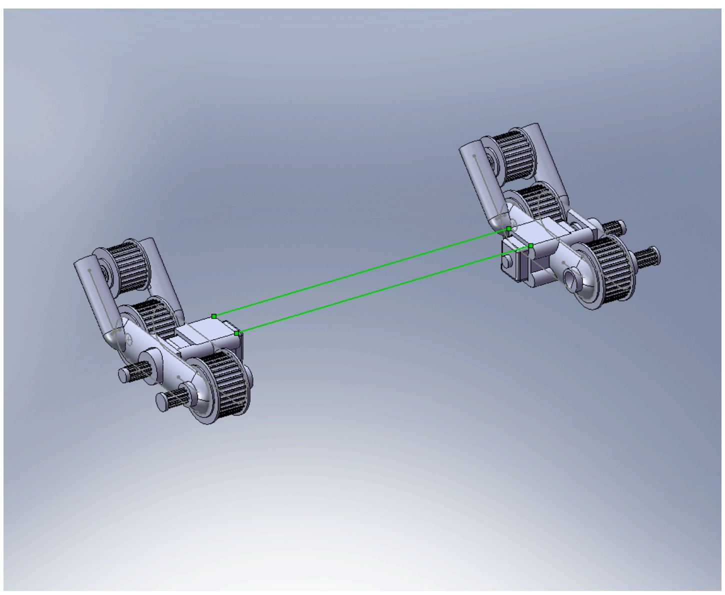

Figure 4: Two modules [1x2]

4.2 Test Case II: 90° Transition

Design Iteration: Two modules [1x2]

Desired Procedure:

In the second test case, the same Mattoid climber as in Test Case I, will be positioned an arbitrarily small distance on a horizontal surface away from a vertical surface. From that position the assembly should:

1. Move along the horizontal surface towards the vertical, and make contact
2. Navigate the 90° angle, transitioning from the horizontal to the vertical surface
3. Continue to ascend the vertical surface

4.3 Test Case III: 45° Turn

Design Iteration: Six modules [3x2]

Desired Procedure:

The final test case will use a Mattoid assembly consisting of 6 modules in a 3x2 array. As with Test Case I, the climber will be attached to a vertical surface. From this position the climber will:

1. Complete a 45° arc with radius of curvature of 1.0m

Figure 5 shows a conceptual six module system in a [3x2] configuration.

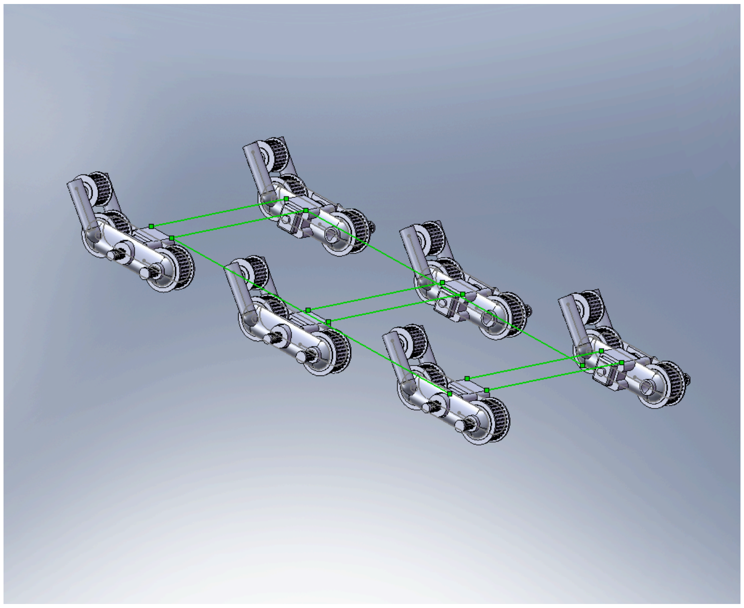

Figure 5: Six modules [3x2]

5 Conclusion

This document clearly defines functional specifications for both a prototype and production Mattoid. Design specifications will be finalized to adhere to the functional requirements described.

The prototype Mattoid is currently being constructed to meet functional requirements in categories I and II. This prototype will be completed in April 2008. Upon completion of the prototype, development of a production version which meets functional requirements in categories II and III will begin.

6 References

[1] Dr. Carlo Menon, Simon Fraser University, “ENSC_489”, Jan 2008, http://www2.ensc.sfu.ca/~cmenon/Teaching/ENSC489/Topic_12_Biomimetics/Topic_12_Biomimetics_v01.pdf

[2] Duke University, “Duke Annual Robo-Climb”, http://robotics.pratt.duke.edu/roboclimb/

[3] ESTEC, “ESA Lunar Robotics Challenge”, http://emits.esa.int/emits/owa/emits_iitt.show_iitt?actref=07.197.49&user=Anonymous

[4]CRTC. www.crtc.gc.ca/

[5]CSA. www.csa.ca

[6] RoHS Compliance in the EU - WEEE / REACH legislation, www.rohs.eu/