Patrick Leung
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Date 1/22/08

Dear Mr. Leung,

I have attached the document, *Proposal for a Wall Climbing Robot*, which outlines our proposed project for ENSC 440/305. Our goal is to design and implement a wall climbing robot that can navigate around a vertical surface and also transition between horizontal and vertical surfaces.

This proposal provides an overview of our design, design parameters, sources of information and funding, a projected budget, and information on project scheduling and organization. Also included are a description of previous, similar attempted robots and a list of objectives we need to meet to consider this project a success.

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 proposal, 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
President and CEO
Wallybot Robotics

Enclosure: **Proposal for a Wall Climbing Robot**

Proposal for a Wall Climbing Robot

Prepared for: Patrick Leung – ENSC 440
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Daniel Law
Johannes Minor

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Executive Summary

Climbing robots have obvious uses in hostile environments or difficult to reach places. Growing demand for development in this area has fostered an increase in research into highly mobile robots, capable of navigating difficult terrain, both man made and natural. Wall climbing robots have countless applications in many diverse fields, and our goal is to develop a lightweight, versatile climber, capable of autonomously navigating a variety of surfaces. This document proposes design directions, and details our resources, project timeline, and development budget.

Many current wall climbing robots are heavy and depend on active adhesion systems like electromagnets and electromechanical suction cups to stick to vertical surfaces. Active adhesion means the robot needs more power to function and will inherently be larger and more complex than a similar climber using a passive adhesive system. At the same time, climbing with active adhesive systems often limits the surfaces on which the robot is useful. A successful transition from the horizontal to vertical surface is a unique mechanical and control challenge which is also disregarded in many existing climbers.

Consider a world with reliable, wall-climbing robots, not limited to specific surfaces and easy to put to practical use. Where robots can transition from horizontal and vertical surfaces and vice versa, and are autonomous in nature. Where we can substitute reliable robots where human safety would otherwise be put at risk. This is the world that Wallybot Robotics envisions.

Our team of experienced Electronic and Systems Engineering students possesses the mechanical and electronic design skills to create and integrate the building blocks of our first wall climbing prototype. Furthermore, regular consultation with Dr. Carlo Menon, Assistant Professor in the School of Engineering Science at SFU, and thorough research of past and present designs and related published work will arm us with the remaining resources to make Wallybot Robotics a success.

With all materials taken into consideration, our research costs are expected to be $825.00. The majority of this expense will be covered by research grants and sponsorships from various organizations.

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Wall Climbing Robot

1 Introduction

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

There are no commercially produced wall-climbing robots to date, but this area of research is growing rapidly and remains highly competitive, with annual competitions in North America and Europe [1], [2]. The topic of wall-climbing robots has fuelled several academic papers and journal articles in the last five years from Universities around the world. This boom in research is no coincidence. There is a race 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 carrying out maintenance tasks on tall structures.

Wallybot Robotics' first research and development project, Mattoid, is a light-weight, durable, fully autonomous robot, designed to explore the possibility of creating wall scaling robots with passive adhesives. Our main goals will be mobility in two dimensions on horizontal and vertical surfaces, but our design will be physically capable of negotiating "inside corners" up to 90 degrees. This "inside" corner challenge or especially a transition from a vertical to horizontal surface is an important development and non-trivial task.

Plans for Mattoid, a first prototype in the Wallybot dream for reliable, practical and inexpensive commercial wall-climbers are now in motion. This proposal first provides a conceptual and functional overview of our robot system then highlights briefly previous research work done. From this we show our possible solutions for a next generation wall-climber and then focus on our proposed "crawler" solution. Proposed resource requirements and project budget and funding details are provided along with a project timeline. Lastly we give a more detailed introduction to the hardworking team at Wallybot Robotics.

2 System Overview

A fully functional wall-climbing robot will meet the following criteria:

1. Ascend a vertical surface, in a line perpendicular to the ground
2. Traverse a vertical two dimensional surface laterally, in a direction perpendicular to the ground
3. Transition from a horizontal surface to a vertical surface (ie. 90 degree inside corner)
4. Transition from a vertical surface to a horizontal surface (ie. 90 degree outside corner)

These functional requirements are illustrated in Figure 1.

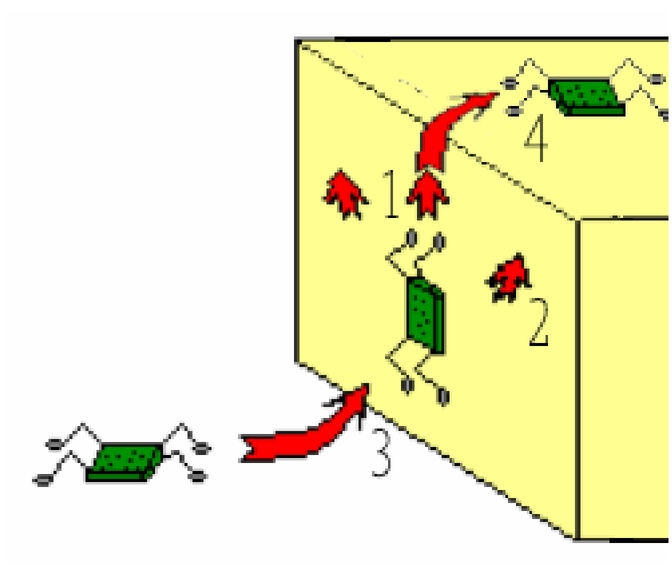


Figure 1: A conceptual diagram of a fully functional wall scaling robot in various stages of operation

The robot attempted for this project is intended to be a proof of concept for achieving functions 1,2, and 3 from the criteria mentioned above, with the option of expanding capabilities to include function 4 in future work.

3 Previous Published Research

A number of different wall climbing robots have been researched and described in academic journals in the past [3][4][5]. Existing climbing robots range in size from several inches to several feet, and have been designed for applications such as window cleaning, surface inspection, and scaling small diameter tubes. Many of these robots, however, use active adhesive mechanisms, which are designed specifically for certain types of surfaces.

Very few are designed to take advantage of passive adhesives for effective use over a variety of vertical surfaces. Advanced passive adhesives are an area of constant research and development, and this creates the possibility for innovation in many fields.

3.1 Under- Actuated Climber

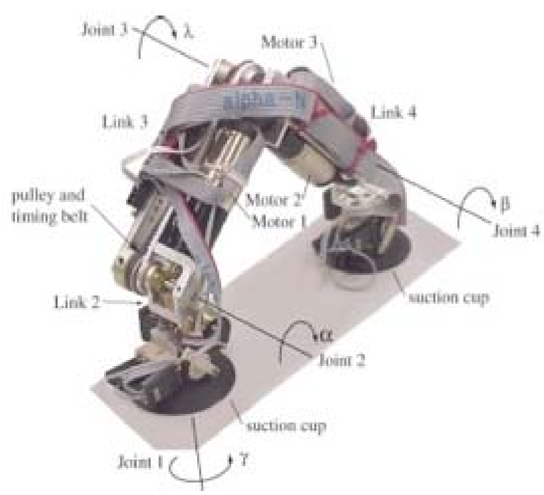


Figure 2. The Under Actuated Climber, University of Utah [3]

The Under Actuated climber was designed for the minimum number of actuators. The design is shown in Figure 2. This robot uses active suction cups for adhesion to a vertical surface, which limits its use to very smooth walls.

This style of robot is not practical for use with passive adhesives because of its low surface area and insufficient number of contact points. Although the minimally weighted mechanical structure can be used for inspiration, a robot designed for use with passive adhesives would require more contact area for stability.

This simple robot design can be used to transition between flat surfaces at any arbitrary angle, which suggests that there are aspects of this design to be researched further.

3.2 Tank Style

Tank tracks have been in use on climbing robots with a variety of adhesion systems. The design shown in Figure 3 from Dalhousie University uses a magnetic track so that it can move vertically up a ferro-magnetic surface. The design was intended for use on large oil and water tanks, to inspect for structural defects and potential cracks.

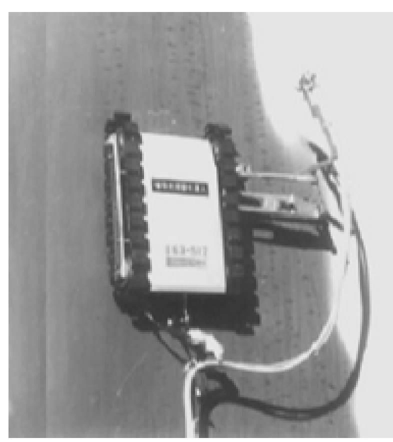


Figure 3: The magnetic tank wall climbing robot, Dalhousie University [4]

This robot is severely limited in its mobility, as it only works on surfaces made of specific materials. Also, it has no ability to navigate laterally, nor can it transition from horizontal to vertical surfaces. This means that the robot must be placed on a vertical surface by a human operator, and can only inspect the area within reach of the vertical line. Similar robots have been created with sticky tracks, but these too are limited in their mobility to vertical motion on a flat, smooth surface.

3.3 Gecko Style

The robot in Figure 4, from Stanford, uses advanced adhesive technology for climbing smooth surfaces. This state of the art robot design will climb straight up a wall, with no turning or corner transition capabilities.

The innovation in this robot is the design of the feet, which use a directional adhesive. An actuator curls up the toes, peeling the adhesive from the surface, allowing the foot to release.

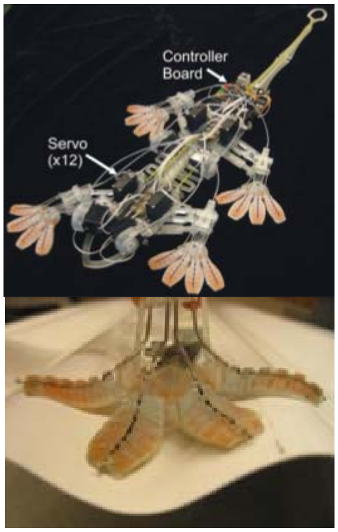


Figure 4: Gecko-style climbing robot, with advanced adhesive feet from Stanford University [5]

4 Possible Design Solutions

Borrowing some techniques from previous robot research, several design solutions may be attempted to meet the functional requirements outlined in the system overview.

4.1 Gecko

The field of biomimetics led us to a possible solution of a robot built in the mechanical shape of a gecko. A gecko style climber would require four gripping points, similar to feet, and a articulated spine system that would be move the left and right sides of the gecko with appropriate timing. Also, due to the nature of a gecko's motion, a simple rotational joint would not suffice as part of the spine. The spine joint would have to provide an extra degree of freedom when gripping and releasing the surface being climbed. A prior implementation of a gecko style climber is seen in Figure 5.

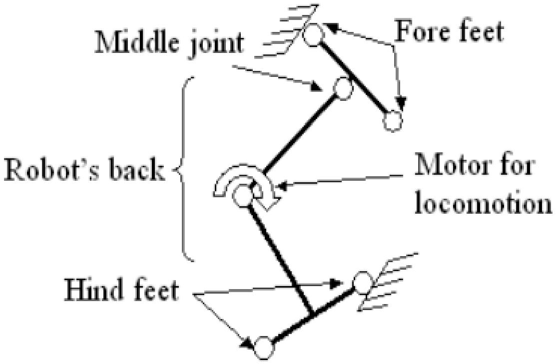


Figure 5: Proposed Operation of a simple gecko-inspired climber [6]

Due to the nature of the spine, the design of the gecko could become mechanically complex. Prototypes of gecko-inspired climbers, and having the gecko transition from a horizontal to vertical surface would be an intricate challenge.

4.2 Caterpillar

Despite being termed the caterpillar, this design has the least biomimetic inspiration, and it is the most obvious engineering design solution to the wall climbing problem. The climbing movement of the caterpillar can be easily interpreted from the sketch in Figure 6.

The fore and aft adhesive pads would release, move some distance forward and re-attach in alternating sequence. The body would then follow. This design is very simple, and allows for the smallest number of actuators for direct vertical climbing.

Because of its elongated shape, this design is likely to have difficulty traversing a 90 degree corner.

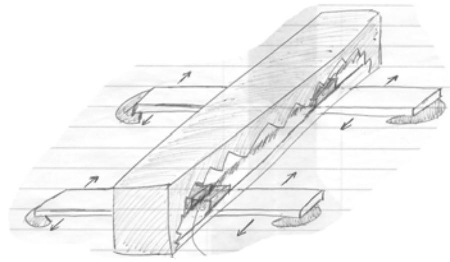


Figure 6: A caterpillar-style robot

5 Proposed Design Direction

Our Mattoid Crawler does not base its shape on the natural world as much as the gecko does, although it does retain some loose animal inspiration, as can be seen in the sketch of Figure 7.

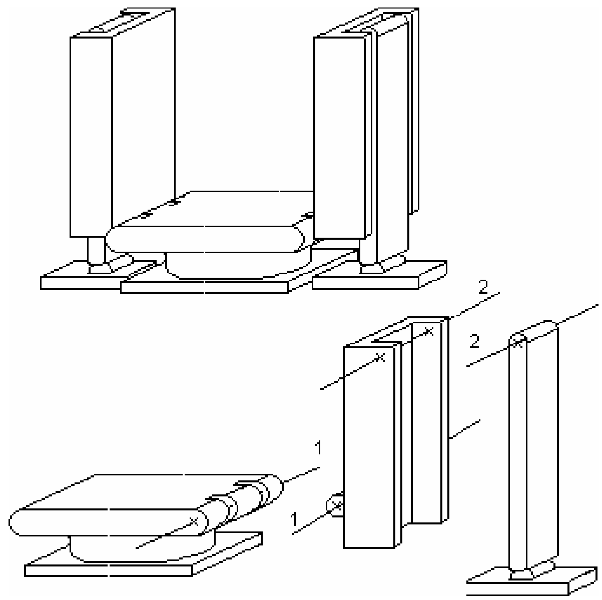
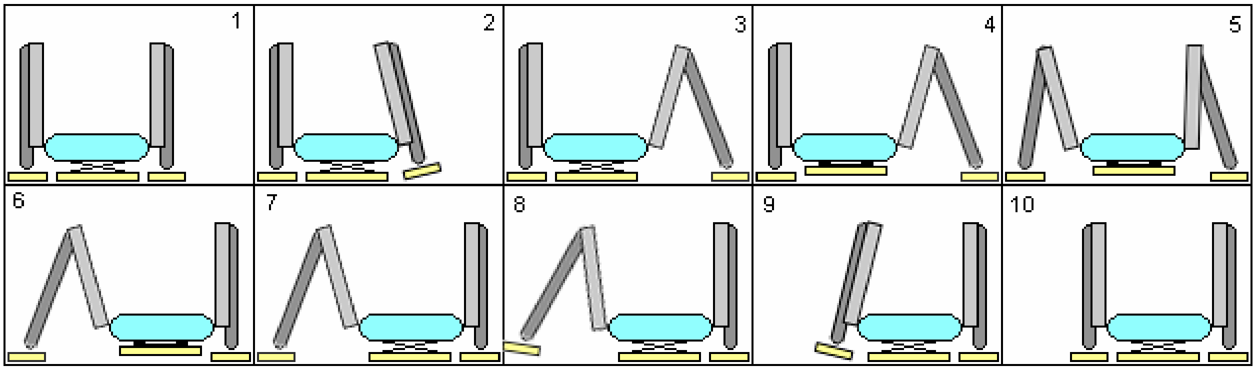


Figure 7: Sketch of the proposed crawler design concept

Mattoid's crawler design consists of three adhesive pads of approximately equal area, linked together by appendages with three points of articulation; two independently actuated joints, and one compliant joint connecting the bonding pad to the appendage. By maintaining two pads on the surface at each time, using a crawling motion to move one pad at a time, the entire robot will be able to climb a vertical plane. Also, having front and back legs that move in the perpendicular plane allows for a transition from a horizontal surface to a vertical surface.

Figure 8 shows Mattoid going through the steps required to move one step along a flat surface, and the steps required to complete a successful 90 degree inside corner transition.

One Step Forward:



Inside Corner Transition:

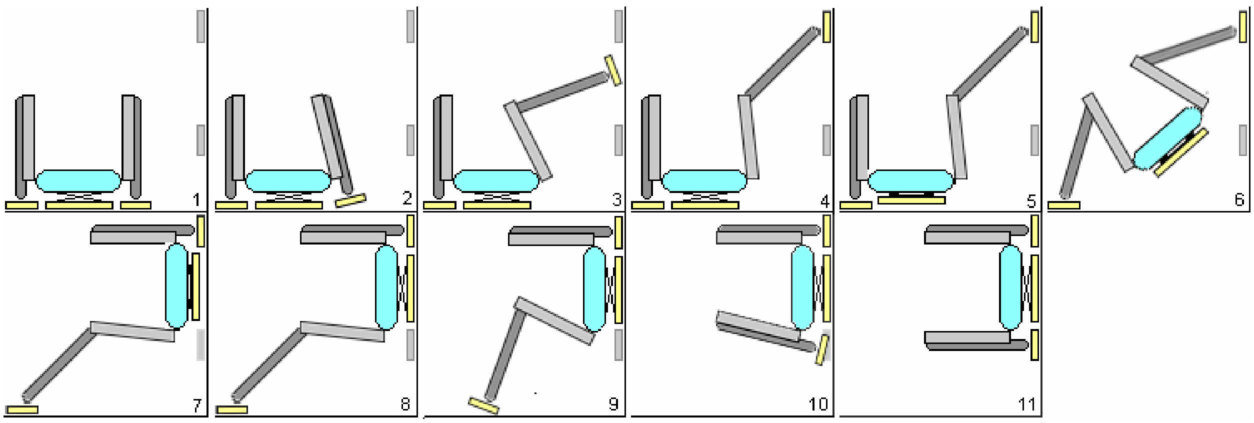


Figure 8: Step by Step Operation of Mattoid

In choosing strong, lightweight, plastic structure, minimally heavy actuators and electronic components, and large adhesive pad area, Mattoid will be able to meet the functional requirements, as outlined in the System Overview.

6 Resources

We are working closely with Dr. Carlo Menon, Assistant Professor in the School of Engineering Science at SFU. Without previous robotics design experience within our team, Dr. Menon serves as an invaluable resource with his expertise in robotics research. He has also provided us with insight into our main design challenges and potential applications and direction for Mattoid and Wallybot Robotics respectively.

As our project progresses, we will continue to consult with Dr. Menon and utilize this resource to produce a robust wall-climber prototype comparable with recent research developments. We have and will continue to rely extensively on web research and related academic papers and journals. Some of these papers have been provided by Dr. Menon.

7 Budget and Funding

The following table outlines our proposed budget. We have done some preliminary research into parts such as motors and a power supply. These parts along with our microcontroller will constitute our most expensive items and hence have been researched most thoroughly.

7.1 Costs

Table 1: Cost Breakdown

Description	Quantity	Unit Price	Cost
Power Supply	-	$30.00	$30.00
Microcontroller	1	$60.00	$60.00
Misc. Electronic Components (Resistors, Diodes, etc.)	-	$20.00	$20.00
Motors and Actuators	6	$50.00	$300.00
Rapid Prototyping	-	$300.00	$300.00
Adhesive	1	$5.00	$5.00
Sensors	4	$15.00	$60.00
Contingency	-	$50.00	$50.00
		Total	**$825.00**

In the initial stages of the design process, inexpensive batteries will be used, along with holders and connecters. As power requirements are more precisely defined, more will be invested in choosing a suitable power solution. A 24-pin PIC microcontroller will be used for control, mounted on a pre-fabricated host board to reduce design time. Six servomotors are needed for the proposed design at a cost of approximately $50.00 each. The body will be fabricated using the rapid prototyping machine at SFU at an estimated cost of $300.00. Dr. Carlo Menon has agreed to sponsor this portion of our cost. The adhesive will be a simple putty for initial prototyping but is subject to change as we follow current research in this area.

7.2 Funding

Dr. Menon has agreed to provide us with free access to the rapid prototyping machine and to cover all Mattoid related rapid prototype fabrication costs including materials. The funds from the student society come from the Engineering Science Student Endowment Fund. Based on awards in recent years, we expect to receive between $200 and $400. We will assume an average amount of $250.

The School of Engineering Science provides $50 per ENSC 440 group. The remaining $225 required for funding will be split between the group members.

Table 2: Sources of Funding

Description	Quantity	Unit Price	Cost
Engineering Science Student Endowment Fund			$250.00
Departmental Funding			$50.00
Group Funding			$225.00
Sponsorship from Dr. Carlo Menon			$300.00
		Total	**$825.00**

8 Project Timeline

Figure 9 indicates the project timeline, broken down into the following categories: Electronics and Mechanical Subsystems, Integration, and Deliverables.

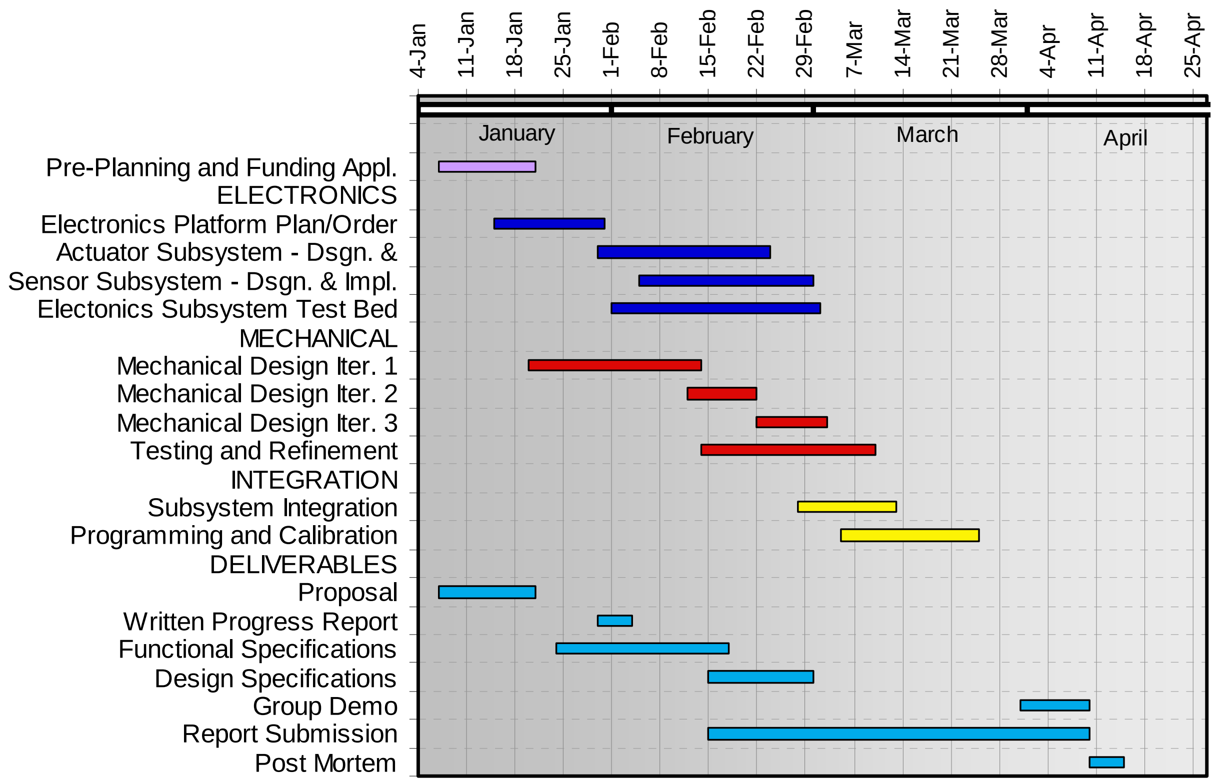


Figure 9: Project Timeline Gantt Chart

The project is scheduled for completion in the last week of March, leaving us two weeks of grace period to deal with unexpected project delays. The important milestones and deliverables are summarized below.

Table 3: Project Milestones

January		February		March		April	
21	Proposal	4	Progress Report	3	Design Specifications	10	Group Demo
	ESSEF Funding Proposal	18	Functional Specifications			10	Final Report
						15	Post Mortem

9 Team Profile And Company Organization

Wallybot Robotics is comprised of four 5th Year Simon Fraser University Engineering students.

Daniel Goundar – Chief Executive Officer (CEO)

- Work terms at Business Objects in software development
- Strong SolidWorks and mechanical design skills
- Experience with technical writing in a corporate atmosphere

With his management skills, Mr. Goundar will ensure maximum productivity from the Wallybot Team. His mechanical design intuition and mastery of CAD tools are key components to the success of Mattoid. His technical writing skills and experience will also factor into quality functional and design specification deliverables.

Johannes Minor – Chief Technical Officer (CTO)

- Research work terms in Control Systems and Vibration Analysis
- In depth background in control theory and mechanical analysis
- Experience with software development and mechanical design.

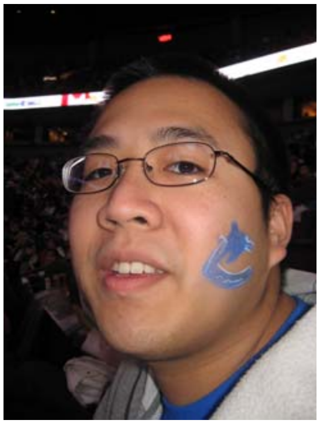
Mr. Minor has a strong background in control theory and analysis of mechanical systems, with recent research experience in control theory and mechanical vibration. His SolidWorks experience project experience will no doubt strengthen the mechanical design team..

Curtis Gittens – Chief Operations Officer (COO)

- Work terms at Barbados Light & Power and Dyaptive Systems Inc.
- Specializes in Digital Hardware and System on Chip Design
- Previous research experience at SFU in digital design.

Mr. Gittens will coordinate team communication and organization. Meetings, team resource access and sharing, scheduling and ordering parts all fall under the umbrella of his responsibilities. He will also act as the lead firmware designer, utilizing his background in digital electronics to ensure smooth completion of an electronics platform for Mattoid.

Daniel Law – Chief Research Officer (CRO)



- Work terms at Omnex Control Systems and HSBC
- Adept with software design (C/C++, Java) and
- Experience with Computer Aided Manufacturing (CAD)

Mr. Law will lead research pertinent to the completion of this project. This research includes financing, parts research and academic papers and publications relevant to the Wallybot goal. His electronics expertise also makes him invaluable to the development of an electronic platform of Mattoid. He will also take a lead role in the hardware programming portion of this project.

The Wallybot team all have previous project experience working with each other. Each member has worked with every other member at some time over our academic careers. This fact will no doubt make for comfortable communication between team members and smooth integration of individually executed tasks. The seamless integration of the mechanical and electronic subsystems will be critical, and effective communication will ensure completion of this project.

Tasks are delegated to allow for the most efficient use of human resources, and to foster an environment of innovation and success. Collaboration between team members and responsibility sharing will be encouraged as well as seeking additional expertise to solve unfamiliar problems. Wallybot Robotics employs an “Interactive Organization” model in order to ensure a high level of communication and task sharing.

The team will meet weekly with Dr. Carlo Menon to review current status, and discuss the next steps in the design process. In addition weekly project team meetings will be held for Wallybot Robotics members to discuss project development, status and deliverables.

A wiki website has been setup to allow for easier file access and sharing and to act as an information center. The wiki is located at http://ensc440-a-team.wikidot.com/ (requires password access).

10 Conclusion

The long term vision of Wallybot Robotics is to create market-ready robots for industrial applications. The Mattoid prototype will serve as proof of concept for the versatility of lightweight wall-climbers using passive adhesion technology.

By applying our combined knowledge in mechanical design, electronic hardware, and software design, our team at Wallybot Robotics will be successful in creating a wall-climbing prototype. Our proposed solution is a simple design, allowing us to minimize cost, complexity, and development time while making Mattoid a benchmark in this burgeoning research field. Mattoid will also bring about innovation in the field of climbing robots.

11 References

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