ELECTRICAL AND COMPUTER ENGINEERING
COLORADO STATE UNIVERSITY

Electrical and Computer Engineering Outreach Team:

RamBOTs

Electrical Engineers:

Alex Kolodzik, Michael Bearly, Kyle Biskupski

Computer Engineers:

Gwyndolyn Tari, Evan Hassman, Eric Percin, Thomas Veldhuizen

Mechanical Engineers:

Eric Olson, Kyle Moore

Junior Outreach Members:

Anna Biolchini, Joey Reback

Advisor:

Olivera Notaros

Industry Advisors:

Jon Lotz

Summary

The RamBOTs senior design project is an extension of the electrical and computer engineering outreach program. It is a quadrupedal robot intended as an educational tool that is open source and more economic than current existing counterparts. As an extension of outreach, the intention is that this project will be demonstrated to many groups of younger students (ranging from middle school to high school age) to show them the possibilities of electrical and computer engineering (ECE) as well as engineering as a whole as this is a multidisciplinary project in nature.

Why This Project is Important

This project is intended to increase exposure and access to robotics through being open source and more economic compared to other options, exemplifying the purpose of ECE outreach. It is important to make ECE accessible to everyone. By sharing exciting projects that inspire younger students it is possible to bring more attention to engineering as a whole and to help encourage the next generation of engineers and problem solvers.

Revision History

Date	Comments	Version	Worked on by	Approved by
9/13	Initial Document	1.0	All Senior Design Students	
9/15	Revised Initial document	1.1	All Senior Design Students	

Figure 1: Revision History Table

Problem Statement

The purpose of this project is to develop an open-source quadrupedal robot as an educational outreach tool to foster interest in engineering and robotics. The mechanical design of the RamBOT is largely based off of an existing open source robotics project—the team primarily intends to improve upon electronics and software to enhance said design. As a 2nd-year continuation project a considerable amount of prerequisite work on the robot has been completed. Most notably, the chassis has been constructed and hardware has been acquired in preparation to begin testing components and programming. The following items have been inherited from the previous year's team:

Multi-Year Project Status and Plans for This Year

- A 3D printed chassis / body
- Motors and drivers (not all have been tested)
- A stand for storage/transportation
- Machine learning algorithms

This year's team intends to test everything received from the previous year's team, beginning with the hardware (e.g. motors and motor drivers) so that there will be sufficient time to reorder any faulty components. Additionally, last year's team consisted of eight ECE students while this year's consists of eight ECE students and two Mechanical Engineering students. This will allow the current team to reevaluate the existing mechanical structure of the robot and to make modifications as necessary, as well as to implement locomotion more seamlessly. Existing machine learning algorithms will be tested for accuracy and modified as needed throughout the project's development cycle.

Goals & Objectives

The seniors and Junior Outreach members on the RamBOTs Senior Design Team at Colorado State University will adhere to the timeline in the final section of this project plan to fulfill a completed design. The definition of a completed design is laid out in the following goals and objectives:

- Stable quadrupedal standing and movement
    - Motors demonstrate consistent and accurate programmed movement (Test 1)
    - Can be controlled or programmed to move towards an objective and does not fall over under common operational circumstances (Test 2)
    - Gyroscope senses and accurately returns movement data (Test 3)

- Machine learning implemented
    - Can, with high confidence, recognize a toy ball compared to surrounding objects (Test 4)

- Useful as tool for ECE Outreach
    - Entirely open-source
    - Chassis and harness that can reliably withstand regular use of product and travel (Test 5)

- Meets budget requirements
    - Cost for team remains below the allocated amount described in budget section of this plan

Tests were designed to assess the functionality of the product and listed below (mark in pass or fail column):

Test #	Description	Pass	Fail
1	Write a test script that includes full rotation of the stepper motors in each direction. Observe encoder response and confirm that angular position returns to original value after script is run.		
2	Using desired method of control, the product can walk 5 ft. forward, turn around, and return without falling over.		
3	Repeat test 2, recording gyroscope sensor response. Compare values with visual observations to confirm gyroscope is returning correct readings.		
4	Place a toy ball in view of camera with several different backgrounds and confirm that machine learning senses with sufficient confidence.		
5	Pick up harness with product installed and place back down. Check that all components are still firmly in place, connections have not been severed, and harness is in-tact.		

Budget Justification

Due to our status as a legacy project—one that has been continued from a previous year—many of the necessary components and materials have already been acquired. This means that our budget for this year should be much smaller than it was in the previous year. Our expenses will likely consist of small but necessary tools or components that were never purchased last year or need to be replaced.

According to documents left by the previous team members our remaining budget is approximately $2100, which we should be able to stay under with little difficulty. Some expected neede materials and replacements are listed below.

Part Name:	**Price:**	**Quantity**	**Total**
ODRIVE V3.6 MotorDrives 56V	$249	2	$498
Eaglepower 8308 Brushless Motor	$62	2	$124
MPU6050 6 Axis Gyroscope	$2.09	6	$12.54
AS5047 encoder	$15.80	8	$126.56
Polytek PlatSil Gel-25 Silicone Rubber (2lbs)	$63.00	1	$63
			Total: $824.1

Proposed FMEA Table

Process Step	Potential Failure Mode	Potenetial Failure Effect	SEV1	Potential Causes	OCC2	Current Process Controls	DET3	RPN4	Action Recommended
What is the step?	In what ways can this step go wrong?	What is the impact on the customer if the failure mode is not prevented or corrected?	How severe is the effect on the customer?	What causes the step to go wrong (i.e. how could the failure mode occur)?	How frequently is the cause likely to occur?	What are the existing controls that either prevent the failure mode from occuring or detect it should it occur?	How probabale is detection of the failure mode or its cause?	Risk priority number calculated as SEV x OCC x DET	What are the actions for reducting the occurenece of the causes or for improving its detection? Provide actions on high RPNs and on severity ratings of 9 or 10
Powering Up	It may not power on	Non working robot	8	• The robot was not properly shut down or charged. • Power system failure.	2		1	11	We will have to write the proper shutdown, start up and charging procedures in the manual.
	Slow startup	It costs the company time	3	• Inefficient code • A slow computer	3		2	8	We will make sure that the computer is as quick as it can be while still being financially viable. We will also try our best to make the code efficient.
Movement	Servo Didn't move	The robot can't complete the desired movements	6	• Wiring failure • Programing failure	2		1	9	We will double check all of the code and the wire connections before the robot is complete and research more durable components.
	Robot won't balance	The robot can't move succesfully	7	• Programing failure	3		1	11	We will be able to push updated code to the robot to fix errors in the old code.
	Sensor malfunctioning	The robot can't sense its environment	6	• Broken sensor	1		2	9	We will test every sensor before the robot is complete and program an alert or alarm to go off if this happens.
	Information transmission error	The robot may move in a way that is undesiered leading to it possibly breaking or just being unpredictable	8	• Error sending or reciving bits • Noise affecting bits during transmission	1		1	10	Twisting wires together can help with noise, and testing and understanding how the information beween parts is encoded.

Figure 2: FMEA Table

Project Risk Analysis Table

#	Risk Event	Probability/ 100	Impact, weeks	Score, hours	Effect	Risk Mitigation Plan	Person responsible for implementing control
1	Short circuit	10	Varies	10	It could delay the project by a few minutes or cause multiple devices to break and cost a lot of money.	We will make sure that all the wires are properly terminated.	Alex Kolodzik
2	Personal injury	10	Varies	60	It can injure one of our teammates.	Make sure everyone involved when testing or working on the robot know what their task is and how to react incase of an emergency.	Evan Hassman
3	Incorrectly calculated power requirements	15	1	55	The robot wont function correctly.	Have another teammate double check the power calculations.	Michael Bearly
4	Damanged components	15	4	70	Work halted until parts are replaced	Purchase extras and take extra caution not to damge any components beyond working state.	Thomas Veldhuizen
5	Delayed testing of motors and Odrives	10	1	20	Work halted until all motors tested	Begin taking motors and Odrives off early enough to ensure enough time for testing.	Eric Olson/ Kyle Moore
6	Team members idling	30	Varies	30	Wasted time as teammates idle	Ensure there are little to no bottlenecks and that all members have something to do.	Alex Kolodzik/ Gwyndolyn Tari
				Total risk :	245		

Figure 3: Risk Analysis Table

Project Timeline

The primary critical path of this project is as follows: motor functionality, ODrive functionality, wiring, leg movement functionality, locomotion functionality. By delegating each of these tasks to team members of relevant specializations, the team plans to have the motors and ODrives working by halfway through the fall semester. This will allow the team to dedicate the remainder of the semester to leg movement–a complicated task which will last well into the spring semester. Once leg movement is deemed sufficient, the team will spend the rest of the spring semester working on general locomotion.

Tasks such as machine learning, website development, and administration are not dependent on the critical path and will be worked on concurrently. Other smaller tasks such as power requirements, 3D printing additional parts, and sensor testing will be conducted as deemed necessary by the critical path.

Project Timeline Semester 1

Tasks	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16
Website		Eric P	Eric P													
Update Wedsite								Eric P				Eric P				Eric P
Budget		Thomas, Gwyn	Thomas, Gwyn	Thomas, Gwyn												
Purchasing					Thomas	Thomas	Thomas	Thomas								
Project Plan	All Team Members	All Team Members	All Team Members	All Team Members												
Project Plan Revisions															All Team Members	All Team Members
FEMA			Evan													
3D Printing Additional Parts					Michael, Evan, Eric O, Kyle M					Michael, Evan, Eric O, Kyle M					Michael, Evan, Eric O, Kyle M	
Power requirements					Michael, Alex	Michael, Alex	Michael, Alex									
Feet Enhancements		Gwyn, Joey, Anna	Gwyn, Joey, Anna													
Motor Functionality		Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M												
ODrive Functionality					Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M								
Leg Movement Functional									Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M
Leg Movement Testing																
Motor Troubleshooting																
Embedded Systems						Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas				
Wiring Schematics							Alex, Michael, Kyle B	Alex, Michael, Kyle B	Alex, Michael, Kyle B	Alex, Michael, Kyle B	Alex, Michael, Kyle B					
Wiring												Alex, Michael, Kyle B	Alex, Michael, Kyle B	Alex, Michael, Kyle B	Alex, Michael, Kyle B	Alex, Michael, Kyle B
Wiring Troubleshooting																
Installing Gyrscopes											Kyle B	Kyle B	Kyle B	Kyle B	Kyle B	Kyle B
Testing Gyroscopes																
Programming					Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas	Gwyn, Evan, Eric P, Thomas
Testing Walk Cycle Code																
Machine Learning Relearning Code					Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B								
Machine Learning Enhancing Code									Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B
Machine Learning Finalizing Code																

Color Meaning								
Not Started	In Progress	Finished	Revision needed	Revision in Progress	Revision Complete	Finished but will need revision	Semester 1	Semester 2

Figure 4: Project Timeline Fall 2022 Semester

Project Timeline Semester 2

Tasks	Week 17	Week 18	Week 19	Week 20	Week 21	Week 22	Week 23	Week 24	Week 25	Week 26	Week 27	Week 28	Week 29	Week 30	Week 31	Week 32
Website																
Update Wedsite				Eric P				Eric P				Eric P				Eric P
Budget	Alex, Gwyn	Alex, Gwyn	Alex, Gwyn													
Purchasing	Alex, Gwyn	Alex, Gwyn	Alex, Gwyn	Alex, Gwyn												
Project Plan																
Project Plan Revisions	All Team Members	All Team Members														
FEMA																
3D Printing Additional Parts				Michael, Evan, Eric O, Kyle M					Michael, Evan, Eric O, Kyle M					Michael, Evan, Eric O, Kyle M	Michael, Evan, Eric O, Kyle M	
Power requirements																
Feet Enhancements																
Motor Functionality																
ODrive Functionality																
Leg Movement Functional																
Leg Movement Testing	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M									
Motor Troubleshooting								Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M	Eric O, Kyle M
Embedded Systems																
Wiring Schematics																
Wiring																
Wiring Troubleshooting	Alex, Michael, Kyle B	Alex, Michael, Kyle B	Alex, Michael, Kyle B	Alex, Michael, Kyle B	Alex, Michael, Kyle B	Alex, Michael, Kyle B										
Installing Gyrscopes																
Testing Gyroscopes	Kyle B	Kyle B	Kyle B	Kyle B	Kyle B											
Programming	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P
Testing Walk Cycle Code	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P	Gwyn, Evan, Eric P
Machine Learning Relearning Code																
Machine Learning Enhancing Code	Michael, Evan, Eric P, Kyle B															
Machine Learning Finalizing Code		Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B	Michael, Evan, Eric P, Kyle B

Color Meaning								
Not Started	In Progress	Finished	Revision needed	Revision in Progress	Revision Complete	Finished but will need revision	Semester 1	Semester 2

Figure 5: Project Timeline Spring 2023 Semester