Unified Sumo Robot

Background Report

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2015-16

Project Sponsor: Northern Arizona University - Mechanical Engineering
Faculty Advisor: David Trevas
Sponsor Mentor: N/A
Instructor: David Trevas

DISCLAIMER

[Use this text exactly, include in all documents.]

EXECUTIVE SUMMARY

[Provide a one-page summary of your project, including description, design, and results.]

[Include in Final Report only.]

ACKNOWLEDGEMENTS

[Use this page for acknowledging those who have substantially supported or assisted you, such as faculty and staff members, fellow students, sponsor mentors, etc.]

[Include in Final Report only.]

TABLE OF CONTENTS

[Use your word processor to delete the following Table of Contents and insert a new TOC. Include front matter (except for the cover page), body of the report, and all appendices. The Table should include four levels of headings, e.g., down to 2.2.1.3, as illustrated below.]

1 BACKGROUND

1.1 Introduction

The project is to compete in a sumo robot competitions a The goal of the project is construct 3 robots, ranging Mega to Nano, that are able to compete in these competitions. The team is to manufacture 2 Dohy, for each class, that can be stored and taken apart with ease. The team must all be able to set up and control each of the devices. With any programming that is written for the this project, it is to be commented with all the pseudo-code and full programming in the final reports at the end of each semester.

For the perspective of the team, the sponsor, the mechanical engineering department at NAU, is providing funds in order to compete in this competition. The benefits to the sponsor is that the university can showcase what their students are capable of and they can show incoming freshmen what the department can do. The issue with this project is that there is no sponsor mentor for this project. The positive of this is how open ended the project is, The negative to this is that we are the clients of the project. Since this is a new project for Capstone, there is no prior information from past teams that the team can compare and acquire new ideas for the project.

1.2 Project Description

Following is the original project description provided by the sponsor:

Two robots compete in a head-to-head match following the basic system of traditional human sumo matches. Robots are allowed no weapons, and are not allowed to flip each other. The sole purpose is a pushing match between the two robots to force the other from the arena. Multiple weight classes and control systems are allowed (autonomous compete against autonomous and R/C against R/C - they are separate classes and do not compete against each other.)

The team was asked to submit a proposal to compete in one other competition from the events page on RoboGames. From the listed events, the choosed to participate in the Art Bots category with the event Bartending. Following is the original project description provided by the website:

A bartending robot is any robot that can prepare mixed drinks for the user.

1.3 Original System

This project involved the design of a completely new robotics competition for the students to participate it. There was no original system when this project began. The only comparison that can be made is within existing designs from others within the competition or personal project which is discussed in later sections.

2

REQUIREMENTS

In order to achieve these objectives, the requirements are made for team to make sure that all that is asked for is completed. Requirements are generated from what the client has asked for from this project. The clients for this project is the team making this project. The

2.1 Customer Requirements (CRs)

[List and discuss all Customer Requirements and weightings. Customer Requirements must fully incorporate all the project requirements provided by the sponsor. Additionally, the Customer Requirements should fully specify and clarify the overall project objectives.]

[Include in Background Report and all subsequent reports.]

2.2

House of Quality (HoQ)

House of Quality (HoQ)

Customer Requirement	Weight
R/C Robot	
1. Remote Controlled	5
2. Long Battery Life	4
3. Digitally Mated Pairs	5
4. Dimension Limitations	4
5. Weight (3000 g)	4
6. Signalled Start	3
7. Push opposing robot	3
Nano Sumo (Autonomous)	
1. Independently acting	5
2. No external signals/movement	5
3. Methods contained within unit	4
4. Dimension Limitations	4
5. Weight (25 g)	4
6. Push opposing robot	3
Mega Sumo (Autonomous)	
1. Independently acting	5
2. No external signals/movement	5

3. Methods contained within unit	4
4. Dimension Limitations	4
5. Weight (3000 g)	4
6. Push opposing robot	3

Approval

Team member 1: RD 9/29/16

Team member 2: DF 9/29/16

Team member 3: JV 9/29/16

Team member 4: YA 9//29/16

Client Approval: N/A

[Summarize project requirements in a House of Quality using the template provided on the course website. Print your HoQ on 11” high by 17” wide paper and replace this page with your HoQ, folded to 11” high by 8.5” wide. If your HoQ takes more than one 11”x17” page, insert extra, “dummy” pages” in this document to preserve proper page numbering. If the HoQ is small enough you may include it here as landscape or portrait.]

For the Background Report include only CRs, Weightings, and approvals: signatures on the HoQ or attached e-mail(s) clearly affirming approval.

For the Preliminary Proposal include only CRs, Weightings, ERs, Target Values (with tolerances), and approvals.

For the Final Proposal and Final Report include all HoQ elements and approvals]

3

EXISTING DESIGNS

There are many examples of designs that have already been created similar to what the team has been doing. Researching for these designs can give us an advantage to compare what succeeded and what failed leading to a more develop design. Integrating previous successful ideas with our original ideas can lead to a well developed robot.

3.1 Design Research

The R/C robot will be a sumo robot that is remotely controlled. The weight for this class, the robot must not exceed 3 kg and not be larger than 20 cm for width or length while height is unlimited. Remote controls must be digitally paired and must not have a frequency of 75mhz. The tournament official will call the start of the match. Winning the match can be determined by the judges call by the amount of Yuhkoh points that were received.

The autonomous class requires the team to construct a robot that works without a controller. The main goal of the robot is to wrestle in a sumo ring against another opponent. The robot should not contain any sharp edges(radius not greater than 0.005 inches) in order to not damage the ring but it has to be durable enough to not break into pieces. Also, since it is an autonomous it should has line's and opponent's sensors so it would be able to perform orders when they are detected. Just like the R/C robot, the mass of the robot should equal or less than 3 kg.

More research is required to better understand what is asked for in the bartending robot. From the description given on *ROBOGAMES*, only one robot is required to compete in the competition. The robot control has to be autonomous. At the minimum, the robot is required to prepare any mixed drink with at least one spirit and one mixer. The competition will be scored based on aesthetics, style, delivery, and versatility.

Patrick McCabe Makes NanoBot is a robot that only had a volume of a cubic inch. Robot was completely created by two guys hundreds of miles apart. One of the partners worked with the code while the other worked with the hardware. The processor for this robot is the size of a quarter. Most of the weight of the robot came from the battery itself. Much hardwiring had to be done in order for the robot to work as expected. In the end, the nanobot was a success.

Stampy Autonomous bot was designed for DC sumo competition. The reason why this robot was so special was because it was limited to the speed and strength it may have for the competition. This made it much more difficult for the robots to compete with each other. By having these limitations, the robots had to be coded in such a way that it was skilled rather than being strong. *Stampy* had rely on its code much more due to it lacking on strength and speed [2].

Doing research for the R/C class, the team came across a bot that caught the team's attention. The competition, unlike *Stampy's* competition, this nameless robot had to be heavy. In 2002, a group of high school kids were competing the sumo competition. The R/C robot they created weighed 20lb and contained some heavy duty parts. After building it, they found out that they had to use a lawnmower battery in order to power their robot. Being pretty heavy and durable, the robot was a success from a group of 10th graders [3].

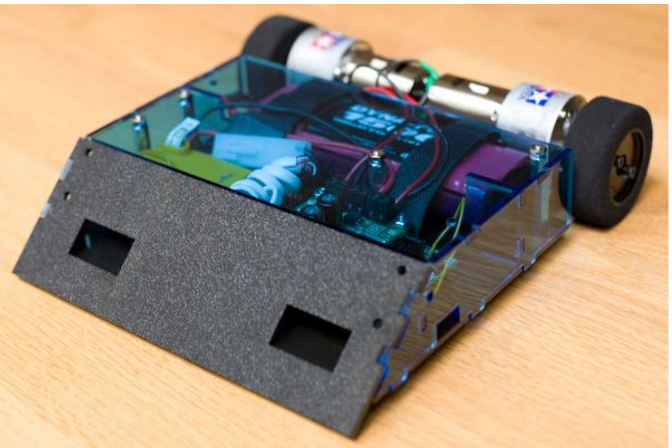
An engineer named Dave Zucker, received a robotic arm for free. At the time, it had malfunctioning parts that impacted the arm itself and did not work. It was not until 10 years later, he decided to take a look at it. Exchanging the malfunctioning parts with working new ones, he turned his gift into a bartending robot.. He customized it into his own idea and name him *Sir Miss-a-Bot*. He finished it in time for his birthday and made a debut at his party by serving his guest their mixed drinks [4].

3.2 System Level

Robots from different competitors have successfully competed in a competition similar to the current sumo completion that team 21 is competing in. Establishing some examples can spark new ideas to bettering the team's robot.

3.2.1 Existing Design #1: Autonomous Robot (3kg)

Tom Saxton designed a 3 Kg sumo robot to compete in Robothon in 2007 [5]. The robot can run as autonomous or by RC controller. It has only two big tires and two independent motors with a steep edge at the front in order to flip another opponent which is called a viper design. The RC motors are outside of the robot's shield Also, the processor is dual high current motor controller board and the battery is Standard 7.2V hobby battery pack. The competitor used two line sensors, two opponent sensors at the front, and two side distance sensors. the language used to program the is C++. Clear acrylic and stainless steel are the materials used to construct the cover for the robot.



(Figure 3.1)

[Include in Background Report and all subsequent reports.]

3.2.2 Existing Design #2: Autonomous Nano

Initial research into nano-sized sumo robots yielded limited results, however, there were many system level reports pertaining to nano-sized autonomous robots. DASH, a dynamic sixteen gram hexapedal robot built by electrical engineering and computer science students at the University of California, Berkeley provided valuable insight into autonomous functions, and more importantly, designs tailored to reach the max power density available in a system. The robotic functions where they experienced high inefficiencies were power transmission, internal imbalance, and material selection. The following is a bulleted list of issues that were experienced during design and their solutions to the problem..[13]

- Common brushed DC motors contain bulky ceramic stators and copper windings that have a large mass in comparison to their volumetric displacement.
    - The solution they arrived at that is applicable to our project is using micro drive neodymium stator DC motors. By using motors with rare earth neodymium magnets the overall size can be reduced due to the increased efficiency.
- For nano-sized robotics one of the most crucial factors is a high strength to weight ratio. Finding a suitable combination is often difficult and can become increasingly expensive.
    - The material they ultimately settled on was a carbon fiber composite. The compromise between aluminum and carbon fiber had many trade offs. Advanced composites can be extremely difficult and more importantly expensive to shape when compared to aluminum, however, many standardized carbon fiber shapes are being manufactured and can be a lightweight, and even more ductile alternative to aluminum,

[Include in Background Report and all subsequent reports.]

3.2.3 Existing Design #3: Taurus: Radio Controlled Combat Robot UIC

The following section describes pertinent information on the design of radio controlled combat robotics, specifically, the components of their mechanical and electrical systems. The content of this section references a consultation with N. Grier, a Mechanical Engineering graduate student from the University of Illinois, Chicago. Grier, along with a team of mechanical and electrical engineering students participated in robotic combat competitions with both R/C and autonomous type robots. The following is a summarized list of design considerations, and a description of electronic components specific to radio controlled systems[14]

- Electronic Speed Controllers (ESC): ESC's are buffers that take input commands and provide PWM signals that allow precise control of drive motors or servos. While many microcontrollers have output pins that emit PWM signals, eliminating the need for an ESC, an ESC may still be necessary due to an input voltage higher than what the microcontroller is capable of. Considerations for choosing the right speed controller include:
    - Number of control channels: Each channel is dedicated to one output load (i.e. motor)
    - Battery eliminating circuit (BEC): A BEC draws power from the input power supply and eliminates the need for separate power source to supply the ESC.
    - Input Method (R/C, Serial,Analog): The radio control input relies on signals from the receiver, opposed to the serial input, which would receive signals via the microcontroller.
    - Reversibility: Some ESC's are not able to switch polarity and, therefore, cannot run motors in both CW and CCW directions

- Motors: Dc motors will be responsible for steering and driving the robot. A sumo bot with greater agility and thrusting power will translate to a better design and ultimately a greater likelihood of winning. Dc motors that we will concentrate on for driving the robot include brushed, geared, and ungeared types. Brushed motors are the most common type used for such applications due to their durability, torque output, and programmability. Internally geared motors include a gearbox that help to reduce weight and overall size. Their output speed is reduced significantly, but as a result have an increased output torque that makes them especially desirable for compact designs. Ungeared motors come in a larger variety of input requirements making design less restricted, but often require larger, more cumbersome, drive trains to step down the speed and step up the torque. The most recent and relevant technological improvement has increased dc motors efficiency by implementing neodymium stators. By replacing ceramic magnets with rare earth neodymium magnets the current is used more efficiently and translates to higher speed/torque ratios for an overall lower unit weight. In summary we plan to further research motors, especially the following attributes.
    - Brushed DC motor
    - Internally geared
    - Preferably a motor constructed with neodymium stators

[Include in Background Report and all subsequent reports.]

3.3 Subsystem Level

Comparing different technology that fall under the same category helps the team by having options. Read etch has been done so the team can have ideas of what parts and subparts can be used for the robots.

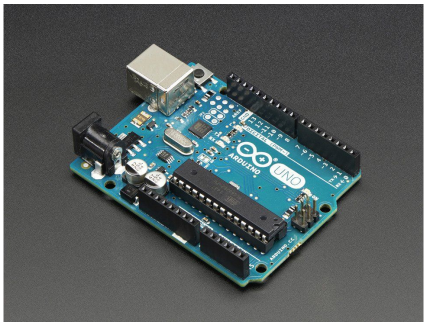
3.3.1 Subsystem #1: Processors for autonomous robot

A processor or a microcontroller is basically the robot's brain. For an autonomous robot, the processor receives signals from lines and opponent detectors to send them to the motor controller to speed up. The reason why robots should have microcontroller and motor driver at the same time is because the microcontroller does not have enough power output. And, the motor controller cannot decide the proper speed for the motors. In conclusion, the importance of a microcontroller in a robot is to compute the proper speed for motors in certain situations and receive and send signals.

[Include in Background Report and all subsequent reports.]

3.3.1.1 Existing Design #1: Arduino Uno

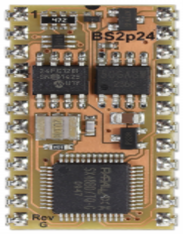
The University of Petrosani in Romania constructed an autonomous sumo robot and they used an Arduino Uno (figure 3.1 shows an Arduino Uno R3) as a processor for the robot [6]. This type of brains could be programmed using programs similar to C++ like Arduino language. If the user gives orders to, this processor is able to run motors, turn on lights, etc. also, it has dimensions of approximately (since there are different versions of Arduino Uno) 75.14 x 53.51 x 15.08mm and weigh 28.00 gram [7]. The average cost for the board is around 30.0$ with an operating voltage of 5V and clock speed of 16mHZ.



(Figure 3.2)

3.3.1.2 ***Existing Design #2:*** basic stamp 2p24

Another source used basic stamp 2p24 as a processor for their sumo robot. This brain can be programmed using a language called PBASIC. The dimensions for it are 31 x 16 x 9 mm and requires a voltage of 5-12 VDC. The approximate cost for the board is 80.00$. the clock speed of the processor is 20MHZ [8]. An advantage about this processor is that PBASIC is an easy language to learn.



(Figure 3.3)

3.3.1.3 ***Existing Design #3:*** Atmel ATmega644

Another user who used his sumo robot to compete at Robothon in 2007 used Atmel ATmega644 as a processor for his robot [4]. It could be programmed using C++. The processor has different speed grades depending on the input voltage. If the user demands a speed grade of 10MHZ or 20MHZ, then the voltage input must be 2.7-5.5V or 4.5-5.5V respectively. The processor has 40 ports and the cost is considered cheap compared to other processors.

3.3.2 Subsystem #2: Autonomous Sensing

Robotic sensors provide quantitative data of its environment and provide the necessary inputs for a controller to dictate the proper command. The autonomous robot will need to perceive how it is oriented to its surroundings, the boundaries of those surroundings, and its proximity to the opponent. The most recent and relevant sensors for an autonomous sumo robot are discussed in detail below.

[Include in Background Report and all subsequent documents]

3.3.2.1 Existing Design #1: Proximity Sensors

Proximity sensors are very simple but yet very powerful. The sensor itself reads to see how far an object is from the sensor itself and provides feedback to the motherboard. A perfect example may be to avoid collision by detecting the distance of the obstacle. Once the feedback is received, then the motherboard can decide to to proceed with that information, whether it is to stop to avoid collision or to just simply turn the robot [9]. The reason why this is relevant to the team's robot is because we need our autonomous robot to be able to detect the opponent. Once the sensor finds the opponent, then it will know what to do. In addition, the robot must detect when it is close to the ring's boundary lines so it does not go out the ring.

3.3.2.2 Existing Design #2: Encoders

A common issue that can arise from proximity sensing or ultrasonic range detection is failure to provide adequate data to the the microcontroller with respect to its own current location within a boundary, or in our case, a sumo ring. By implementing an electro-mechanical encoder the robot will be able to sense and log both velocity and linear displacement. Aside from valuable data that would benefit us as designers more than the actual microcontroller, encoders could be used as a failsafe to notify the controller if the the robot has travelled too close to the exterior ring. Continuous tracking data produced by the encoder during preliminary testing could also be used to more accurately calibrate the robot's environmental perception and reduce the number of environmental inputs necessary to provide adequate autonomous functionality.

3.3.2.3 Existing Design #3: Force sensors

Force sensors can become very helpful in a combat robot. A force sensor senses the force between two objects or surfaces, in this case, between the two robots when in contact. The sensor is sensing the whole area of the surface that is applying force [11]. Adding this feature to the robot can give us an advantage due to the reason the robot will know if it needs an extra push when it is in combat.

3.3.3 Subsystem #3: Battery

Batteries have revolutionized the world by being able to make devices portable. Batteries vary in type and the chemical compound that it is made up of. Different types of batteries will exceed performance when applications vary. For example, a lead acid battery will suit best in applications where large amount of power is needed and weight is not a concern. A nickel cadmium battery is best used when long life and low price is needed. These are just a few examples of batteries and their applications [12].

3.3.3.1 Existing Design #1: Lithium Ion battery

Lithium batteries are the fastest growing types of battery and was first commercialized by Sony in 1991. These are best used when a high-energy density and lightweight is the importance of the application is needed in. Because of several chemicals, the battery itself is fragile and and must contain circuit protection. The most common applications for this type of battery are computers, tablets and cell phones [12]. Our robots must be portable in order to compete so looking for the best options of our battery setup can give us an advantage if lithium ion can be super lightweight.

3.3.3.2 Existing Design #2: Lithium Polymers

Dating back to the 1970s, the first lithium polymer was created from a dry solid polymer electrolyte. What makes this battery special is that it may be a flexible battery and it is not limited to size. It is also a very safe due to the slight chance of electrolyte leakage and can have a profile of a credit card. Although ,it may have less charge cycle count compared to lithium ions and can become expensive to produce [12]. Due it being safe, this battery may be able to last more in combat due to its slight chance of leakage.

3.3.3.3 Existing Design #3: Nickel Metal Hydride

This type of battery is mainly used for satellites, it is good to compare batteries in many forms. They are bulky in size and expensive to produce. This calls for a more stable battery and has a 30-40% higher battery capacity compared to the other types. It is also the most economic friendly type of battery in the long run. Due to it expensive set up, this battery needs a lot of maintenance and it is much more complex than any other battery [12]. Due to it being expensive, this setup would not benefit us for the team's robots. This is relevant due to the attractive specs of it having a high battery capacity and is economic friendly.

DESIGNS CONSIDERED

[Using the information and data collected as a result Current System analyses and benchmarking (if used), the design team should complete a group brainstorming session of how to solve the design problem(s). Provide **at least TEN complete possible designs for your system. Each possible design must include all subsystems in your functional decomposition**. List advantages and disadvantages of each using brief but compelling technical analysis.]

[Do not confuse Designs Considered with Existing Designs. Designs Considered are new concepts you generate. Existing Designs are entities that currently exist.]

[Include in Preliminary Proposal and all subsequent reports.]

3.4 Design #1: Descriptive Title

[Describe in detail a design solution you have considered. Include a list of Pros and Cons.]

[Include in Preliminary Proposal and all subsequent reports.]

3.5 Design #2: Descriptive Title

[Describe in detail a design solution you have considered. Include a list of Pros and Cons.]

[Include in Preliminary Proposal and all subsequent reports.]

3.6 Design #3: Descriptive Title

[Describe in detail a design solution you have considered. Include a list of Pros and Cons.]

[Include in Preliminary Proposal and all subsequent reports.]

[Note: You must discuss **at least TEN** Designs Considered. More are encouraged. Copy & paste additional headings as necessary. Be sure to update your Table of Contents.]

4

DESIGN SELECTED

4.1 Rationale for Design Selection

[Use this section to explain / justify the design solution selected. Your selection must be one of the possible solutions described in the previous chapter or a combination of several, and you should discuss why, given the various advantages and disadvantages of all of the options given, the selected solution is most appealing. All teams must include a Pugh Chart and Decision Matrix to justify their findings. Use an Appendix for any lengthy engineering calculations or large figures/tables.]

[Include in Preliminary Proposal and all subsequent reports.]

4.2 Design Description

[Use this section, with additional subsections as appropriate, to fully describe your design. Show engineering calculations (or if lengthy, place them in an Appendix and refer readers to that part of the report) to justify the proposed design. Create, and refer to, detailed engineering drawings, 3D models, parts and materials used, simulations, facility layouts, or other appropriate tools to completely specify all aspects of the design. Include pictures of the prototype constructed during Fall Semester with a description of what you learned by doing the prototype and what changes to the final design were made due to the construction of the prototype.]

[Include each individual Analytical Analysis as a separate subsection in Section 5.2 (i.e. 5.2.1: Stress/Strain Analysis, 5.2.2: Economic Analysis, etc.) The full CAD package of the final proposed design must be included in the Appendix, but you may add several views here to discuss the CAD package.]

[Include in Final Proposal and all subsequent reports.]

5

PROPOSED DESIGN

[Use this chapter to provide a complete description of how you plan to implement your design (e.g. by fabricating a prototype, creating a proof-of-concept, programming a simulation, writing software or operator procedures, or making physical and operational changes to the current system.). It must include a detailed breakdown of all resources needed to implement the chosen design: information, people, materials, facilities, etc. As appropriate, include a complete bill of materials, including sourcing (if manufactured, by whom and how, if purchased, from what company). Unless your bill of materials is very brief, place it in an Appendix. A comparison of the implementation costs and budget must be included. The plan must also include a detailed schedule for all implementation activities. Include an Assembly view and Exploded view of the CAD model for your proposed design.]

[Include in Final Proposal and all subsequent reports.]

6

IMPLEMENTATION

[**Note**: This section documents all design / prototype changes made **before testing begins** (i.e., changes due to implementation issues). Changes made due to test results are to be described in the next chapter.]

[Include in Midpoint Report and all subsequent reports. Continually update this section as you progress in ME 486C Spring semester.]

6.1 Design of Experiments

[Each team will be required to do a Design of Experiments (DOE) at the beginning of the Spring Semester. Include a description of the experiment, the statistical results, and the conclusions drawn from the DOE here.]

[Include in Midpoint Report and all subsequent reports.]

6.2 Design Changes

[Discuss how the implementation actually occurred and describe problems encountered. Update this section as the project progresses, and add sections as necessary if the design is subsequently changed due to implementation problems. For design changes, include engineering calculations and revised part drawings or other design specifications (probably in appendices) as necessary.]

[Include in Midpoint Report and all subsequent reports.]

7

TESTING

[Discuss your testing plan. Referencing the Chapter 1 design requirements, listed specifically and exactly, explain how you independently and scientifically tested each. Provide complete test results and discuss problems encountered. **Clearly show which of the design requirements are satisfied, which are not, and which are ambiguous.** For every failed test, (i) provide a compelling technical argument of why success was expected, (ii) provide a detailed and technically justified redesign to address the problem including supporting engineering calculations, part drawings, and other documentation as necessary

[**Note**: This section documents design / prototype changes made **after testing begins** (i.e., changes made due to test results). Changes due to fabrication issues should be described in the previous Chapter.]

[Include in Final Report only.]

8

CONCLUSIONS

[Include here a Post Mortem analysis of the project following the guidelines given in lecture. Organize the information into two categories as you answer the seven fundamental questions of a Postmortem: “9.1 Contributors to project success” and “9.2 Opportunities/areas for improvement”]

8.1 Contributors to Project Success

[Answer the seven fundamental questions of the Postmortem in a report format and include information on how the project was a success here. DO NOT list the questions and your answers; compile your answers into cohesive paragraphs of information that flow from topic to topic.]

[Include in Final Report only.]

8.2 Opportunities/areas for improvement

[Answer the seven fundamental questions of the Postmortem in a report format and include information on how the project could have been better. DO NOT list the questions and your answers; compile your answers into cohesive paragraphs of information that flow from topic to topic. Structure this section in a positive voice; it is unwise to ever write formal reports that are negatively worded.]

[Include in Final Report only.]

9

REFERENCES

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12) By Submitting This Form, You Are Providing Your Express Consent to Receive Electronic Communications from Battery University. "What's the Best Battery?" *Basic to Advanced Battery Information from Battery University*. N.p., n.d. Web. 27 Sept. 2016.
13) Birkmeyer, P., K. Peterson, and R.S Fearing. "DASH: A Dynamic 16g Hexapedal Robot." *Department of Electrical Engingeering and Computer Sciences University of California, Berkeley* (n.d.): n. pag. Web.
14) Grier, Nicholas. "Taurus: R/C Robot." Telephone interview. 24 Sept. 2016.

APPENDICES

[Use Appendices to include lengthy technical details or other content that would otherwise break up the text of the main body of the report. These can contain engineering calculations, engineering drawings, bills of materials, current system analyses, and surveys or questionnaires. Letter the Appendices and provide descriptive titles. For example: Appendix A-House of Quality, Appendix B- Budget Analysis, etc.]