Restated Project Definition Report

Team 23
Development of a Multi-functional Mobile Robotic Platform

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ABSTRACT

Each year the American Society of Mechanical Engineers (ASME) hosts a unique Student Design Competition (SDC) at its Student Professional Development Conference (SPDC). For the 2016-2017 school year teams have been tasked with the development of a multi-functional robotic platform to compete in a series of five athletic-based competitions: a sprint, tennis ball throw, stair climb, golf ball hit, and weight lift. While the components of the robot are still being finalized, our team has continued to iterate our design such that it addresses all of the imperative criteria for the competition determined by the team to be mobility, power, stability, size, durability, and safety. In the future, the team is looking forward to ordering and machining the remainder of the components and starting the assembly process so that testing with the actual unit can begin.

ACKNOWLEDGMENTS

Team 23 would like to thank Dr. Camilo Ordonez and Mr. Keith Larson for their expert technical advice on the structure and many of the mechanisms to be employed by our robot. Additionally, team 23 would also like to thank the FAMU-FSU College of Engineering for funding this endeavor and as well as the ASME for organizing this competition.

1. Competition Overview and Approaches

There are some strict requirements set by the competition organizers which all robots must satisfy. The first, and arguably the most limiting, is that the robot must be able to fit within a 50 cm x 50 cm x 50 cm sizing box. This includes not only the robot itself, but the controller, any spare batteries, any spare parts, and even the weight which will be used in Event 2. This is especially limiting as the more weight which we would like to lift, the smaller the robot itself will have to be in order to accommodate the extra weight.

Also, each robot is only permitted to use conservable forms of energy. Therefore uncontrolled chemical reactions like gasoline or gunpowder are not permitted and rechargeable batteries of any kind are the only allowable core power source. Other conservable energy sources such as springs or compressed air are permitted so long as the energy can be restored to its initial state by the robot at the end of each event.

1.1: The Sprint

The first event in the competition is rather straightforward. Each robot must complete a straight-line sprint down a ten-yard long track and return. The event is scored based on the fastest time with penalties for each time the robot touches the sideline. The team is taking a rather unorthodox approach to this event. Early on in the competition, the event organizers responded to a question from another team and, in doing so, revealed that during any event, a robot is allowed to segment itself into smaller pieces as long as those pieces stay attached the entire time.

Team 23 intends on taking advantage of this caveat by employing the use of a small extending shaft, or projectile, which would fire out in front of the robot as it leaves the starting box, make contact with the wall, and return to its initial configuration as the robot moves back into the starting box. Powered by a small DC motor, the team believes that a design such as this has the ability to net a much faster event time than a conventional approach could. Though this is not to say that there is no backup plan. In the event that the competition organizers ban such an approach, the robot will have the capability to move rather quickly using a differential steering system.

1.2: The Lift

The next event of the competition requires the robot to lift a weight of the team’s choosing as high as possible. This event is scored according to the product of the mass lifted and the height lifted. However, a flat 50 cm is subtracted from any measured height which the robot can lift the weight. This is, not coincidentally, the maximum robot height allowable in the completion. This forces the team to attempt to start the lift at as high of a height as possible in order to minimize score. The weight being lifted must be in the form of a rectangular prism with no gripping or holding features whatsoever.

While preparing for this event, the team is taking the approach of lifting as heavy of a weight as possible a short to medium distance. In order to maximize the amount of weight the robot will be lifting, the team will be filling rectangular containers with fine, lead shot, typically used in shotgun shells. This will allow a maximization of empty space as each rectangular prism can be of arbitrary size and filled to capacity with lead such that virtually all of the unused space in the robot is filled with lead. In the event that cost constraints prevent the use of lead shot, other options, such as wet sand, are equally viable.

To perform the lift itself, the team decided to use a device known as an air jack. These are pneumatically-powered devices capable of exerting very large lifting forces at a very low operating psi. The particular jack that is under consideration for buying is capable of lifting 1.5 tons to a height of about

75 cm. It takes about 45 seconds to inflate completely and 5 seconds to deflate. Because the weight is initially starting at a height just under 50 cm, the team is expecting a very respectable score for this event.

1.3: The Throw

Event number three is straightforward as well. The robot is required to launch a tennis ball as far as possible. The means by which it does this is up to the discretion of the team. Distance for this event is measured on a fixed axis and if the ball falls off center, the distance it traveled *along that axis* is taken as the score, not the total Euclidean distance. The distance the ball bounces and rolls after its initial landing is also included in the score.

The team's approach for this event is to utilize what is essentially a glorified potato cannon. Employing the same pneumatic system used to inflate the air jack, the robot will pressurize a small reservoir with compressed air and release it into the barrel at pressures approaching 200 psi. Testing and individual personal experiences lead us to believe that this approach will allow for us to launch the ball a significant distance.

The outcome of this event primarily rests in the amount of air that is able to be released into the launch tube as well as how quickly that air can be "dumped". For this reason, further research has been done to investigate methods of optimizing both criteria. It was found that a popular method to achieve effective air dumping is to use the "Supah Valve", a piston-actuated quick-release valve designed by SpudGun Technology Center for this specific application.

1.4: The Climb

This event is markedly more challenging than the ones preceding it. In this timed event, the robot is tasked with climbing up, and then back down, a set of three steps. The fastest recorded time for the robot to do this wins the event and a team is disqualified if their robot falls off of the stairs during the attempt. Each step will be between 8 and 15 cm tall with a landing of *at least* 50 cm^2 between each step. This means that the robot will be able to completely fit on each step while remaining perfectly level. This gives us a very low overall angle of approach to overcome; the maximum angle is approximately 17 degrees.

In order to succeed in the climb, the team decided to design a robot mimicking the "chaos" frame design. Originally developed by ASI Robotics, robots with this frame behave very similar to a skid-steered tank, except that instead of two-static tracks, there are four individual tracks which can each rotate a full 360 degrees about their own axis, independent of each other. This frame has a high degree of dexterity and has been proven to be able to overcome virtually any obstacle, including stairs.

The design adopted by Team 23 is slightly modified from this framework in order to save costs. Instead of each leg rotating independently of one another, the fore and aft legs are powered by the same motor, and thus, paired to rotate at the same angular velocity. Similarly, the tracks on the right and left side of the robot are paired as well such that the robot maintains a differential drive characteristic. The ingenuity of the design lies in the fact that no matter what orientation the legs are in, there is always track contact with the ground. This means that no matter what position the legs are in, the robot will drive and control virtually the same.

This choice of frame offers many other passive advantages which can be utilized in many other events. For example, during the Event 3: The Throw, the front arms can be rotated such that the robot pitches upwards a controlled amount. This will give us control over the exit angle of the ball from our cannon. The arms will also allow us to "stand" during the lift, given that the structure is strong enough, to gain additional height.

Figure 1: The true chaos platform built by ASI Robotics

1.5: The Hit

Arguably the most difficult event, The Hit requires the robot to "hit" a golf ball from the ground as far and as straight as possible. The scoring for this event is similar for the hit except now, the distance which the ball lands from the measuring line is subtracted from the distance traveled along the measurement axis, placing a significantly higher emphasis on accuracy. The ball is only allowed to have a small clearance above the ground, a maximum of 0.2 cm. Additionally, the score distance is taken from the first contact of the ball with the ground, as opposed to the bounce distance taken from the throw.

Team 23 had initially planned to use a pneumatic rotary vane actuator to rotate a shaft attached to a sawed-off golf club in order to strike the ball. However, recent discoveries have revealed that this approach would not result in a distance that could be deemed acceptable for the team. After reviewing the fruits of earlier brainstorming sessions, the team determined that a spinning wheel approach could net in a better score, though much of the robot would have to be redesigned around this change.

The spinning wheel approach is very similar to that of a pitching machine one might see on a baseball field or tennis court. This device works by forcing a ball into contact with one or two wheels spinning at a high velocity. The wheels compress the ball and impart some of their energy onto it. Calculations for this approach resulted in ball exit velocities of approximately 20 m/s using attainable wheel speeds, which is an improvement over the vane actuator design by a factor of three or four. This approach also gives the team much greater control over the exit angle of the ball and its degree of backspin, which can greatly impact the distances achieved.

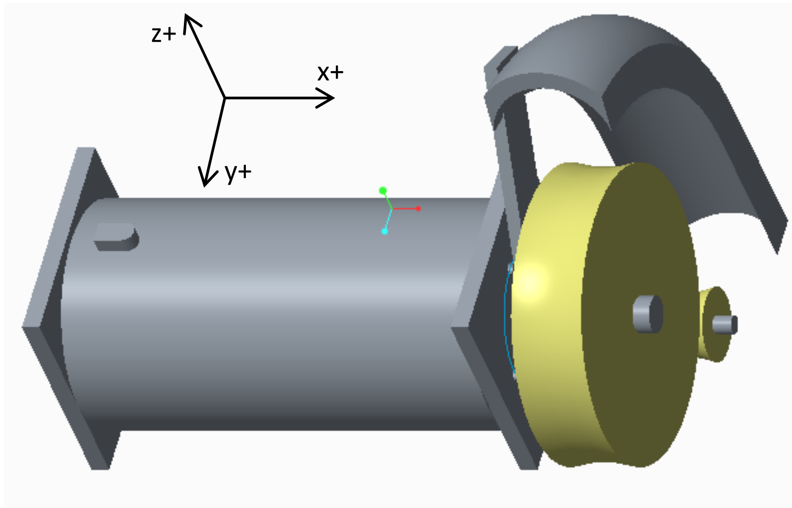

Figure 2: A 3-D model of the assembly to be utilized in "The Hit" event.

To implement this approach, the robot would utilize the chaos frame design yet again. The robot will “stand” over the ball and lower the wheel assembly downwards using a structural system of drawer slides so that it “sucks up” the ball. The ball would be driven vertically and roll up a ramp which is designed to add a backspin in order to increase the distance achieved.

In adopting this approach, there are certain elements which have to be added to the current design. Firstly, it would be prudent to install a laser-alignment tool onto the base of the robot so that it can be made certain that the wheels, and not some other part of the new assembly, will make the initial contact with the ball every time. There will also be two additional motors required. One must be powerful enough to spin up the wheel assembly to the desired velocity. The second need not be as powerful as the first since it will only have to raise and lower the assembly. It will likely do this through a worm gear system attached to a set of drawer slides. Currently, it is Team 23’s highest priority to fully design and analyze this new system so that the lag imparted on our project timeline is minimal.

2. Component Selection and Analysis

2.1 Control

To control our robot, Team 23 needs a microcontroller capable of taking input from a controller. A suitable microcontroller for our robot is the Arduino Uno with USB shield to allow us to connect a bluetooth hub to our device for connection to a controller with bluetooth capabilities. It is likely that the team will need two Arduinos as a result of the sheer amount of onboard electrical components. The handheld controller that will be used for our device is an Xbox One controller since it’s easier to sync with our robot due to Microsoft’s built in library with all of their devices. This will alleviate many of the programming issues which would arise if Team 23 were to use a third party controller such as one from Sony or any other company.

2.2 Drivetrain

In order to drive the system with full authority, a total of four motors would be required. Two of the motors will be used to power the rotation of the arms, and the other two will be used to power the tracks. The front and rear arms will operate independently from each other, as will the left and right tracks. This gives a differential steer capability, while reducing the number of required motors.

The primary motors will be responsible for driving the tracks. For these, we have selected the AM9015 motor with an attached 27:1 planetary gearbox from AndyMark. These motors will be able to provide a constant output torque of approximately 400 oz-in at 150 rpm and will be able to drive a 50lb robot at approximately 3 m/s with an additional gear ratio of 6:1.

Our secondary motors will be used for controlling the motion of the arms. For these, we have selected the RS775 gear motor and Encoder with a 188:1 planetary gearbox also from AndyMark. This motor is ideal for our purposes due to its high cost to torque ratio and will be able to provide sufficient torque to our legs with an additional gear ratio of approximately 12.5:1. We plan on operating both of these motors at their nominal operating points to avoid any possibility of damaging or destroying them during our months of testing the system.

Additional gear reductions on the drive system will take place through a series of sprockets and gears. The primary drive system will consist of only sprockets with the final output shaft mated to the rear wheel of the arm in a shrink fit. The secondary drive system will first transmit power through a sprocket reduction system which will drive the armshaft, a shaft running the breadth of the robot. In this design, a small gear will be affixed to the end of the shaft. In order to actually rotate the arms, a gear must be mated to the inner face of each arm of the robot. When this gear meshes with the gear affixed to the end of the armshaft, it will cause a resultant motion of the arm.

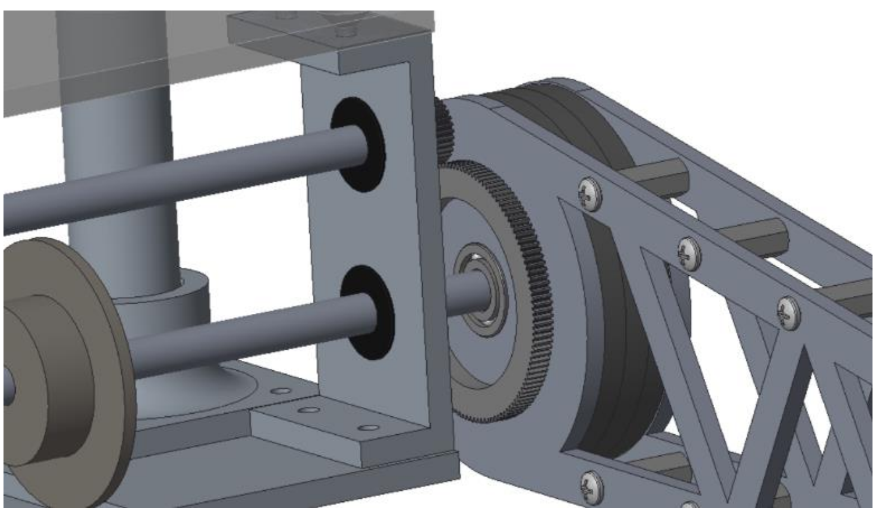

Figure 3: Closeup of the mesh between the arm gear and the gear attached to the armshaft

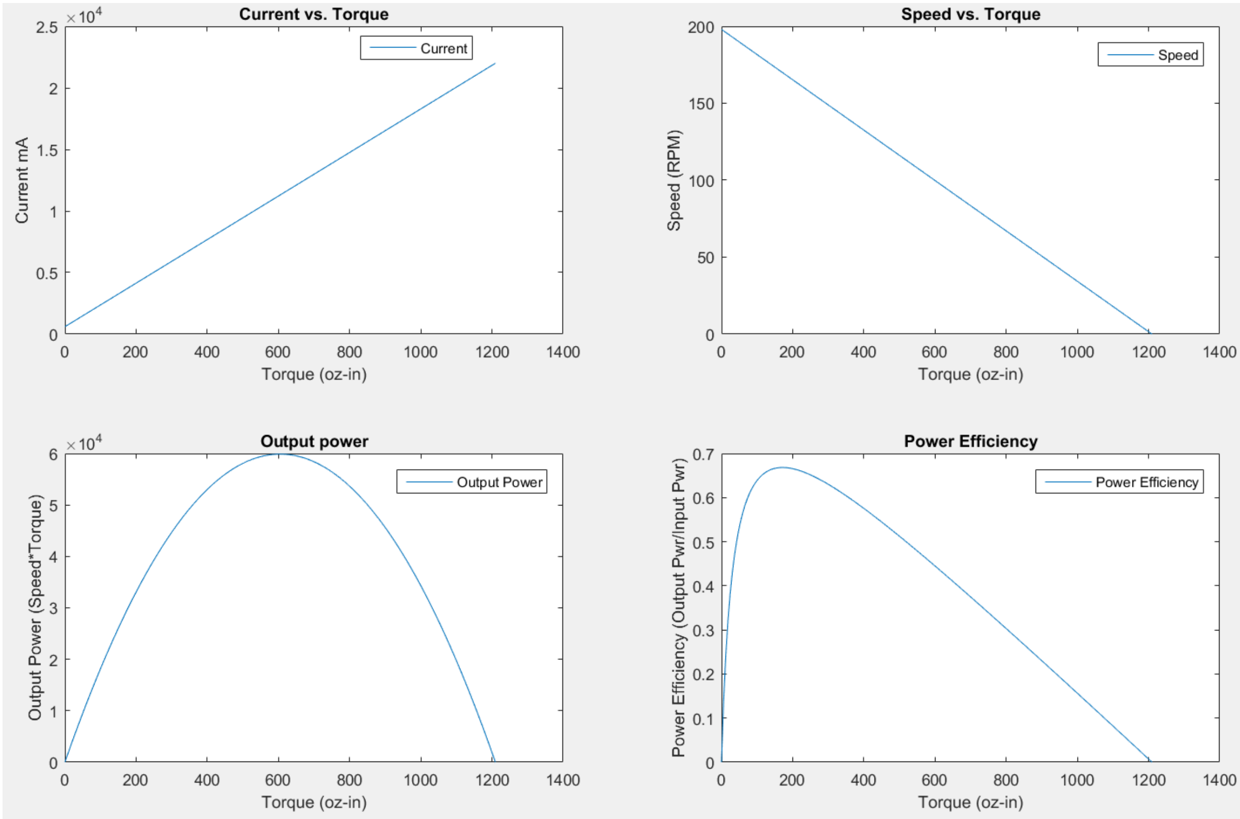

Figure 4: Torque curves of primary (track) motors. Calculated in Matlab

Figure 5: AM9015 gearmotor from AndyMark

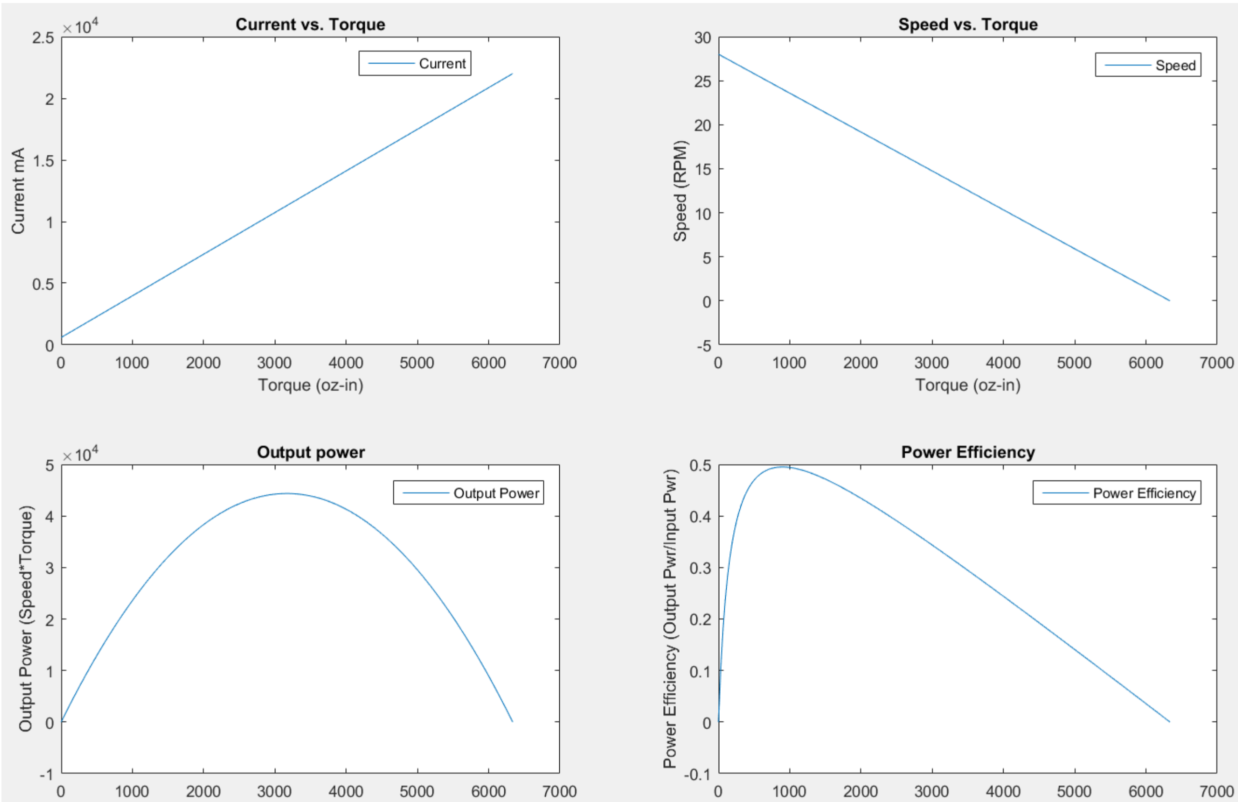

Figure 6: Torque curves of the secondary (arm) motors

Figure 7: RS775 gearmotor from AndyMark

2.3 Pneumatic System

2.3.1 Core

At the core of the pneumatic system lies the air compressor and air tank array. The plan is to use small SCUBA tanks to store the air and power the pneumatic system. These tanks will work great for this design because of their relatively high volume capacity and exceptional psi rating. The air tanks used on the robot will be aligned in a parallel such that the air storage capacity of the robot can be increased dramatically. The current configuration is utilizes a two-tank, 0.5 gal system. However, expansion of this array into a four-tank 1.0 gal system may become possible in the future. The main limiting factor in this approach is the physical space that each tank consumes.

The air compressor being used is a model rated for 200 psi from the manufacturer VIAir. Team 23 has maintained correspondence with VIAIR for a time, and has recently obtained a sponsorship from the company. In doing so, VIAir shipped a best-in-class portable air compressor to the team at no cost. This model has the ability to fill a 2.5 gal tank to 150 psi in approximately 3 minutes. This fill time is much too long to be viable in this competition, however a significantly smaller tank will be used on the competing robot. It was calculated that this compressor would be able to fill a 0.5 gal tank to just shy of 200 psi in 58 seconds. This is perfectly suited to the competition and it is for this reason that the VIAir 480C compressor will be used on the robot.

Figure 8: 480C air compressor from VIAir Corp.

2.3.2 Air Jacks

Air jacks are lightweight devices which use relatively low pressures to lift very heavy objects. They are generally used to lift overturned freight trucks and to lift a car off its axle in order to change a tire. For the lift event, air jack will be placed on the top of the robot. This particular air jack is used to lift a car in order to change a tire by inflating it through the car’s exhaust pipe.

It lifts 75 cm, is hard to puncture, and is designed to lift 1.5 tons. This will be particularly useful during the competition because it will allow the team to lift a weight a relatively high distance in comparison to the weight's heaviness.

Figure 9: An example of an air jack in action. Team 23 is actively looking into using an air jack of similar construction to the one pictured.

2.3.3 Air Cannon

An air cannon is the most promising design to launch the tennis ball. Essentially a glorified potato gun, this cannon will use a release of pressure from the pneumatic system in order to propel the tennis ball accurately along the target axis. It is a relatively simple and straightforward design. The compressor would function to fill the pressure vessels to a desired state and released using a quick-release system. Team 23 is interested in using what is known as the "supah valve" to accomplish this. This valve is typically used in potato cannon designs and is a favorite of enthusiasts in the hobby. This is mainly because of the speed at which it opens and its lack of many flow restricting features seen in many other similar valves. The main concern in using this type of valve is its physical size. If this makes it exceedingly difficult or impossible to implement on the robot, it is possible for the team to construct their own. This is, however, the worst-case-scenario as it would draw valuable resources from other aspects of the project.

Figure 10: A basic "supah valve". The valve to be used by Team 23 will be actuated electronically, unlike the model pictured here.

2.4 Electrical Systems

<u>Motor Relay Circuit</u>

The circuit design for the motor relay circuit will be used for movement and control. This will allow the robot to climb stairs, move in any direction, and set up the arms of the tracks to place itself in different positions for each event. The Motor Relay circuit will operate on a 8-18V Battery Source (shown in Appendix A). This will act as an effective switching mechanism that uses low power signals for control. Switching efficiency is important because it will be able to catch any input faults or incorrect commands during specific tasks. Digital switches will be used for switching between individual motors for different task functions.

<u>Controller</u>

The controller used for the robot will be a Playstation 3 sixaxis controller. The PS Home button in the center of the controller will be used to toggle between the different events. For each event that the controller is toggled to, an LED on the back of the controller as well as an LED on the robot will light up to represent which event the controller's buttons will be mapped to. This is beneficial because it allows the user to select a specific task so if there is any misclick or incorrect input command during the task, the robot doesn't act based on incorrect user input. Both the relay circuit and the controller will be designed so eliminate any possible incorrect commands that may cost the robot any additional loss of power by triggering anything that should be off during the competition or throughout the testing process of this project.

Microcontroller

The microcontroller is going to be the robot's brain and will be helpful in reducing any input error. Developing circuits and products based on microcontrollers is simpler and cost effective due to few additional hardware components required. The commands for the competition are going to be fairly simple and do not require complex computing. Therefore, a simple micro controller is the way to go rather than using a more complex microprocessing unit.

Batteries

Lithium ion/polymer batteries are the best option for powering the robot. They have small dimensions, can be recharged quickly, and have a high energy density. These batteries are typically used in robotics for controlling and require less to power the electric motors. It is in the best interest for this competition to use multiple batteries in parallel. This will allow further design manipulation regarding space and when it comes to possible task assignment. There are disadvantages to using multiple batteries: multiple batteries to recharge and multiple parts of the robot will stop working at different times. However, the way the competition is laid out, it is possible to program the robot so that everything that is not to be working during the task being performed can be turned off using the relay circuit. Everything the robot is designed to do is not going to be running simultaneously, so that eliminates the second concern mentioned for the use of multiple batteries.

3. Design Challenges

3.1 Drive System

Designing a drive system for the primary motors has proved considerably challenging. Space constraints on the robot have lead the team to make considerable compromises. Originally, the design had called for a gear reduction of 3.5:1. However, this is unachievable. Space in the undercarriage of the robot is extremely limited and any sprocket with enough teeth to accomplish this gear ratio is too large. It is very likely that this gear ratio will have to be cut down to 2.5:1 in order to allow necessary clearance of the chain with the armshaft.

Team 23 also had to design a custom sprocket to complete this drive system. There are no sprockets readily available on the market which are able to drive two opposite shafts at the same rate, given the geometry of this system, have an appropriate bore to mate with the motor, and have sufficient teeth to maintain the gear ratio. This sprocket new sprocket is designed such that it satisfies all of these requirements while also providing a more reliable chain drive design. This sprocket is currently modeled and is ready to be machined.

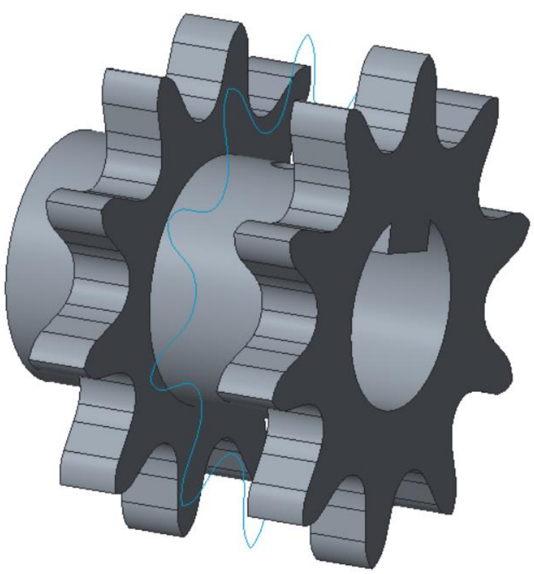

Figure 11: Sprocket designed to overcome some of the challenges of the track-drive system

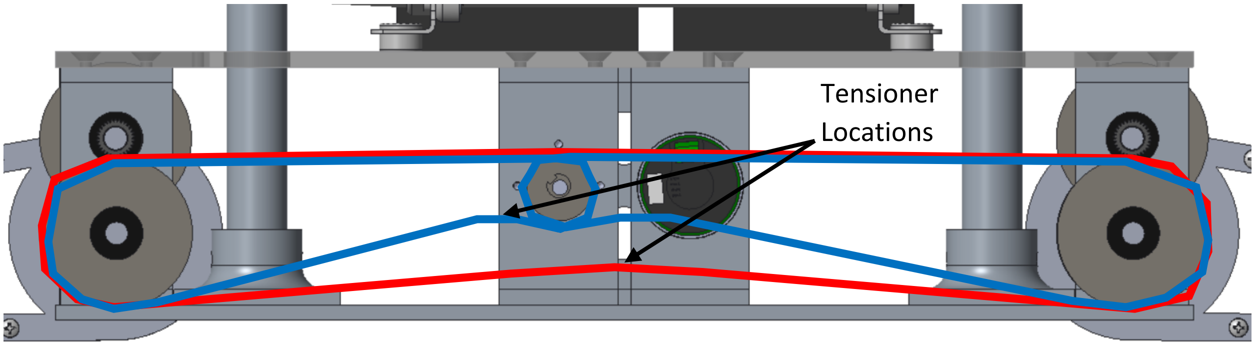

Figure 12: Side view of the track-drive system. Red lines trace the path of the chain with a standard manufactured sprocket. Blue lines trace the path of the chain with the newly-designed sprocket. The new paths are much more natural and less prone to misalignment.

3.2 Hit System

In the process of redesigning the hit system in order to achieve desirable results, the system had to be redone from the ground up. A different approach was brainstormed, and the new design was modeled after a single pitching wheel. This approach was not without its struggles.

The first major struggle with the hit system was finding a way to raise and lower the system while maintaining stability of the spinning wheel. Drawer slides were selected as the structure in order to keep the mechanism stable while it is lowered using a worm gear type of system.

During component selection, it was decided that a wheel would need to be small enough to wedge the ball against the wall while the ball is still perched on the tee, but this is counterintuitive to the purpose of distance, due to the positive relationship between the size of the wheel and the speed of the ball. This was remedied by adding a small second wheel that will rotate freely on a shaft, and a rubber belt will be added turning the previous wheels into pulleys. This will give a textured surface to the wheels that will give it better grip onto the ball, which will impart more energy into the ball, and therefore increase distance. The second wheel will lift the ball along the chute and into the main wheel which will impart the majority of the energy into the ball.

4. Conclusion

Large strides have been made in this project since the Fall Final Report. Component selection has been finalized for all of the vital parts and the ordering and machining process has begun. All necessary components required to construct the arms are in possession. The drive system is nearly completed, as is the pitching wheel assembly. Once a handful of final details have been ironed-out, the components for these assemblies will be ordered as well.

From a programming aspect, a preliminary version of the code used to control the motors has been written and is continuing to develop as parts of the robot come together. However, it is imperative that an electrical system be developed as soon as possible to ensure that all power requirements of the robot can realistically be met.

It is the development of this power system which is the new priority of the team. Now that all other systems have been developed, the selection of the power components and the manner in which they are connected falls onto the critical path of the project.

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Biography

Ryan Alicea is a senior in the Department of Mechanical Engineering at Florida State University from West Palm Beach, Florida and is the project lead. Currently, he is designing and machining the drive system of the robot.

Abdur-Rasheed Muhammed is a Senior Computer Engineering student from Jacksonville, FL currently enrolled at FAMU. He is overseeing the programming aspects of the robot competing in the robot pentathlon under ASME.

Ben Edwards is a Senior Mechanical Engineering student at Florida State University from Tampa, FL. He is currently developing the pitching wheel mechanism for "The Hit" event.

Natalia Cabal is a Senior Electrical Engineering student from Cali, Colombia currently enrolled at Florida State University. She is currently overseeing the circuit design and power aspects of the robot.

Troy Marshall is a senior in the Department of Mechanical Engineering at Florida State University from Panama City, Florida. Troy is the Webmaster responsible for designing and managing the Team 23 website.

Michael Jones is a senior in the Department of Mechanical Engineering at Florida Agricultural & Mechanical University from Ft. Lauderdale, Florida. Michael is the Financial Advisor and is currently overseeing the design of the pneumatic system as it relates to the tennis call cannon.