Worcester Polytechnic Institute

Team Oryx

RASC-AL Exploration Robo-Ops

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Abstract

Team Oryx has sought to fulfill the requirements of the competition by customizing the rover to meet each specific task. Careful deliberation and selection of wheels, motors, and overall design will allow the rover to easily clear ten centimeter obstacles and climb a thirty three percent slope. The three degree of freedom arm that will be implemented is going to be capable of picking up the needed rocks and depositing them in the carriage.

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Introduction

As set by the Rascal Robo-Ops competition, the rover must have ability to be remotely operated from the team's home campus. Within an hour time frame, the rover should be able to find, identify, collect, and carry at minimum, five colored rocks. It should be capable of clearing up to ten centimeter obstacles, be smaller than one meter by one meter by half a meter and weigh no more than forty five kilograms. The collecting mechanism for the rover should be capable of picking up rocks ranging from two to eight centimeters in size and weighing twenty to one hundred fifty grams.

Methodology

Drive-train

The drive-train for team Oryx's rover was designed to enable it to clear ten inch obstacles, drive on sand, and climb a thirty three percent slope. It was initially arranged for the drive train to use six wheels for stability and traction. After some deliberation, it was later decided that four wheels would be sufficient enough to allow skid steering with the added benefit of less friction from the wheels. The rover is moved by four direct driven Maxon motors with planetary gear boxes to allow it to be tank driven with skid steering. Having four motors instead of two also removed the need to run an unreliable chain to connect the wheels.

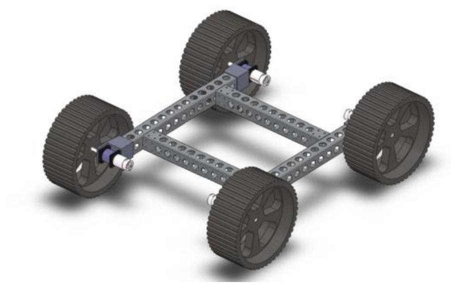


Figure 1: Design of Frame and Drive-Train

Arm

It was found that the Arm was most effective if it had a large range of motion; so the rover would not waste energy repositioning itself. The turret also needed some sort of camera to give the operator feedback as to what exactly was being picked up. Furthermore, looking at all the previous rover designs made by NASA, they all had one thing in common, they used scoops for arms. This design greatly simplified operation and did not over-complicate the griper mechanism.

Figure 2: Arm and Griper Design

Software

Java was chosen as the software language for the rover due to the team's familiarity with it as well as the relatively high level of it. Not having to perform much abstraction will aid the team in rapid development of the software. Additionally, Java's abstraction of network capabilities will simplify communications between the rover and WPI's campus during the competition. The final reason why Java was chosen was the large number of pre-written libraries that the team can utilize. Utilizing these libraries will save the team a lot of time and effort which is a priority due to the time constraints of the conversation.

Power Systems

In order to power the rover for the full duration of the competition, it was necessary to calculate the average power consumption of the major drawing components. Because Team Oryx's rover uses a netbook to drive it, this component runs off its own independent batteries. Since the main components draining the batteries are the driving motors, the batteries have to be capable of handling their loads. Furthermore, the batteries have to be light enough to keep the rover within the weight restrictions, as the batteries make up a large portion of the weight.

Camera

To suit the needs of the competition, the team decided to use two Axis network cameras, a P55 and M1011. The cameras needed to have relatively good resolution, low network bandwidth usage, and one of the two needed to have pan, tilt, and zoom capabilities (P55). The P55 will be the primary camera for the rover and will be located on a boom while the M1011 will be used when picking up rocks. The camera was perhaps the most important aspect of the design. The competition would be lost without a good camera, as it would be nearly impossible to find any rocks.

Figure 3: Axis Boom Camera

Analysis

Drive-train

Knowing that the maximum weight of the rover can not exceed forty five kilograms, it was possible to calculate the force required to move the rover, therefore yielding an approximation of which motor to purchase. The calculation was done at the point where the motors would require the most torque to get the rover to move. Logically, this point was when the rover would be starting at a standstill on the thirty three percent grade slope.

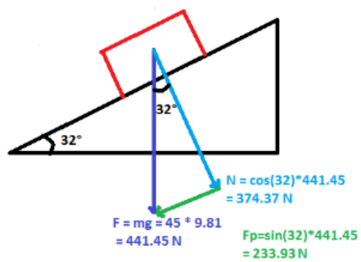


Figure 4:Force Calculations on Slope

Using the information calculated above, the total force the motors would need to overcome could be calculated by finding the force of the rover due to gravity along the slope. This meant that the motors would have to be able to move at least 233.93N from a standstill on a slope.

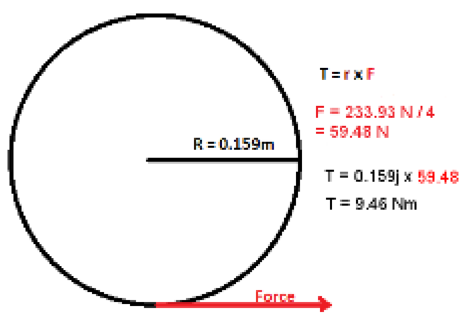


Figure 5: Torque Calculations

In order to find the torque necessary to move the rover, a few simple calculations were applied to the wheel. To determine the necessary torque, the radius of the wheel was crossed with the total force the rover had to move (divided by the four motors). The maximum necessary torque turned out to be 9.46Nm (assuming a near infinite coefficient of static friction between the wheels and the ground) .

With the motors donated by Maxon motor corporation, the stall current force was ten newton meters, so these motors suited our needs well. The snow blower wheels were chosen because of their ability to handle nearly all terrains; Their grippy and deep treaded nature suited the team’s purpose well.

Arm

The arm of the robot is designed with 3 degrees of freedom. It allows for ease of control, while still providing an ample range of motion.

Turret

The pivots about a ball bearing turret, with a custom designed gearbox. This gives it the ability to reach rocks located 270 degrees about the robot. Having a turret makes maneuvering the arm much easier, allowing robot and arm control to be split between two people

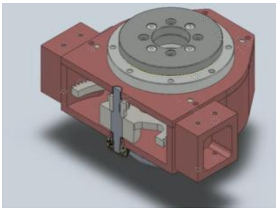


Figure 6: Gearing and Ball bearing for turret

End Effecter

The scoop allows for a simple, yet effective solution to pick up the rocks. This is more efficient then our original 3 fingured griper design, because it can be operated more quickly and does not require the same precision. The scoop will contain holes to allow excess dirt to spill out of the griper, while retaining the goal rock. The camera mounted directly above the scoop gives the operator the ability to see exactly what the scoop is picking up and anything in the immediate vicinity of the rover scoop.

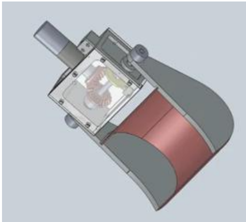


Figure 7: Scoop (without holes)

Software

One of the major design decisions for the rover's software was whether to use transmission control protocol (TCP) or user datagram protocol (UDP) when communicating across the Internet. UDP is the simplest to implement, however it lacks some of error correction and data integrity aspects that are found in TCP. The team decided that TCP was well worth the added complexity in order to gain these aspects, especially so when considering the time sensitive nature of some of the packets that will be sent; such as the wheel encoder values.

Power Systems

As for the batteries, once the motors were chosen, it was just a matter of calculating a worst case scenario on the power draw from the motors and other electrical components. Because the Maxon motors' specification sheet stated that their continuous current draw would be seven amps and peak draw would be eleven to twelve amps, it could be determined which battery would be needed. Knowing that the peak current draw would only be achieved for short periods of time when starting the robot from a standstill, it was assumed that the average current draw per motor for the competition would be roughly ten amps. So to power just the four motors, the rover would require a forty amp hour battery. In order to obtain the maximum power to weight ratio, lithium polymer batteries were used.

Results and Testing

Drive-train


Figure 8: Testing on Campus Stairs

Upon testing the drive train, it was clear that it exceeded the teams needs and expectations. The rover was able to easily navigate sand, steep slopes of upwards to thirty five degrees and higher, and overcome obstacles ten centimeters in height. The main concern in using skid steering and deep treaded tires was turning capabilities. After attempting to turn in place from a complete stop, it was discovered that the rover executed this perfectly. We also drove the rover up tree stumps, up stairs and around campus for a long span of time to test its endurance. We also experimented with motor failures, finding that we can still operate the motor with up to two failed motors (one on each side.)

Arm

Although not complete, the Arm should be capable of performing as expected to pick up rocks. The only downside to the current design is that it was built on the assumption that the rocks would be placed on a giving surface like sand. We using our prototype scoop, we found that the Arm will not be able to pick up a rock on a solid surface like concrete or cement as well as on a sandy surface. This should not prove to be a problem, seeing as the JSC Rock Yard has no solid surfaces. Also, the scoop has the added downside of picking up unintended items along with the rock, but small holes in the scoop allow for some of this excess material to be sifted out.

Software

The current version of the software is capable of correctly displaying the two Axis network cameras located on the robot. In addition the user has full control of the frame rates of both cameras as well as the pan, tilt, zoom functionality of the P55. Furthermore, basic drive functionality has been written for the base platform. The next revision of the software will enable the user to control the robot over the Internet via TCP as well as enabling more advanced drive functions such as velocity and position control.

Power Systems

The current battery system is capable of lasting the duration of the competition according to the calculations made. Because the rover has one set of batteries powering both the rover itself and a netbook, it is desired that the netbook last longer, as it will be the brains of the robot. This is why there was special care taken to make sure the netbook's battery life is much longer than the rover's overall running time.

Camera

The color pan tilt zoom camera from axis communications was immensely helpful in giving us eyes to drive the rover. Alone, the zoom allows for the operator to stay in the current location and scan the landscape for rocks with the forty eight times zoom. A downside to having a panning camera is that the operator can get confused as to what position is forward for the rover. To compensate for this, the graphic user interface for the operator has a home button which the operator can press and will pan the camera to the forward facing direction of the rover. Although we have yet to attach the camera to the rover, we tested how it reacts to a mobile platform using a preexisting high-speed fixed wheel platform. This proved that our camera will be stable and useable even while driving over rough terrain.

Public Outreach

Facebook

As a way to easily share videos, and photos with the public a Facebook group entitled “WPI Robo-Ops Team Oryx” was created. This has several advantages over a conventional website. Having a team Facebook allows anyone on the team to add posts, pictures, and make changes that relate to what they are contributing to the project. For example, if someone was working on mechanical design it is unlikely that the team member managing the website would be able to report on it effectively. Also, Facebook gives each member the ability to communicate with people in an informal manner, telling the public what they are doing without having to polish what and how it is said.

Twitter

Twitter also gave our team the advantage of being able to informally communicate with the public. Using twitter, people can give quick and up to date status reports on how the rover is developing, what recent components have been added, when people are meeting and what design decisions are being made. This also gives us another method of communicating with other team members, outside of email and meetings. It enables us to quickly share ideas as well as the status of our individual tasks.

Website

As the main framework linking together all aspects of our web presence, we have our own web domain “http://robo-ops.wpi.edu/WPI_Team_Oryx/Home.html.” This gives us a more flexible platform where blogs can be written, information about team members can be found, links to other sites and stream competition footage can also be found. We consider the website to be the most formal representation of our team, and it is a useful tool for respectfully recognizing our sponsors as well as making more official project announcements.

Video

Our three minute video clip is probably the most efficient way of communicating to the public who we are and what we are doing. We give a broad overview of what Robo-Ops is, what we have achieved as a team so far and how we plan on completing in the upcoming forum. We also gave a general overview to anyone unfamiliar with the history of planetary rovers, covering both Russian lunar rovers as well as US mars rovers. This video will give a short synopsis of our project, and will be both informative and concise.

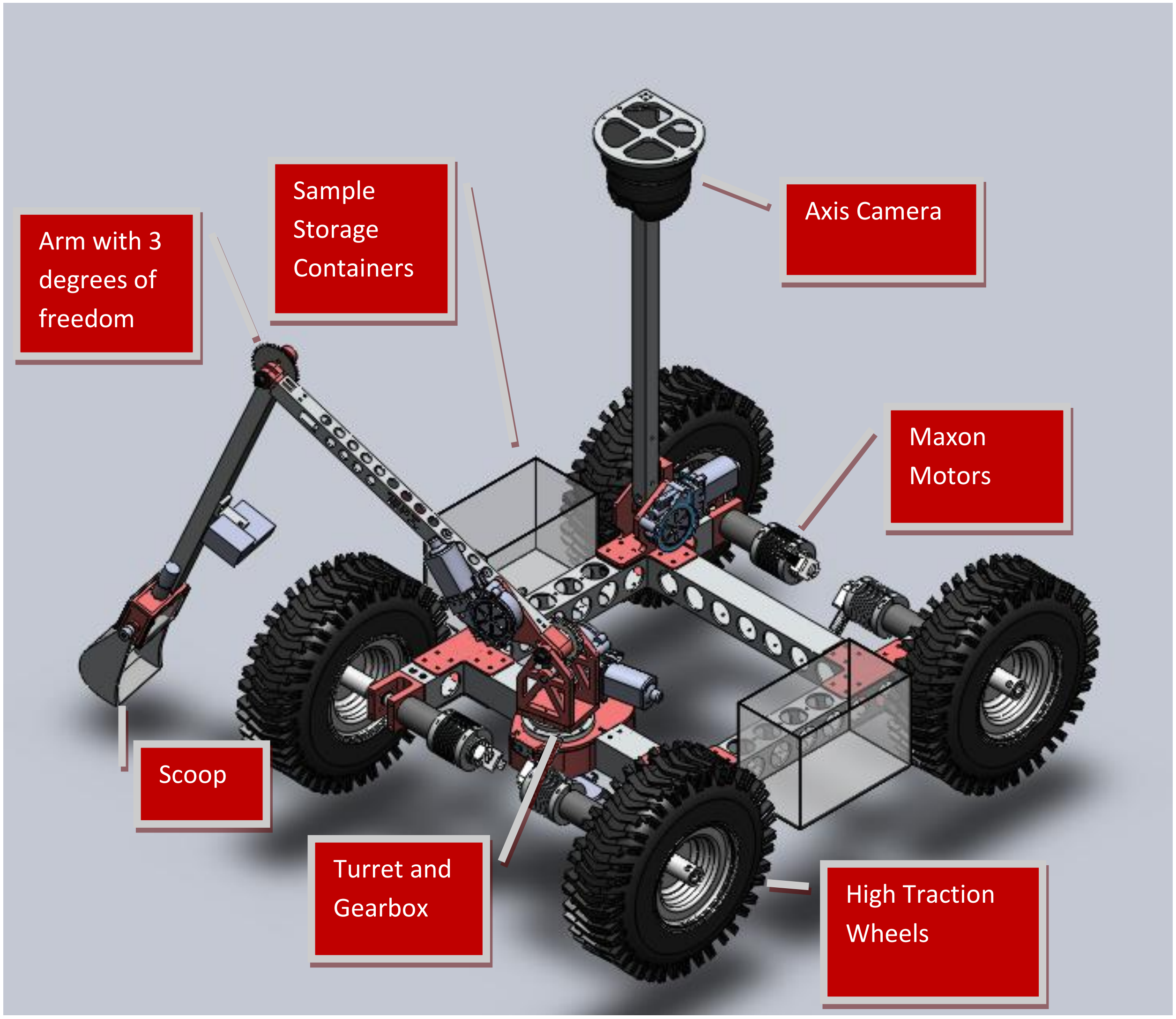
Public Outreach Events

The team's leader in public outreach is a member of a club which invites intercity children from a local group to come to campus to learn more about engineering. Unfortunately, due to transportation issues, they were unable to attend our scheduled robot presentation in which we would explain what we were doing, as well as allow children to control our robot via a hand-held controller. This group comes to campus every Thursday, and we plan on rescheduling this presentation to a later date before the competition.

Conclusion

In conclusion the rover has had a lot of thought put into it so that all the competition mandates could be fulfilled. The rover has everything it needs to accomplish the given tasks and gives WPI a good standing in the competition based on the current design. The Maxon motors are able to drive the rover from a thirty three percent slope from a standstill and the camera gives us a good view of the surroundings. The turret and scoop are capable of finding, picking up, and identifying the rocks, and our batteries will be able to last the duration of the competition. Finally, the netbook and network card will be able to communicate with our home computer, allowing the robot to be remotely driven

Appendix A: Solid Works Assembly



Appendix B: 2D Drawing Representation