University of Arkansas – CSCE Department
Capstone II – Final Report– Spring 2020

NASA Lunabotics Robotics Mining Competition

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Abstract

Every year NASA presents a contest for colleges around the country to participate in. The goal of the competition varies slightly every year in specification, but the core principles stay the same. Each team is to design, manufacture, and operate their own robotic platform to dig gravel from an arena bed. The goal is for this system to be fully autonomous, but this is not always achieved. This competition is meant to instill excitement for the field of robotics and autonomous systems in college students.

1.0 Problem

The main problem the team faces is the autonomous aspect. In the arena there are various boulders and ditches that the robot needs to avoid during its trip from the landing site to the excavation zone. The reasoning behind the fully autonomous system design is for scalability. Theoretically this robot should lead to further advancements in autonomous design that could pave the way towards planetary exploration by autonomous robotics.

The autonomous aspect is important due to the delay in sending and receiving transmissions over vast distances. Another important part of the puzzle is the excavation design, or the process by which we will extract the gravel from the excavation zone. Finally, the overall design of the robot is a challenge, but we do have previous designs to base this on.

2.0 Objective

The objective of this project is to create a working robotic platform that is able to excavate gravel from a regolith covered arena through autonomous driving and excavation methods.

3.0 Background

3.1 Key Concepts

- Computer Vision- This is the concept of turning what we as humans see through a camera into something that a computer can read. Usually this also involves having the computer try to understand what it is seeing, like having it identify between a picture of an umbrella and a pillow. It can also be used to create a 3D map of an area by storing key points that it sees.

- ROS- Robotic Operating System, aka ROS, is a platform meant to make programing robotic systems much easier. It does this by being modular and multilanguage supportive. That means that you can create different programs in different languages and ROS will interface them together, which can be really nice if one language is better suited to a task than another.
- ODrive Motor Controller- This motor controller is responsible for powering and commanding a set of two ODrive motors, which will be used to power the excavation auger. They will achieve this by lifting the casing of the auger with one motor, and turning the auger with the power of a second motor, with the assistance of a 100:1 gearbox.

3.2 Related Work

A large amount of research has been done on subjects similar to this project, as computer vision integration with robotics makes a lot of sense. However, most research done has been focused on object detection/avoidance, whereas our project includes that but takes it a step further. With the added goal of excavation and retrieval, we add a new layer of complexity to an already complex situation. Luckily there are resources already built that give us a baseline to start with our computer vision idea, such as OpenCV which is an open source project that helps with object detection [2]. Also, we will be using an Intel RealSense camera for our robot which has built in object detection protocols and depth finding capabilities which can be used to create a 3D map [6]. It will be our job to learn more about these resources, compile them together to create a functioning system of automation, and tailor it to our unique situation.

4.0 Design

4.1 Requirements and Design Goals

- The robot must be able to move around the arena.
- The robot must be able to excavate no less than 1kg of gravel from the regolith.
- The robot must be able to perform at least two trips between the drop off station and the excavation zone.
- The robot should be autonomous, both for excavation and transportation.

4.2 High Level Architecture

The robot will most likely maintain a similar design to our previous competition robot, though this is subject to change as we further test and design the robot. The mobility of the robot will be rooted in a standard four-wheel design, two on each side of the robot operated by a single electronic motor. These motors will receive instruction from Arduino boards that will act as motor controllers. These in turn will receive their instructions from the TX2 motherboard, which is the central processing center for the robot. Also, this TX2 will control the motors that operate the scoop, excavating auger, and movement of that auger.

The TX2 distributes the instructions it receives over a wireless network connection, transmitted from a laptop using a standard wireless router. The laptop will connect to the robot via a socket connection through the router. From the laptop controls are dictated through a controller similar to a fighter jet stick controller. The goal is that this will not need to be used as the functions of the robot should be dictated by onboard autonomy protocols, however, it does serve as a backup should manual control be required. These protocols will be dictated by a Intel RealSense camera, and a variety of other sensors such as InfraRed timing sensors and low range Radar. Below is a picture of the previous robot, as this will set the standard for our design.

4.3 Risks

Risk	Risk Reduction
Loss of University property through misuse of on campus resources	We use a number of resources from the university including 3D printers and metal working machines. To minimize the risk of damage and/or personal harm we maintain that all students must be properly certified with the university to use the machines they operate.
Personal harm through robot operation	With so many moving parts the robot does stand as a moving hazard when in operation. To mitigate the risks with its operation we maintain a safety perimeter around the robot at all times. Also the robot has two ways of shut down, one through the controlling software threat is used to operate the robot and an Emergency mechanical stop that cuts off all power to the robot, located at the very top of the robot.
Accidentally using proprietary/copyrighted software in our program without the proper permissions.	Most of the software we are/will be using is either open source (ex. Ubuntu and ROS) or is freely accessible code found through various sources. To mitigate the chance of crossing any legal boundaries we are careful to follow proper documentation and reference to all sources of code.

4.4 Tasks –

Due to the nature of the project I am working on, not all of my tasks can be broken down into two-week sprints. Some will require much longer stretches of time but can not be simplified any further.

1. Research into Computer Vision APIs and object detection software
   a. This will involve doing more research into what resources are available to us to complete the task of automation and autonomous driving.
2. Testing integration between ROS and CV applications.
   a. This will involve writing real code and implementing it into the ROS system to allow for basic autonomous capabilities such as driving around objects.
3. Development of algorithm to process CV data into usable map information for robot.
   a. This will be the longest part of the project, as it involves writing and tweaking the code needed to allow for all aspects of the robot's controls, such as excavation and retrieval of material.
4. Autonomy testing and revision.
   a. This step is meant as the time we will spend testing the robot in various types of environments and orientations. Here we will verify that our robot is able to complete its task no matter where it is placed in the arena.
5. Thorough revision of documentation for all process taken.
   a. During this step we will verify that we have properly documented and stored all of the data relevant to our project as dictated to us by NASA. This will also be the period of final preparations before competition.
6. Robotic Competition
   a. This is the period in which we will go down to Cape Canaveral to participate in the actual competition for a period of days.
7. Final group meetings and closing design notes.
   a. This will be one last final meeting before dispersing for the summer, where we will review our competition results, talk about what went good/bad, and take down and suggestions we have for next year's team.

4.5 Schedule –

Tasks	Dates
1. Research into Computer Vision APIs and object detection software	11/1-11/15
2. Testing with integration between ROS and CV applications.	11/15-12/13
3. Development of algorithm to process CV data into usable map information for robot.	12/13-1/17
4. Develop motor controls and design electronic setups	1/17-2/3

5. Integrate autonomy software and physical hardware.	2/3-3/2
6. Autonomy testing and revision.	3/2-4/10
7. Thorough revision of documentation for all process taken.	4/10-5/18
8. Robotic Competition	5/18-5/22
9. Final group meetings and closing design notes.	5/22-5/23

4.6 Deliverables

- A robot capable of autonomous functions for driving, excavating, and depositing gravel. This platform will be fully functional and complete the tasks as needed.
- A Systems Engineering report, which details the steps we made for our design, implementation, and testing processes. This will contain a thorough account of the steps we took along the way to creating the report.
- An Outreach document that details what events we performed outreach for to our local community to promote robotics.
- A Computer Systems OneNote that details research results and references for our code repositories.
- A collection of C++, Python, and other ROS approved language based applications for the operation of the robot.

5.0 Key Personnel

James Hand – Hand is a Senior Computer Science major in the Computer Science and Computer Engineering Department at the University of Arkansas. He has completed Programing Foundations 1 and 2, Programing Paradigms, Software Engineering, Computer Networks, and will be taking Industrial Robotics next semester, all of which are relevant to the project. Hand is responsible for object detection and identification for the robot research support, excavation systems motor engineering, and outreach event support.

Dr. Wejinya– Dr. Wejinya is a Mechanical Engineering professor at the University of Arkansas. He specializes in Robotics/ Mechatronics, Control Systems, Nano/Micro Systems Engineering, and Modeling of Mechatronic Systems. Dr. Wejinya has been leading the RazorBotz team for many years now and is very dedicated to its development and growth.

6.0 Results

The results of this project were less than expected as a result of the COVID-19 outbreak. Starting in the month of February production began to experience setbacks related to the virus. Soon after the pandemic started in Arkansas the university restricted our access to the labs. With a project like this having access to the physical labs is incredibly important. As this shut down took place during the beginning of our build phase, we were left with very little physical results.

While physical results were lacking, we were able to do some research that will make things easier for next year. We left behind resources we found for both vision systems and the ODrive motor controller. These results were a collection of websites, detailed descriptions of software, and other written resources. We stored these resources in both the team's Slack channel and the team's OneDrive, so that it is accessible to future teams.

7.0 Future Work

For the future, the team will be looking more into autonomy and unmanned designs. This is the focal point of the competition, so it remains a highlight of the team's focus. In addition, the team is looking more into the ODrive motor controllers. This is because we had difficulties using these new motors and their controller. Many issues popped up after another one was solved while working with these. We came close to a solution for most of the issues, but were unable to implement them due to the current health crisis.

8.0 Facilities and Equipment

University of Arkansas Robotics Laboratory – This laboratory is designed for robotics classes and is used as a staging ground for all team meetings and research. Inside the lab are a variety of computers that we use for the research and software development.

University of Arkansas Mechanical Engineering 3D Print Lab – This is the Mechanical Engineering department's in-house 3D printing space. We use this to create parts for the robot such as chassis mounts and electronics covers.

9.0 References

[1] Autonomous Navigation using Computer Vision with ROS, https://medium.com/@aderabiruk/autonomous-navigation-using-computer-vision-with-ros-d6bc1bc56ddf

[2] Open CV, https://docs.opencv.org/master/d1/dfb/intro.html

[3] Modeling Rugged Terrain by Mobile Robots with Multiple Sensors, https://www.ri.cmu.edu/pub_files/pub3/kweon_in_so_1991_2/kweon_in_so_1991_2.pdf

[4] 3D Map Creation, https://software.intel.com/sites/landingpage/realsense/camera-sdk/v1.1/documentation/html/doc_ot_3d_map_creation.html

[5] ROS_Object_Analytics, https://github.com/intel/ros_object_analytics

[6]Intel RealSense for Linux- Object Library: Developers Guide, https://software.intel.com/sites/products/realsense/object/developer_guide.html

[7]ODrive Motors, https://docs.odriverobotics.com/