CSCE 4561 Capstone II

Spring 2021

Project:

NASA/Robotic Mining Competition Rover

Group Members:

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Jett McCullough, Carson Molder

April 27th, 2021

About us

Andrew Burroughs
Comp. Sci.
Senior

Calvin Franz
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Z. Gunner Lawless
Comp. Sci./Eng.
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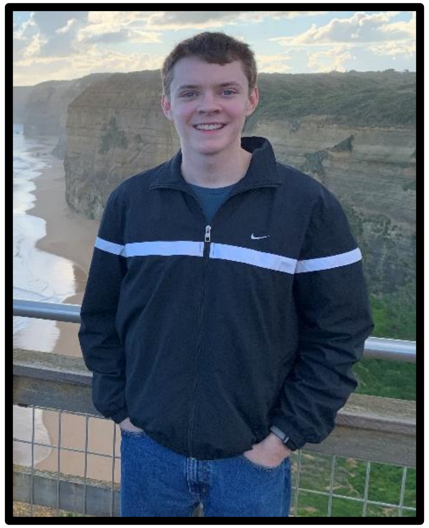
Jett McCullough
Comp. Sci.
Senior



Carson Molder
Comp. Eng.
Senior

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Problem

It costs about $1.2 Million/kg to send materials to the moon (2019 est.)[1]

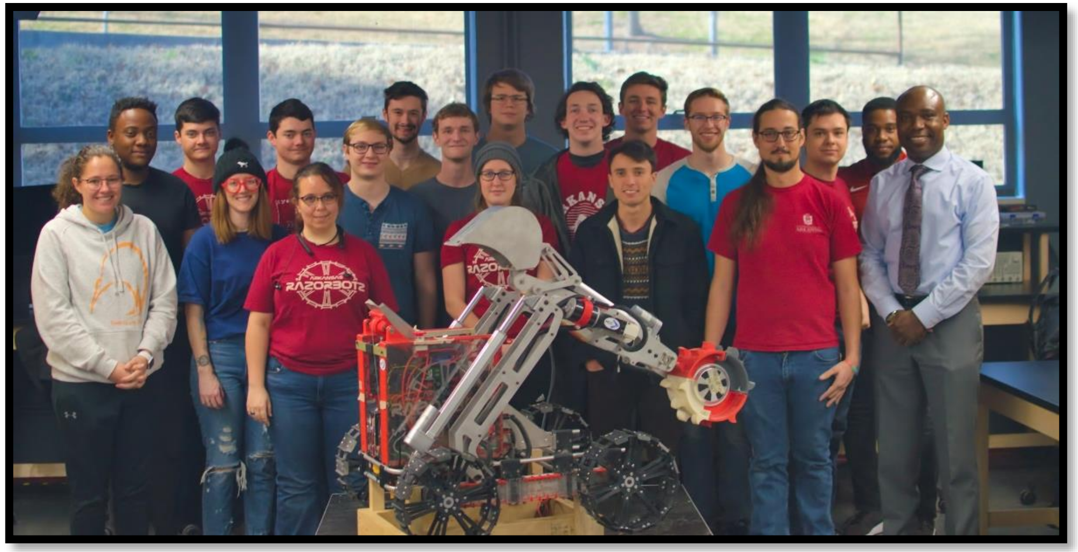
- NASA’s Artemis program:
  - 2024 — Return to Moon
  - 2030s — Visit Mars
- Extended missions are too expensive
- Need to gather and process materials while in space
- We did not have as much experience with robots

Image Source: nasa.gov [1]

Objective

Our goal was to develop the software for a robot that can autonomously mine rocks on the moon.

- NASA Artemis Student Challenge
  - Traditionally at Kennedy Space Center
  - Competition between universities for the best mining robot
- Razorbotz
  - Team of UARK students competing in RMC
  - Led by our project champion, Professor Uche Wejinya



Last Year's Team and Rover

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Background

- Refactor existing code
- Automation with computer vision
  - Identify objective locations and key targets
  - Path generation/discovery
  - Tools and libraries
    - ZED SDK
    - Git
    - Darknet
- Robot Operating System 2 (ROS2) to program robot
  - Multi-language support (Python, C, etc.)
  - Logical units ("nodes") coded for autonomy, navigation, etc.

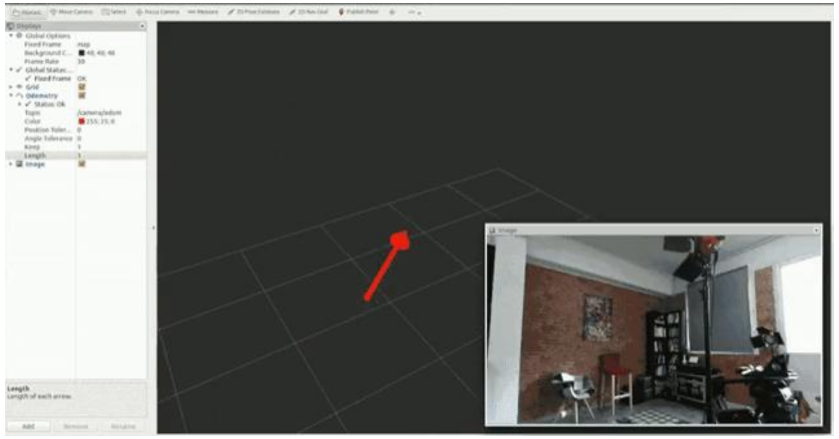

Image Sources: ZED Docs [2], pjreddie.com [3]

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Facilities and Equipment

Mechanical Engineering Robotics Lab

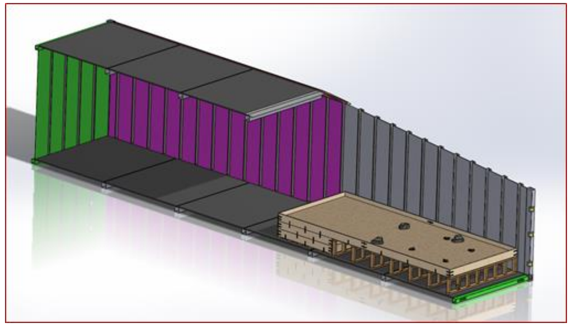
Campus Test Pit

- Contains moon-like rocks and dust

Autonomy / AI development

- Jetson Nano
  - Small embedded system that can run AI workloads for the robot
- Nvidia GeForce RTX 2080 Ti

Campus Test Pit:



Jetson Nano:

Image Source: nvidia.com [6]

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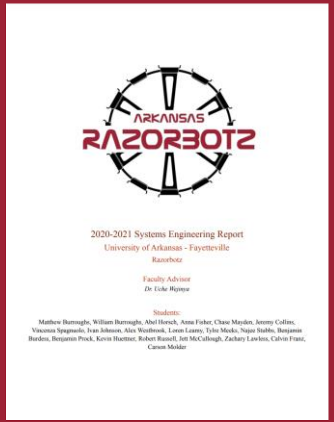
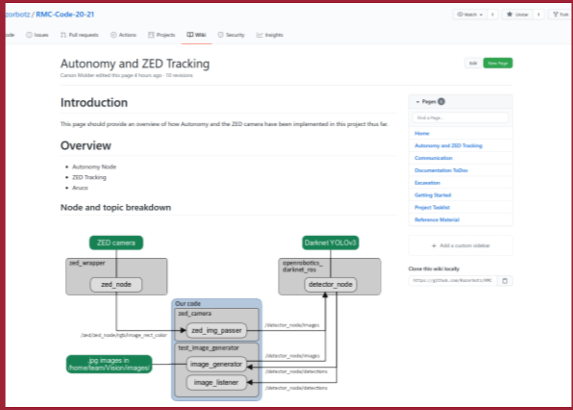
Deliverables



Design document

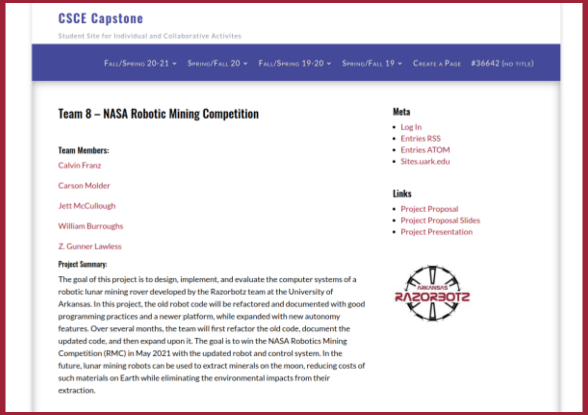
ROS2 nodes



Documentation

Dockerfiles

Rock image datasets



Final report and website

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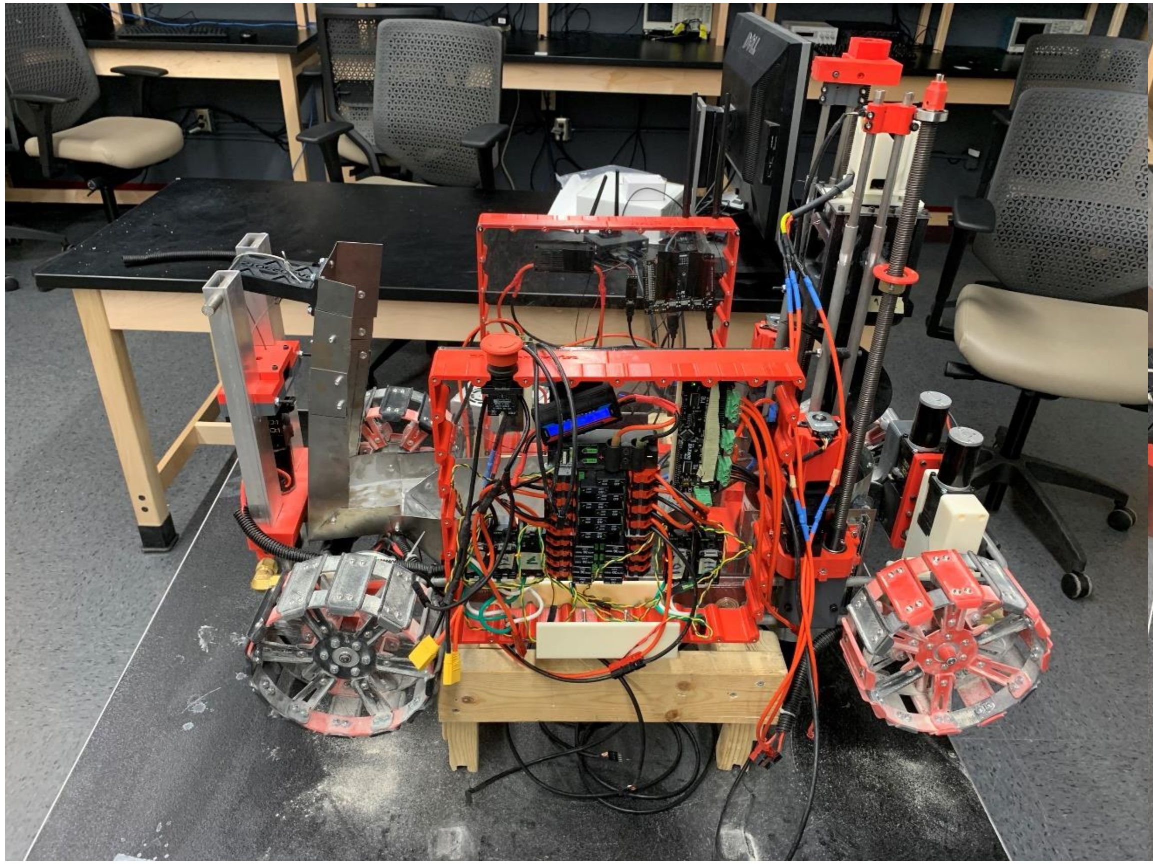
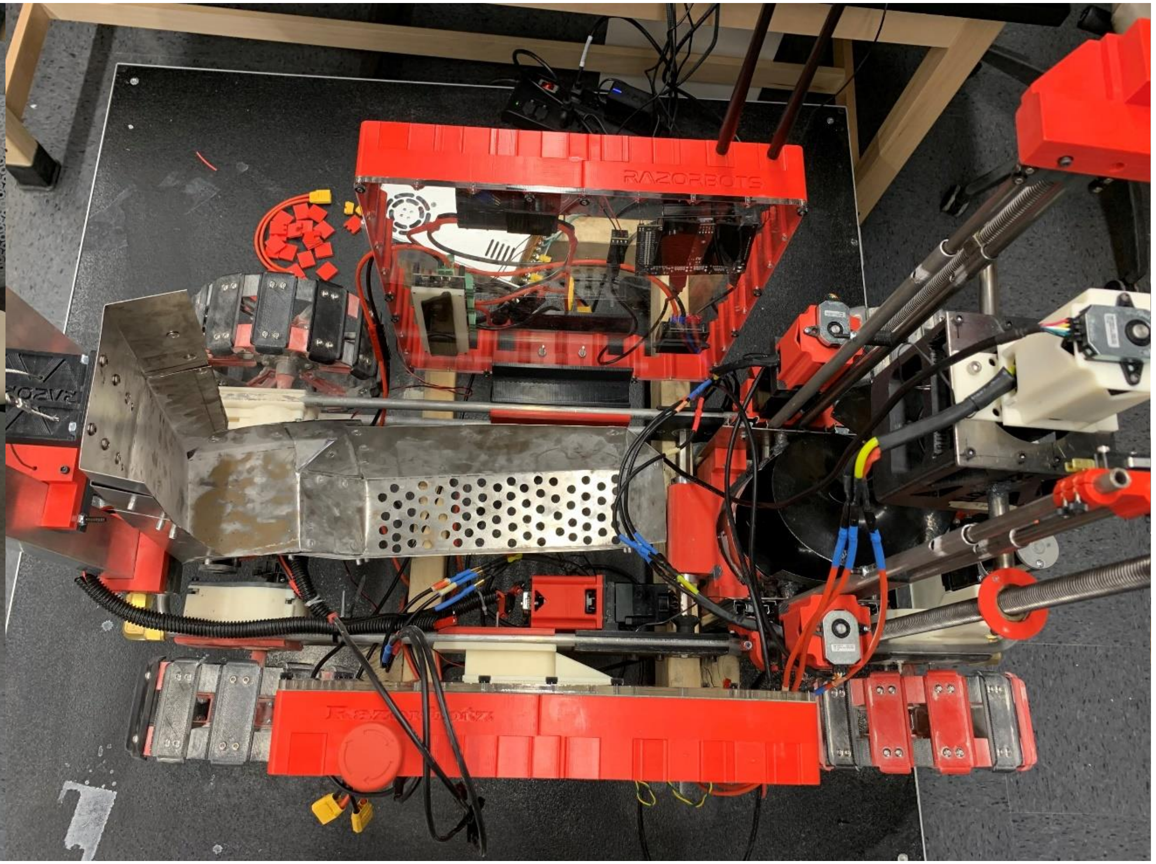
Current State of the Robot





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Manual Control Demo

Vision Overview

- ZED Camera
  - Depth Sensing Capabilities
    - Each pixel has an associated depth (Depth Map)
  - All detected objects given depth
- YOLO: “You Only Look Once” [8]
  - Neural network that performs real-time object detection
  - Trained on COCO dataset (DEMO) [9]
    - Over 80 categories
    - book, person, dog, bicycle, airplane, etc.
  - Runs on Darknet
    - Coded in C, more compatible with ROS2 than PyTorch
- Lunar Rock dataset

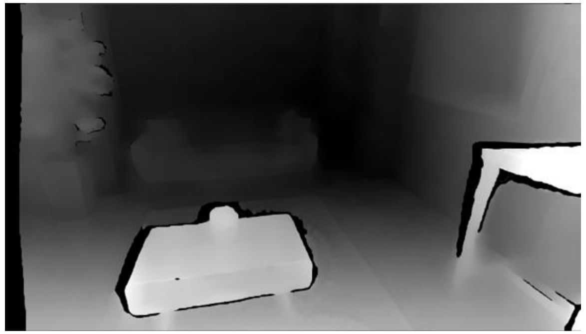


Image Source: stereolabs.com

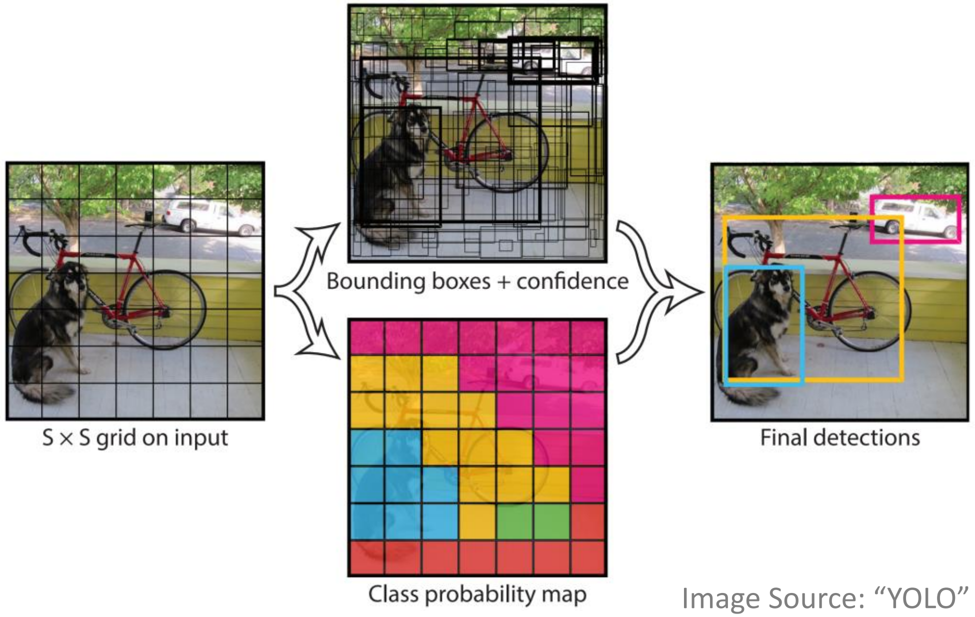


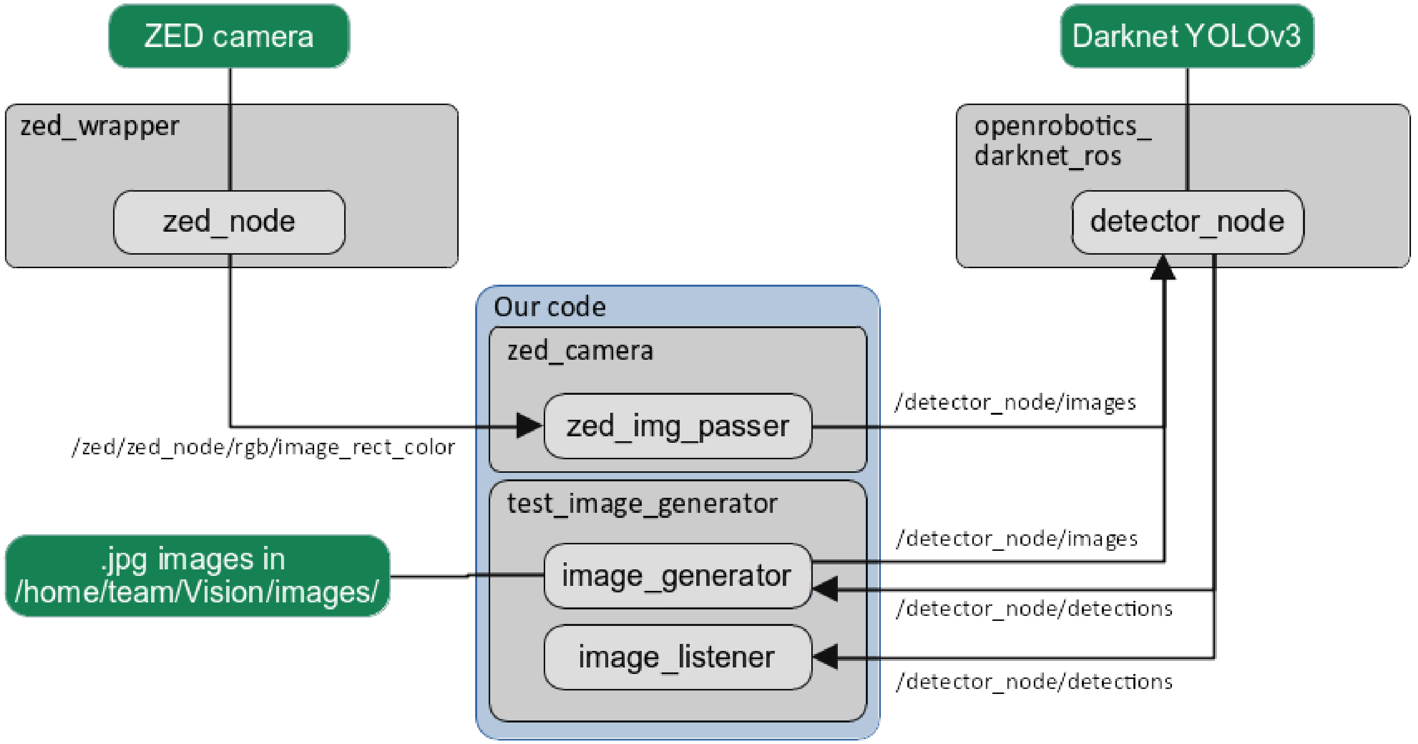
Image Source: “YOLO” [8]

Rock Image Datasets

- Two rock image datasets:
  - Bulk (3700+ images)
  - Small (260 images)
- Images generated from videos taken in testing pit
- Script using OpenCV to extract images
- Manual construction of image labels using labelImg tool [10]
  - Labels in YOLO VOC format
- Datasets are ready-to-use to train Darknet for rock detection

Vision Nodes

- Vision modules
  - `zed_wrapper`:
    - Communicate with ZED camera
  - `openrobotics_darknet_ros`:
    - Communicate with YOLO
  - `*zed_camera`:
    - Passes ZED camera feed to YOLO for object detection
  - `*test_image_generator`:
    - Logs YOLO detections to console
    - Can send a series of test images to check YOLO



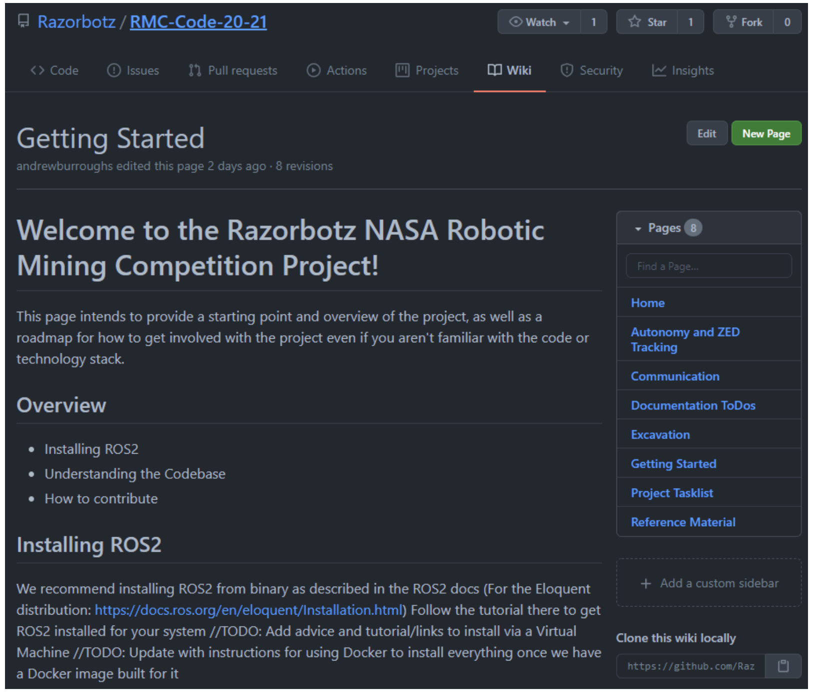
* = new code we contributed

Vision Demo

- Live Demo

Documentation

- Github Wiki
  - New nodes are commented
- "Getting Started" and other guides
    - YOLO vision nodes
    - Communication nodes
    - Excavation nodes
  - Details on how to run nodes
  - Useful references for team members new to programming
- Workflow documents



Dockerfiles

- Steep learning curve to learn ROS2
- ROS2 is difficult to install
  - Lengthy process
  - Dependency issues
- Using Dockerfiles allows:
  - Increased portability
  - Quick install & run time
  - Easier access for non-computer students to learn
- Basic documentation is provided to get other up-to-speed with Docker Images

Future Work

- Full navigation autonomy
  - Use vision data to navigate to key targets
  - Train YOLO on lunar rock dataset
  - Automatically control motors, steering, etc.
- Full excavation autonomy
  - Mining, dumping
- Extending documentation
  - Comment old nodes as they are updated
  - Extend GitHub wiki to include every node
  - Finish guides so they can help familiarize new members with the project
- Complete robot chassis
- Compete in 2022!

References

[1] “NASA Robotic Mining Comptetiton (RMC) Lunabotics 2021, Registration, Rules and Rubrics,” NASA, 2020. url: https://www.nasa.gov/sites/default/files/atoms/files/000_rmc_lunabotics_rules_rubrics_2021.pdf

[2] “Getting Started with ROS and ZED,” Stereo Labs, 2020. url: https://www.stereolabs.com/docs/ros/

[3] Darknet Homepage, Darknet, 2021. url: https://pjreddie.com/darknet/

[4] "ROS2 Github Repository", Github, 2020. url: https://github.com/ros2

[6] “Jetson Nano Developer Kit,” Nvidia, n.d. url: https://developer.nvidia.com/embedded/jetson-nano-developer-kit

[7] "Sterolabs Homepage", Stereolabs, 2020. url: https://stereolabs.com

[8] “You Only Look Once: Unified, Real-Time Object Detection,” Redmon, J., Divvala, S., Girshick, R., and Farhadi, A. *IEEE Conference on Computer Vision and Pattern Recognition*. 2016, pp. 779-788.

[9] “Microsoft COCO: Common Objects in Context,” Lin, T., Maire, M., Belongie, S., Hays, J., Perona, P., Ramanan, D., Dollar, P., and Zitnick, C.L. *European Conference on Computer Vision*. 2014, pp. 740-755.

[10] "labelImg Github Repository", Github, 2021. url: https://github.com/tzutalin/labelImg