P.V.I.R Final Presentation

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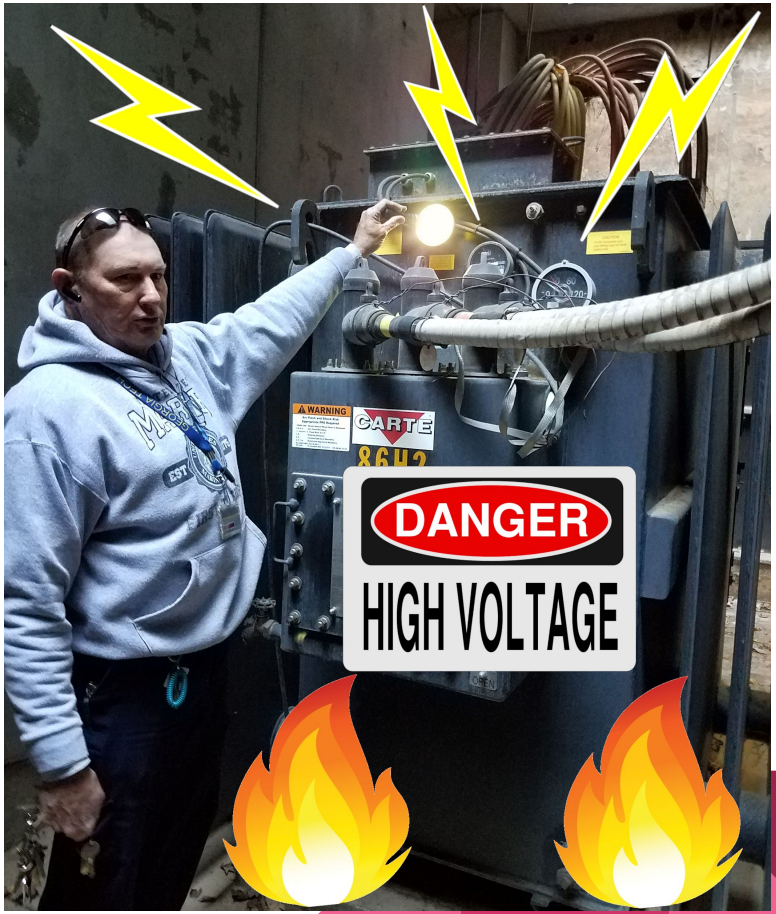
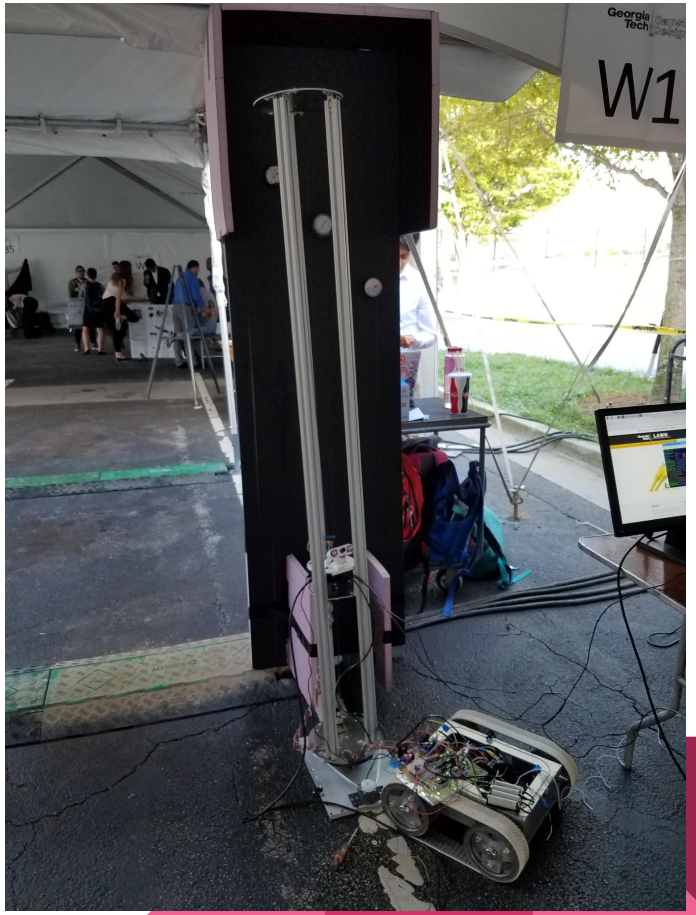
Motivation

1. Protect inspection workers from the dangers of powervaults
    a. Electrical parts are responsible for 80% of electrocution deaths among workers [1]
2. Simplify the process of logging data and inspecting powervaults



Objectives

1. Design, program, and build a remote controlled Power Vault Inspection Robot
2. Create a user-friendly GUI
3. Assemble a sensor package to examine the quality of the environment using video and gas sensors
4. Design and build a mechanical lift
5. Design and build a test environment to demonstrate the robot at the Capstone Design Expo

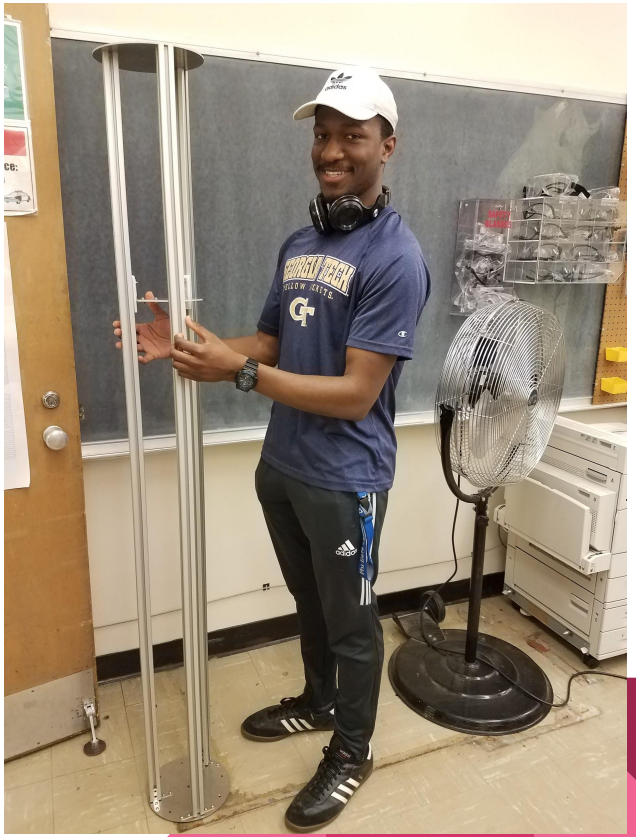


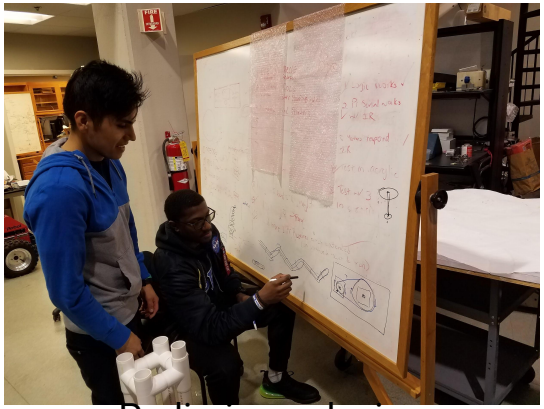
Specifications

Mechanical Arm Specs
Height : Variable height from 1 - 6 feet ✔
Degrees of Freedom : 2 degrees of movement ✔
Base Size : Fits in a 760mm Diameter Manhole ✔

Sensor Package Specs
Video : Can Stream Video to GUI ✔
Gas Sensor : Check Air Quality ✔
IR Thermal Camera : Record Thermal Images ✔
Microphone : Record Sounds

GUI Specs
Mobile: Usable on Mobile Platforms ✔
Control Capabilities: Remotely Controllable Robot ✔
Logging: Log Information ✔
Data Streaming: Real-Time Data Streaming ✔

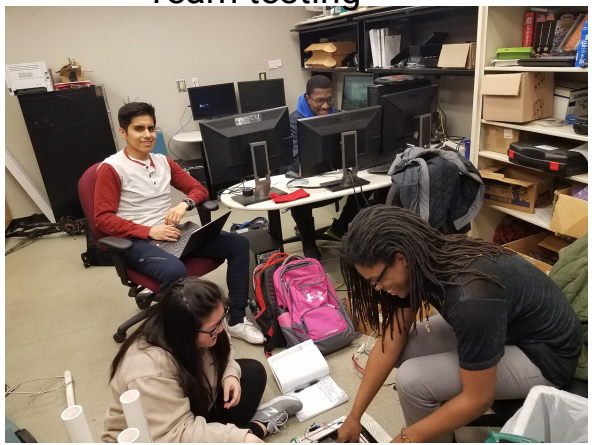




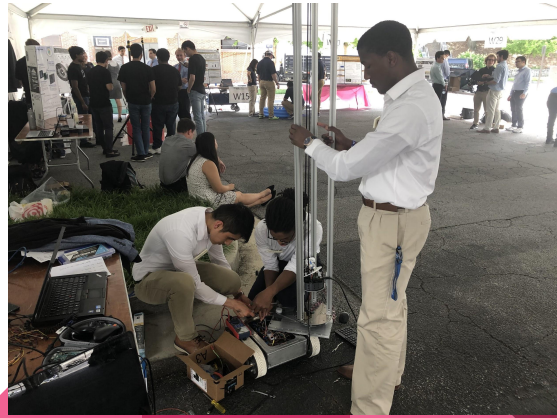
Preliminary design

En route to Capstone

Team testing



EXPO!



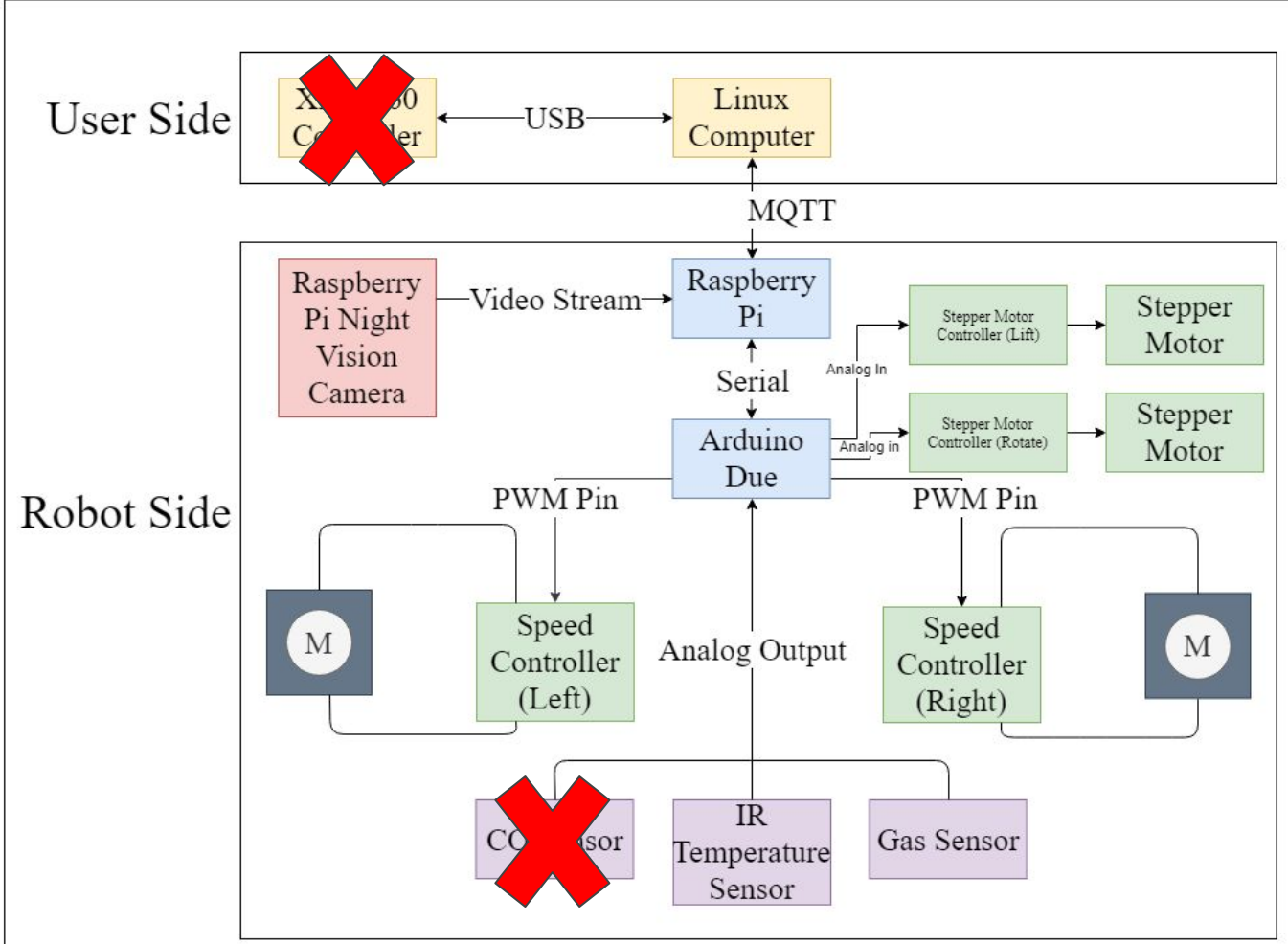
Video

Expo Troubleshooting ft. Lemek

Design Overview

Design Problems:

1. Too many steps to get XBox inputs to the arduino
2. CO Sensor needs a mounting board and multiple voltages to operate



Mechanical Arm

- Utilizes 2 Nema 17 stepper motors to lift the platform and rotate the T-slots
- T-slots sit on an 8” turntable
- Sensor package casing is not waterproof (3D printed)
- Nema stepper motor mounts 3D printed
- Sliders attached to T-slots used to enable lift of sensor package
- GT2 block used to enable the rotational motion of pulley to a mechanical lift
    - GT2 block also used in the open belt closures for the 2GT belt.

GUI

- Kivy:
  - Task organization
  - Matplotlib for graphics building
- Video streaming
  - Worked well but computationally heavy for the raspberry pi
- Data collection
  - Subscribe to a MQTT server on the raspberry pi
  - Data logging option
  - Live audio and object temperature plot
  - Live gauge graphic
  - Live temperature bar graph

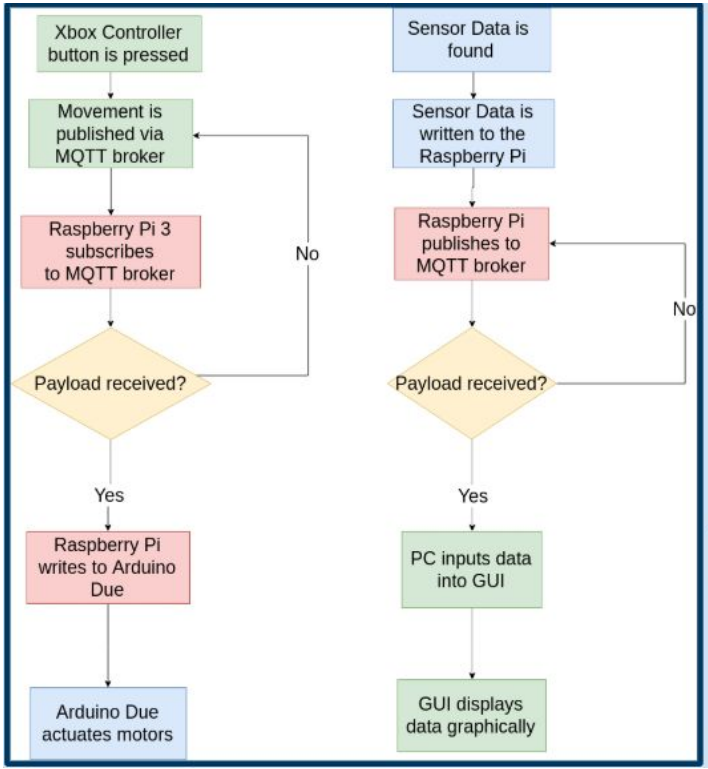
GUI

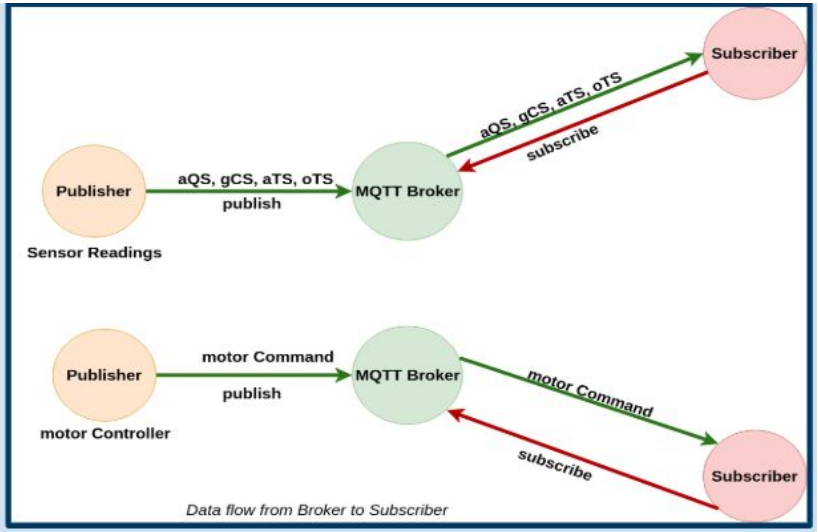
- Graphing functions
  - Toolbar to manipulate zoom or save data to host pc
  - T to switch between live graph and static graph
    - Static data has more points and is easy to manipulate
  - F to toggle freeze of live graph

Arduino

- Data acquisition from sensors
- Sends motor instructions
  - Stepper library on digital pins for the arm motors
  - Pwm signal for the movement motors
- Communicates to the raspberry pi via serial connection
- Due analogReference minimum

Software Comms





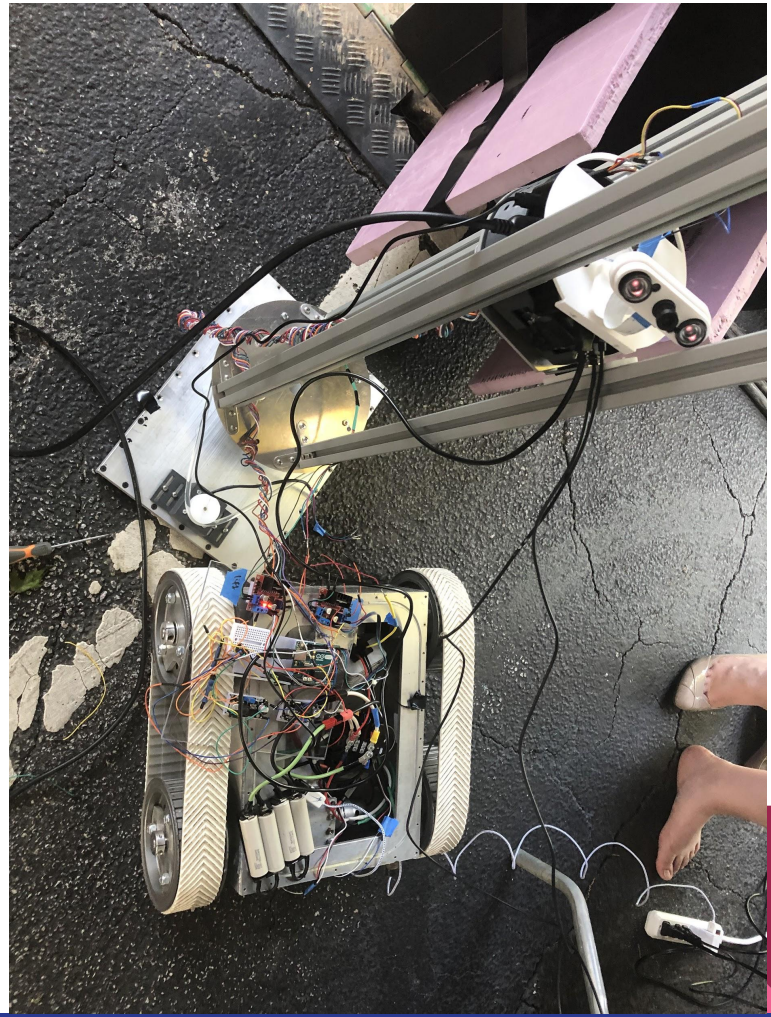
Diagrams for MQTT protocols for motor control and GUI data transfer.

Challenges with Hardware

- Challenge: Constantly updating Bill of Materials and ordering new parts
  - Future Solution: Finalizing arm assembly design and schematic earlier
- Challenge: Waterproofing sensor package
  - Future Solution: Buy waterproof box; sensors that must be exposed to the environment can have sealed openings
- Challenge: CO sensor implementation
  - Future Solution: Buy arduino board to mount it to
- Challenge: Machining
  - Future Solution: Waterjet holes so they are perfectly aligned the first time

Challenges with Hardware

- Challenge: Cabling and final assembly
  - Had a lot of parts and connections inside the robot body making it very easy for things to become disconnected
  - Powering everything off the same battery caused cabling to be messy
- Challenge: Mechanical Arm Assembly
  - Conducting better research on different mechanical lift and rotational designs.
  - Learning how to use a CAD software for arm design
  - Length of T-slots made sliding for the sensor plate difficult
  - Pulley belts slipping when operating



Challenges with Software

- Challenge: Serial communication to and from the Arduino is too slow to process controller commands efficiently leading to dropped inputs and a delay
  - Future Design Solution: Have arduino directly receive controller inputs; possibly a bluetooth module with antenna receiver
- Challenge: Video stream lag
  - When processing mqtt code in parallel the pi could not keep up
- Challenge: controller input retention
  - The Xbox controller only registers inputs when it refreshes and is unable to retain the last button pressed

BUT THE BIGGEST CHALLENGE...

Staying under budget:

Arm and Robot Lid	$511.84
Sensors and Control	$146.10
Power and Cabling	$150.37
Lab Testing and Debugging	$26.73
Demo Environment	$29.60
Total Cost	**$864.64**

Ways we could have saved money

- Lab had a lot of assembly parts that we didn’t need to buy (screws, taps, wires, cables etc)
- Could have gone without testing environment (usescrap wood in lab instead)
- Could have used lower end power supply

Future Improvements

1. Collapsible arm
    - Scissor lift
2. Implement audio capture hardware in sensor package design
    - GUI contains audio track already
3. Write training manual for utility workers
    - This will give everyone the ability to troubleshoot the robot

Figure Source: (Anon, 2019) [2]

Lessons Learned

- Reduce the number of design iterations and assure at least one is complete and make changes accordingly.
- Don't worry about ordering lab testing materials and check lab for assembly parts before ordering
- Complete the CAD design, assembly and schematics before ordering parts
- Provide more slack on cables then one might think is needed
- Allow for more time to integrate software with hardware
- Simplicity is best - trying to integrate too many parts results in things not working last minute

Works Cited

[1] Cpwr.com. (2019). *Chart Book (6th edition): Fatal and Nonfatal Injuries - Fatalities from Contact with Electricity in Construction | CPWR*. [online] Available at: https://www.cpwr.com/chart-book-6th-edition-fatal-and-nonfatal-injuries-fatalities-contact-electricity-construction-0 [Accessed 22 Apr. 2019].

[2] Anon, (2019). [online] Available at: https://www.robotshop.com/en/uarm-swift-pro-standard-4-dof-metal-robotic-arm-bluetooth-suction-cup.html [Accessed 22 Apr. 2019].