Modular Open-Source Machine Monitoring Tool

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Intro and Background

- SME Manufacturers do not invest in R&D like OEMs
- Many generations of machines in shops
  - New machines having integrated computers
  - Some older machines only have a power switch
- Conditions of machines is typically only understood by the operator using the machine or by management when they walk out to the machine
- Maintenance programs are typically fix the machine when it breaks
- COTS options are available to monitor equipment at continuous service costs on cloud services
- Data leaving the shop is a Intellectual Property concern for owners
- Many price points of sensors can be used to monitor machines

- How much data and what quality do shop owners need to improve?

The Project

- Goals of the research are:
  - Determine what price point of sensor and what types of sensors are needed to provide useful information to shop owners.
    - Low cost – Self developed with low cost sensors and processors
    - Medium cost – A combination of the low and high cost systems
    - High cost – Commercial off the shelf solution
  - Determine what/if features can be extracted from machine data relating to the part being manufactured
  - Develop a system to capture machining knowledge to allow the machines to train future operators

Phase 1 – Low-Cost System

- Development of the low-cost system will provide a low barrier for trial and error of sensor applications
- Develop requirements for high cost systems
- Provide a baseline of data quality for future systems
- Most work intensive due to the self development
- Provide the architecture for additional systems to be added to the system
- Determine the relationship between the data received and machine conditions
- Produce a system that is imitable and implementable by other academics and in industry

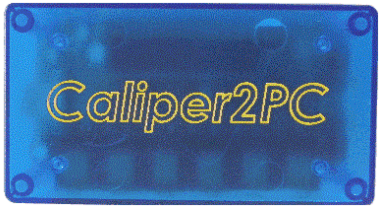
Modular Open-Source

- Low cost system is developed using open-source technology and the combination of other existing hardware and projects
- Using Linux based computing to allow for non–restrictive use
- Processors, controllers, and most sensors are open-source hardware

- System being developed use a baseline of sensors, but allows for additional sensors to be added to the system
- Base line sensors track the power usage by the machine, vibration at the vise, and rotation speed of the tool
- Additional sensors being developed for integration are linear scales, RFID scanner, and acoustic microphone

Issues in Project - Hardware

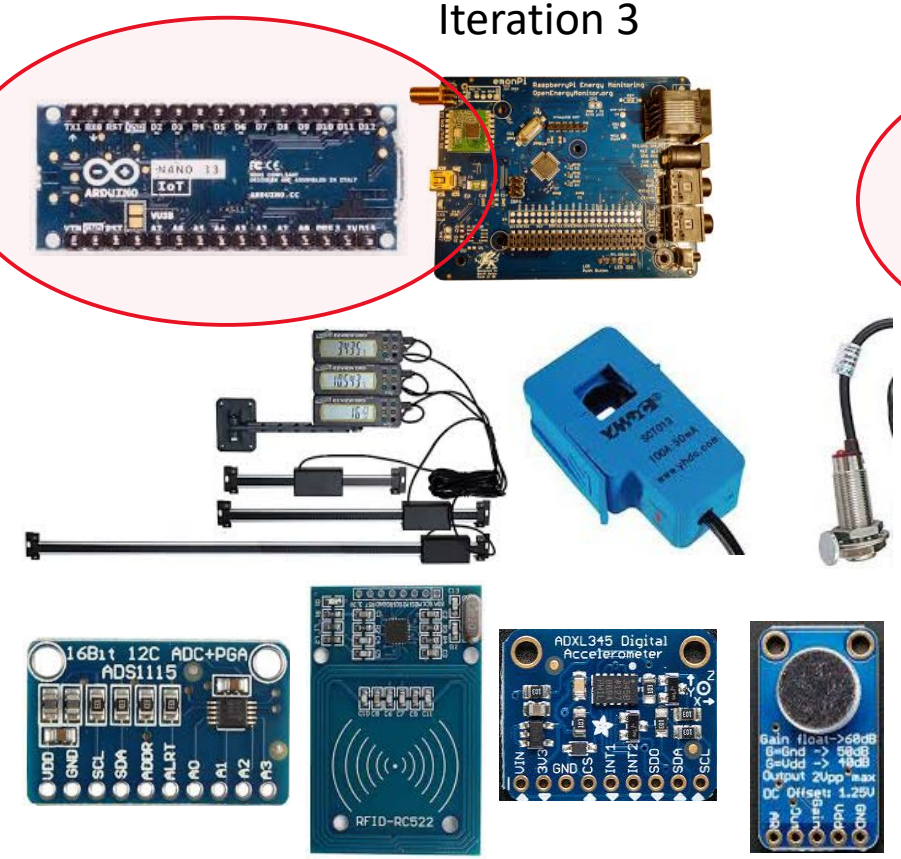
Iteration 1



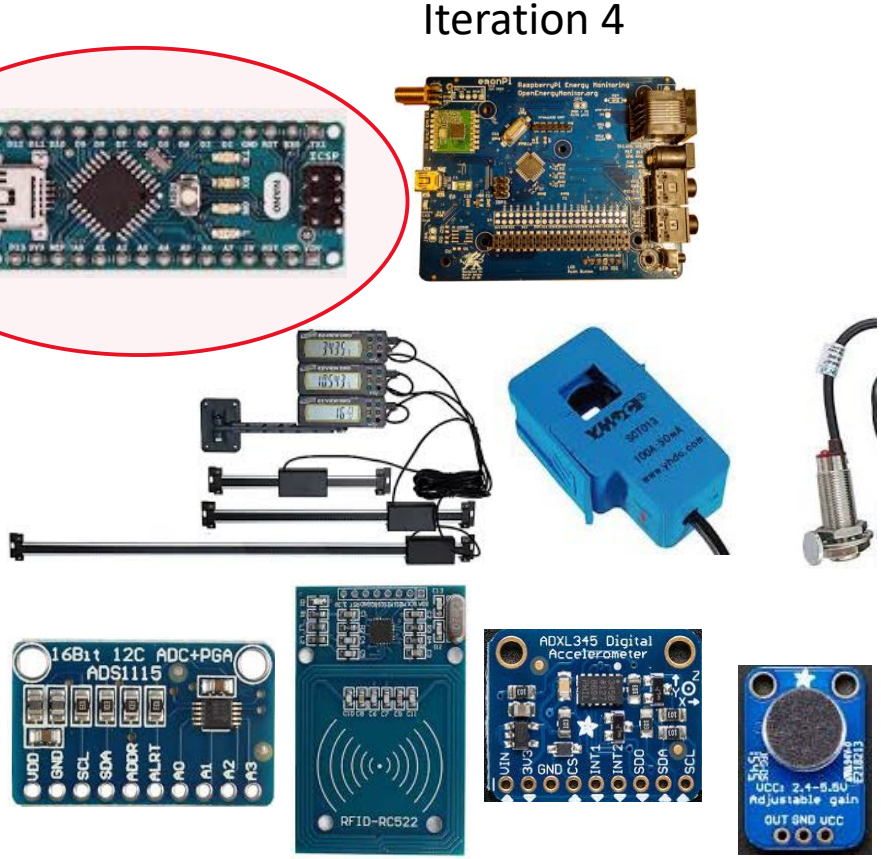
Iteration 2

Issues in Project - Hardware

Iteration 3

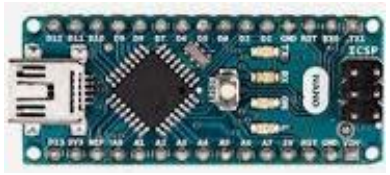


Iteration 4



Issues in Project - Hardware

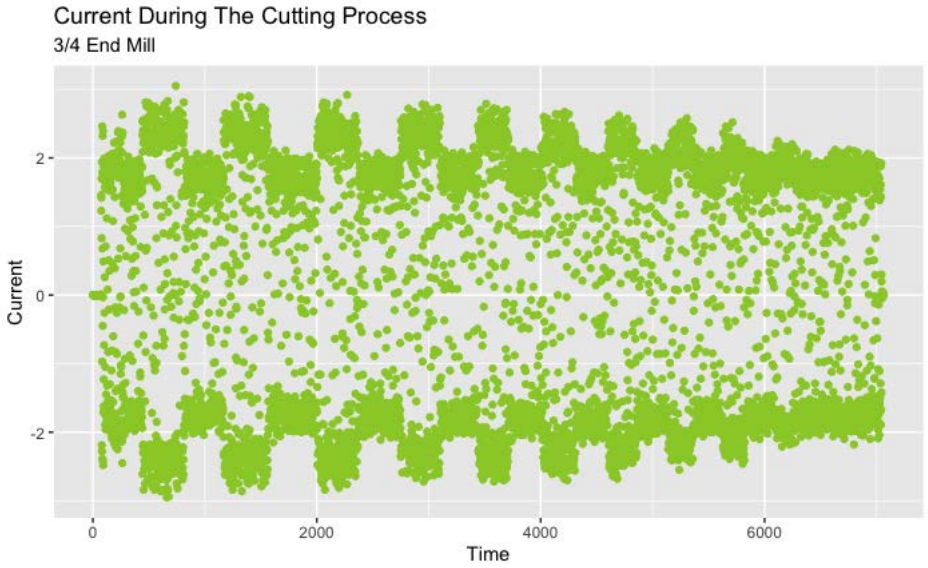
Iteration 5

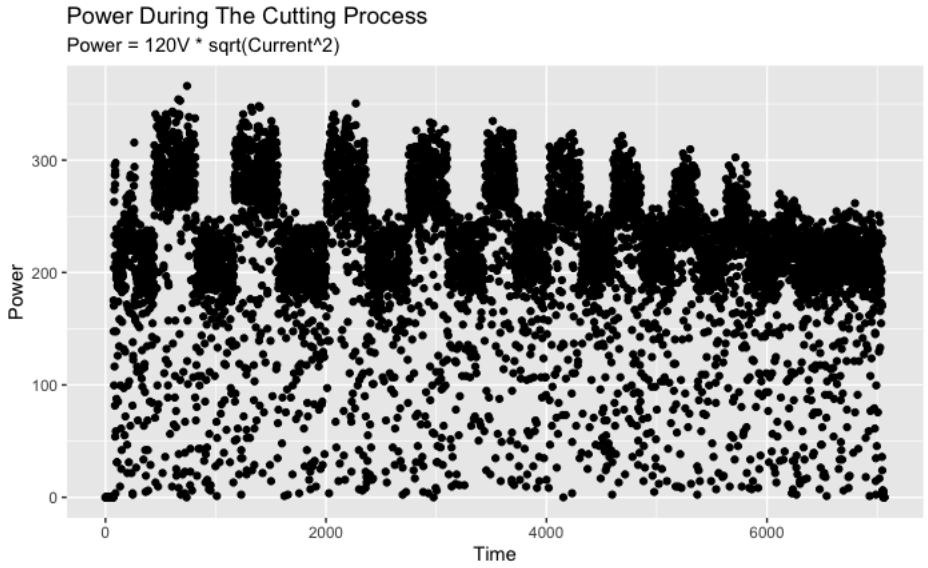


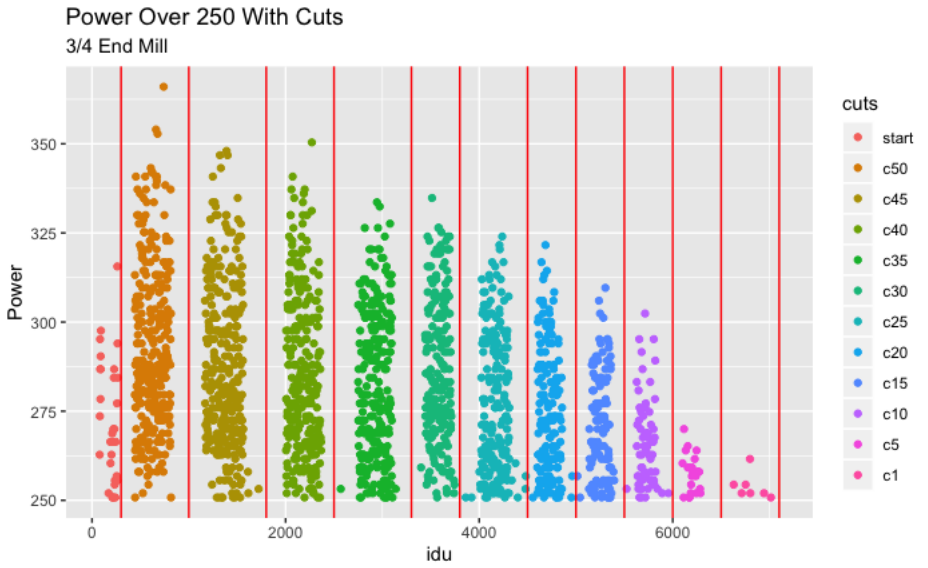
Iteration 6

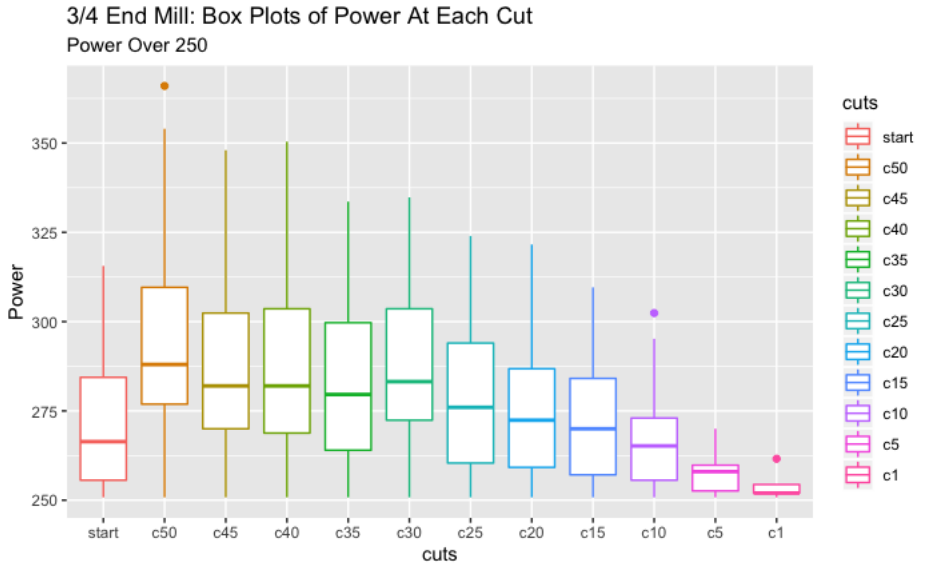
Current Project - Hardware

Data – Power

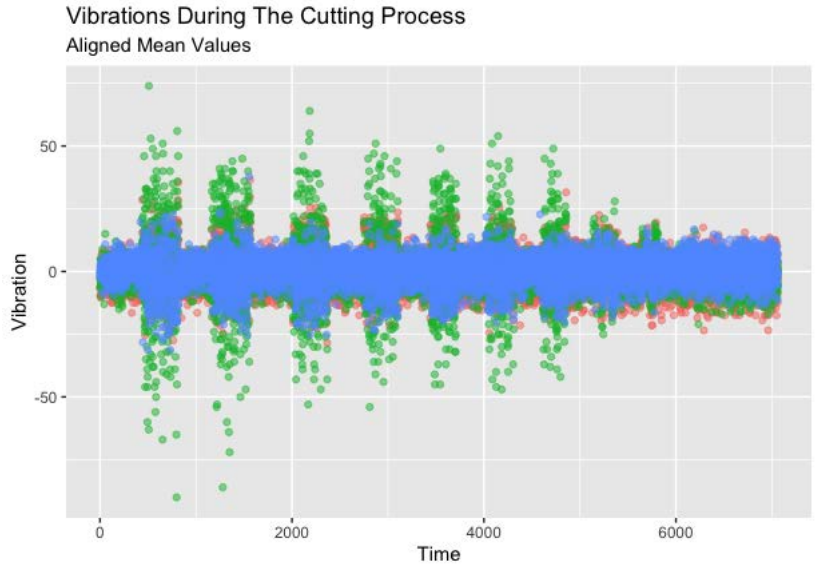

Current During The Cutting Process
3/4 End Mill
Current
Time
2
0
-2
0
2000
4000
6000

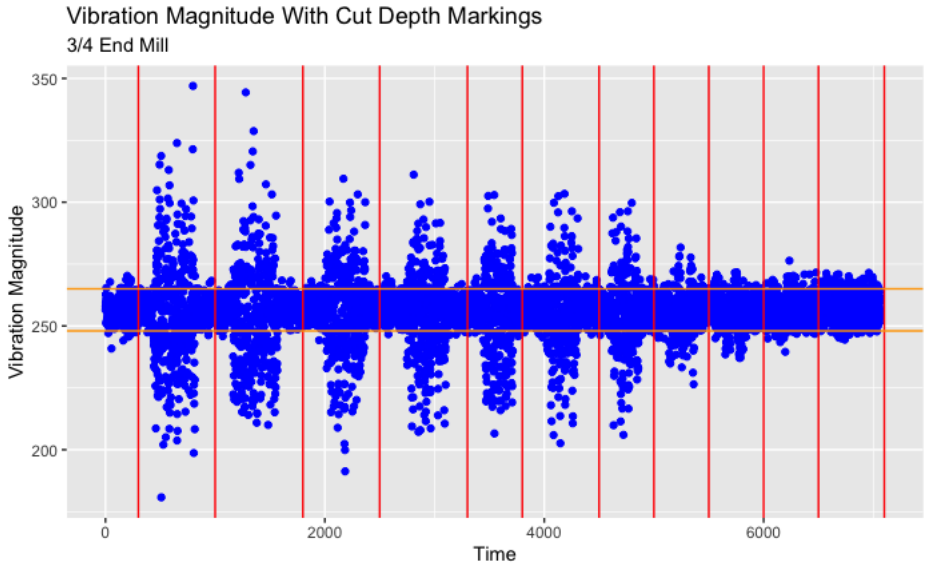

Power During The Cutting Process
Power = 120V * sqrt(Current^2)
Power
Time
300
200
100
0
0
2000
4000
6000

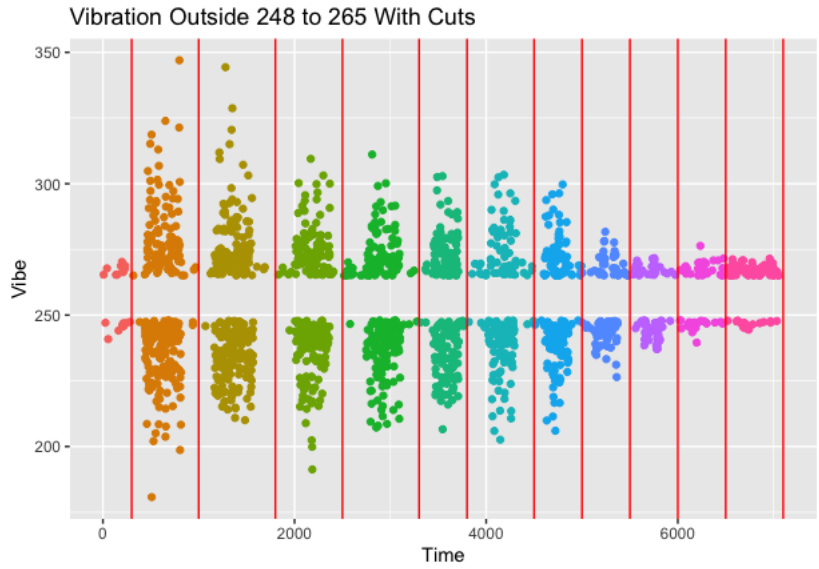

Power Over 250 With Cuts
3/4 End Mill
Power
idu
cuts
start
c50
c45
c40
c35
c30
c25
c20
c15
c10
c5
c1
350
325
300
275
250
0
2000
4000
6000

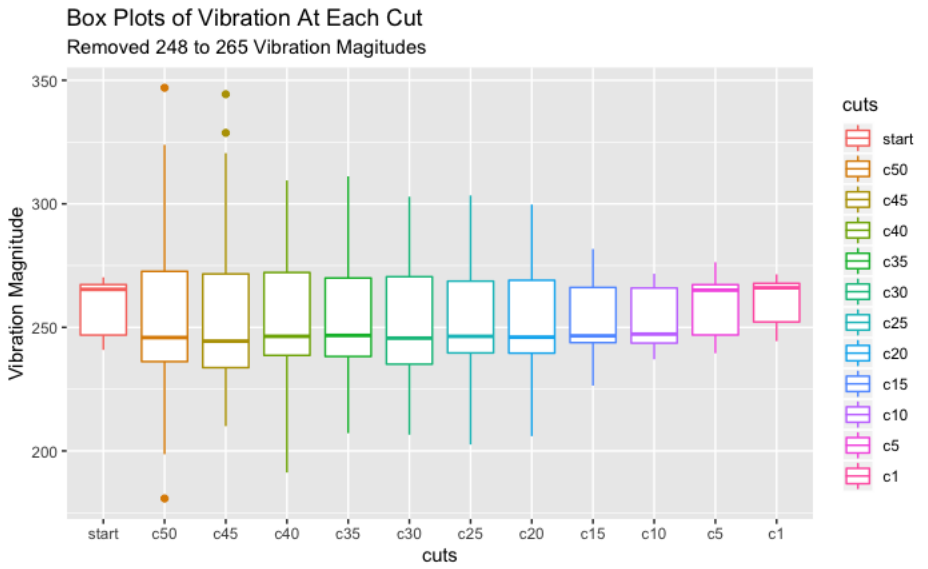

3/4 End Mill: Box Plots of Power At Each Cut
Power Over 250
Power
cuts
start
c50
c45
c40
c35
c30
c25
c20
c15
c10
c5
c1
350
325
300
275
250

Data – Vibration

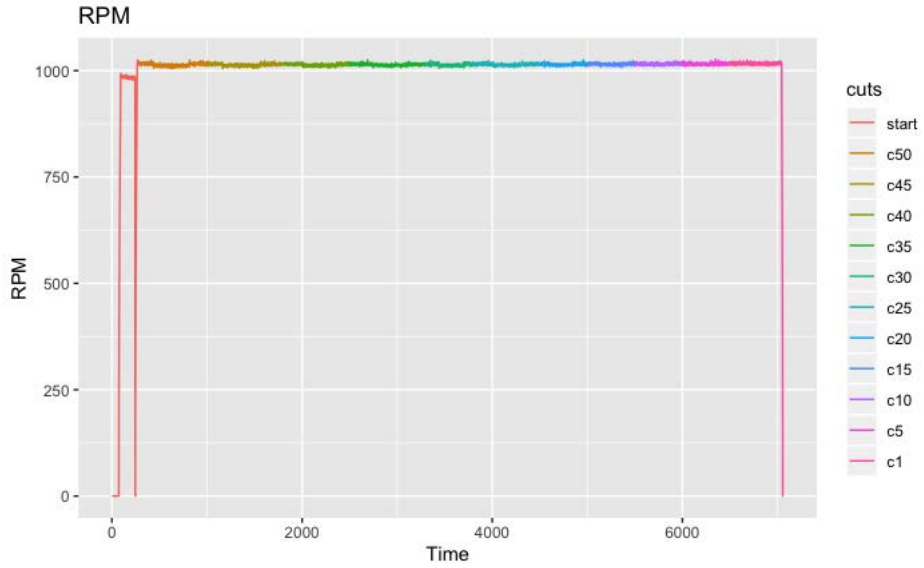


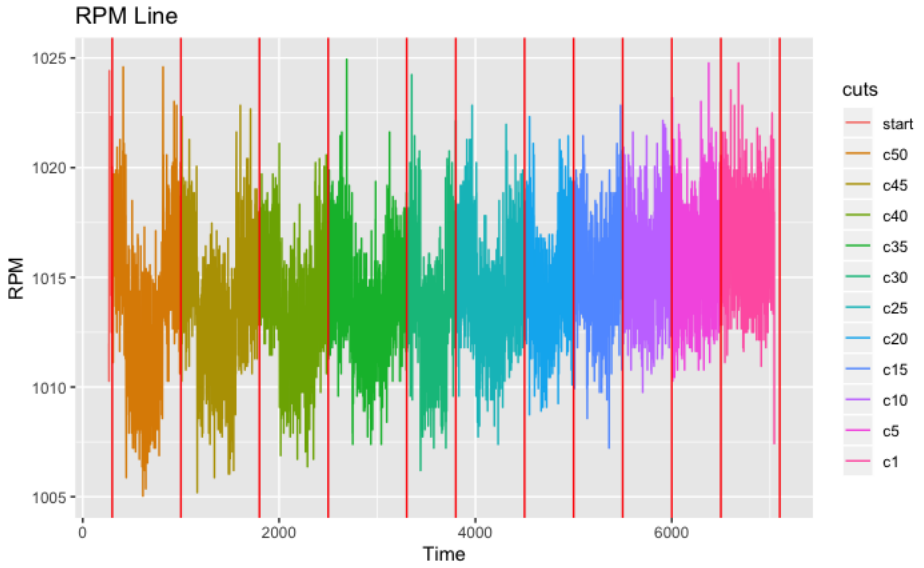


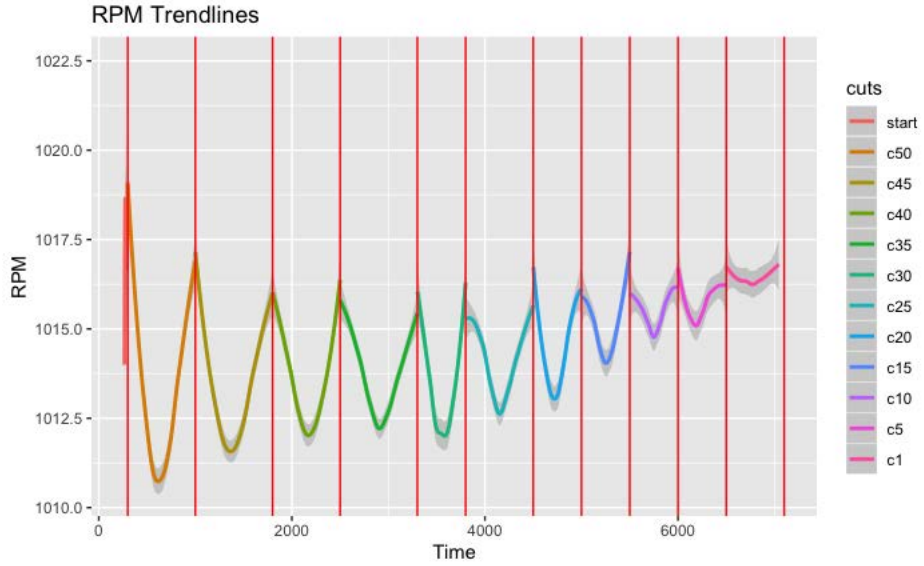


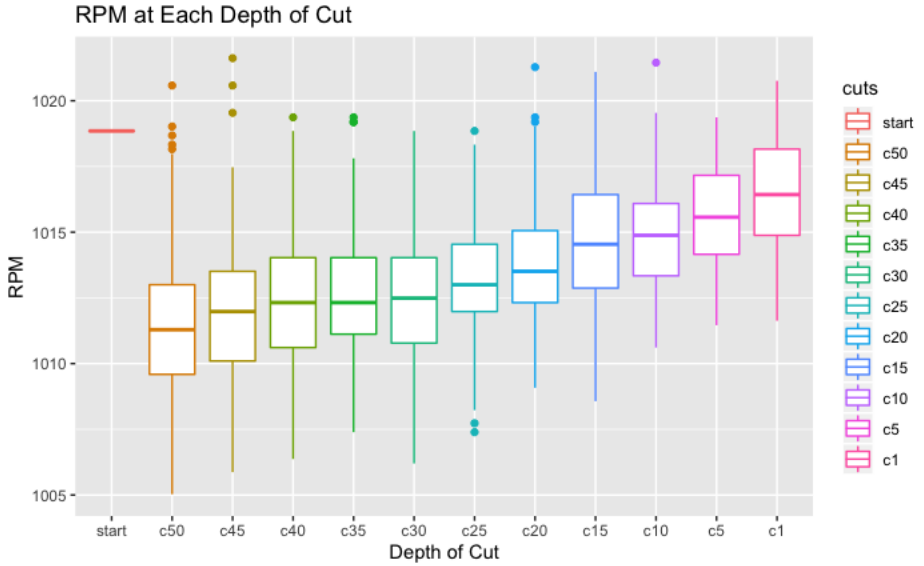


Data – Speed


RPM
RPM
Time
cuts
start
c50
c45
c40
c35
c30
c25
c20
c15
c10
c5
c1


RPM Line
RPM
Time
cuts
start
c50
c45
c40
c35
c30
c25
c20
c15
c10
c5
c1


RPM Trendlines
RPM
Time
cuts
start
c50
c45
c40
c35
c30
c25
c20
c15
c10
c5
c1


RPM at Each Depth of Cut
RPM
Depth of Cut
start
c50
c45
c40
c35
c30
c25
c20
c15
c10
c5
c1
cuts

Summary

- This is where we are:
- Able to collect data from a single machine using an Arduino and a laptop
- Able to collect data from a single machine using a Raspberry Pi and saving locally
  - Python script written for data collection
- Able to collect the speed, vibration, and current draw of the machine

Plans

- Installation Raspberry Pi based systems onto machines in student lab
  - Allow for passive collecting of data
- Develop a Linux based server to collect CSV files from Raspberry Pi
  - Use a laptop as the server
- Configure a Proxmox virtual environment distributed system server
- Develop GUI for Raspberry Pi machines
  - Provide user feedback and guidelines based on sensor readings
- Designing a defense in-depth methodology
- Cybersecurity for continuous monitoring for data availability, integrity, and confidentiality

End

Thank You

Questions?