Group M2.05 - Digital Twin Foundations

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Digital Twin Foundations for Ingram Hall's Makerspace

Problem

The Ingram Makerspace currently lacks real-time visibility into how its manual machines are being used. Without usage data or automated oversight, it is difficult to monitor equipment activity, enforce safe operation, or plan for maintenance. This gap creates safety risks and limits the makerspace's ability to manage its equipment effectively.

Objectives & Requirements

The primary objectives of this system are to provide real-time usage tracking for makerspace management and to automatically detect and shut down machine misuse.

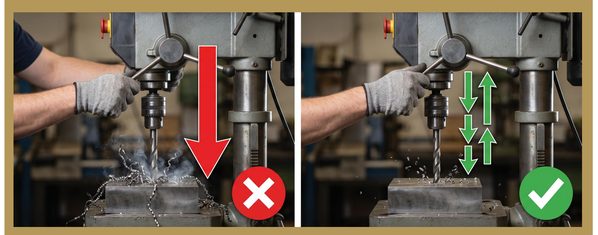
Key requirements:

- keeping the system low-cost, non-invasive to existing equipment
- scalable for future deployment across additional machines

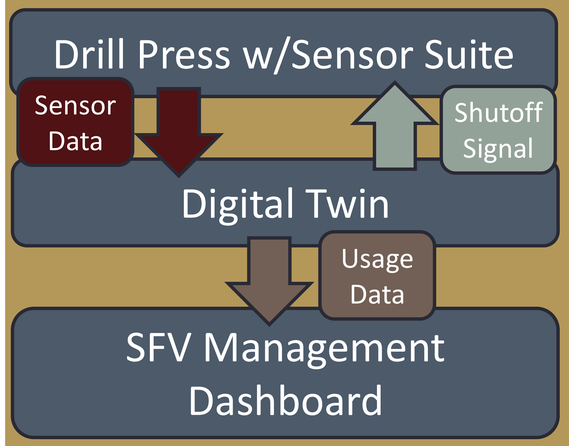
Defining 'Misuse'

The misuse case we focused on in this project was overfeeding and lack of peck drilling, which leads to

- Machine overcurrent, causing damage
- Rapid tool wear



System Design



The system is built around an Arduino Opta PLC housed in a repurposed enclosure mounted near the drill press. Sound and electrical sensors feed data to the PLC, which controls a relay-based power shutoff if misuse is detected. Industrial Andons light stack gives visual status indication, and the accompanying dashboard enables remote usage tracking and reporting. All components are off-the-shelf to support replication on additional machines.

Software Design

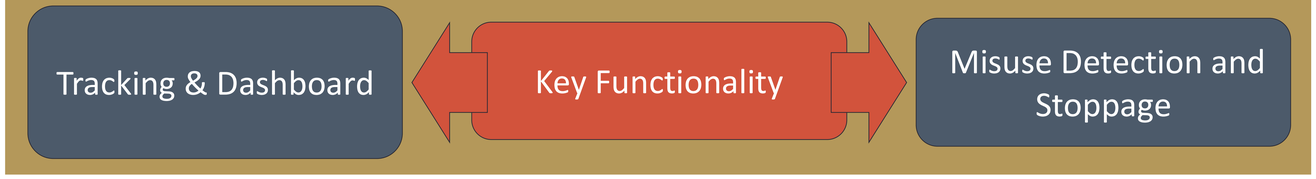
Dashboard showing sensor data used development, tuning, and debugging

Both sensors sample at 1500 Hz, with data processed in 200ms windows. Each sensor has its own pipeline. The electrical sensor uses the window mean while the acoustic sensor uses the peak value. They then compute a deviation from a calibrated baseline. A z-score-based threshold, tuned independently per sensor, flags anomalous readings. Misuse is only confirmed when both sensors flag within a short time window of each other, a cross-sensor coincidence approach that reduces false positives.

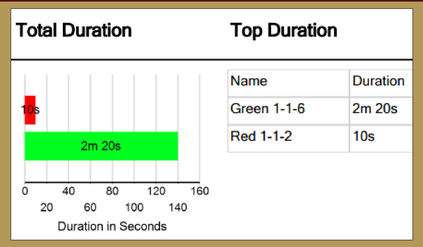
Results

Our final completed system is one that can

- Provides automatic stoppage for drill bits 1/16 – 3/8 on steel
- Can connect to any manual machine such as a Bandsaw, Table saw, Belt-Sander, etc.
- With some tuning, provide automatic stoppage functionality for inexperienced users.
- Tracks ground-truth usage data of machines as well as misuse data for makerspace management to influence things like maintenance, machine need, etc.



Equipment Tracking



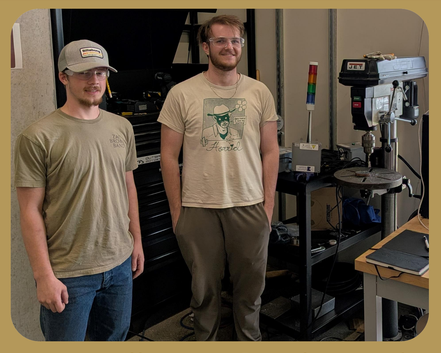
This project implements a tracking dashboard for machines using a program called Shop Floor Viewer, a dashboard program, allowing management to see real time usage, history, analytics

Conclusion & Next Steps

This Project successfully turns manual 'dumb' machines into smart ones with sensor outputs. We can use this system on manual equipment in the makerspace for digital twin functionality and dashboards containing representations of:

- Manual Mills & Lathes
- Bandsaws & Tablesaws

Team



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