MEASURING MAKING: INSTRUMENTING MAKERSPACES

8th International Symposium on Academic Makerspaces

ISAM 2024

MEASURING MAKING: INSTRUMENTING MAKERSPACES

Layal A. Barakat[1], David Brancazio[2], Jack A. Greenfield[3], and Martin L. Culpepper[1]

[1]Layal A. Barakat; Dept. of Mechanical Eng, MIT; e-mail: layal@mit.edu
[2]David Brancazio; Exact Engineering, e-mail: db@exactingengineering.com
[3]Jack A. Greenfield; Office of Env. Health and Safety, MIT; e-mail: jagreen@mit.edu
[1]Martin L. Culpepper; Dept. of Mechanical Eng., MIT; e-mail: culpepper@mit.edu

Synopsis

The intent of this project is to share early work that has been done to define means and methods used to instrument makerspaces for the purpose of collecting data about *who* is using *what,* and *when* they are using it. This capability is important to helping staff understand how students engage with their makerspaces. This poster discusses the link between goals, hardware, software, implementation and other choices/decisions that were used to instrument a makerspace. Having this example is important as these results can be adapted to other types of makerspaces, thereby enabling staff to better understand which tools students are using and impact of pedagogical interventions in makerspaces.

Motivation and Background

There are a few data collection methods to help makerspace staff understand the use of their makerspaces. Check-in stations, ID tap stations, and gates help monitor user count and frequency of user engagement [1]. Surveys and interviews of users, staff, and other stakeholders are also common [1]. Researchers have also experimented with motion sensing and facial recognition using Microsoft Kinect to track collaboration and user engagement within makerspaces [2][3]. Digital data entry systems are also in place for keeping track of material or stock inventory for logistical or financial purposes [4]. There is currently no known instrumentation system within makerspaces which tracks machine-specific usage over time or machine usage for specific users for research purposes.

The novelty of our approach is in instrumenting the machines in these spaces to collect more detailed data on user habits and to monitor continued engagement or withdrawal from that environment. There are many reasons why collecting this data is useful, but in particular, we are focused on understanding how people from diverse backgrounds engage with makerspaces. In tandem with existing tools, such as sign in data and surveys, this novel data collection approach will allow makerspace leaders to implement targeted interventions and improvements to makerspace environments.

Design Requirements

Requirements were primarily based on the qualities of the makerspace itself, but the system is generalizable for many spaces. The SHED is a new prototyping space on MIT's campus in collaboration with the Office of Environmental Health and Safety (EHS). Its goal is to increase multi-disciplinary research through safe and rapid access to advanced technologies. The SHED offers a wide variety of machines, from common makerspace tools such as a bandsaw, laser cutter, and soldering irons, but also includes more advanced technologies such as a metal 3D printer, 4-axis CNC mill, and an electrical discharge machine (EDM).

Given this context, the instrumentation system should be (1) largely generalizable to a diverse array of machines, without wide variations in data quality. The system should also be (2) low profile and not hinder use of the machines. In addition, because of ever changing research needs, the sensors chosen should be (3) easy to deploy, relocate, swap, and remove for maximum flexibility. In alignment with the SHED's goal of developing knowledge, the system should also be (4) low-cost and (5) easy to manage, for straightforward implementation across MIT and other makerspaces globally.

The SHED itself is set up within different "bays", with machines laid out close to each other within a single bay, and one prototyping room. The layout is shown in Fig. 2. Given this layout, another requirement is that (6) the sensors are set up so that data can be collected from each machine without having wires running between different bays.

In terms of the data management system, it needed to be (1) easy to manage and monitor over time. It must be (2) flexible in terms of adding and removing machines to mirror the ever-changing landscape of a makerspace like the SHED. The data collected should also be (3) linked to specific users in the case of individual use monitoring.

Methods

Six different sensing and data collection types were explored in the implementation stage. These are (1) vibration sensing using accelerometers, (2) current sensing, (3) pressure sensing floor pads, (4) motion sensing of a general area, (5) RFID scanning of an ID card, and (6) a sign in station. A summary and explanation of all sensing types are explored in Fig. 1.

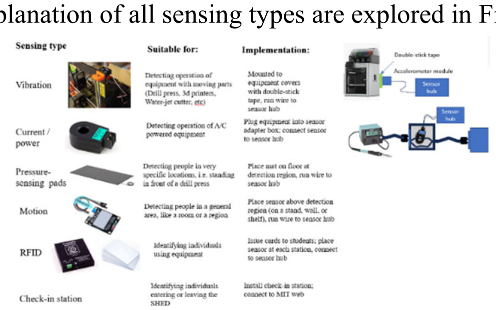

Figure 1: Summary of the six sensing types explored for instrumentation

The final approach involved installing Phidgets accelerometers (vibration sensing) taped onto each machine.

The prototyping room has a motion sensor to detect people using the space. This is particularly useful because the 3D printers are able to be remotely started. These sensors were linked to wireless sensor hubs, one for each of the two bays and a wired sensor hub in the prototyping room. These hubs shared data to a laptop through two wireless receivers running on USB sticks. The laptop runs data collection software, coded in LabView, which can be remotely accessed. A block diagram of this setup can be found in Fig. 3.

RFID scanners (yet implemented) are planned to be used to connect usage to specific users by cross referencing timestamps between the accelerometer and motion sensor data. Current sensing was not used due to compatibility issues with electrical codes. Pressure sensing pads were not used as they did not provide additional benefit over motion sensors.

There are different ways to retrofit different maker tools to ensure compatibility with sensor systems. For example, a soldering iron alone may not generate enough vibration to trigger an “on" state. However, exhaust fans automatically turn on when the SHED’s soldering irons are in use. Instrumenting them enables the accelerometers to detect when the soldering irons are in use.

Overall, considerations when selecting optimal sensing methods include the particular makerspace setup, the specific tools, and the questions researchers are looking to ask.

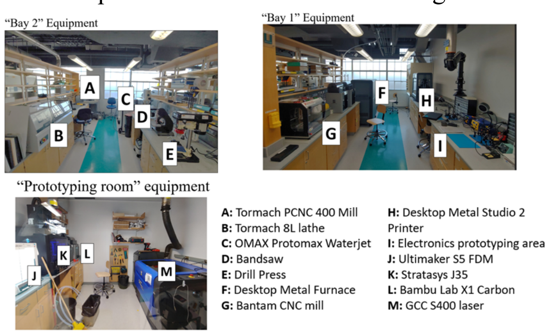

Figure 2: Machines in the SHED and their associated bay/area.

Calibration

Calibrating the sensors and overall instrumentation system, the data acquisition needed to be fine-tuned. Machines connected to accelerometers needed their thresholds to be adjusted for the system to recognize that the machine was in use. The machines in the SHED have different vibration levels and patterns and that must be taken into consideration. For example, the Bambu printer constantly moves whereas the Stratasys bed rotates.

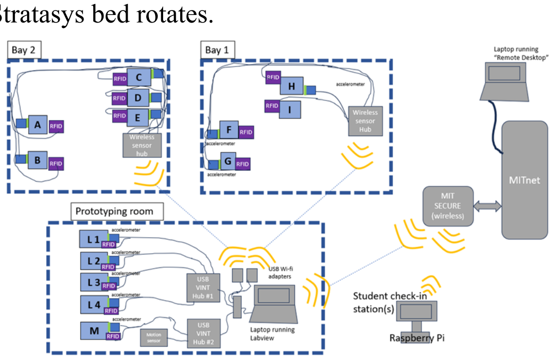

Figure 3: Overview - Blue blocks are deployed, purple to be deployed.

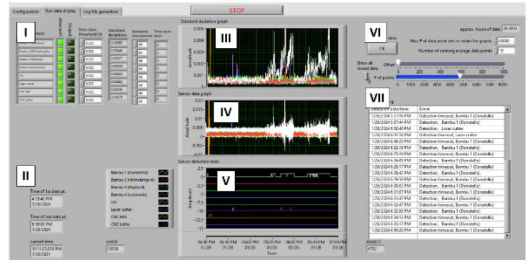

Figure 4: Data acquisition software - I: Equipment list. II: Time of first, last data point. III: Raw data. IV: Processed vibration data. V: Digital data, i.e. “on” and “off” signals approximated by thresholds and persistence time. VI: Chart data settings. VII: Detection log.

In addition, some machines have vibration that varies over time. Apart from setting the threshold, it’s critical to set up how long to hold the data “on” or “off” after sensing to avoid false positives and negatives. This is called the persistence time. In the case of the Bambu printers, it is not uncommon for them to stop moving during a filament purge or change, which could cause the sensor to read “off”. Where the persistence time is greater than the expected “stopped” time on the Bambu, the digital data will still read that the machine is “on”. The data acquisition system is explained in Fig. 4.

While the hardware and sensors were chosen for their compatibility and longevity, IT issues will likely be the main long-term concern for this iteration of the instrumentation system. Any IP address change or network issue results in needing to reset the computer to access the data. This issue can be avoided if remote data handling is not needed.

Conclusion

In this poster, we demonstrated a synopsis of the process of instrumenting the SHED, a new makerspace at MIT with a focus on advanced technologies. This system is unique because it allows for thorough analysis of user habits and actions. This has consequential implications for possible research questions, though in our case, understanding how users of different backgrounds and experiences enage.

References

[1] M. N. Cooke and I. C. Charnas, “The Value of Data, Metrics, and Impact for Higher Education Makerspaces,” *IJAMM*, vol. 1, no. 1, Oct. 2019, doi: 10.21428/70cb44c5.72b2375c.

[2] G. Sung, T. Yoo, E. Chng, S. Yang, and B. Schneider, “Automated Tracking of Student Activities in a Makerspace Using Motion Sensor Data,” Jun. 2021, Accessed: Jun. 12, 2024. [Online]. Available: https://repository.isls.org//handle/1/7312

[3] E. Chng, M. R. Seyam, W. Yao, and B. Schneider, “Using Motion Sensors to Understand Collaborative Interactions in Digital Fabrication Labs,” in *Artificial Intelligence in Education*, I. I. Bittencourt, M. Cukurova, K. Muldner, R. Luckin, and E. Millán, Eds., Cham: Springer International Publishing, 2020, pp. 118–128. doi: 10.1007/978-3-030-52237-7_10.

[4] R. Banerjee, L. M. Ferron, D. Bailey, R. Imam, and A. S. Jariwala, “IoT in Makerspaces - Review of Usage and Future Potential 4th International Symposium on Academic Makerspaces,” *IJAMM*, Mar. 2020, Accessed: Jun. 13, 2024. [Online]. Available: https://ijamm.pubpub.org/pub/yuj0rxvr/release/1