Active Monitoring of Chemical Fume Hood Sash Position for Energy Conservation

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MSRP MIT Summer Research Program | Massachusetts Institute of Technology | LEAC Lab Energy Assessment Center | University of San Diego McNair Scholars

Motivation

- One chemical fume hood consumes the same amount of energy as 3 to 4 American households
- Closing the fume hood sash can result in up to 75% in energy savings
- It is difficult to measure the energy consumed by an individual fume hood in a laboratory due to building parameters and other complications
- We sought to design and create a monitoring system to measure the energy consumed by a single fume hood and also to implement an audio feedback system to reduce wasted energy

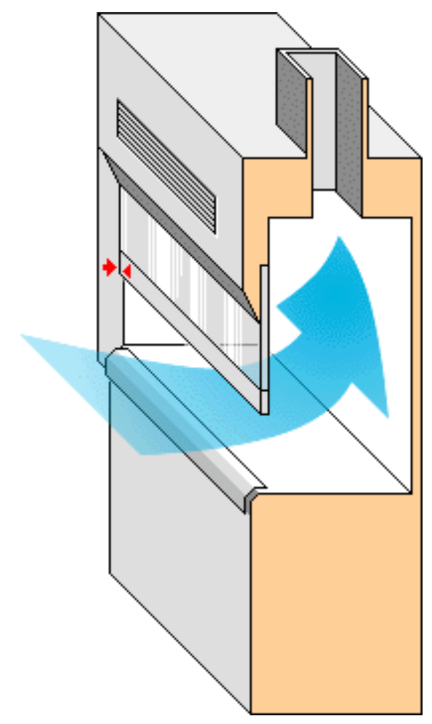

Figure 1. Schematic of a chemical fume hood – conditioned air is pulled in to the hood from the lab space and rejected from the building

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Methodology and Setup

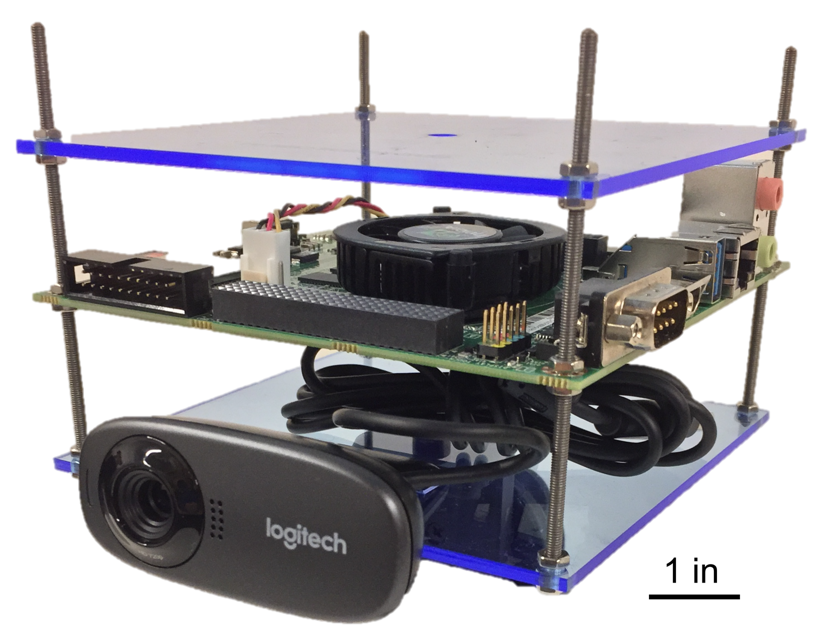

Figure 2. Jetson TK1 microcomputer in case

Figure 3. Standing fume hood monitor setup

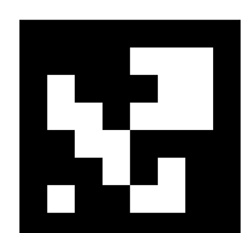

Figure 4. Augmented reality (AR) tag

Figure 5. Fume hood monitor side view, with detail of ports on TK1 and profile of the camera

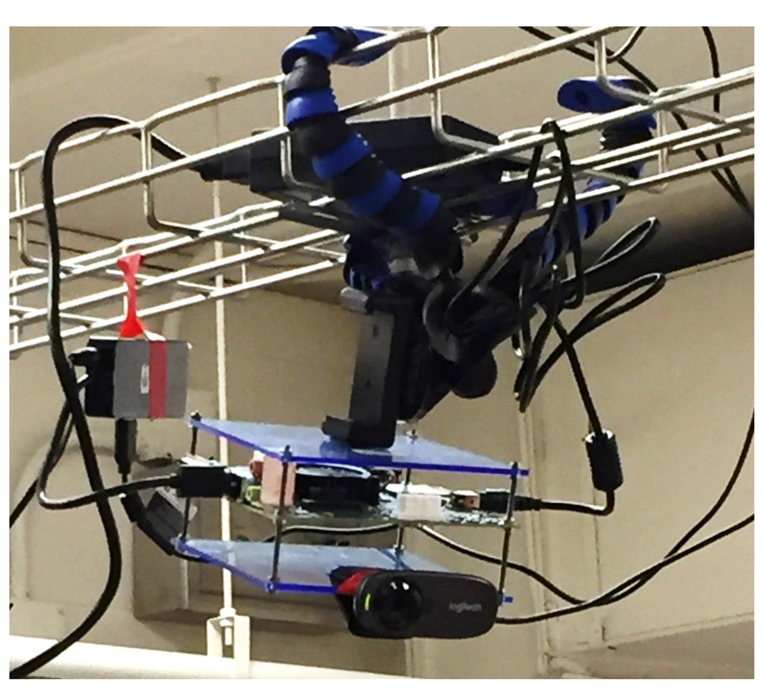

Figure 6. Hanging fume hood monitor setup

Total Distance = Top Tag Height – Bottom Tag Height

Sash Distance = Middle Tag Height – Bottom Tag Height

Distance Ratio = $\frac{\text{Sash Distance}}{\text{Total Distance}} \times$ Actual measured distance from top to bottom tag

- Convert distance ratio to sash distance from middle tag to bottom tag
- Determine sash opening height from calibration when the sash is closed

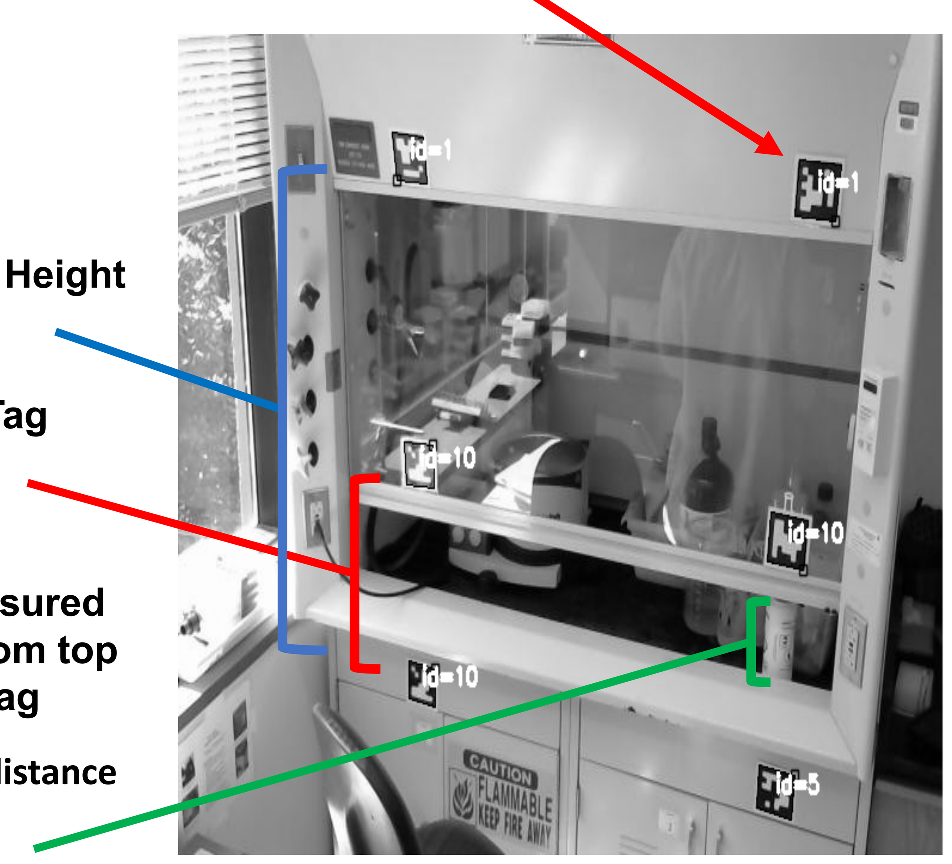

Figure 7. Image taken with fume hood monitor showing detected AR tags

Audio Feedback Implementation

- Software programmed in Python coding language using Aruco module in Open Computer Vision library
- Onboard alarm activated on fume hood monitor to alert users to close the hood when it is not in use
- Sash position, motion level, and alarm status are stored in an accessible comma separated values (csv) file for post-processing

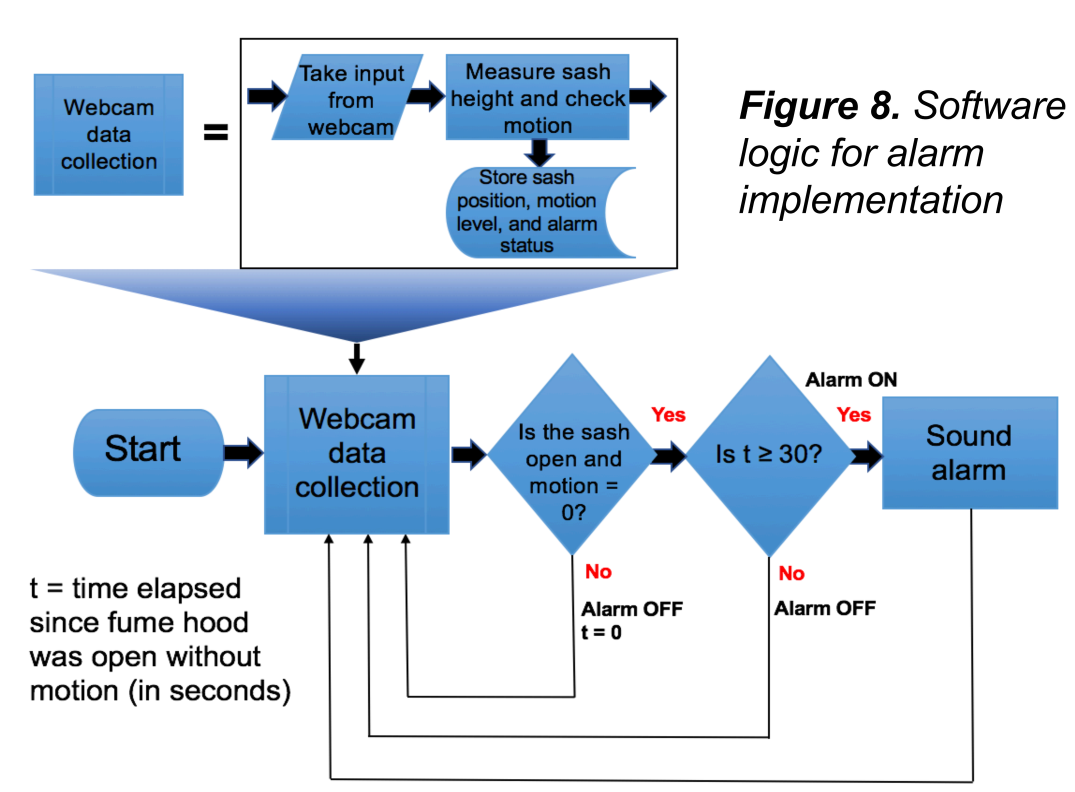

Figure 8. Software logic for alarm implementation

Results

- Experiment was designed to determine energy use baseline without audio feedback and compare to energy use with audio feedback
- Devices were installed at 4 fume hoods on MIT's campus and operated for one week without any feedback for lab users to take baseline data, then for one week with audio feedback in the form of an alarm that activated when the hood was left open and not in use for over 30 seconds. An additional device was installed on USD's campus and operated for 3 weeks without the feedback followed by 3 weeks with the alarm.

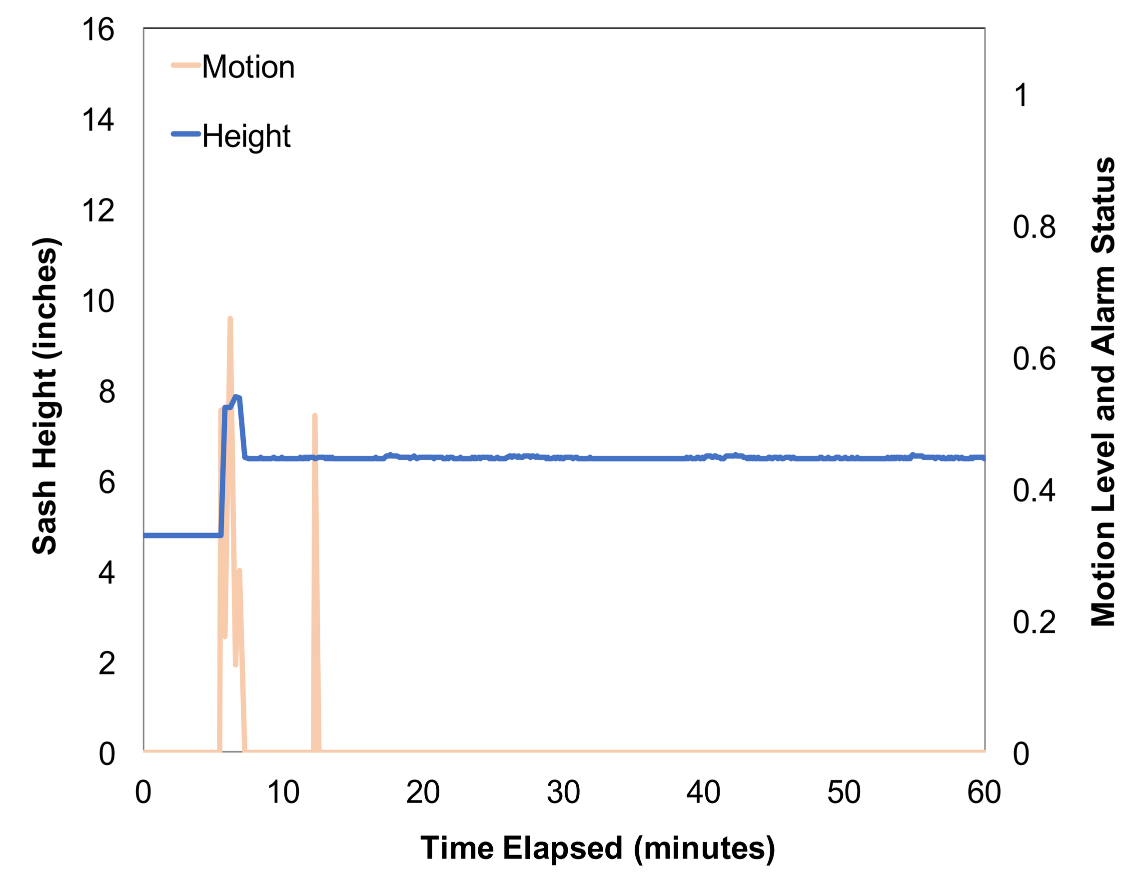

Figure 9. Sash position and motion level recorded by fume hood monitor during baseline (control) period with no alarm

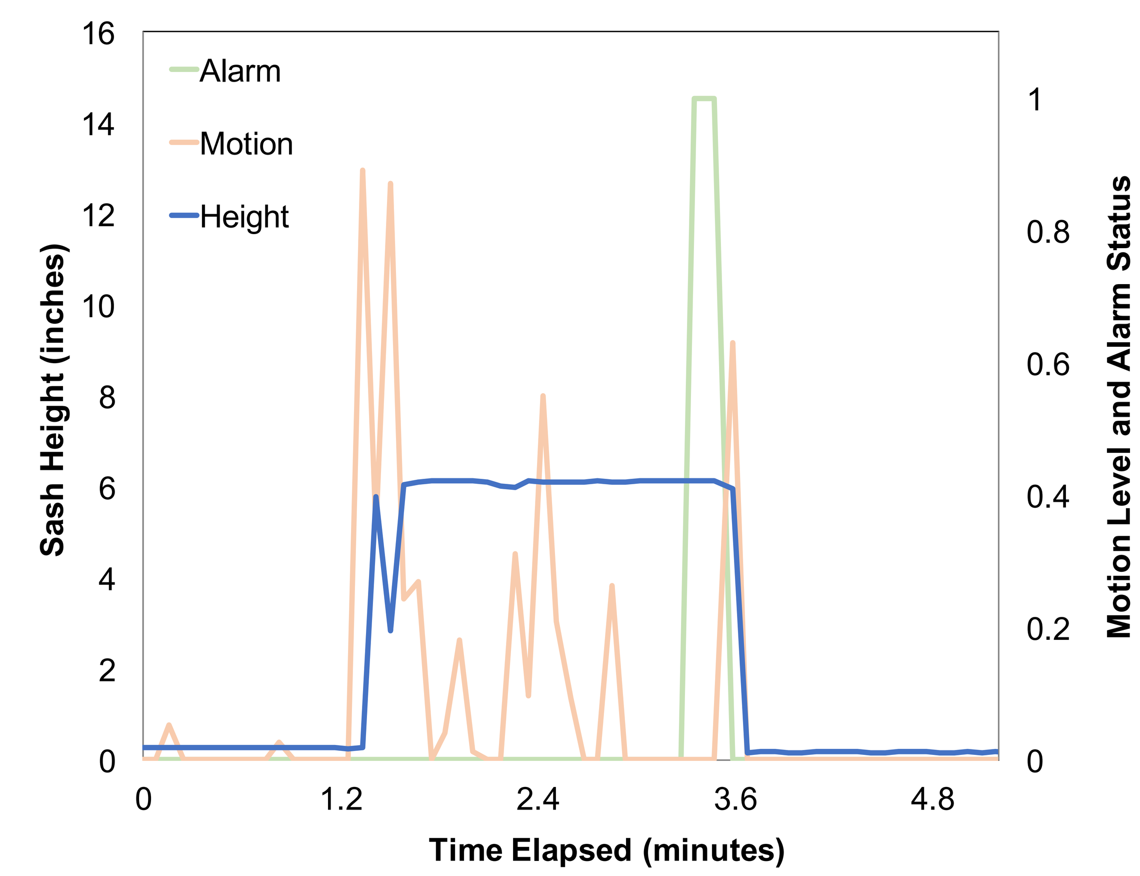

Figure 10. Sash position, motion level, and alarm status with alarm activated on fume hood monitor during test period

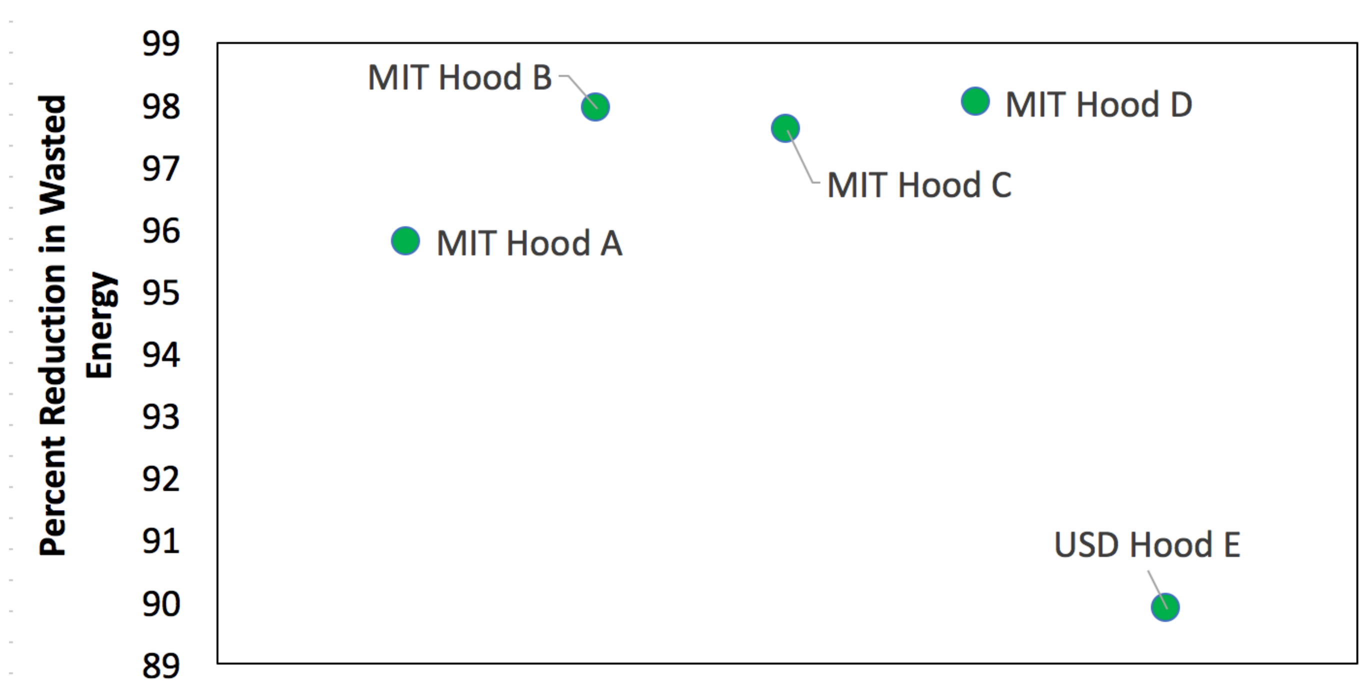

Figure 11. Average wasted energy levels for each fume hood during baseline (control) and test (alarm) periods of the experimental study

Device Cost
$264.34

Device Power
61.3 kWh/year

Hood	Control Wasted Energy (kWh/year)	Alarm Wasted Energy (Including Device Power) (kWh/year)	Reduction in Wasted Energy (kWh/year)	Cost Savings ($/year)	Payback Period (months)
A	1662.05	69.99	1592.06	211.27	15.0
B	3812.01	78.88	3733.13	495.39	6.4
C	2678.30	64.93	2613.37	346.79	9.1
D	5048.33	99.36	4948.97	656.73	4.8
E	672.34	68.01	604.33	86.84	36.5

Conclusions

- The data showed significant reduction in time during which the fume hood sash was open after the alarm was implemented on the monitoring device.
- Implementing the fume hood monitoring device resulted in a projected annual energy savings from 604 – 4949 kWh/year (90% to 98% of the baseline wasted energy) and up to $656 in saved energy bill costs.
- The payback period after purchasing and installing a device in a lab ranged from 4.8 to 36 months, demonstrating that the audio feedback device is a promising and cost efficient waste reduction method for fume hoods.

Acknowledgments

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