MIOS Cage Cam – A Cloud-based Homecage-Integrated Waste Monitoring Device to Improve Animal Care

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Abstract

Mice are critical to the cutting-edge research being conducted at the National Institutes of Health (NIH). As a result, NIH houses hundreds of thousands of mice on the Bethesda campus alone that are part of ongoing research efforts. Caring for all these mice is a time consuming and expensive effort that requires many man hours and millions of dollars in federal funds. Currently, for most protocols and animal facilities, cage bedding is changed by animal care staff on a weekly basis regardless of the number of animals or research conditions. Changing the bedding in cages is a necessary process to remove animal waste and ensure the animals live in a healthy home-cage environment. The consequence is this relatively frequent process can disrupt mouse behavior and introduce stress when the animals are moved from cage to cage. Changing cages less frequently, especially for low density cages with 1 or 2 mice, could not only reduce the frequency of this stress factor but also save hundreds of thousands of dollars in animal facility operation costs. The goal of the MIOS Cage Cam project is to enable researchers and animal care staff with an automated, quantitative measuring device for cage cleanliness to reform the current paradigm for cage changes so that it is need-based instead of being based on a rigid schedule.

Objectives

- Develop a tool to automatically monitor mouse waste in ventilated rack cages with the following driving features:
  - Tolerance for different room lighting conditions
  - Does not disrupt circadian cycle of mice
  - Battery powered
  - Easy to use and easy to set up
  - Cost-effective
  - Cloud connectivity for data reporting
- Use the above tool to develop a better system for changing mouse cages at NIH

Hardware

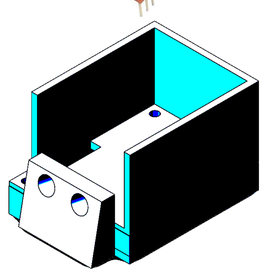
The MIOS Cage Cam is currently designed for Allentown NexGen Cages although the hardware likely can be retrofitted for other cages.

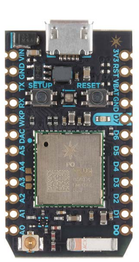
OpenMV Cam M7

- Image acquisition and local processing
- Small and cost-effective
- Contains color CMOS VGA camera, RGB LED, Arm Cortex M7 microprocessor, dedicated RAM, local storage, GPIO pins, and SD card slot
- 5v power adapter, in the future will use battery

3D printed enclosure

- Designed in SolidWorks
- Printed on Eden260vs 3d printer with polypropylene-like material (Rigur)
- Protects OpenMV M7 microcontroller
- Attaches to food hopper using magnets





Particle Photon

- Connects to OpenMV via I2C or SPI
- Sends data to MIOS Cloud via Blynk
- Contains microprocessor, GPIO pins, Wi-Fi module

Figure 1: Images of the Cage Cam Mounted in an Allentown NexGen Cage

Methods

The MIOS Cage Cam acquires and processes images using an OpenMV Cam M7 microcontroller. The OpenMV Cam M7 features a programmable LED that is used for constant illumination across different lighting conditions. However, before any images are acquired with LED illumination, a test image is always acquired without illumination and is processed to determine if the room's circadian cycle is in its night period. Once the device verifies the room is in its daytime portion of the circadian cycle, an image is acquired with brief LED illumination. Waste pellets are segmented in the image using a combination of thresholds and filters. Additionally, waste pellets on the edges of the image are not considered as these regions often include shadow and/or portions of the cage walls. After segmentation, a value is formed based on the number of detected pellets and is used as a measure of cage cleanliness. For the duration of the summer, waste pellet data was stored locally on the OpenMV Cam M7 however the final system will transmit the data to a Particle Photon via I2C or SPI connection and then to the MIOS Cloud via Blynk where it can be accessed on the MIOS App.

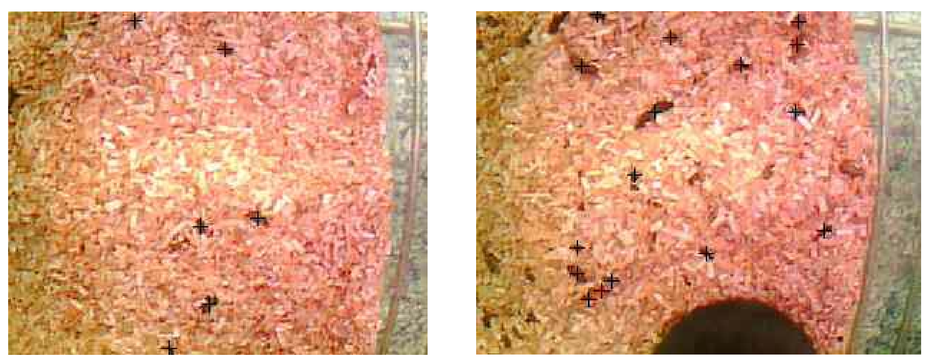


Figure 2: Processed Cage Cam Images

Want to learn more?

https://hackaday.io/project/158599-mios-cage-cam

Preliminary Results

The work this summer has helped bring this project from an idea into a promising prototype with its first proof of concept dataset. We were able to acquire and process waste pellet data from 2 separate 6-day periods in the animal facility using the Cage Cam in Allentown NexGen Cages. Each period began with a clean cage containing 1 mouse. The cage cam acquired images every 30 minutes during the facility's 12 hour day cycle. Results from each day were averaged and reported day by day in the graph below. Each line on the graph represents data from a 6-day period. Our expected outcome was an increase in the number of detected waste pellets from day to day and the below graph shows this trend.

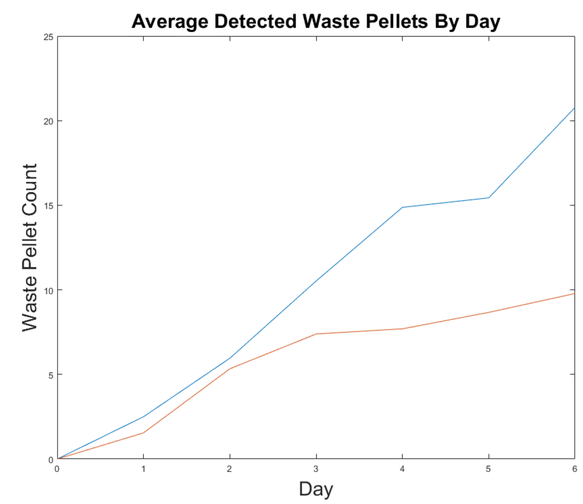


Figure 3: Graph of Cage Cam Results Averaged By Day

Future Developments

The above preliminary results were encouraging; however, much more work is needed to fully evaluate and fine tune the system to meet the proposed objectives. The next steps for the project are:

- Evaluate the error in our current processing algorithm
- Understand the rate of false-positives and false-negatives
- Refine the processing approach to minimize error
- Deploy and test the hardware for MIOS Cloud connectivity
- Optimize the system so it can run on a battery for an extended period of time
- Further demonstrate system utility and reliability by working with our collaborators to implement the system in a study

References

Rasmussen, S., Miller, M. M., Filipski, S. B., & Tolwani, R. J. (2011). Cage Change Influences Serum Corticosterone and Anxiety-Like Behaviors in the Mouse. *Journal of the American Association for Laboratory Animal Science : JAALAS*, *50*(4), 479–483.

Acknowledgement

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