Data Acquisition Involving Low Cost Scientific Automation

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Abstract

Automation in scientific research inhabits a wide range of uses, but is often cost-prohibitive for research budgets. Its absence wastes valuable time, and can introduce or increase the possibility of human error. This project, inspired by the lack of cheap, available automation equipment, sought to provide an easily scalable, fault-tolerant solution, providing maintainable and cheap hardware as well as user friendly and consistent software for collecting data. While the actual physical design and construction of the product were handled by another project, the electrical design and hardware needed to be robust, while still remaining cheap and easy to reproduce. Using new technologies, like consumer grade microcomputers, as well as popular hobbyist hardware, also allows the end result to be progressively updated, as time permits. The intent of the software is to provide a stable, error free ability to record subject interactivity, as well as automate feeding in general, with the ability to limit and control the relation between activity and feeding, or as to measure and evaluate the subject motivation. In addition to this software, the embedded controllers within the devices are designed to be easily reconfigurable, low power, and reproducible within consumer specifications, incorporating up to a limit of 32 individual devices.

Background

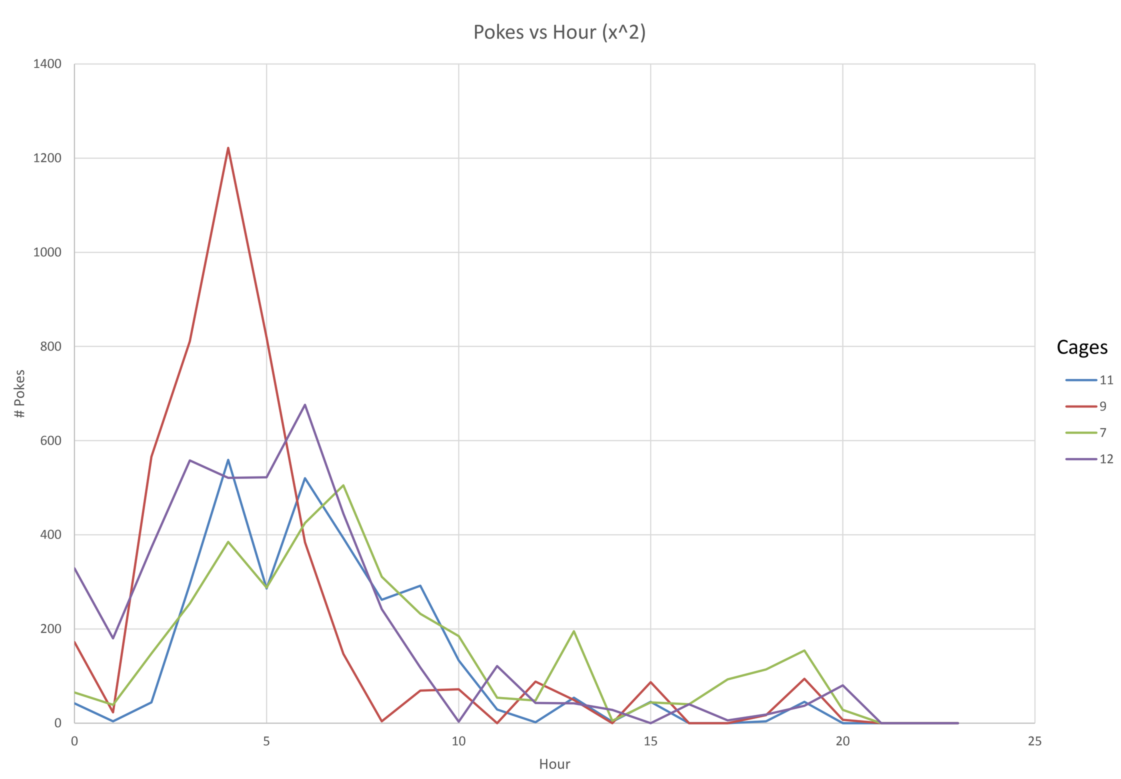
Instrumental equipment and software are necessities for most avenues of research, and is usually one of the major costs inherent in the work they do. Like any other product, the price can be arbitrary, in the absence of any direct competitors. Often, companies with the means to produce this niche equipment can set any price they want, driving up costs in research labs, and diverting funds and resources away from scientific pursuits. Other alternatives in the field of automated/activity driven feeding systems are few, far between, with costs that are prohibitive to small labs. The data remains necessary, despite the costs of the equipment, leaving smaller research labs without options.

Objective

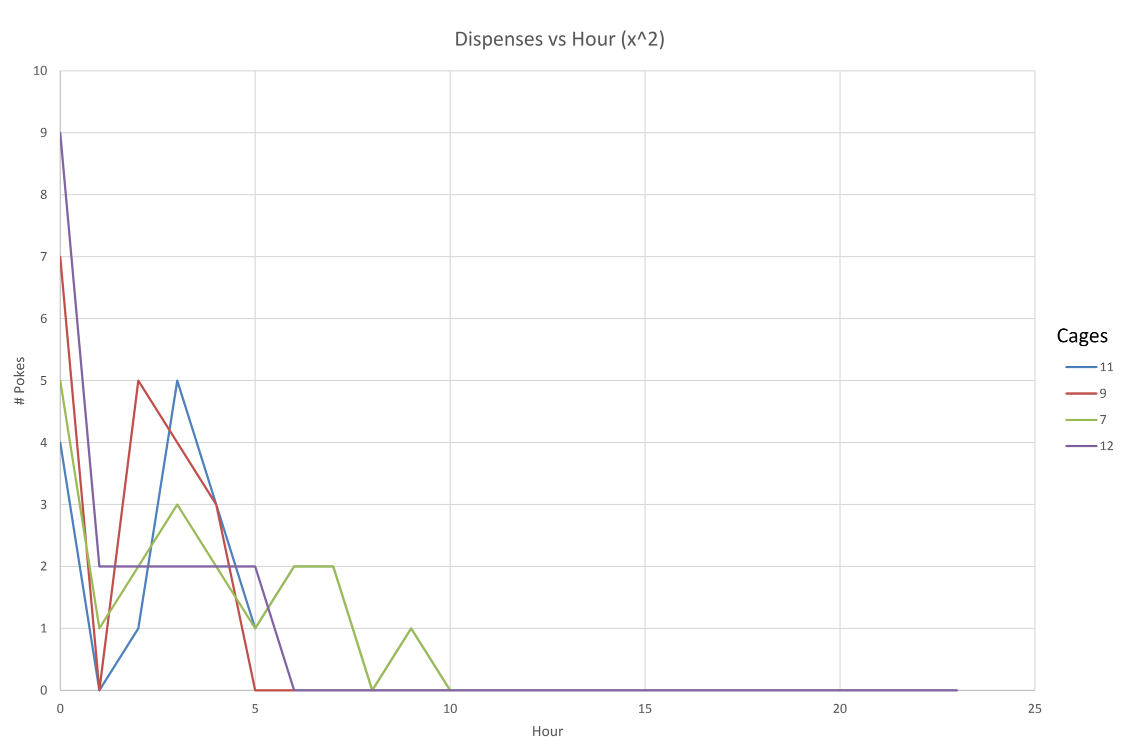
The development of a scalable software utility to manage and report data from multiple feeders was the intent of the project. The requirements included the ability to manage at least 8 feeding apparatuses, as well as accurately sensing and recording nose-poke activity of the subjects. The feeders, as a system, were also required to be capable of different feeding schedules, feeding a certain amount of food to the subject after a pre-specified, or regulated amount of activity. An easy to use interface was also necessary, as well as an ability to schedule feedings, regardless of activity requirements. The electronics in each apparatus were the last aspect of the project, requiring collaboration with another expert.

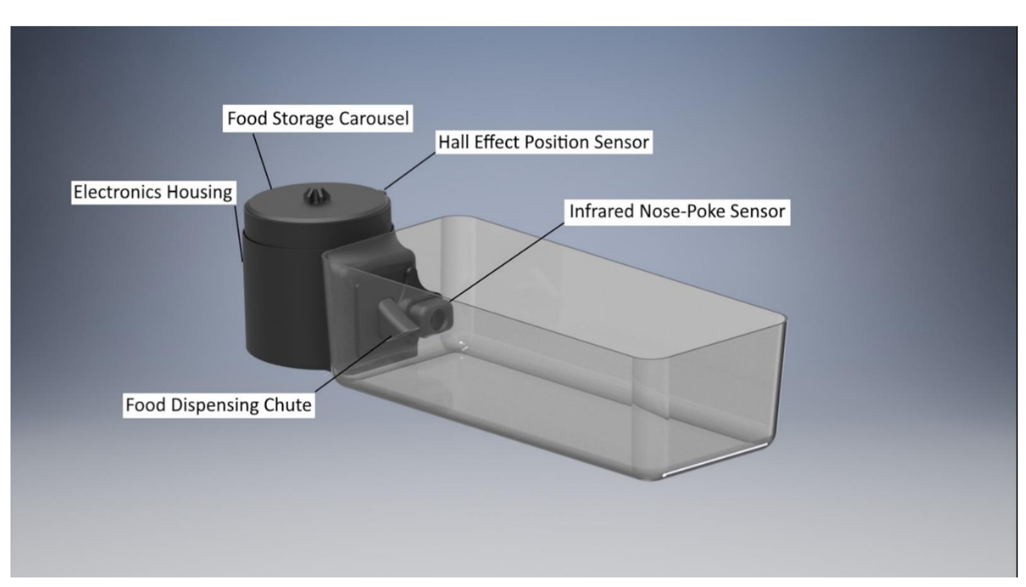
Materials And Methods

The structure of each feeder is an easily to assemble group of 3D-printed parts, with only the carousel body and nose-poke sensor requiring integrated electronics. Those parts of the apparatus that are within the containment area are coated in a food-safe resin, to prevent contamination or possible chewing. The electronics within each feeder are comprised of an Arduino Pro Mini, a cheap hobbyist microcontroller programmed in C, a stepper motor powering the feeder carousel, an infrared break-beam sensor for 'poke' detection, and a magnetic encoder, to detect carousel rotation. The feeders are managed by a Raspberry Pi, running a Pi-based variant of Debian Linux, communicating over the I2C protocol. The I2C protocol was chosen, as it provided easy, fast communication over a minimum of signal lines, allowing the Raspberry Pi to connect to each feeding apparatus with only 2 signal lines, as well as providing power. The Raspberry Pi continuously runs an application that handles retrieving information from each feeder, and communicating dispense actions. The application currently has a version written in C and Python, with the Python version being slightly more featureful and versatile. The manager (the Raspberry Pi) can run in a headless, scheduled-job mode, as well as with a user-configurable frontend, written in Python.



Graphs of Pokes and Dispensed per hour, during a 24 hour test, running a configuration of x^2 pokes for the xth food dispense.





Conclusion

Successfully completing the project required integration with another expert, but in the end, all project requirements were met. Some issues required additional testing, including extra work with the apparatus' carousel and encoder. There were a few revisions of the basic material structure of the feeding device, but they resulted in stronger, easier to monitor equipment. Post usage and testing, the hardware is now undergoing long-term installation and finalization. The output data required a small after-testing parser, but the data provided is currently under study, helping describe the relation of food anticipatory behaviors in the chosen test subjects.

Future Work

As another project, another set of testing devices has been undergoing development; in this case to track the movement of subjects in cages. This other system is for the most part finished, going through its last steps and final testing. The tracker is theoretically infinitely scalable, with appropriate load balancing, more so than this feeding apparatus, which is technically limited to a 32 feeder maximum, per Raspberry Pi managing controller. Both provide a specific avenue to measuring the activity of the subjects- food anticipation and intake for the feeders, and movement and metabolic rate for the tracker. However, there do exist other avenues of development, for instance the measure of oxygen usage of the subjects, or the amount of energy radiated as body heat. There are sources from which this equipment could be purchased, but again, they can cause unnecessary increases in cost for any lab, like this one, studying Mus musculus. The intent remains to provide light continued maintenance, as well as possibly more development on the existing products.

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