Raspberry Pi and Arduino Prototype

Measuring and Displaying Noise Levels to Enhance User Experience in an Academic Library

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Problems associated with noise in academic libraries are an ongoing concern for patrons and library administration. Noise disruptions come from numerous sources including people, cell phones, sounds from eating, and audio players. Noise studies from Nigerian universities found that some of the major sources of noise were environmental factors such as automobiles, airplanes, and equipment (photocopiers, scanners, outdoor lawn mowers, air conditioners, and ceiling fans).[1] Based on the 2013 LibQUAL+ survey, noise and the ensuing lack of quiet study space continue to be challenges faced by Concordia University Libraries.[2] When I worked as a business reference librarian in Concordia University's Webster Library in collaboration with the web services librarian, we felt that the noise issue was an interesting problem to solve.

Noise Studies in Academic Libraries

Noise is a prevalent problem in academic libraries, and it is one of the major complaints from students.

There have been a number of studies that collected subjective and objective data to measure noise levels.[3] It was important to capture both forms of data because objective noise data, collected through sound-monitoring devices, may not necessarily reflect how patrons perceive the noise level.[4] Loudness is subjective; what may be noisy to one person is acceptable to another.[5] Examples of collecting subjective data include the administration of questionnaires or surveys. Objectively, sound and noise are measured with a metric called the decibel. The decibel scale reads the sound pressure and translates the range of sound to a logarithmic scale.[6] The range varies from 0 to 140 decibels (dB), where 0 dB is the threshold of hearing, normal speech registers at 60 dB, and 120 dB is the noise level near a jet aircraft engine.[7] Luyben and colleagues found subjective data to be the better measurement of the two because information collected from patrons "reflected only noise that was perceived as annoying" and the electromechanical system was not discriminatory in the type of sounds generated, including dropped books,

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jacket zippers, chairs bumped into tables, and other random sounds.[8]

Academic libraries explored numerous interventions to reduce noise. Noise-level zoning was one of the common strategies, including furniture rearrangement on different floors of the library. In one study, researchers removed tables and upholstered chairs from the central area and relocated them to other areas of the floor, but they found that the reallocation produced no measurable reductions in noise.[9] Crumpton discussed the benefits of reducing clusters of furniture and carefully selecting furniture such as carrels and cubicle-like walls to minimize group socialization.[10] The separation of printer and copier rooms and group study rooms from the quiet study areas focused on space allocation in containing noise levels to specific areas in the library.[11]

Other intervention strategies have also been explored, including staff monitoring by students, library staff, guards, or campus security.[12] Hronek conducted a study to determine if reducing light levels would minimize the amount of noise made by patrons when they entered the library but concluded that reducing light levels had no significant impact on noise levels.[13] Libraries enforced policies and procedures in creative ways. One method of communication involved the staff handing out cards (slips or bookmarks).[14] For instance, one message read, "Don't be Cellfish! Please set your cell phone to vibrate."[15] A number of libraries used signage, posted policies on their websites, created handouts, or used a combination of these interventions to inform patrons of their policies.[16] The key was to maintain consistent messaging for the policies to have credibility.

McGill University developed a creative noise intervention project with NoiseSign, an electronic monitoring device that measured the current noise level of particular areas in the library.[17] The researchers established an acceptable noise threshold, and when the noise threshold was reached, the LED sign would light up. They hypothesized that the sign would provide real-time feedback to inform students that they were being too loud, which would facilitate self-monitoring among the students. However, their findings showed that the intervention did not significantly change the amount of noise generated.

The common theme across all studies demonstrates that interventions tend to not produce measurable results in reducing noise. Students also responded negatively to the interventions. Some found it more difficult to complete their work, and some students were upset with the change and felt that library staff were encroaching upon their personal study areas.[18] Rather than implementing an intervention to minimize noise, we wanted to implement a solution that would inform users about the particular noise levels of different areas in the library, provide real-time and objective, quantitative feedback on noise, and allow patrons to choose which environment they prefer.

Method

Our goal is to have decibel measurement data visualized on screens to enable visitors to see the noise levels in each area of the library. This display would allow visitors to choose the area with the right amount of noise for their purposes (e.g., two students working quietly together would go to a semi-silent area; one student going to read a book would want to pick the quietest area in the library). In addition, decibel levels taken at regular intervals would be sent to a database, which could be queried in order to make informed and targeted interventions.

To implement this project, we first worked on a proof-of-concept prototype that would use sensors to measure decibel levels and quantify what is "silent" versus what is "quiet." The parts used to build the prototype included Arduino and Raspberry Pi components, a microphone sensor on the Arduino, and a computer monitor.

Implementing the Prototype

Step 1

Due to our limited knowledge of Arduinos and Raspberry Pis, we needed to have a better understanding of how they work. Reading and working through the exercises from the books *Getting Started with Arduino* and *Getting Started with Raspberry Pi* helped guide the project.[19]

Step 2

In *Getting Started with Arduino*, there is a sample exercise that teaches you how to add a light sensor to the Arduino, which is a microcontroller (small computer) dedicated to one specific purpose. We tested this out and after successful implementation of the light sensor exercise, we changed the sensor to a microphone to measure noise levels. In order to communicate the decibel measurement readings from the microphone, the sensor was connected to the Arduino on a circuit. The Arduino continually measured the decibel levels in an area by running one program on a continuous loop as long as it remained on. Using the Arduino was ideal since there was no need to build circuits from basic components, it is very affordable, and it is open source. Arduinos also come with an IDE (Integrated Development Environment) software, the suite of software that is needed with which to code the program. For example, the following code was used for the Arduino programming:

```
int DIG = 8;
  int ANA = A0;
  int sound = 0;
  int start = 0;
  int DELAY = 1000;

  voidsetup()\{
  Serial.begin(9600);
  start = millis();
  }

  void loop()\{
  // put your main code here, to run
     repeatedly:
  sound = analogRead(ANA);
  Serial.println(sound);
  delay(DELAY);
  }
```

As shown in the code above, variables must be declared first by defining some settings. There are always two parts in the programming. The *setup* defines the serial port and starts the clock. This is executed only once when the device is powered on. The *loop* retrieves the reading from the A0 connection and sends the information over the serial port, then waits one second and repeats, ad infinitum.

Step 3

The Arduino was then connected on a port to a Raspberry Pi computer, which listened to the Arduino, read the sensor data (i.e., volume from the microphone), added a timestamp, and output a data file, all using the Python programming language.

Step 4

Python communicates information to the world by using a web framework. We used Flask, a type of Python web framework, to turn the Raspberry Pi into a basic web server that sent the sensor value and timestamp to a webpage. The data file was in JSON format (though it could be XML, too), which enables several output functions, including the generation of real-time displays on screens or kiosks in the library and the website (via HTML5, jQuery, and Google Charts), and writes to text files to produce reports. Figure 3.1 outlines the schematic of the prototype.

Challenges and Lessons Learned

During the initial stages of the project, there were challenges in learning how to use command line, understanding networking and IPs, learning Python, and implementing technology-based changes in an academic institution. Discussions were needed with the university's library administration to allow our prototype project to move forward.

Calibrating the microphone was a challenge. The readings from the sensor were not in decibels, and it required many modifications to find the right calibration so that the sensor reading corresponded accurately with the decibel measurement.

Locating the proper sensor was key to the project. We wanted to obtain a reading that we could reliably translate into a decibel reading. The microphone needed to measure sound in the pitch range we were interested in and give feedback on the amplitude of the noise in the room. We started this project with a small sensor meant for Arduinos, but it wasn't sensitive enough to obtain reliable readings.

We have created the prototype and are still in the testing phase of this project. In order to continue the testing phase, several challenges need to be addressed. Finding the right microphone sensor is critical, and this could be accomplished in one of two ways: using a more sensitive microphone sensor that is compatible with the Arduino or incorporating a programmable gain amplifier into the prototype. A programmable gain amplifier allows the device to measure small voltages with increased resolution, which could increase the strength of the signal and make the microphone more sensitive in picking up noise levels. The internet connectivity will be attached to the Raspberry Pi component by using a USB wireless stick, but it is uncertain how the device will be able to connect to the university's network. Networking issues in academic environments are generally caused by the security measures in place (i.e., being locked down), and as a result, working closely with colleagues from the IT department may alleviate some of the internet connectivity challenges.

Since the prototype will be situated in a public environment, tamper-proofing the device is necessary. One potential solution is to place the pieces in the ceiling boards so that they are hidden and out of the way. The placement of the prototype will also require some preliminary testing to determine whether or not the proximity of the microphone sensor and users who are generating noise is acceptable. If the distance is too far for the microphone to detect noise, the accuracy of the decibel reading would be at risk. Collecting data points and displaying the information on the web will also require thoughtful planning and execution.

Next Steps and Future Opportunities

Since the prototype has not been tested in a library setting yet (the prototype has only been tested in the private residence of a home), there are a number of locations in the library environment that still need to be tested such as group study rooms, large study
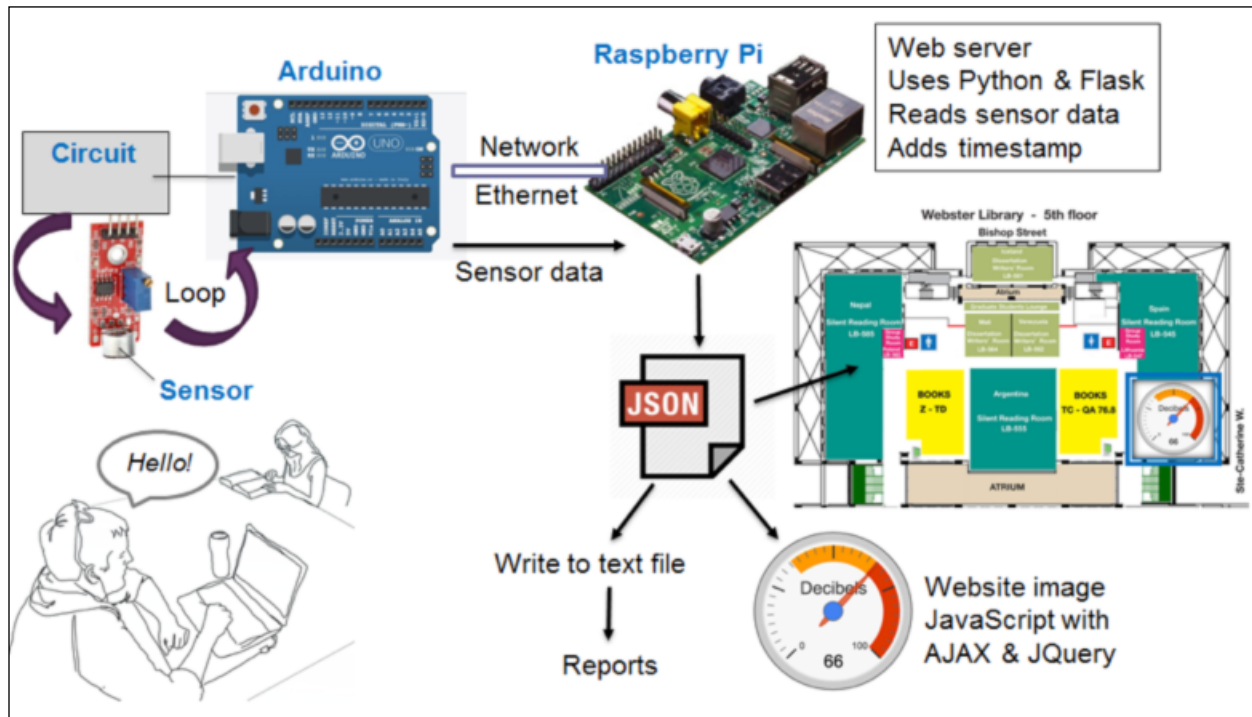
Figure 3.1
Schematic of the prototype

halls, computer labs, or collaborative spaces (e.g. makerspaces). The unpredictability of noise levels in such library spaces make them ideal sites to measure noise due to the variability in decibel readings likely to be captured at different times of the day. As in many noise intervention studies that have been done in the past, qualitative data may be helpful as a basis for comparison with quantitative data. Therefore, it would also be helpful to gather feedback from library patrons through surveys and questionnaires to determine what they perceive as the current noise levels. Having noise levels projected onto library display monitors and the library website will also require some assessment. For example, have patrons noticed the information being displayed, and what do they feel about the real-time information about noise levels? Could the information help inform their decisions on where to go in the library?

While the sensor created in this project was a prototype, it offers many possibilities for noise management in the future. This project provides a way of experimenting with "makerspace" tools such as the Raspberry Pi and Arduino to solve real-world problems for libraries. Other opportunities exist with this type of technology such as the adaptation of temperature sensors, integrating user interactivity where they may provide ratings to the real-time readings, and incorporating Raspberry Pi and Arduino with noise-cancelling technologies. Results and conclusions drawn from the pilot project will help inform

library policies on space planning, library services, and enhancing the user experience.

Acknowledgement

Notes

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