Automated Sound Panel Modification for Audio Lab

ECE 445 Project Proposal

—

Team 3 - Rishi Kalluri, Zachary Bryl, Rajat Vora
TA: Shaoyu Meng
Spring 2021

1. Introduction

1.1 Objective

The Illinois Augmented Listening Laboratory is one of a handful of acoustic labs in the country. In order to allow others to contribute more easily towards this field, they intend to build a fully automated, remotely accessible, audio lab. Researchers would be able to submit a configuration to run an experiment, and the experiment will be autonomously set up (speakers, mic arrays, sound panels, etc.) and run to capture data. By constructing a space like this, research on hearing aid technology, the "cocktail party problem" [3], and other acoustics research becomes much easier for any research group to study by using this automated, fully remote, lab space.

Our goal to contribute to this automated lab space is to construct a system to autonomously set up sound panels around the room based on the incoming configuration. We will construct a motorized shutter system that will sit over each individual sound panel. When the shutter is open, it will allow sound into the panel to be trapped. In the closed position it will lie flat over the shutter and will mimic a wall for the sound to bounce off, not allowing any sound to reach the panel. In any given set of sound panels (some N x N configuration of panels), each panel's shutter will be controlled by a controller, which determines each panel's state (open/closed) based on the experiment's configuration file. This allows the acoustics of the room to be modified from experiment to experiment, allowing the space to simulate different acoustic environments on the fly.

1.2 Background

Most hearing aid devices struggle to clearly articulate incoming noise (voice, tv, music, etc.), from surrounding noise, and result in unclear audio assistance. A report published by the International Journal of Audiology even lists background noise as the second most contributing reason to the underutilization of hearing aids [4]. A report by the National Institute on Deafness and Other Communication Disorders (NIDCD) states that only 30% of people aged 70 and older with hearing loss have ever worn them [2]. That number is even lower (roughly 16%) for those aged 20 to 69 [2]. Consequently the NIDCD highlights one of its priorities as improving performance of hearing aids, especially in separating background/ambient noise from relevant input [2].

In order to solve these problems, equipment to simulate a variety of environments as well as technology to simulate in-ear acoustics is required. However, equipment of this nature is inherently expensive, making funding and purchasing power a restricting factor in this research. This problem exists in other fields as well, with some having created ways to share their equipment across research spaces. The Robotarium at Georgia Tech is a swarm robotics research space that allows remote access by researchers who want to test new algorithms or experiments, without needing to buy robots or travel to the lab themselves [5]. This idea can now be applied to the acoustics lab space. By allowing other researchers remote-access to an autonomous lab, it greatly increases the opportunity to contribute towards research. This allows improvements in hearing aid technology and other acoustics problems to be solved more quickly, which would be a huge benefit to those who use acoustic technology like this.

1.3 Physical Design

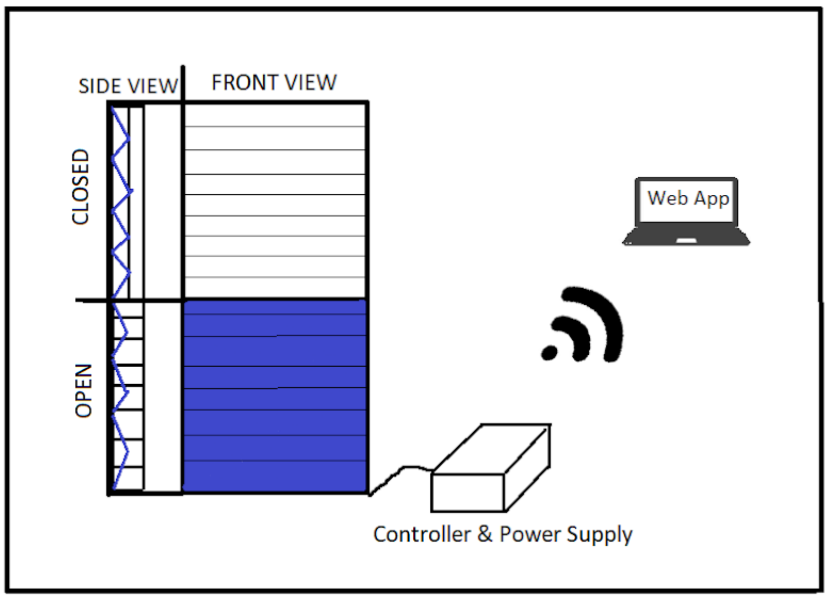

Figure 1. Block Diagram

1.4 High Level Requirements

1. The system should significantly change the acoustics of the room, measurable by the T60 Reverberation Time
2. The time from sending configuration (assuming normal network conditions) to complete execution of instructions on each shutter should be < 10 seconds
3. The system should be easily scalable up to a 5x5 set of acoustics panels (25 total panels)

2. Design

2.1 Block Diagram

Our system requires various components for full functionality. These components are the Power Supply, WiFi Module, Control Unit, and Shutter Subsystem. The power supply consists of batteries and a voltage generator that supplies 3.3V to various components. The Control Unit consists of a microcontroller to handle the data from the user and send the corresponding information to the shutter subsystem and the WiFi module. The WiFi module will allow for a remote connection to a web application to provide our system with a wireless functionality. The shutter subsystem will consist of a servo motor and potentiometer per panel and will allow the shutters to open and close depending on the desired configuration.

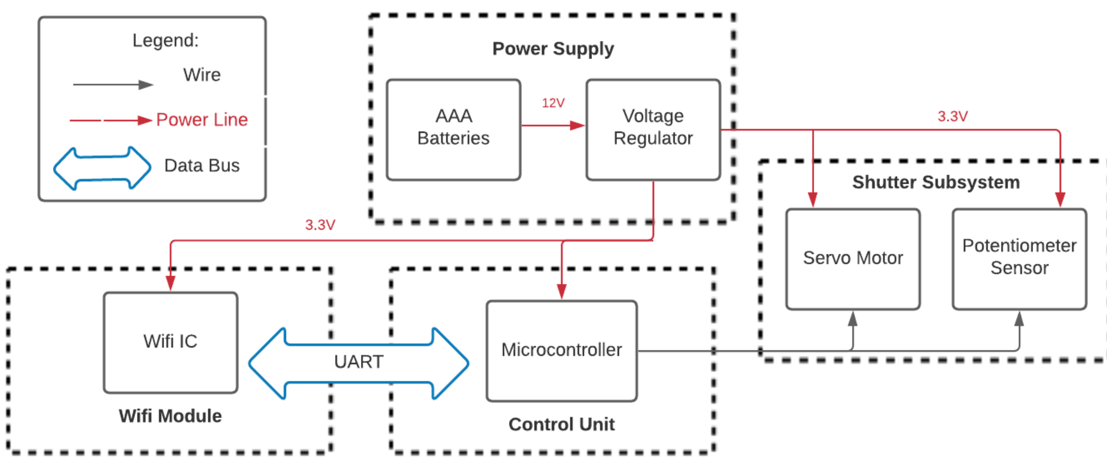

Figure 2. Block Diagram

2.2 Control Unit

The control unit should be able to collect the data from the user via a config file and control the servo motors. It will also control the data being sent and received from the Wifi module. We will use UART to communicate between the Wifi module and the microcontroller.

2.2.1 Microcontroller

The microcontroller will be implemented using the PIC 32 chip embedded into the control PCB. The PIC will receive data from the user via a config file and will send a signal to control the servo motors. The PIC also has on-chip memory that can be used to store data that will be communicated to the Wifi module via UART.

2.3 Shutter Subsystem

The shutter subsystem will be used to control the motors which will then control if the shutters are open or closed. It will communicate with the control unit as that will let the shutters know whether they should be open or closed.

2.3.1 Servo Motor

The servo motors will be used to open and close the shutters. With the SG90 9G Micro Servo Motor, the shutters should be able to open and close with good speed.

Requirement: Powerful enough to turn shutters.

Requirement: Shutters should be able to open/close in 1 second.

2.3.2 Potentiometer

The potentiometer will be used to have an accurate amount of change with our motors. We want to shift the motors 90 degrees so that the shutters can go from flush to parallel which the potentiometer can insure.

Requirement: Know the degrees of spin for the shutters within 1 degree of accuracy.

2.4 Power Supply

The power supply is used to power the components in the system. These components are servo motors, potentiometers, and the WiFi IC. The power supply will consist of AAA batteries and a voltage regulator to step down to 3.3V.

2.4.1 Battery

The batteries will be AAA batteries, and they will supply power to the servos and other components of the system.

Requirement: Battery must be 12V battery to power servos

2.4.2 Voltage Regulator

The voltage regulator will be used to step down the voltage to 3.3V for the shutter module, control unit, and Wifi module components.

Requirement: Must step down voltage to 3.3V +/- 5% from battery back.

2.5 WIFI Module

The Wifi module will be used to receive information from the microcontroller via UART and then transmit that information across a wireless network in order to create a remote monitoring functionality.

2.5.1 WIFI IC

The WiFi IC will be implemented using the ESP8266 chip by Espressif Systems. The chip will be able to transmit data through a wireless network via TCP/IP connections.

Requirement: Receive signals from control unit using UART I/O pins.

2.6 Risk Analysis

The Shutter subsystem will provide the greatest risk to the completion of our project. One possible source of failure is that the shutters will be too heavy for the servo motor to rotate efficiently. This may increase the time it takes for the shutters to open/close, and therefore reduce the response time for our overall system.

Another possible limitation is that it is possible for the shutters to not be completely flush when closed, therefore allowing sound to seep through the gaps. This source of error would most likely be caused by slight servo motor error or shutter design flaws. A large part of this problem will be working with the design lab so that the shutter design allows it to be completely closed.

The last limitation that we will deal with in terms of the shutter system is the space constraint. We need to have the shutters be thin enough where they do not take up a ton of space in the audio lab but the shutters still need to be capable of reflecting sound and acting as a wall. We will need to come up with a certain thin material that takes up less space and still is able to function as a blocker of the sound panels.

3. Ethics and Safety

The sound shutter project is fully automated and is intended for unsupervised use, and there are a number of associated safety concerns associated with the system. Most of these concerns are related to the motion of the shutters and potential damages to the motors driving the shutters. This is especially a concern because the priority is to contain any potential damages that might occur to just our system, because the lab would be unsupervised.

The most likely failure situations are motor burnout or an obstruction that prevents the shutter from closing. The other concern is motors overheating, but the motor should turn off automatically if it gets too hot, which can be treated as an offline motor. Additionally, the likelihood of this event happening is very low, considering the motors are only rotating back and forth occasionally, and only with a range of 180 degrees.

To handle such situations, the shutter subsystem software will be designed to recognize when a shutter is unable to close, or has lost connection (burnout, offline motor). The program will then mark the experiment as a failure to run, and log the error, specific to the exact panel with a malfunction. This logging will also aid the lab staff in identifying the problem, and ensuring that the issue does not occur again. This is in accordance with IEEE Code of Ethics #5, to acknowledge and correct errors [6].

Additionally, due to the valuable nature of experimental data, results from experiments run using the system should only be accessible by the researcher who commissioned the experiment. This is intended to follow the ACM Code of Ethics, 1.6., to respect privacy [7]. While we cannot verify the intentions of the lab as a whole, our iteration of this system will follow this guideline, since it is our priority to maintain privacy when relevant. Our system would share system reports, configurations, and any gathered data privately with the researcher, to prevent data from spreading in the community.

References

[1] Illinois Augmented Listening Laboratory. 2021. [Online] Available at: https://publish.illinois.edu/augmentedlistening/about-us/

[2] National Institute on Deafness and Other Communication Disorders. Strategic Plan, 2017-2021. [Online] Available at: https://www.nidcd.nih.gov/about/strategic-plan/2017-2021-nidcd-strategic-plan#sp3

[3] Bee, Mark A, and Christophe Micheyl. "The cocktail party problem: what is it? How can it be solved? And why should animal behaviorists study it?." *Journal of comparative psychology (Washington, D.C. : 1983)* vol. 122,3 (2008): 235-51. doi:10.1037/0735-7036.122.3.235

[4] McCormack, Abby, and Heather Fortnum. "Why do people fitted with hearing aids not wear them?." *International journal of audiology* vol. 52,5 (2013): 360-8. doi:10.3109/14992027.2013.769066

[5] Pickem, Daniel, et al. *"The Robotarium: A remotely accessible swarm robotics research testbed"* 2017 IEEE International Conference on Robotics and Automation (ICRA). IEEE, 2017.

[6] Ieee.org. 2021. IEEE Code Of Ethics. [Online] Available at: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed 16 February 2021].

[7] Acm.org. 2021. Code of Ethics. [Online] Available at: https://www.acm.org/code-of-ethics [Accessed 16 February 2021].