**Proj Mgmt & Tech Proj prep (sec 001)**

**Assignment 1**

**Group 2**

Rohit Heer(301368708)  
Janice Duque(301243912)  
Arjun Suraj(301368698)  
Alwin Benoy(301368424)

**Sequential Wave Imprinting Machines**

# Introduction:

Sound waves are a fundamental part of our daily experience, yet they remain largely invisible to the human eye. Typically, sound is understood through hearing, but there is great potential in visualizing sound for a more immersive and multi-sensory experience. The 'Sequential Wave Imprinting Machines' project aims to translate acoustic phenomena into both visual and physical representations in real-time, making sound waves tangible. By integrating various hardware components like RGB LEDs and stepper motors, the project seeks to build a system where sound is experienced not just through hearing, but also through sight and motion. This fusion of light, motion, and sound offers a new way to understand and interact with audio data.

# 1. Problem Definition

- Goal: The aim is to visualize sound waves in real-time and real-space, converting invisible acoustic oscillations into a visual format using hardware components such as LEDs and stepper motors.  
- Challenge: The challenge lies in capturing sound waves and representing them through dynamic, physical elements like RGB LEDs and motion-based systems, ensuring that these visualizations correspond accurately to the real-time sound data.

# 2. Background Research

- Sound Wave Visualization: Traditionally, sound waves are visualized on screens using oscilloscopes or spectrograms. In this project, the goal is to leverage a physical display—using RGB LEDs and motion control via a stepper motor—to provide a more immersive, real-time experience.  
- LEDs and Motion Control in Sound Visualization: LEDs are often used for visualizing sound by mapping amplitude to light intensity or color. The addition of motion control enables a spatial representation of sound waves as the gantry moves at a constant velocity.

# 3. Hypothesis or Design Specifications

- Hypothesis: By using a Mic/Preamp board to capture sound and a Raspberry Pi RP2040-Zero for real-time processing, we can map sound wave data to an array of RGB LEDs while moving a gantry system at a constant velocity using a stepper motor. This will allow users to experience sound as both a visual (light-based) and physical (motion-based) phenomenon.  
- Core Components:  
 - Mic/Preamp Board: Captures sound and amplifies the signal for processing.  
 - Raspberry Pi RP2040-Zero: Acts as the central processing unit, sampling the analog sound waveform and driving the LED display accordingly.  
 - RGB LED Strip: Provides a visual representation of the waveform by mapping the analog audio input to brightness or position within the strip.  
 - Stepper Motor and Driver Board: Moves the gantry at a fixed velocity, ensuring that the LEDs imprint a sequential representation of the waveform over time.

# 4. Development of the Model or System

- Sound Capture and Processing:  
 - The Mic/Preamp board captures sound from the environment. This signal is then passed to the RP2040-Zero, where it is sampled in real-time. The raw analog waveform is directly visualized by modulating the LED brightness.  
- RGB LED Visualization:  
 - The RGB LED strip will act as a real-time visualizer for the sound waves. The analog waveform determines the LED brightness at each position along the moving gantry. Over time, this results in a visible imprint of the waveform as the gantry moves.  
- Stepper Motor Integration:  
 - The stepper driver board controls a stepper motor that moves the gantry at a fixed speed. The purpose of this movement is to translate the time-domain waveform into a spatially imprinted representation, allowing for direct visualization of sound waves in real space.

# 5. Prototyping and Experimentation

- Prototype: A working prototype consists of a microphone connected to the RP2040-Zero, which processes the sound and controls the RGB LED strip while the stepper motor moves the gantry at a constant velocity. The LED strip will light up in response to the analog waveform, creating a spatial representation of the sound.  
- Experimentation: Different types of sounds (e.g., music, speech, white noise) will be tested to observe how the system responds. Key factors include the clarity of the waveform imprint and the coordination between the light patterns and gantry movement.

# 6. Testing and Evaluation

- Accuracy: Evaluate how well the LED patterns reflect the real-time sound waveform. For example, does the brightness of the LEDs accurately follow the amplitude of the sound input?  
- Latency: Measure the system's response time to ensure real-time sound processing and visualization, minimizing any noticeable delay between the sound input and its visual output.  
- Mechanical Performance: Ensure that the stepper motor moves at a consistent speed to produce an accurate spatial representation of the waveform.

# 7. Optimization and Refinement

- LED Strip Optimization: Adjust the mapping between amplitude and LED brightness for greater clarity and aesthetic appeal. Ensure that the system can handle a broad range of sound amplitudes without distortion.  
- Gantry Refinement: Fine-tune the stepper motor speed to optimize the resolution of the imprinted waveform, balancing the trade-off between sampling rate and motion speed.  
- System Synchronization: Ensure precise timing between the LED activation and gantry movement to achieve a smooth and coherent visualization.

# Conclusion:

Based on the Engineering Method and the inclusion of hardware components such as an RGB LED strip, Mic/Preamp board, Stepper motor, and RP2040-Zero, the development of a machine that visualizes sound waves through light and motion is highly feasible. The integration of these components allows for a dynamic, real-time representation of sound, offering both visual and physical feedback that makes sound waves tangible in new ways.