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

**Assignment 1**

**Group 2**

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**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 frequency and amplitude to light intensity or color. The addition of motion control can add another layer of visualization, potentially mapping wave properties to physical movements or patterns.  
  
**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 and motion via 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, performing real-time analysis of the sound (e.g., breaking down amplitude and frequency using Fourier transforms).  
 - RGB LED Strip: Provides a visual representation of sound waves, where frequency and amplitude are mapped to color and brightness.  
 - Stepper Motor and Driver Board: Adds physical movement corresponding to the waveform, potentially visualizing sound intensity or rhythm through mechanical motion.  
  
**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 processed in real-time. Using signal processing algorithms, the system extracts key characteristics like frequency (pitch) and amplitude (loudness).  
- RGB LED Visualization:  
 - The RGB LED strip will act as a real-time visualizer for the sound waves. Frequency can be mapped to different colors (e.g., low frequencies in red, higher frequencies in blue), while amplitude can be represented by brightness or length of the illuminated section. This creates a "wave" effect that corresponds directly to the sound.  
- Stepper Motor Integration:  
 - The stepper driver board will control a stepper motor to add a physical, motion-based element to the visualization. For example, the stepper motor could rotate or move in patterns that correspond to changes in sound intensity, rhythm, or frequency modulation, enhancing the sensory experience of the sound wave.  
 **5. Prototyping and Experimentation**- Prototype: A working prototype could consist of a microphone connected to the RP2040-Zero, which processes the sound and controls both the RGB LED strip and the stepper motor. The LED strip will light up in response to the sound, and the stepper motor will move according to the sound properties.  
- Experimentation: Different types of sounds (e.g., music, speech, white noise) would be tested to observe how the system responds. Key factors would include the accuracy of the LED strip in representing the sound and the coordination between the light patterns and motor movements.  
  
**6. Testing and Evaluation**- Accuracy: Evaluate how well the LED patterns and motor movements reflect the real-time sound characteristics. For example, when a sound becomes louder, does the corresponding brightness and motion increase in a smooth and precise manner?  
- 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/motion output.  
- User Interaction: Assess how effectively the system allows users to understand the properties of the sound waves through both visual (LED) and physical (motion) feedback.

**7. Optimization and Refinement**- LED Strip Optimization: Adjust the mapping between frequency, amplitude, and the RGB LED colors/brightness for greater clarity and aesthetic appeal. Ensure that the system can handle a broad range of sound frequencies and amplitudes.  
- Motor Refinement: Refine the stepper motor's movement patterns to reflect complex sound characteristics, such as modulating motion based on rhythm or waveform shape (e.g., sine, square, or sawtooth waves).  
- System Synchronization: Synchronize the motion control with the LED visualizations to create a coherent and immersive representation of the sound.  
  
**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.