Implementation of Basic Sound Processing Techniques: Audio Synthesis and Manipulation

1 Objectives

- Understand the basic principles of sound synthesis and manipulation.
- Learn how to generate basic sounds using sine waves and other waveforms.
- Implement basic audio processing techniques, including filtering and pitch shifting.
- Visualize sound waveforms and apply transformations to manipulate audio.

2 Theory

Sound processing is a field that involves manipulating sound signals, typically in digital form, to create new effects or modify existing sounds. The process includes various techniques like synthesis, filtering, and effects processing. In this lab, we will focus on audio synthesis, which is the creation of sound from simple waveforms, and basic audio manipulation, such as filtering and pitch shifting.

Audio Synthesis

Audio synthesis involves the generation of sound waves using mathematical functions. A common waveform used in audio synthesis is the sine wave, which represents a pure tone.

$$y(t) = A\sin(2\pi ft + \phi)$$

Where:

- A is the amplitude (volume),
- f is the frequency (pitch),
- t is time, and
- ϕ is the phase shift.

Other waveforms, such as square waves, sawtooth waves, and triangle waves, can be used to create more complex sounds. These waveforms can be manipulated by adjusting their frequency, amplitude, and phase.

Audio Manipulation

Audio manipulation refers to modifying the characteristics of an existing sound. Common techniques include:

Pitch Shifting

Pitch shifting alters the frequency of a sound. For example, increasing the frequency raises the pitch, while decreasing it lowers the pitch.

$$y(t) = A\sin(2\pi f_{\text{new}} t + \phi)$$

Where f_{new} is the altered frequency.

Filtering

A filter is used to modify the frequency content of a sound. Common types of filters include low-pass, high-pass, and band-pass filters. A simple low-pass filter allows frequencies below a cutoff frequency to pass, while higher frequencies are attenuated.

$$y(t) = \int_{-\infty}^{t} h(\tau)x(t-\tau)d\tau$$

Where $h(\tau)$ is the filter impulse response, and $x(t)$ is the input signal.

3 Tasks

1. Generate a sine wave at 440 Hz (A4 note) and plot its waveform.
2. Synthesize a sound using a square wave and manipulate its amplitude and frequency.
3. Implement a low-pass filter on a noisy sine wave and observe the effect.
4. Apply pitch shifting to a sine wave and plot the resulting waveform.
5. Explore the effect of combining multiple waveforms (e.g., sine and square waves).

4 Expected Outcomes

By the end of the lab, students will be able to:

- Understand how different waveforms contribute to sound synthesis.
- Generate and manipulate basic sounds (e.g., sine, square, and sawtooth waves).
- Implement basic audio effects like pitch shifting and filtering.
- Visualize sound waveforms and understand their frequency content.
- Develop skills in using audio manipulation techniques in practical applications.

5 Assessment

- **Correctness of Implementation (30%):** Ensure the proper implementation of synthesis, filtering, and pitch shifting techniques.
- **Waveform Visualization (20%):** Accurate plots of the generated sound waveforms before and after manipulation.
- **Analysis and Interpretation (30%):** Analyze the effect of the applied techniques (e.g., changes in pitch, frequency content).
- **Report (20%):** Submit a detailed report summarizing the implementation, including equations, plots, and observations.