# Sound Project

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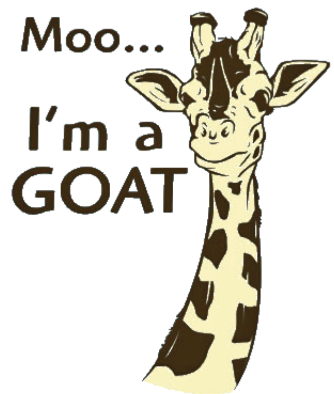


**CS-435 Computational Science and Applications**

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## 1 Introduction

This project is about sound, and how to use MATLAB to process sound file. These sounds can be either created through the speech production mechanism, or sound heard by a machine or human.

In this project you will learn the following:

1. Basic mechanism of sound.
2. How sound is stored and represented in MATLAB.
3. How to load and play a piece of sound file.
4. How to plot a sound file.
5. How to record sound with MATLAB.
6. Various experiments with sound file.

### 1.1 Sound and Sound Representation in MATLAB

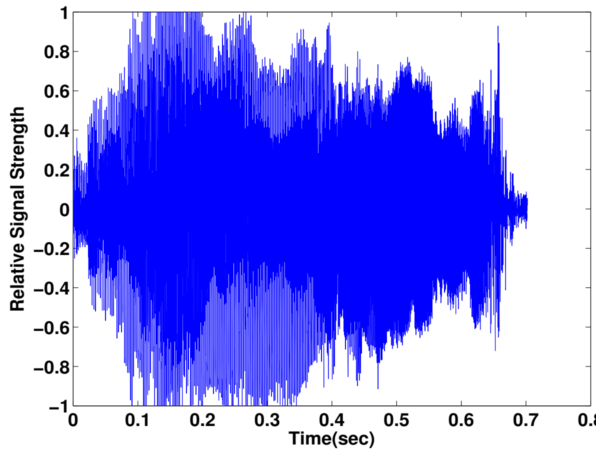
Sound is a wave traveling through some media due to the vibration of molecules. When traveling in the air, it vibrates along the same direction as their traveling direction (called longitudinal wave.) When traveling through other media, the vibration direction is perpendicular to the direction it travels (called transverse wave.) Check out these cool animations of different waves: Acoustics and Vibration Animations - Dan Russell, Grad. Prog. Acoustics, Penn State.

Sound is measured with unit Hertz (Hz), named after the German physicist Heinrich Hertz who made important scientific contribution to the electromagnetism field. Hertz defines sound frequency that is measured as cycle per second.

In MATLAB, sound is stored as a one-dimension array of double-precision floating point numbers. These number sequence represents a sample sound. Another piece of information is also needed, which is the sample rate associated with the sound.

The plot shown in Figure 1 is a 30964-by-1 array of double type floating numbers. When played with sample rate 16000, you will hear a moo of a cow.

**Figure 1.** A Piece of Sound is a Vector in MATLAB




### 1.2 Sound Generation

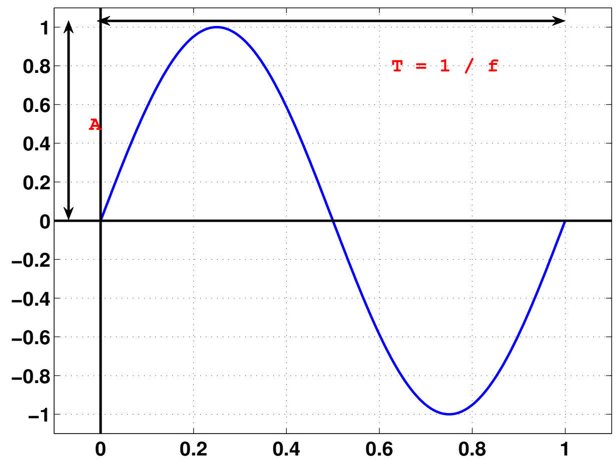
Sound waves are created when a wave form is used to vibrate molecules in a medium using audio frequencies ($300\text{Hz} \leq f \leq 3000\text{Hz}$). The basic waveform shown in figure 2 is generated from:

$$y = A\sin(2\pi f x) \tag{1}$$

in which $A$ represents the amplitude, $f$ is the frequency and $t$ is the time. The relationship between the period of the wave and the frequency is: $T = 1/f$. So if $T$ is measured in seconds, then $f$ is measured in Hertz.

The formal concept of the sampling in digital signal processing field is the process of converting a continuous time signal to a discrete time signal. The reconstruction process is the reverse process of recovering the original continuous process from the discrete time signal. The sampling process is performed by measuring the continuous signal values every $T$ units of time (sampling interval) to generate *samples*. These samples are then used to represent the original signal. The sampling rate (or sample frequency) is the reciprocal of the sampling interval ($f_s = 1/T$), which is number of samples per second in a sound. Usual sample rates are 44100 Hz (CD quality) and 22050 Hz (speech), meaning a recording with a duration of 1 second will contain 44100 samples or 22050 samples.

**Figure 2.** A Sinusoidal Wave




### 1.3 Sound Capturing

MATLAB can also be used to capture speech, the relevant MATLAB commands include **audiorecorder**, **record**, **stop**, **play**, **pause**, **resume**, **play**, and **getaudiodata** etc.

## 2 In-Class Project

In this project, we will perform simple sound creation, read from and write to .wav file, plot the sound and play the sound in MATLAB with different frequencies. Finally we will record voice and change the sound quality.

### 2.1 Load Existing Music

1. Read in the **cow.wav** file and observe the content of the returned variables.
2. Plot and play the sound wave. Plot partial signals near the beginning to observe the sound signals.
3. Play the sound wave with a different sampling frequency.
4. Repeat the above with different sound file: **funky.wav** and **asharp.wav**.

### 2.2 Sound Creation

1. Create a sine wave of amplitude $A = 1$, at audio frequency of 466.16 Hz (which corresponds to $A\#$) using the sample frequency of 8000 Hz for duration of 5 seconds.
2. Plot the sound wave and play the sound piece.
3. Write a function `note` to generate desired notes sound by passing their frequency values. The music note frequencies can be found here: Piano Key Frequencies.
4. Repeat the above experiment with square wave instead of sine wave, play the sound and compare with the sine wave sound.
5. Use the simple notes to create a piece of music: ABC song, and save it to **abc.wav**.

### 2.3 Note Detection

1. Download the **mystery1.wav** and **mystery2.wav** files from the WISE website. Each file contains a pure music note simulated from a piano keyboard.
2. Read into MATLAB and extract necessary information.
3. Figure out a way to determine the exact note by calculating their corresponding frequencies.

## 3 Lab Project

1. Write a function `puretone(frequency, duration, fs)` to generate a tone with a given frequency for a given duration. Using this function to create a MATLAB script to **birthday.m** to play Happy Birthday song (or any of your favorite music piece). Please save the song to a file named **birthday.wav**.
2. Write a function `squarewave(frequency, duration, fs)` to generate a tone using a square wave oscillator instead of a sinusoid, and play the same tune. Please save the song to a file named **birthday2.wav**.
3. Using the piano key frequency chart as reference, determine the highest and lowest note your computer's speaker can play and you can hear. Implement your idea and write code into a file called **main.m**, use comments to describe your finding about the highest and lowest notes.

### 3.1 Lab Project Submission

Please create folders for each problem. If there are source data required to run your program, you need to put the data under the same folder, so that as soon as I unzip your code, I can test your code. Please zip all the folders that contain programs you want to submit and name it `YourFirstname_P6.zip`, submit the zipped file to the WISE dropbox before 11:59PM on Dec 1. You need to demonstrate your program on or before Dec 1's lab and answer questions in order to get credits.