Lecture One

- Administrative Matters
- Motivation: A Brief Survey of Audio Software
- Basics of waves and sound
- Audio Programming Fundamentals: A Simple Python Framework for Audio Programming with .wav files

Next Time:

- Digital Signals and Sampling
- Amplitude tracks and window-based analysis of features of music files

Fundamentals of Digital Audio

- What is sound? How do we describe it scientifically?
- How do we convert the analog information in sound into digital form?
- What are the consequences of digitizing on our uses of sound (for music, for example)?
Physical Basis of Sound

Sound is produced by vibrating material which produces pressure waves in air, traveling at 340.29 meters/sec (767 mph, or a mile in 5 seconds), which are sensed by the ear and interpreted by the brain.

These waves are longitudinal waves (the motion is along the direction of travel), as opposed to transverse waves (motion is at right angles to the direction).

These waves are typically described graphically by curves which record the pressure (on the Y axis) vs time (on the X axis); this is called the Time Domain.

![Figure 4.1: A pressure sound wave from a guitar string and its graphical representation.]

Sound Wave Properties

**Wavelength:**
- distance between waves (affects pitch -- high or low sounds); measured in Meters.

**Amplitude:**
- amount of energy (air pressure) in a wave at a particular point in time, measured in Decibels.

**Frequency:**
- the number of times a wave occurs in a second. Measured in Hertz (Hz) or KiloHertz (kHz).

**Phase:**
- Where in the oscillation the wave is at a particular point in time (e.g., relative to other waves), measured as offsets around a circle, in Radians (more details later).

The time domain representation thus represents the amplitude over time......

Let's hear some examples and examine the evidence....
Sound Wave Properties: Frequency

**Frequency and wavelength are inverses of each other:**

\[ \lambda = \text{Wavelength} \]
\[ f = \text{Frequency} \]
\[ v = \text{Velocity of Sound in air} = 340.29 \text{ m/s} \]

\[ \lambda = \frac{v}{f} \quad \text{or} \quad f = \frac{v}{\lambda} \]

**Example:** A 440 Hz
\[ \lambda = \frac{340 \text{ m/s}}{440 / \text{s}} \]
\[ \lambda = .772 \text{ meters} \]

**Punchline:** Only frequency, amplitude, and phase are necessary to completely describe a simple wave.

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**Sound Wave Properties: Frequency**

**Frequency** is an absolute measure, and is strongly related to but not absolutely identical to the notion of pitch.

**Pitch** = perceived frequency of a sound

Pitch is subjective, and inaccurate at extremes of frequency or amplitude, and not measured precisely by the ear throughout the range of hearing.

**Human:** 20Hz – 20 kHz

**Dogs:** 67 Hz – 44 kHz

**Cats:** 55 Hz – 79 kHz

**Bats:** 1Hz – 200 kHz

Sensitivity of human ear at various frequencies; curves represent impressions of equal loudness at various frequencies:
Sound Wave Properties: Sinusoids

Sound is a wave, but simple waves are not very interesting:

Let’s hear (and look at) a single sine wave of frequency A 440 Hz.....

The MOST FUNDAMENTAL fact about sound that we will use is the following:

Sound Waves are the superposition (sum of amplitudes) of individual sine waves of various amplitudes, frequencies, and phases:

Here is a nice web page showing a number of examples of two sine waves interacting:

http://www.acs.psu.edu/drussell/demos/superposition/superposition.html
Superposition of two or more waves can create a variety of sinusoids, and can even cancel each other out (create silence):

We will use this fundamental principle (all sound waves can be represented as the superposition of sum of a collection of individual simple sine waves) in two ways:

**Additive Synthesis:** Create a complex sound by adding together a collection of sine waves;

**Fourier Analysis:** Analyze a complex sound by decomposing it into its constituent simple sine waves.