CS 4455: Video Game Design & Implementation

March 31, 2006: Audio

(Insert Disclaimer Here)

Overview

- Today's Lecture
  - What I'm talking about now
  - Audio Theory
  - Digitizing Sound
  - Game Implementation
    - High Level APIs

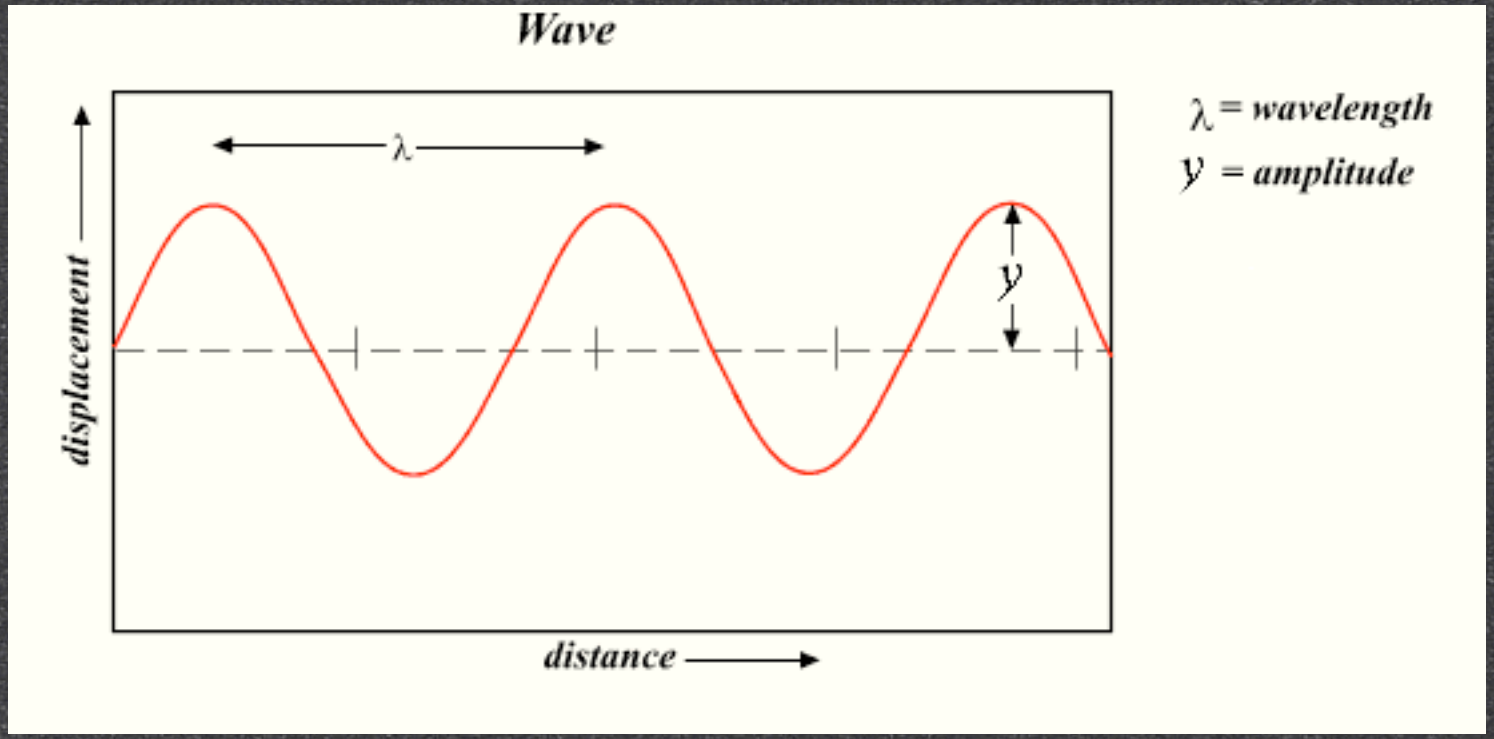
Why is Audio important?

What is audio?

- Inside your ear is an eardrum
  - A thin piece of skin
  - When it vibrates, your brain interprets this as sound
  - Changes in air pressure often cause this vibration

How Audio Works

- An object produces sound when it vibrates
  - This moves air particles
  - Those particles in turn move other particles



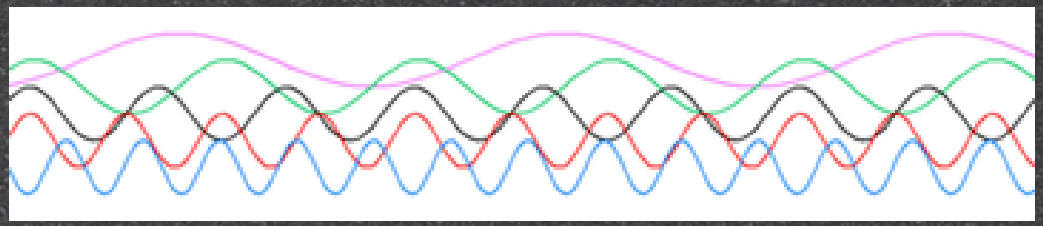
- Terms to Note:
  - Wavelength - distance between repeating points
  - Amplitude - non-negative height of the wave

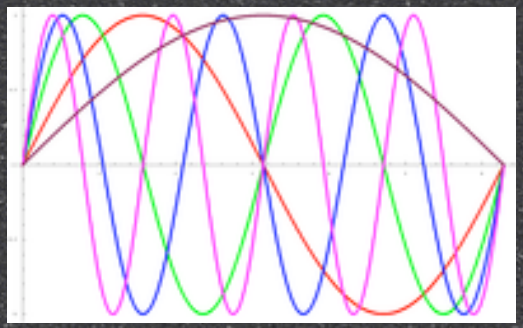
Audio Terminology

- Terms:
  - Period - How long it takes between cycles
  - Frequency - How many cycles occur
  - (These are inverses)

$$f = \frac{1}{T}$$

Audio Terminology





The faster they loop,
the higher their frequency.

The SI unit for this is Hertz (Hz).
1 Hz = once a second,
1 KHz = one thousand times a second

Audio Terminology

- Intensity = the “power” of the sound
- A fairly large scale, so usually expressed logarithmically:

$$I_{\mathrm{dB}} = 10 \log_{10}\left(\frac{I}{I_0}\right) \quad \text{or} \quad P_{\mathrm{dB}} = 10 \log_{10}\left(\frac{P}{P_0}\right),$$

- With Sound, I0 ~= 10^-12 W/m^2

Common DB Levels

0dB	Threshold of hearing
10dB	Human breathing at 3 meters
30dB	Theatre, no talking
60dB	Inside of office or restaurant
70dB	Busy traffic at 5m
90dB	Loud factory, heavy truck at 1m
100dB	Jack Hammer at 2m; inside disco
120dB	Rock Concert
150dB	Jet engine at 3m
250dB	Inside tornado; nuclear bomb @ 5m

+10dB means 10 times as powerful

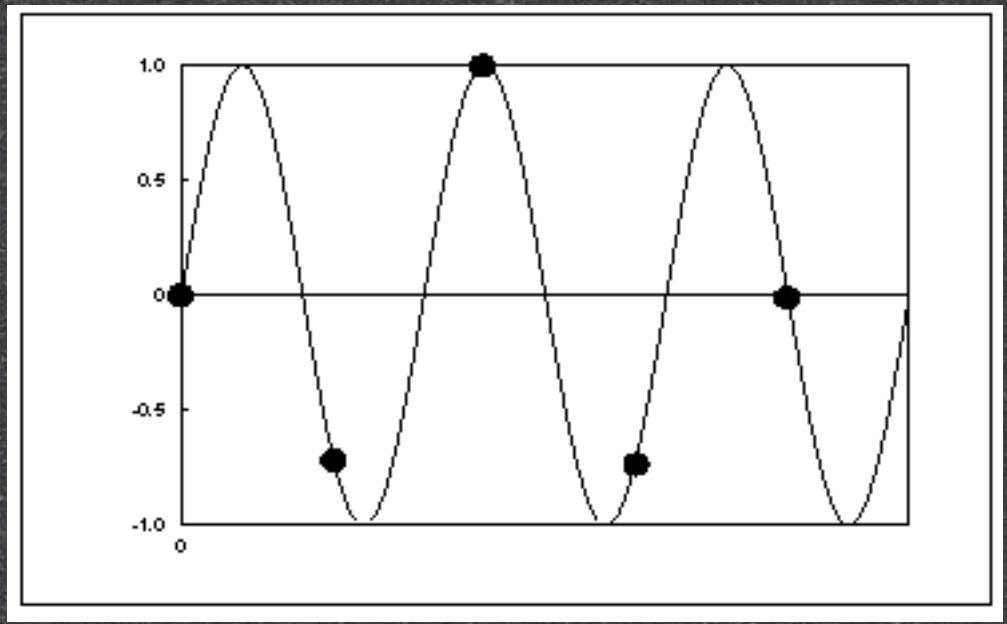
+3dB roughly twice as powerful

Fun facts about audio strength

85dB	potentially harmful to hearing
120dB	unsafe
150dB	physical damage to body
163dB	windows break
19xdB	eardrums rupture
200dB	can cause death

Digitizing Sound

Sampling



- At a given interval, “sample” the amplitude of the wave

Sampling: Nyquist Limit

- Nyquist Limit - a given sampling rate can only represent frequencies up to one-half that rate

Sampling

- Typical factors on a computer
  - How many times per second?
  - How many levels can we differentiate between?
  - How many channels?

Sampling

- CD Quality audio
  - 44kHz (44,100 samples/sec)
  - 16-bit (65,536 possible levels)
  - 2 channels (left and right)
- 176,400 bytes/sec
- This is approximately 6 seconds per megabyte!

Sampling

- Low Quality Audio
  - 8kHZ (8 samples per second)
  - 8-bit (1 byte)
  - 1 channel
- 8,000 bytes/sec
- About two minutes per megabyte

Sampling Comparison

Sampling Comparison

What can we do?

(Or, a brief history of computer audio)

FM synthesis

- Used in early systems like the GameBoy
- Hardware continually produced one or more sine waves (sometimes other shapes, too)
- Software could modify frequency and amplitude
- Can be done in very little space (the BIGGEST GameBoy games were about 1/2MB)

FM synthesis demo

MIDI synthesis

- Common in PC sound cards and many consoles, such as the Super Nintendo (SNES), Genesis, your cellphone...
- MIDI files contain instructions to turn on or off various instruments
- Instruments are externally defined
  - Therefore, small file format
  - Sound can differ player-to-player

MIDI synthesis demo

Module Audio

- Like MIDI, but you can (or are required to) supply your own instruments
- .MOD/.S3M/.XM/.IT file formats
- Used in the PlayStation, also common on the GameBoy Advance
- Usually still small, if you can share instruments

Module Audio Demo

RedBook Audio

- Music is streamed from CD
  - Commonly used on the SegaCD
  - May need to buffer or avoid when you need to read from the CD!
  - Takes a lot of space

RedBook Audio Demo

(Realistic Depiction of Bonus Stage)

Compressed Audio

- General Compression
  - Lossy - small changes okay
  - Loseless - must be 100% preserved

Compressed Audio

- Audio Compression
  - Bit Reduction
    - DPCM encodes the differences between subsequent samples (the D is for differential or delta)
    - ADPCM is a more advanced version

Compressed Audio

- Audio Compression
  - Psycho-acoustic
    - Designed with human hearing in mind
    - MP3, AAC, OGG, WMA, .etc

Compressed Audio Demo

- Nah.

Gaming Implementation

Gaming Implementation

- Sound in most games is divided into two parts:
  - Background music
  - Sound Effects

Background Music

- Unlike movies and TV, not timed
- Ambient and looping
- Can be streamed

Sound Effects

- Characteristics
  - Typically very short
  - Often tied to an event
  - Examples: Gun fire, character is hit, explosion, speech, .etc
- Generally stored in memory

Mixing

- In many game consoles, separate HW for these functions is not unusual
  - Hardware MIDI standard in some
  - If not, convert to sampled in software

Mixing

- Software mixing is easy
  - If sample rates are the same
  - Just add!
  - Beware of exceeding the max

Mixing Example

```
def mixSound(dest, source):
  for i in range(1, min(getLength(dest), getLength(source))):
    sourceValue = getSampleValueAt(source, i)
    destValue = getSampleValueAt(dest, i)

    setSampleValueAt(dest, i, sourceValue + destValue)
```

Buffering

- When reading or converting sound, you need to stay ahead of the audio out device but can’t convert the whole song
- Two techniques for buffers:
  - Circular buffers - read and write in same buffer
  - Buffer chaining - write to buffer, read from the other, swap

High Level APIs

- Audio is a lot simpler than graphics (in a game).
- A lot of APIs can be condensed to:
  - Play(sample, loops)
  - Stop(sample)
  - SetPan
  - SetVolume
  - SetSpeed

Example Sound APIs

- Cross platform 2D APIs
  - Java Sound
  - SDL
  - QuickTime
- Sound APIs with 3D support
  - OpenAL
  - DirectSound (NOT crossplatform)

Example (JavaSound)

```
Sequence sequence =
   MidiSystem.getSequence(new java.net.URL(url));

// Create a sequencer for the sequence
Sequencer sequencer = MidiSystem.getSequencer();
sequencer.open();
sequencer.setSequence(sequence);
sequencer.start();
```

See packages under javax.sound such as javax.sound.midi and javax.sound.sampled

Positional Audio

- Basic Theory
  - Sound distance and volume are inversely related
  - Sound differences in the ears help determine position

3D Audio

- Problem with traditional two speaker or headphone setup
  - Forward vs. Behind
- Speaker setups available that have 5, 6, or 7 speakers
- Speaker setup tends to differ, so this is difficult!

3D Audio Example

```
    // Load wav data into a buffer.

    alGenBuffers(1, &Buffer);

    if (alGetError() != AL_NO_ERROR)
        return AL_FALSE;

    alutLoadWAVFile("wavdata/Footsteps.wav", &format, &data, &size, &freq, &loop);
    alBufferData(Buffer, format, data, size, freq);
    alutUnloadWAV(format, data, size, freq);

    // Bind buffer with a source.

    alGenSources(1, &Source);

    if (alGetError() != AL_NO_ERROR)
        return AL_FALSE;

    alSourcei (Source, AL_BUFFER,   Buffer   );
    alSourcef (Source, AL_PITCH,    1.0f     );
    alSourcef (Source, AL_GAIN,     1.0f     );
    alSourcefv(Source, AL_POSITION, SourcePos);
    alSourcefv(Source, AL_VELOCITY, SourceVel);
    alSourcei (Source, AL_LOOPING,  AL_TRUE  );

    // Do an error check and return.

    if (alGetError() != AL_NO_ERROR)
        return AL_FALSE;
}
```

```
    // Initialize OpenAL and clear the error bit.
    alutInit(NULL,0);
    alGetError();

    // Load the wav data.
    if (LoadALData() == AL_FALSE)
        return 0;

    SetListenerValues();

    // Begin the source playing.
    alSourcePlay(Source);

    // Loop
    ALint time = 0;
    ALint elapse = 0;

    while (!kbhit())
    {
        elapse += clock() - time;
        time += elapse;

        if (elapse > 50)
        {
            elapse = 0;

            SourcePos[0] += SourceVel[0];
            SourcePos[1] += SourceVel[1];
            SourcePos[2] += SourceVel[2];

            alSourcefv(Source, AL_POSITION,
SourcePos);
        }
    }
```

Resources

- OpenAL tutorials:
  - http://www.devmaster.net/articles/openal-tutorials/lesson1.php
- Sound Editing Software:
  - http://audacity.sourceforge.net/
- Sound Effects
  - /net/dvfx/hollywood_edge
  - http://www.sounddogs.com/