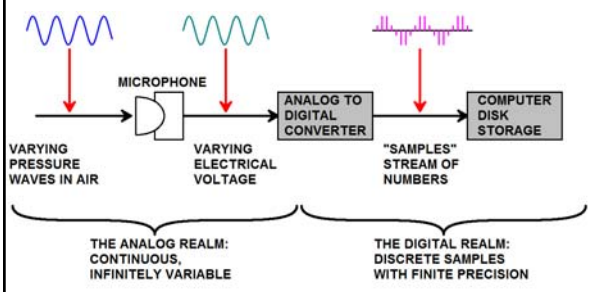
COMPSCI 105: Lecture #16
Introduction to
Multimedia with Spreadsheets

AUDIO

Audio

- Transforming signals from the analog realm into the digital realm.
- Storing and processing of audio numbers.
- Transforming numbers back into sounds.

Capturing Audio



Three Questions:

- 1: How many channels (independent audio streams)?
  - 1: Monaural
  - 2: Stereo
- 2: How "good" is each sample?
  - 1 Byte per Sample (256 levels, OK for voice)
  - 2 Bytes per Sample (65536 levels, OK for music)
- 3: How many samples per second are needed?

3: How many Samples per Second?

- 3A: What is the Highest Frequency that Humans can hear?
- 3B: How does Frequency map onto Samples per Second?

2-Second Sound Samples

- 1000 Hz
- 2000 Hz
- 4000 Hz
- 8000 Hz
- 12000 Hz
- 16000 Hz
- 18000 Hz
- 19000 Hz
- 20000 Hz
- 21000 Hz
- 22000 Hz

3A:What is the Highest Frequency that Humans can hear?

- 22KHz (22,000 cycles/second) as infants
- 12KHz in middle age
- <6KHz in old age, as hairs in ear canal stiffen with age and become less capable of vibrating at the higher frequencies.

3B: How does Frequency map onto Samples per Second?

- Answer: Nyquist Sampling Theorem
- Harry Nyquist (1889-1976), AT&T, Bell Telephone Laboratories
- You must sample at least twice the rate of the highest frequency you wish to capture.
- For example: to capture 1000 Hz with enough information to play it back correctly, you need to sample at least 2000 times per second.

3: How many Samples per Second?

- For Compact Discs:

To capture 22 KHz we will need to sample at:

44,000 samples/second/channel

Actually, we use:

44,100 samples/second/channel

because 44,100 is $2^2 \times 3^2 \times 5^2 \times 7^2$ which is divisible by 2, 3, 4, 5, 6, 7, 9, 10, 12, 14, 15, 18, 20, …

Compact Discs

- For CD Music:
  - **2** channels (stereo)
  - **2** bytes/sample
  - **44,100** samples/second/channel
- Therefore:
  - 2 channels × 2 bytes/sample × 44,100 samples/second/channel = **176,400 bytes/second**

Megabytes per Minute

You can reduce the byte-load by dropping the sampling rate, number of bytes per sample, or number of channels:

	Samples per Second per Channel	Max Frequency Hz	1 Channel		2 Channels	
			1 Byte/Sample	2 Bytes/Sample	1 Byte/Sample	2 Bytes/Sample
MUSIC	44100	22050.0	2.646	5.292	5.292	10.584
	22050	11025.0	1.323	2.646	2.646	5.292
VOICE	11025	5512.5	0.662	1.323	1.323	2.646
	8000	4000.0	0.480	0.960	0.960	1.920

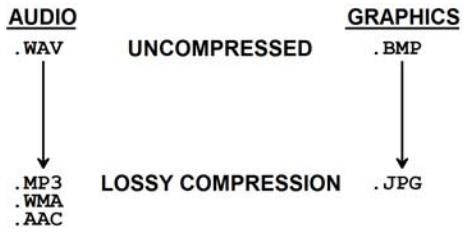
Lossy Compression

- Perform Fourier Analysis (Spectrum Analysis) to convert samples into a sum of instantaneous frequencies,
- Discard high frequencies that some people can't hear anyway,
- Discard audible frequencies that are being "shouted out" by other louder frequencies,
- Drop sampling rate on quiet passages.

Compression

- **.WAV** – Uncompressed (raw data as ripped directly from a CD)
- **.MP3** – Lossy Compression, roughly 10:1
- **.WMA** – Supported by Windows, Roughly 20:1 compression for same quality as .MP3
- **.AAC** – Supported by Apple

Thinking About Compression



Analyzing Audio in Spreadsheet Land

	A	B	C	D	E	F
1						
2		2	Channels			
3		2	Bytes per Sample			
4		44100	Samples per Second per Channel			
5						
6		=B4*B2	Samples per Second			
7		=B3*B4	Bytes per Second per Channel			
8		=B3*B4*B2	Bytes per Second (overall)			
9						
10		60	Seconds per Minute			
11		=B8*B10	Bytes per Minute			
12		3.5	Length of Song in Minutes			
13		=B12*B11	Size of Song in Bytes (Uncompressed)			
14		10	Compression Factor			
15		=B13/B14	Size of Song in Bytes (Compressed)			
16						
17		700000000	Size of CD in Bytes			
18		=B17/B11	Minutes of Music per CD			
19						

Analyzing Audio in Spreadsheet Land

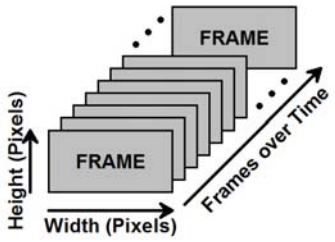
	A	B	C	D	E	F
1						
2		2	Channels			
3		2	Bytes per Sample			
4		44100	Samples per Second per Channel			
5						
6		88200	Samples per Second			
7		88200	Bytes per Second per Channel			
8		176400	Bytes per Second (overall)			
9						
10		60	Seconds per Minute			
11		10584000	Bytes per Minute			
12		3.5	Length of Song in Minutes			
13		37044000	Size of Song in Bytes (Uncompressed)			
14		10	Compression Factor			
15		3704400	Size of Song in Bytes (Compressed)			
16						
17		700000000	Size of CD in Bytes			
18		66.137566	Minutes of Music per CD			
19						

VIDEO

Video

- Has all the issues associated with audio, and…
- …much more!
- Video is a series of frames (images) rapidly shown on screen to simulate movement.
- Often has a linked audio track (maybe more than one).

Video



Video Issues

- How Wide is each Frame (pixels)?
- How High is each Frame (pixels)?
- How many Bytes per Pixel (colors)?
- How many Frames per Second?
- Is the video Compressed in some way?

Frame Size (Bytes)

- Number of Pixels per Frame = Width × Height
- Number of Bytes per Frame = Pixels × Bytes per Pixel
  - 24-Bit RGB Color: 3 Bytes per Pixel
  - 256 Color: 1 Byte per Palette Index
  - 16 Color: ½ Byte per Palette Index
  - 2 Color: ⅛ Byte (1 Bit) per Palette Index

Bytes and Frames

- Bytes per Second = Bytes per Frame × Frames per Second
- Frames per Second:
  - Traditional Movies: 24 frames per second
  - Old Analog TV: 30 frames per second
  - Modern HDTV: up to 120 frames per second
  - Minimum: 10-12 frames per second (any slower and you will see each individual frame)

An Example

- A 3½ minute Video which is 360 × 240 pixels (very small), 3 bytes per pixel, playing at 10 frames per second (very slow) would have:
  - Bytes per Frame = 360 × 240 × 3 = 259200
  - Bytes per Second = 259200 × 10 = 2592000
  - Length of Video = 3.5 × 60 = 210 seconds
  - Length of Video = 2592000 × 210 = **544,320,000 Bytes** (uncompressed)

Another Example

- A 60 minute Video which is 1024 × 768 pixels (full screen), 3 bytes per pixel, playing at 30 frames per second (full speed) would have:
  - Bytes per Frame = 1024 × 768 × 3 = 2,359,296
  - Bytes per Second = 2,359,296 × 30 = 70,778,880
  - Length of Video = 60 × 60 = 3600 seconds
  - Length of Video = 70,778,880 × 3600 = **254,803,968,000 Bytes** (uncompressed)

Compression Helps!

- **.AVI** – Audio Video Interleave (Windows)
  - A frame of Video is followed by a chunk of Audio
  - Several compression methods
  - Every frame stored, played at constant rate
- **.MOV** – Quicktime (Apple)
  - Frames can play at variable rates
  - Multiple Audio tracks (secondary audio programs)
- **.MP4** – Variation of **.MOV** for small devices

Compression Helps!

- **.MPG** – Motion Picture Experts Group
  - Sometimes **.MPEG**
  - Start with key-frame (full image),
  - For next frames only the differences between current frame and previous frame are stored (much smaller amount of information).
  - Takes a LONG time to compress, but…
  - Very fast Playback (video over HDTV)

Cut to the Videos…