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CS 334
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Assignment 1: Multimedia Digitization

Problem 1:

Using the Nyquist criterion, we must use at least double the highest frequency for each range as our sampling frequency.

What is the bit rate produced for the speech signal if 12 bits are used per sample?

The highest frequency for speech is 10kHz, so we must sample at least twice this fast. So our sampling frequency is 20kHz, and if bit rate is the product of our sampling frequency and bits per sample, our bit rate is equal to:

20kHz *12 bits per sample = 240 Kbps

Perform the same for the music signal when 16 bits per sample are used.

With music producing sound up to 20kHz, we must sample at least twice this fast. Our sampling frequency is now 40kHz. With 16 bits per sample, the bit rate is the product between our sampling frequency and bits per sample.

40kHz * 16 bits per sample = 640 Kbps

How many megabytes of storage do you need for 10 minutes of stereo music given the parameters above?

To calculate the storage for 10 minutes of stereo music, we must use a base rate of double the mono music bit rate calculated in the previous part (640Kbps * 2), we are converting from Kilobits to megabytes, so the ratio is 1:8000, and we are storing 10 minutes = 600 seconds:

1280 Kbps * 1/8000 Kb per Mb * 600 seconds = 96 megabytes

Problem 2:

What output voltage does this value correspond to?

With an 8-bit representation, we have hex values 00 to FF, and value B3 represents value 179 in base 10, but in the voltage scale, we are converting to 255 different quantization steps between 2V and 6V resulting in approximately 0.01568 volts per step, and at step level 179, this corresponds to voltage 2V + 0.01568 V/step * 179 steps = 4.807 V

- What is the digitization (quantization) error in the voltage?

The quantization error in the voltage is equivalent to half the quantization step, so this digitization error is equal to 0.01568 volts per step / 2 = 0.00784 V

By how much percent would this error change if 12 bits were used to approximate the output instead of 8 bits?

To represent this scale using 12 bits instead of the previous 8 bits, we would now be using a step size of 4V / 2^12 = 0.0009765625 V / step, with a quantization error of 0.0009765625 / 2 = 0.00048828125 V

% Change = (New - Old) / Old
= (0.00048828125 - 0.00784) / 0.00784
= -0.000732421875 / .00784
= -0.093
= -93%

Problem 3:

Justify why the sampling rate for an audio compact disc (CD) is 44.1 kHz. What is the Nyquist rate for reliable speech communications?

The sampling rate for audio CDs is 44.1 kHz because of the Nyquist theorem, which requires that the sampling frequency be at least twice the highest frequency of the signal to retain the audio digitally. Sampling at a multiple rate of the frequency range allows for maintaining the details and range of the sampled version of the audio. The Nyquist rate for relatable speech communication is about double the highest frequency in the range of speech, which is 20kHz. (According to question 1)

Why do you think people sound different on the phone than in person?

I think people sound different on the phone than in person because perfect-sounding speech over the phone is likely too intensive to transfer for the amount of information that is

required all the time for phone calls. Some compression must be done to allow for a good mix of quality and data size

Suppose intelligible speech requires 7 bits per sample. If the phone system is designed to precisely meet the requirements for speech (which is the case), what is the maximum bit rate allowable over telephone lines?

With 7 bits per sample, and we want to sample at 20kHz, the maximum possible bit rate over telephone lines would be: 20kHz * 7 = 140 Kbps

CDs use 16 bits per sample. What is the bit rate of music coming off a CD? Is a modem connection fast enough to support streamed CD quality audio?

With 16 bits per sample and a]Nyquist rate of 44.1 kHz, the bit rate coming off a CD is 44.1Khz * 16 = 706 Kbps. With modern connections that can support up to multiple gigabits per second, there should be no limitations to support CD-quality audio.

Problem 4:

Determine the number of bytes necessary to store an uncompressed RGB color image of size 640x480 pixels using 8,10,12, and 14 bits per color channel.

For each pixel on our display, we are using 3 color channels, and each channel requires a certain number of bits. Our display uses 640*480 = 307,200 pixels

Bits/Color channel	8 bits / channel	10 bits / channel	12 bits / channel	14 bits / channel
	8*3 bits/pixel * 307200 pixels = 7372800 bits / 8 = 921600 bytes	10*3 bits/pixel * 307200 pixels = 9216000 bits / 8 = 1152000 bytes	12*3 bits/pixel * 307200 pixels = 11059200 bits / 8 = 1382400 bytes	14*3 bits/pixel * 307200 pixels = 12918400 bits / 8 = 1614800 bytes

Problem 5:

Does your image show an instance of geometric aberration? Are the lines straight in the images or curved.

My image mostly shows no geometric aberration, but at some angles, the top left corner of the red line is unnaturally curved inward, suggesting some aberration this occurs more with my zoomed-out “lens” compared to my closer ones.

Does your image show chromatic aberration? Check the pixel values to see if there are values that might not be expected.

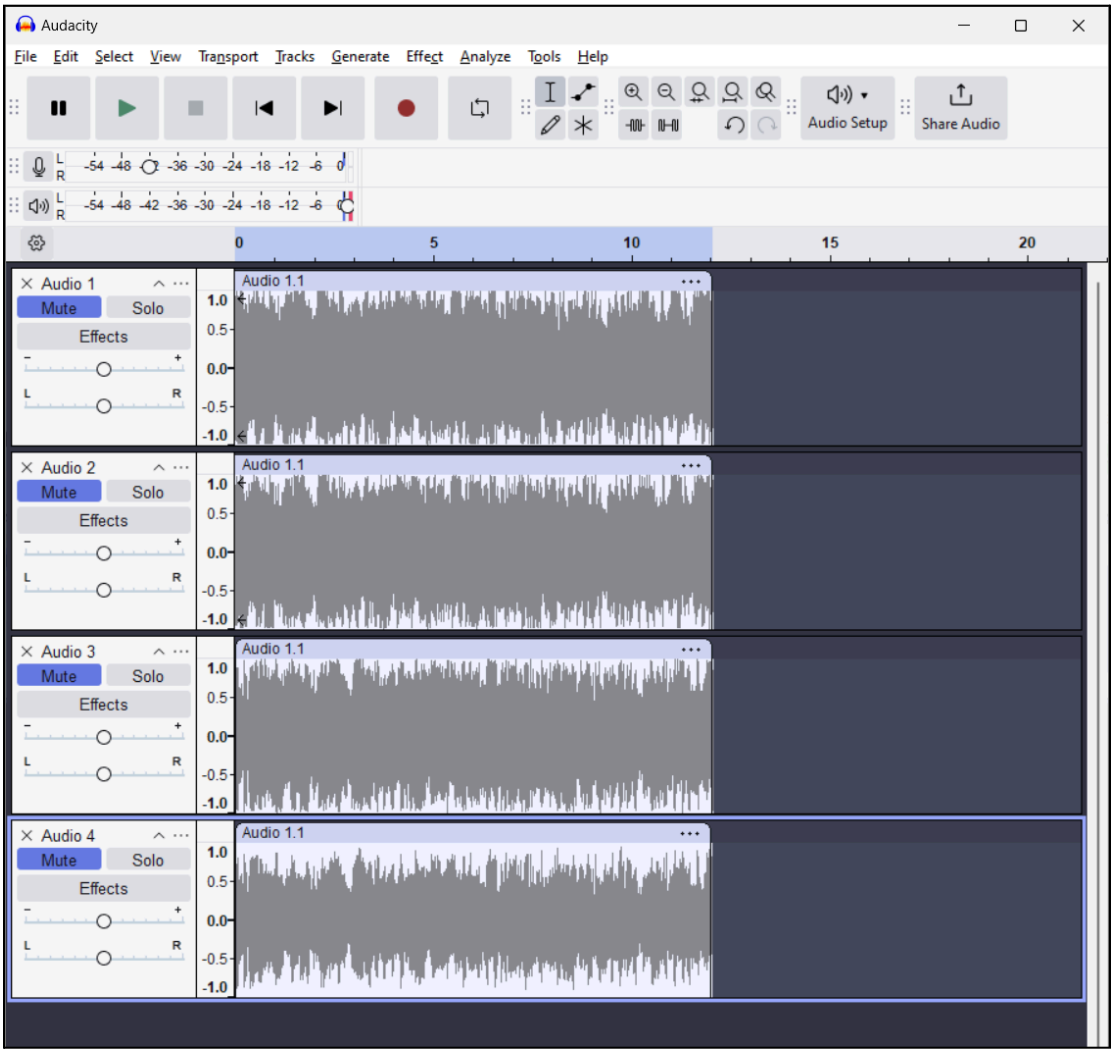
My image seems to retain the correct colors, though the lighting in some images has caused the paper to appear more blue than it would seem to the naked eye.

Problem 6:

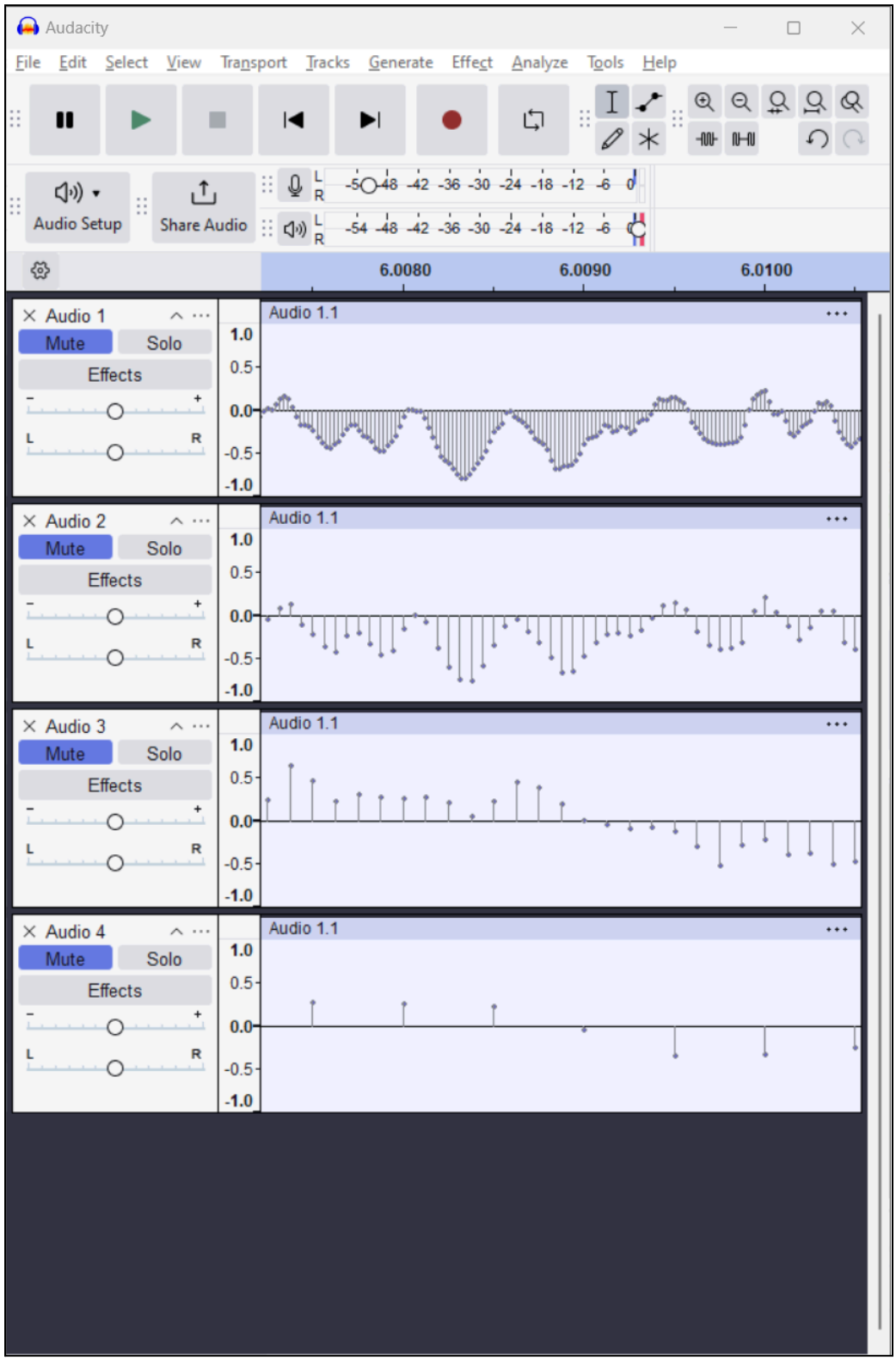
Song Used: Sunbather by Shoobies
https://open.spotify.com/track/3fKgPBDUxatIcNK99lp14o

The first track, at 44kHz, was our baseline. Compared to 16kHz, the music sounded like some detail was missing and a little fuzzy, like music from an older speaker. Going down to 8kHz sampling, the music loses its punchiness and detail and is very fuzzy, Going all the way down to 2kHz, the music is noticeably quieter, and the music sounds almost like certain notes from certain instruments are missing at specific points, attributing to the extremely low sampling rate. No instrument stands out (the guitar is very smeared). I would not listen to any track below the 44kHz threshold, as the loss of quality is too great compared to our baseline.

Fully Zoomed Out



Fully Zoomed In:



Audio Spectrograms: