CS 576 – Assignment 1
Instructor: Parag Havaldar

Assigned on Monday 08/28/2023,
Solutions due on Monday 09/18/23 by midday 12 pm noon

Late Policy: None, unless prior arrangement has been made

PART 1: Theory Questions for practice, no need to submit, answers will be posted later

Q.1 Suppose a camera has 450 lines per frame, 520 pixels per line, and 25 Hz frame rate. The color sub sampling scheme is 4:2:0, and the pixel aspect ratio is 16:9. The camera uses interlaced scanning, and each sample of Y, Cr, Cb is quantized with 8 bits

- What is the bit-rate produced by the camera? *(2 points)*
- Suppose we want to store the video signal on a hard disk, and, in order to save space, re-quantize each chrominance (Cr, Cb) signals with only 6 bits per sample. What is the minimum size of the hard disk required to store 10 minutes of video *(3 points)*

Q.2 The following sequence of real numbers has been obtained sampling an audio signal: 1.8, 2.2, 2.2, 3.2, 3.3, 3.3, 2.5, 2.8, 2.8, 2.8, 1.5, 1.0, 1.2, 1.2, 1.8, 2.2, 2.2, 2.2, 1.9, 2.3, 1.2, 0.2, -1.2, -1.2, -1.7, -1.1, -2.2, -1.5, -1.5, -0.7, 0.1, 0.9 Quantize this sequence by dividing the interval [-4, 4] into 32 uniformly distributed levels (place the level 0 at -3.75, the level 1 at -3.5, and so on. This should simplify your calculations).

- Write down the quantized sequence. *(4 points)*
- How many bits do you need to transmit it? *(1 points)*

Q.3 Temporal aliasing can be observed when you attempt to record a rotating wheel with a video camera. In this problem, you will analyze such effects. Assume there is a car moving at 36 km/hr and you record the car using a film, which traditionally record at 24 frames per second. The tires have a diameter of 0.4244 meters. Each tire has a white mark to gauge the speed of rotation. Assume that the tire rotates without skidding.

- If you are watching this projected movie in a theatre, what do you perceive the rate of tire rotation to be in rotations/sec? *(5 points)*
- If you use your camcorder to record the movie in the theater and your camcorder is recording at one third film rate (ie 8 fps), at what rate (rotations/sec) does the tire rotate in your video recording *(5 points)*
- If you use an NTSC camera with 30 fps, what is the maximum speed that the car can go at so that you see no aliasing in the recording

PART 2: Programming Questions(140 points)

This part will help you gain a practical understanding of Resampling and Filtering and how it affects visual media types like images and video.

Firstly, you need to be able to display images in the RGB format that we will give to you for testing. We have provided a Microsoft Visual Studio C++ and java projects that read a given image and displays it correctly. This source has been provided as a reference for students who may not know how to read and display images. You are free to use this as a start or write your own. For this assignment you are required to use a non-scriptable language (such as C/C++ or java, *no python, no matlab*) where you will implement algorithms/operations. You are not allowed to make use of external libraries.

Images are getting larger and larger in size and sometimes cannot be properly viewed on a computing screen. Here you are asked to create an application that will help view the image in a resized format and optionally browse through all the details. Input to your program will take four parameters:

- The first parameter is the name of the image, which will be provided in an 8 bit per channel RGB format (Total 24 bits per pixel). You may assume that all images will be of the same size for this assignment (16xHD format 7680x4320).
- The second parameter is a *floating-point* value ***S*** (between 0 and 1) suggesting by how much the image has to be down scaled so as to fit in a window for display. This will result in resampling your image.
- The third parameter will be a Boolean value ***A*** (0 or 1) suggesting whether you want to deal with aliasing. A 0 signifies do nothing (aliasing will remain in your output) and a 1 signifies that anti-aliasing should be performed by using an averaging low pass filter.
- The fourth parameter will give the square window width/height ***w*** for showing the original image overlaid if the *control key is pressed*. As you move your mouse around the image *with your control key pressed*, you should see the original detailed image overlaid about the mouse area in a ***w*** x ***w*** window.

To invoke your program, we will compile it and run it at the command line as

YourProgram.exe C:/myDir/myImage.rgb S A w

where *S A w* are the parameters as described above. Example inputs are shown below, and this should give you a fair idea about what your input parameters do and how your program will be tested.

1. *YourProgram,exe image1.rgb 0.25 0 200*

Here you are in S is 0.25, so you are showing the image by scaling down it resolution by 0.25 in width and height per the original. This will bSSe a HD 1920x1080 size image. Anti-aliasing is turned off, so you will see aliasing effects. The output should look like an image shown below.

If antialiasing is set to 1 then:

If control key is pressed, then.

2. *YourProgram,exe image1.rgb 0.125 0 200*

Here you are in S is 0.125, so you are showing the image by scaling down it resolution by 1/8th in width and height per the original. This will be an image of size 960x540 size image. Anti-aliasing is turned off, so you will see aliasing effects. The output should look like an image shown below

If antialiasing is set to 1 then:

If control key is pressed, then. Centered around your mouse cursor

.

What should you submit for part 2 ?

- Your source code, and your project file or makefile, if any, using the submit program. ***Please do not submit any binaries or images***. We will compile your program and execute our tests accordingly.
- If you need to, please include a readme.txt file with any special instructions on compilation for compilation.

PART 3: Analysis Question (40 points)

In this analysis part, you will understand how to measure reconstruction errors and image quality by using interpolation/filtering. Please use the analysis-images folder of images for this exercise. Each image is a 1920x1080 high-definition image.

Given an image,you can randomly remove ***x***% of the samples. These missing samples may then be computed from the neighborhood of good samples and create a corrected image. An example is shown below for ***x***=10%. Samples have been removed at random locations and given a black color (r=g=b=0);

These missing sample can be filled in by using the valid neighborhood samples around each missing sample – by weighted averaging, interpolation, or other ways. An example is shown below. While not obviously visible, zooming in a missing region or quantitively taking differences will show the error.

Write a process than can randomly remove (or set to 0) x percent of sample and recompute new values for each using valid neighborhood samples. Once a reconstructed image is obtained, find the error in the reconstruction. This might be computed as the sum of the absolute differences or sum of squared differences between all the pixels of the original and reconstructed image. Plot a graph that shows this reconstruction error as a function of percent missing samples $\boldsymbol{x}$. Use the X axis to plot $\boldsymbol{x}$ as it varies from 0 to 50% and Y axis to plot the error. Your graph should signify the reconstruction error from nothing missing to 50% of the samples missing.
Answer the following questions:

- For each of the given images, plot a graph for the reconstruction error
- Which image has higher errors, which image has lower error? Why are all the plots different?
- From your quantitative analysis, can you *qualitatively* describe which image will have higher error and which image will have lower error.

Extra Credit
Knowing that the samples lost/removed will always have a random sampling, can you give a mathematical formula or a methodology to predict the reconstruction error given a *specific image with it content* as input and a number $\boldsymbol{x}$ as percentage input?
How well does your formula or method work? You may actually compare your predicted error to the actual error obtained above for the images given.

What should you submit for part 3?

- Do NOT submit any code for this section although you may have modified your program, written additional functions to compute what is needed.
- Only submit output image results, graphical plots showing reconstruction error and any other quantitative analysis or formulas. As with part 1, please submit only electronic documents.