# Written Part (20 points)

## 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.

1. What is the bit-rate produced by the camera? (2 points).
2. Suppose we want to store the video signal on a hard disk, and, in order to save space, the signal is re-quantized so that each channel (Y, Cr, Cb) uses 6 bits. What is the minimum size of the hard disk required to store 10 minutes of video (3 points).

A.1

Bit-rate produced by the camera is calculated as:

Hence,

A.2

For storing the video, the luminance and chrominance channels should be changes to 4:2:0, where the average bits for a pixel should be changed to the followings:

Hence, the total bits used for storing is

## Q2

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).

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

A.1

Based on the definition, all the intervals are listed as follows:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Level 0 | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Level 6 | Level 7 |
| [-4, -3.75] | (-3.75, -3.5] | (-3.5, -3.25] | (-3.25, -3] | (-3, -2.75] | (-2.75, -2.5] | (-2.5, -2.25] | (-2.25, -2] |
| Level 8 | Level 9 | Level 10 | Level 11 | Level 12 | Level 13 | Level 14 | Level 15 |
| (-2, -1.75] | (-1.75, -1.5] | (-1.5, -1.25] | (-1.25, -1] | (-1, -0.75] | (-0.75, -0.5] | (-0.5, -0.25] | (-0.25, 0] |
| Level 16 | Level 17 | Level 18 | Level 19 | Level 20 | Level 21 | Level 22 | Level 23 |
| (0, 0.25] | (0.25, 0.5] | (0.5, 0.75] | (0.75, 1] | (1, 1.25] | (1.25, 1.5] | (1.5, 1.75] | (1.75, 2] |
| Level 24 | Level 25 | Level 26 | Level 27 | Level 28 | Level 29 | Level 30 | Level 31 |
| (2, 2.25] | (2.25, 2.5] | (2.5, 2.75] | (2.75, 3] | (3, 3.25] | (3.25, 3.5] | (3.5, 3.75] | (3.75, 4] |

Hence, the given data are quantified to:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Input | 1.8 | 2.2 | 2.2 | 3.2 | 3.3 | 3.3 | 2.5 | 2.8 |
| Level | Level 23 | Level 24 | Level 24 | Level 28 | Level 29 | Level 29 | Level 26 | Level 27 |
| Output | 2 | 2.25 | 2.25 | 3.25 | 3.5 | 3.5 | 2.75 | 3 |
| Input | 2.8 | 2.8 | 1.5 | 1 | 1.2 | 1.2 | 1.8 | 2.2 |
| Level | Level 27 | Level 27 | Level 22 | Level 20 | Level 20 | Level 20 | Level 23 | Level 24 |
| Output | 3 | 3 | 1.75 | 1.25 | 1.25 | 1.25 | 2 | 2.25 |
| Input | 2.2 | 2.2 | 1.9 | 2.3 | 1.2 | 0.2 | -1.2 | -1.2 |
| Level | Level 24 | Level 24 | Level 23 | Level 25 | Level 20 | Level 16 | Level 11 | Level 11 |
| Output | 2.25 | 2.25 | 2 | 2.5 | 1.25 | 0.25 | -1 | -1 |
| Input | -1.7 | -1.1 | -2.2 | -1.5 | -1.5 | -0.7 | 0.1 | 0.9 |
| Level | Level 9 | Level 11 | Level 7 | Level 10 | Level 10 | Level 13 | Level 16 | Level 19 |
| Output | -1.5 | -1 | -2 | -1.25 | -1.25 | -0.5 | 0.25 | 1 |

A.2

There are 32 levels, which is , resulting in 5 bits for each sample. Moreover, there are 32 samples, leading to , in all.

## Q3

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.

1. If you are watching this projected movie in a theatre, what do you perceive the rate of tire rotation to be in rotations/sec? (2 points)
2. If you use your camcorder to record the movie in the theater and your camcorder is recording at one third film rate (i.e. 8 fps), at what rate (rotations/sec) does the tire rotate in your video recording (5 points)
3. 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 (3 points)

# Programming Part (130 points]

# Implementation (70 points]

# Analysis Part A – dealing with Pixel Aspect Ratio (30 points]

# Analysis Part B – dealing with Pixel Aspect Ratio (30 points]

# Optional Extra Credit – temporal content aware remapping