CS576 Multimedia System Design

Assignment#1

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Theory Questions

Q.1 A 5-minute video is recorded with 1080i resolution (1920x1080 pixels, interlaced) and 30 Hz frame rate. The color sub sampling scheme is 4:2:0, and each sample of Y, Cr, Cb is quantized with 8 bits.

- What is the size (MB) of this video without compression? (*2 points*)

  pixels per frame = 1920 x 1080 = 2,073,600 pixels/frame

  4:2:0 sub sampling on average= (4 x 8+8+8)/4 = 12 bits per pixel

  For 30Hz frame rate = 2,073,600 x 30 x 12 = 746,496,000= 746.496Mbits/sec

  For 5 mins = 746,496,000 x 5 x 60 = 223,945,800,000/(8 * 1024 * 1024) = 26,696.4 MB

- In order to save space, we re-quantize each chrominance (Cr, Cb) signals with only 6 bits per sample. What is the compression ratio needed to store this video in a USB flash drive with 256 MB storage *(3 points)?*

  Pixels per frame = 1920 x 1080 = 2,073,600 pixels/frame

  4:2:0 sub sampling scheme of 6 bits = (4 x 8 + 6 + 6)/4 = 44 /4 = 11 bits per pixel

  For 30 Hz frame rate 2,073,600 x11 x 30 = 684,288,000 bits/sec

  For 5 mins = 684,288,000 x 5 x 60 = 205,286,400,000/8*1024*1024 bits = 24,472.04 MB

  Compression ratio = uncompressed size / compressed size =24,472.04 MB/256 MB

  Compression ratio needed is ~ 95.5

Q.2 Suppose we have a medical imaging that records brain activity and store as gray-scale images. The raw signal in a small region in a moment is given below:

-6.7	0.6	0.8	0.4	0.3	0.5	0.2	-5.7
-0.1	-6.6	0.6	0.3	0.2	0.1	-5.9	0.8
0	1.0	-6.5	0	-0.3	-5.5	0.4	0.5
-0.2	0.8	0.2	-7.0	-5.8	-1.0	0.2	0.6
0.1	0.6	0.3	-6.0	-6.9	-0.6	-0.3	0.1
0.3	0.5	-6.1	0.1	0.2	-6.9	0.2	0.3
0.2	-5.6	-0.1	0	-0.5	-0.1	-6.4	0.2
-6.2	0.7	0.2	0.3	-0.1	0.4	0.6	-6.3

Quantize this data by dividing the interval [-8, 8] into 64 uniformly distributed levels (place the level 0 up to -7.75, the level 1 up to -7.50, and so on. This should simplify your calculations)

- Write down the quantized region above. *(5 points)*

  The entire data range is -8+8 = 16

  There are 64 levels: with level 0 : -8 to -7.75 and level 63 : 7.75 to 8

The intervals thus correspond to

5	**34**	**35**	**33**	**33**	**33**	**32**	**9**
31	**5**	**34**	**33**	**32**	**32**	**8**	**35**
31	**35**	**5**	**31**	**30**	**9**	**33**	**33**
31	**35**	**32**	**3**	**8**	**27**	**32**	**34**
32	**34**	**32**	**7**	**4**	**29**	**30**	**32**
33	**33**	**8**	**32**	**32**	**4**	**32**	**33**
32	**9**	**31**	**31**	**29**	**31**	**6**	**32**
6	**34**	**32**	**33**	**31**	**33**	**34**	**6**

- Down-sample this quantized region to the size 4x4 using a specific sampling. Is there any better way to down-sample this region? *(1+2 points)*

Using Random/choosing alternate regions sampling

5	**35**	**33**	**32**
31	**5**	**30**	**33**
32	**32**	**4**	**30**
32	**31**	**29**	**6**

Better way of down-sampling this region is by applying some filters like gaussian filter

0	**5**	**34**	**35**	**33**	**33**	**33**	**32**	**9**	**0**
5	**5**	**34**	**35**	**33**	**33**	**33**	**32**	**9**	**9**
31	**31**	**5**	**34**	**33**	**32**	**32**	**8**	**35**	**35**
31	**31**	**35**	**5**	**31**	**30**	**9**	**33**	**33**	**33**
31	**31**	**35**	**32**	**3**	**8**	**27**	**32**	**34**	**34**
32	**32**	**34**	**32**	**7**	**4**	**29**	**30**	**32**	**32**
33	**33**	**33**	**8**	**32**	**32**	**4**	**32**	**33**	**33**
32	**32**	**9**	**31**	**31**	**29**	**31**	**6**	**32**	**32**
6	**6**	**34**	**32**	**33**	**31**	**33**	**34**	**6**	**6**
0	**6**	**34**	**32**	**33**	**31**	**33**	**34**	**6**	**0**

X

1	**2**	**1**
2	**4**	**2**
1	**2**	**1**

= 1/16

15	**30**	**32**	**33**	**33**	**31**	**25**	**18**
23	**23**	**27**	**31**	**31**	**26**	**23**	**26**
30	**26**	**23**	**23**	**24**	**23**	**27**	**32**
32	**32**	**24**	**16**	**15**	**23**	**30**	**33**
33	**32**	**25**	**16**	**15**	**22**	**32**	**32**
33	**27**	**23**	**24**	**23**	**21**	**25**	**31**
25	**23**	**26**	**30**	**29**	**25**	**22**	**24**
16	**25**	**31**	**32**	**32**	**31**	**25**	**16**

Fill the edges with non-zero values then multiple the value with 3x3 gaussian filter

Now down sampling this to 4 x 4 using average sampling will give better result

22.75	**30.75**	**30.25**	**23**
30	**21.5**	**21.25**	**30.5**
31.25	**22**	**20.25**	**30**
22.25	**29.75**	**29.25**	**21.75**

- What is the size (kB) of this quantized image, if its resolution is 400x400? *(2 points)*
  400*400*6 / (8 * 1024) = 117.18 kB

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/h and you record the car using a film, which records at 8 frames per second. The tires have a diameter of 0.4244 meters. Each tire has a white mark to gauge the speed of rotation.

- If you are watching this projected movie, what do you perceive the rate of tire rotation to be in rotations/sec? Explain your result *(5 points)*

  Speed = 36km/h = 10m/s
  Diameter = 0.4244m
  Circumference = 3.14 * 0.4244 = 1.333m
  Rate of rotation = 10 / 1.333 = 7.5 rotations / sec.
  Nyquist sampling rate is = 2 * 7.5 = 15 fps
  Film is shot at 8 frames per sec : 8 fps < 15 fps hence aliasing is seen
  Degree to turn per frame is 7.5*360/8 = 337.5 (360 < 337.5 < 180)
  At a speed covering 360 – 337.5 = 22.5
  Hence a total turn of 22.5 * 8 / 360 = 0.5 rot/ sec in the backward direction
  Since there is aliasing the wheel will look rotate in backward direction.

- What is the highest speed of the car so that you perceive the rate of tire rotation correctly? *(5 points)*

  8 fps is standard for digital video.
  To perceive the rate of tire rotation correctly, the Nyquist sampling rate should be >=8/ 2
  At this rate, distance covered per second is 4 * 1.333m = 5.33 m/s = 19.19 km/h