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Assignment 1

Answer to Question 1:

Camera: 450 lines/frame
Pixels: 520 pixels/line

Pixels/Frame = 450 * 520 = 234,000 pixels/frame

1) *Sampling Scheme:* ***4:2:0***
   Per 4 pixels – there are 4 Y and 2 (U, V) hence
   4 * 8 = 32 bits
   2 * 8 = 16 bits
   Total = 48 bits
   Hence 48 / 4 = 12 bits/pixel

   Frame rate = 25 Hz which means 25 frames/sec
   Pixels/sec = 234,000 pixels/frame * 25 frames/sec
   = 5,850,000 pixels/sec

   Bit/sec = 5,850,000 pixels/sec * 12 bits/pixel
   = 70,200,000 bits/sec

   Bitrate = 70,200 Kbits/sec = 70.2 Mb/sec

2) If we **re-quantize only Cr and Cb** then the bits/pixel will change

   Per 4 pixels – there are 4 Y and 2 (U, V) hence
   4 * 8 = 32 bits
   2 * 6 = 12 bits
   Total = 44 bits
   Hence 44 / 4 = **11 bits/pixel**

   Bit/sec = 5,850,000 pixels/sec * 11 bits/pixel
   = 64,350,000 bits/sec

   Bitrate = 64,350 Kbits/sec

10 minutes of video = 600 sec
Space occupied = 64,350 Kbits/sec * 600 secs
= 38,610,000 Kbits
= **4.82625 GB**

Answer to Question 2:

1) Quantized Values:
1.75, 2.25, 2.25, 3.25, 3.25, 3.25, 2.5, 2.75, 2.75, 2.75, 1.5, 1, 1.25, 1.25, 1.75, 2.25, 2.25, 2.25, 2, 2.25, 1.25, 0.25, -1.25, -1.25, -1.75, -1, -2.25, -1.5, -0.75, 0, 1

Quantized Levels:
8, 24, 24, 28, 28, 28, 25, 26, 26, 26, 21, 19, 20, 20, 22, 24, 24, 24, 23, 24, 20, 16, 10, 10, 8, 11, 6, 9, 12, 15, 19

2) We would require **5 bits/sample** as there are **32 unique levels**.

Hence, we would need 5*32 = **160 bits**

Answer to Question 3:

Car speed = 36 Km/hr. = 10 meters/sec
Tire Diameter = 0.4244 meters

Circumference of wheel = 2 * 3.14 * 0.2122 = 1.33 meter
Tire Rotations = 10/1.33 = 7.51 rotations/sec

1) The tradition recording is given as 24 frames/sec
Since this is greater than Nyquist frequency of tire rotation which is 15.03 rotations/sec
Hence the viewer will witness the tire rotation to be **7.51 rotations/sec**

2) Recording camera = 8 frames/sec
This is less than the Nyquist frequency so we will have aliasing.

No. of rotations per frame = 7.5 / 8 = 0.9375

In degree = 0.9375 * 360 = 337.5’
Which is 337 – 360 = -22.5’ (which indicates that the wheel is spinning backwards)

This is -22.5’ in one second, since the frequency is * frames/sec then the no of degrees will be -22.5’ * 8 = -180’

Since it is negative I will seem to be rotating in reverse at **0.5 rotations /sec.**

3) Frame rate = 30 frames/sec
Max frequency without aliasing = 15 frames/sec
Hence max tire rotation frequency = 15 rotations/sec

Distance covered = 15 * 1.33 = 19.95 meters
Speed of car = 19.95 meters/sec
= **71.82 Km/hr.**

Answer for Analysis Question 1:

In this we have to analyze the degradation caused by subsampling and individual influence of subsampling in Y, U & V channels, independently.

As directed by the question we can accomplish this by scaling each of the channel at different values, while keeping the other two channel scales at 1 and observe the effects.

So, we have scaled each channel from 1 to 30 and calculated the error with respect to the original image without scaling that is Y=1, U=1 & V=1.

It’s important to note that the Quantization factor remains = 256

Mean Squared Error method to determine the error:

error = (pixel from original image) – (corresponding pixel from up-sampled image)
sum_squared += error^2
mean_square_error = sum_squared / (height * width);

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All the error values were normalized to 1 to show it in the graph below.

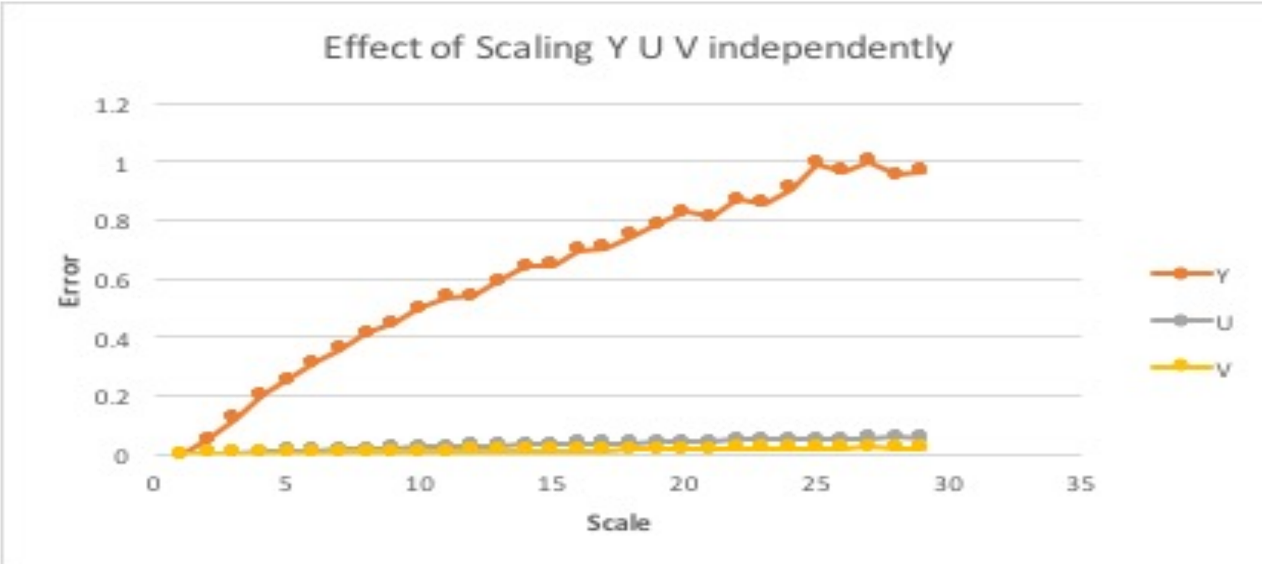

Figure 1

As shown in the Figure 1 we can determine increase is error is more substantial when the Y channel is scaled compared to U & V. We also notice that scaling U has a slightly leads to slightly more error than V.

Example Images:

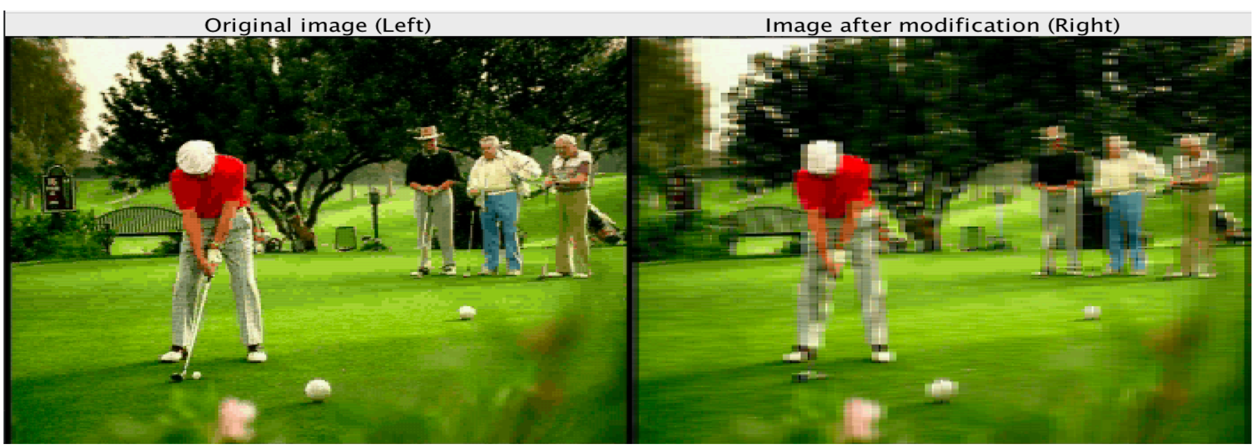

Figure 2 (Scaling Y:5 U:1 V:1)

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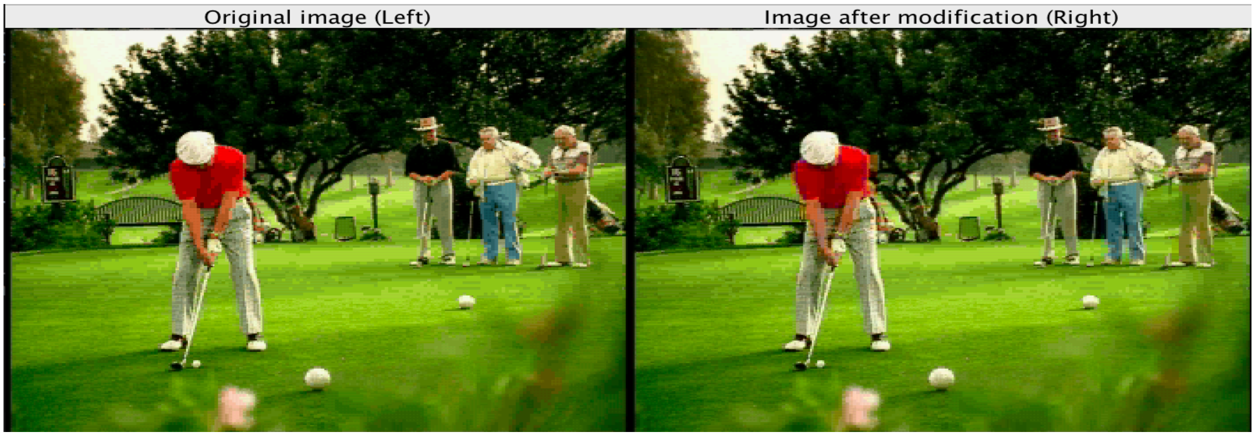

Figure 3 (Scaling Y:1 U:5 V:1)

Figure 4 (Scaling Y:1 U:1 V:5)

As we can notice the Figure 2,3,4, in each of the image each channel has been scaled equally. Even though the scaling is equal we notice the maximum amount of aliasing in Figure 2, and nothing much is noticeable in Figure 3 & 4.

This analysis from the graph concludes that the scaling of Y channel has the maximum effect in the image and leads to maximum aliasing and hence is the most important out of Y U & V channels.

Answer for Analysis Question 2:

As we noticed in the previous analysis question sub-sampling of the Y channel has the maximum effect on the image. The Y channel accounts for the luminescence which U and V also knows as Cr & Cb account for the chrominance of Red & Blue respectively.

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The below sets of images are outputs of the varying U & V at various scales. They have been up-sampled using the averaging methods as explained in the programming section of the assignment.

Figure 5 (Scaling Y: 1, U:10, V:10)

Figure 6 (Scaling Y:1, U:15, V:15)

Figure 7 (Scaling Y:1, U:20, V:20)

As we can notice from Figures 5,6,7 the artifacts increase as we keep sub-sampling and up-sampling the images in U & V channel. Another interesting aspect to notice here is that even-though there is distortion of the images in terms of the color, in terms of the actual clarity of the image it is not affected. It is because the Y channel is not sub-sampled. Just to put some clarity on the point. Take a look into the below image.

Figure 8 (Scaling Y:1, U: 250, V:250)

As you can see the U and V are sub-sampled at a scale of 250 but Y is not sub-sampled. As a result of which the image is still clear even-though there is high level of distortion in chrominance because of U & V channel.

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This distortion in the chrominance occurs due to the averaging algorithm used in up-sampling the U and V channel after sub-sampling them.

Eg: Scale U:4 V:4 Y:1

This means we have:

Y1 U1 V1	**Y2**	**Y3**	**Y4**	**Y5 U5 V5**	**Y6**	**Y7**	**Y8**	**Y9 U9 V9**	**Y10**
Y1 U1 V1	**Y2**	**Y3**	**Y4**	**Y5 U5 V5**	**Y6**	**Y7**	**Y8**	**Y9 U9 V9**	**Y10**

Here based on the averaging methods:
U2 = (U1+U5)/2; V2=(V1+V5)/2;
U3 = (U1+U5)/2; V3=(V1+V5)/2;
U4 = (U1+U5)/2; V4=(V1+V5)/2;

Similarly, the values for U6, V6, U7, V7, U8, V8, U10 & V10 are calculated.

Since we are doing an averaging for the color values as the scaling factor increases the distance between two real samples reduced and the average values leads to more error for the up-sampled pixel locations. Since the same average value is used for all the intermediate pixels we can notice a uniform color rectangles patches in the images on the shirt of the person playing golf.

To avoid this aliasing effect, we can try to smoothen the up-sampled values so that they are closer to the original values using a **linear interpolation** method. In this method instead of just using average we can use the weights to each value before taking average.

Now based on the linear interpolation methods:
U2 = (3*U1 + 1*U5)/4; V2 = (3*V1 + 1*V5)/4;
U3 = (2*U1 + 2*U5)/4; V3 = (2*V1 + 2*V5)/4;
U4 = (1*U1 + 3*U5)/4; V4 = (1*V1 + 3*V5)/4;

The idea here is more weightage is given to the pixel values which is much closer to the pixel being up-sampled. For e.g. When U2 is calculated the U1 has more influence in its average then U5 as U1 is closer to it.

When this is applied the image is sub-sampling is much smoother than before. Please look into the below images.

Figure 9 (Scaling Y:1, U:20, V:20)

As shown in the figure 9 the left side image is a result of an averaging algorithm whereas the right-side image is the result of the interpolation algorithm. As you can notice the image on the left has a significant rectangle shaped color distortion while the same in image on the right is much subtler and smoothed out.

This can even more made better using better forms of interpolations.

Answer for Analysis Question 3:

Currently for the quantization we use the approach which has been specified in the programming section of the assignment which splits the R, G & B channel space of 0-255 in to Q equal segments and snaps the existing R, G & B space to its closest integer. This leads to loss of various colors and leads to multiple artifacts in the processed image. We are now going to see the outputs of quantization at the values of Q = 2, 3, 4 keeping the Y, U & V unchanged at scale 1.

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Figure 10 (Quantization:4)

Figure 11 (Quantization:3)

Figure 12 (Quantization:2)

As it can be noticed the artifacts keep increasing as the number of colors keep decreasing to represent the image. But it is important to understand that every image is generally skewed towards a particular set of colors. Hence during the process of uniform segmentation which we perform now there is a high probability that we select the colors which are used less over the colors used more in the image.

Uniform Quantization:

In this approach we go through the color space of the image and assign importance to each of the values from 0 - 255 based on their no. of time of their occurrence. Once this is done we divide the color space of 0 - 255 into Q segment and we select the one value from each segment based on the weighted average of the occurrence. These values form the new quantization levels for the image.

Figure 13 (Uniform Quantization: 4)

Figure 14 (Uniform Quantization: 3)

Figure 15 (Uniform Quantization: 2)

Compared to Figures 10, 11, 12 what we can notice in Figures 13, 14, 15 is that the colors are much closer to the original image when it is Quantized at 2, 3 & 4. This is because we have retained the most prominent colors in each segment which leads to much closer approximation when they are re-quantized and values are snapped to closest neighbors.

We can achieve much better results using other methods like popularity algorithms, median-cut algorithm and octree-based algorithm. The results become better and better when we are able to retain the most closely resembling colors in our limited bit space.