EE475 Compression
Fall 2019

Turgut Yıldırım
Berkay Gümüş

SUB-SAMPLING	PCM	DPCM	VQ	DCT	JPEG	Total
						/200

1. **Try to give concise one or two sentence answers, explanations**
2. **Copy and past images from the VC Demo program to enhance your answers**

IMAGE COMPRESSION SOFTWARE

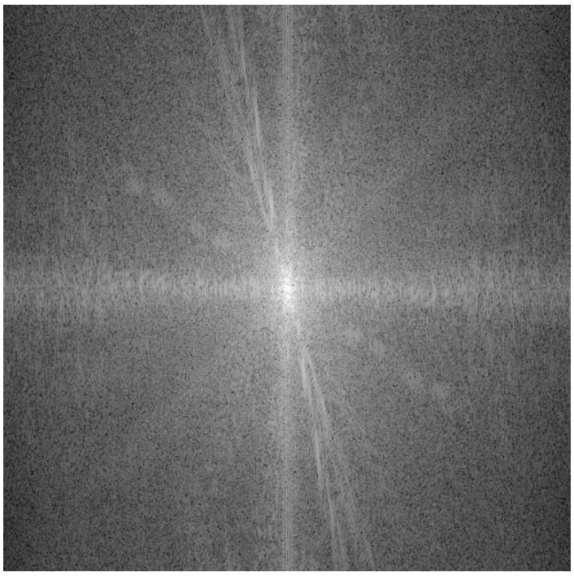
In the following, study the image processing function experimenting with various parameters, report your experience briefly in a few sentences. Copy and paste the images and graphs to accompany your commentaries.

SUBSAMPLING

- Inspect the spectrum of the image Build512B.bmp. The DC component is in the center. Give explanations for the observed line structures. Note: *SS Button* → *Spectrum* → *Apply*

a) Why there are strong horizontal and vertical spectral lines passing through the origin?
Edges of the image are at high frequency due to zero padding and they create horizontal and vertical lines. When DC component shifts to the center, edges pass from the center.

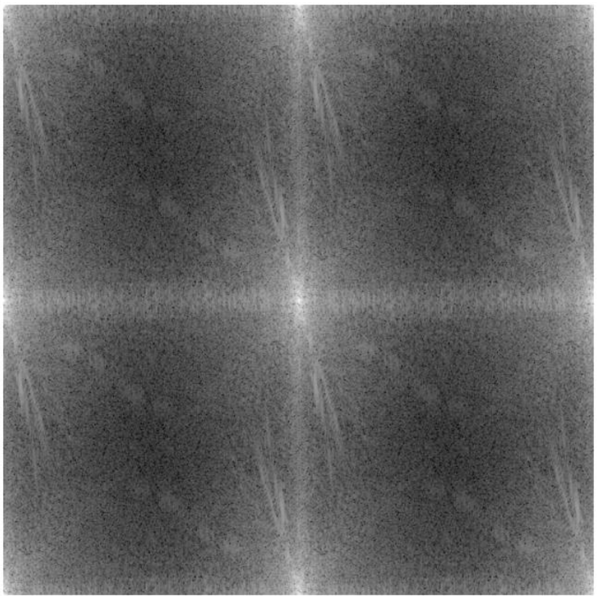
b) Plot the image and its spectrum side by side, and identify two main image structures corresponding to two strong lines in the spectrum.

c) Which details in the image would cause the highest frequency components in the spectrum?

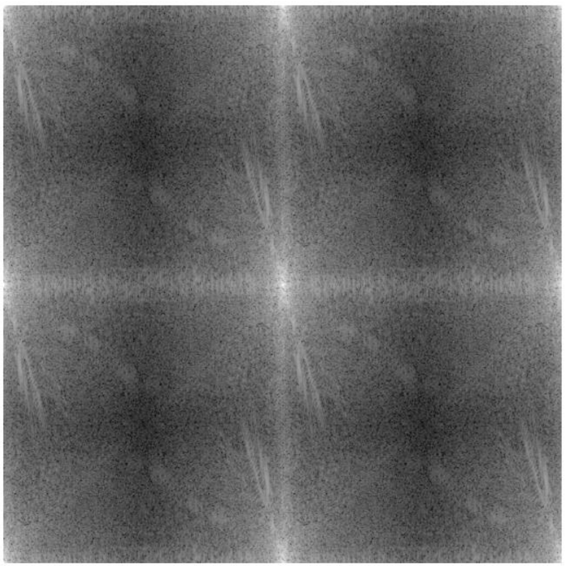
The changing at pixel colors cause high frequency components. Borders of the image, white walls of the house and white roads at the garden cause the highest frequency components.

d) Plot the images and their spectra side by side: Can you pinpoint the aliasing events in the subsampled image without anti-aliasing filtering? Where would you expect these distortions to occur?



The frequency components of the samples intersect, and it causes aliasing. These components belong to bars at the house, white roads and walls. Distortions can be expected at the components with higher frequency.

e) Does anti-aliasing filter improve it? Explain the improvements in the image and the changes in the spectrum.

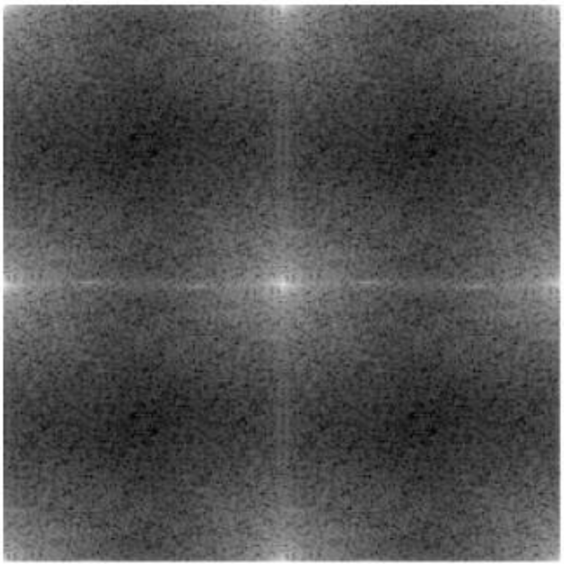


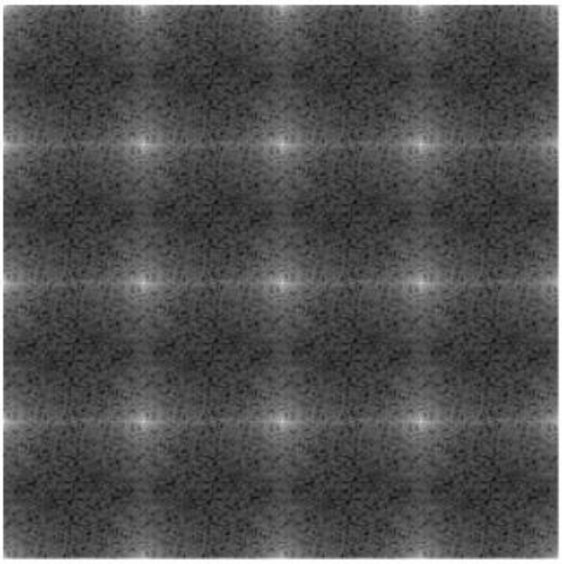
The intersection points at the Fourier spectra are attenuated and result image is improved a bit. The components with high frequency and with low details are improved. The white roads and walls are improved.

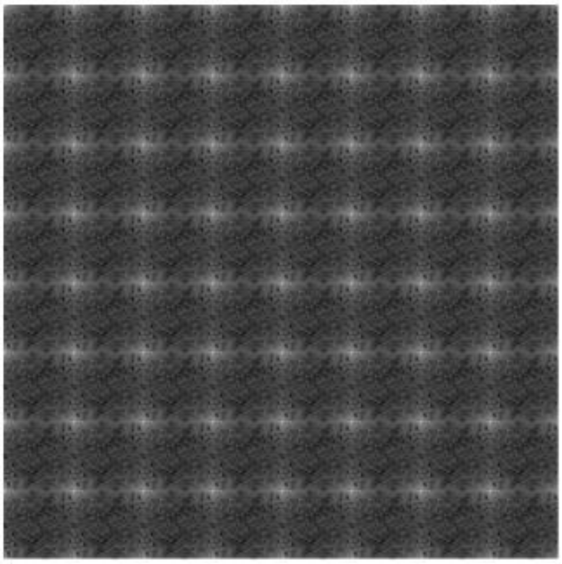
f) In turn, does the anti-aliasing filter cause any distortions? Explain the difference in the spectra of the subsampled images with and without anti-aliasing filters.

The components with high frequency and with high details are attenuated. The details of bars at the house are lost.

g) Subsample the Clown image by factors of 2, 4 and 8, and plot the spectra, side-by-side.

PCM

- Study the images Lena256B, Clown256B, Odie256B. Note: *PCM button → Select bitrate → Apply*. *Do for bit rates 7 to 1.*

a) At which rate do the coding artifacts become objectionable? Where do you observe these artifacts most clearly? At this rate how many gray values are available to represent the image?

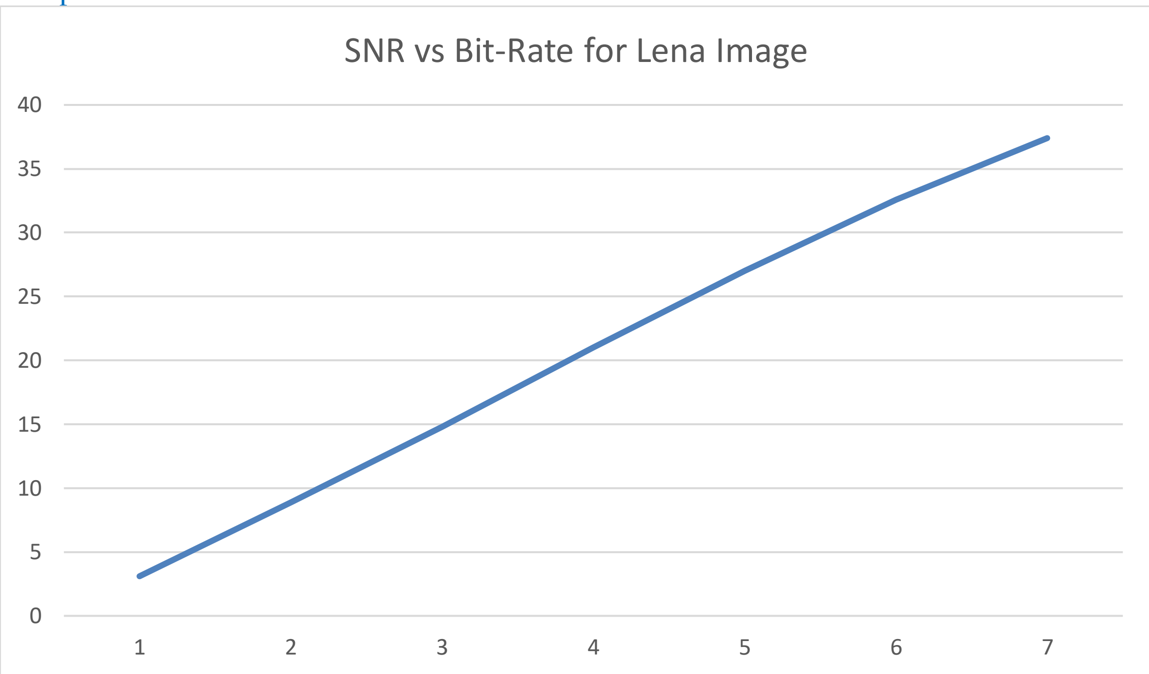
We can observe that at hat of the woman, the feather of this hat, shoulders of the woman for Lena image; at the hair of the man, lines at the wall and lamps at the mirror for clown image; at the eyes and shadow at the ground for Odie image.

	Bit-rate at which artifacts become objectionable	Gray values at this rate
Lena256B	4	16
Clown256B	4	16
Odie256B	2	4

For Lena256B, Fill in the table.

Bit rate	SNR (dB)
1	3.1
2	8.9
3	14.8
4	21.0
5	27.0
6	32.6
7	37.4

b) Draw an SNR-versus-bit-rate plot for Lena256B. Explain the reason why you are getting such a slope for this curve.



SNR is calculated as logarithmic and bit rate exponential, so their ratio comes as linear curve.

c) Explain the behavior of Odie under PCM, which is quite different than that of Lena. What distortions occur in Odie? What distortions occur in Lena?

Lena image is RGB, more complex while Odie image is gray and has less detail. Therefore, for odie image, we can get same SNR with less bit rate. The shadow and the tongue are lost at 1 of bit rate. The lena image consists of the parts with light and without light at 1 of bit rate. For other low bit rate (2-3), the details of the hair and hat are blurry.

DPCM

- Select the Lena256B image and the 1-D predictor. Note: *DPCM button → Model → Select the first prediction model. Select Bit Rate from 1 to 6.*

a) Carry out compression at bit rates 6 to 1 bpp and obtain the SNR – Observe the gain over PCM.

For Lena256B, Fill in the table.

Bit rate	DPCM SNR (dB)	PCM SNR (dB) Copy from previous table
1	7,4	3,1
2	13,2	8,9
3	18,5	14,8
4	24,3	21,0
5	31,2	27,0
6	36,5	32,6
7		37,4

DPCM is better than PCM in terms of SNR values.

b) Compare visually the images with their PCM version and state at what rate DPCM achieves a performance equal to that of PCM?

DPCM performance at 2-bit rate similar to PCM performance at 4-bit rate.

c) Use four types of prediction region for DPCM at bit rate level 5 and comment on the performance differences. Sketch the prediction context (the orange diamond is the current pixel) and write the coefficient values. Plot the Lena image and its three prediction error images in a quadriptych.

0	0	0
0,936	X	

0	0,722	0
0,264	x	

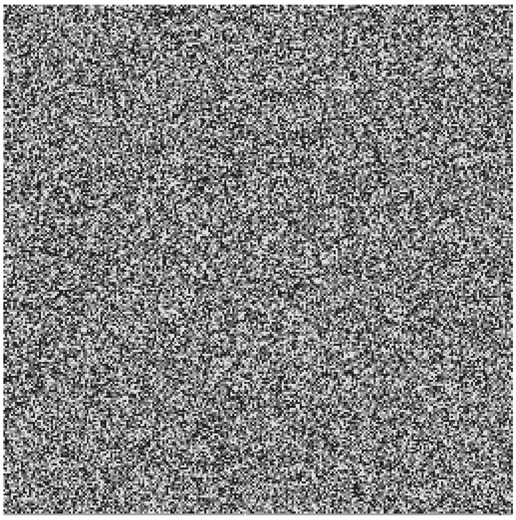
-0,343	0,812	0
0,511	x	

-0,279	0,574	0,21
0,493	x	


d) Observe the correlation matrix. What is the theoretical gain over PCM in terms of bit rate reduction at the same quality? Does the experimental result match the theory? Recall the prediction gain for one-tap predictor: $\frac{1}{1-r^2(1)}$ where r(1) is the normalized correlation coefficient.

The experimental prediction gain is 8,0 and theoretical gain is 8,07 for the first prediction model. These values are so close, and the experimental result matches the theory.

e) If DPCM is used on the noise image below, what do you expect the coding gain to be? What would be the prediction coefficients?



There are too noise so it's difficult to predict other than noiseless images. The prediction gain for this noisy image would be lower than it is for noiseless image (8,0).

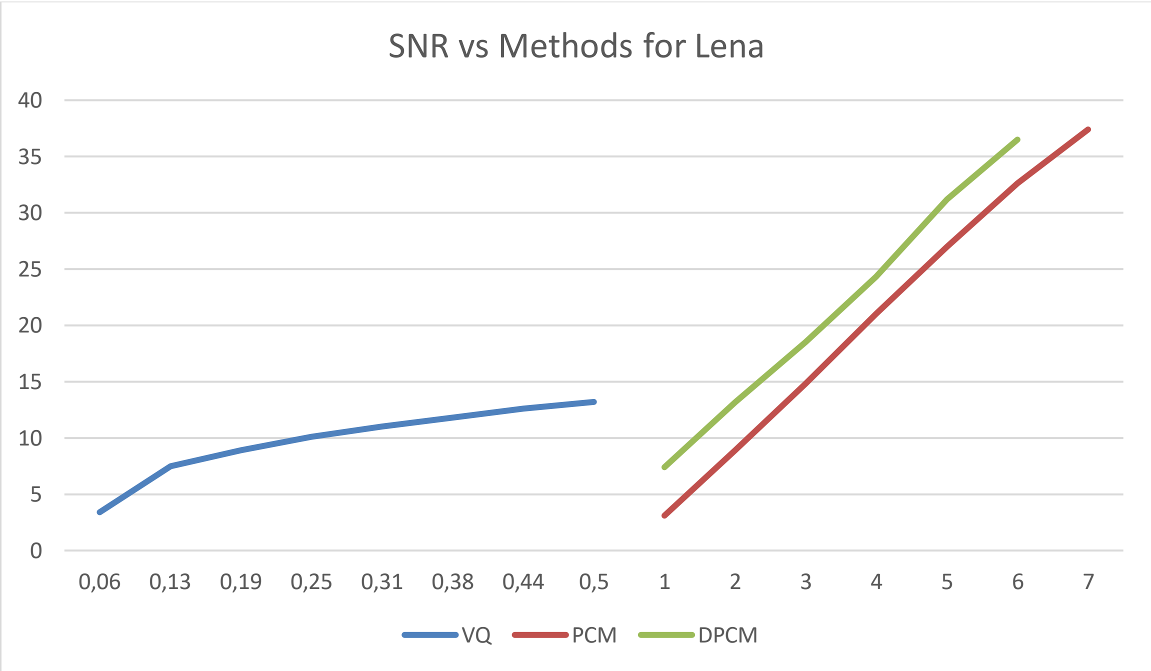
VQ

Load the predesigned codebook Standard_4x4_min1-max12.cbk. This codebook has been designed on 4 other images other than Lena.

Note: *VQ button → Codebook → Load codebook → Select Standard_4x4_min1-max12.cbk → Open*

Bits → Select

a) Make an SNR-bit rate plot of VQ on the same curve as PCM/DPCM, i.e., copy first the PCM-DPCM plot. Note: Be careful to first calculate the VQ bit rate (bits/pixel) before you plot.



Start this curve from 0.

b) What type distortion do you observe at low bit rates? Does it appear to be additive white Gaussian noise? Plot the VQ coded images.

Pixel values are quantized for low bit rates, these values are rounded to the closest quantization values. It creates Gaussian noise. Yes, it appears because of this quantization.





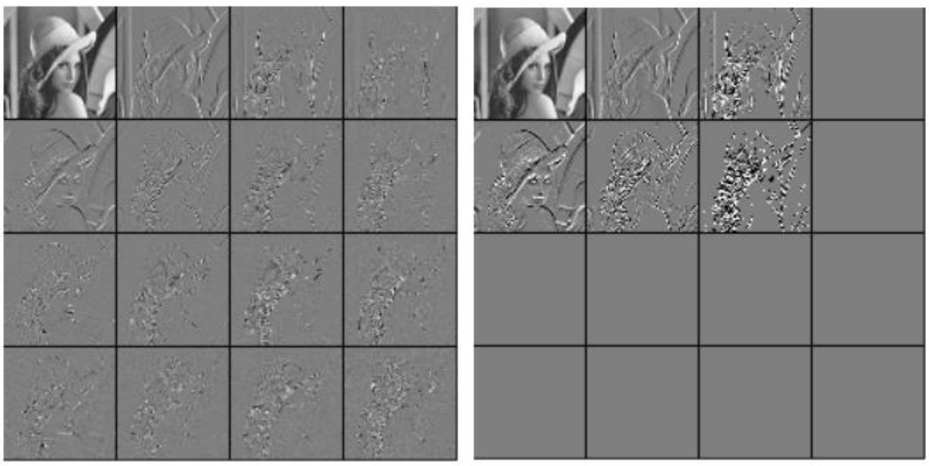
c) Can you use codebooks obtained by Lena-type images on cartoons and maps? If yes, how? If not, why not?

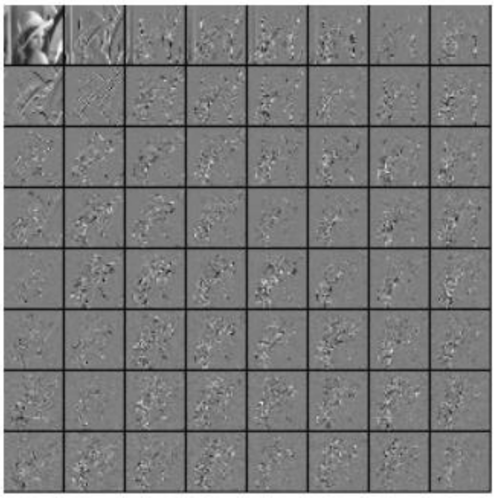
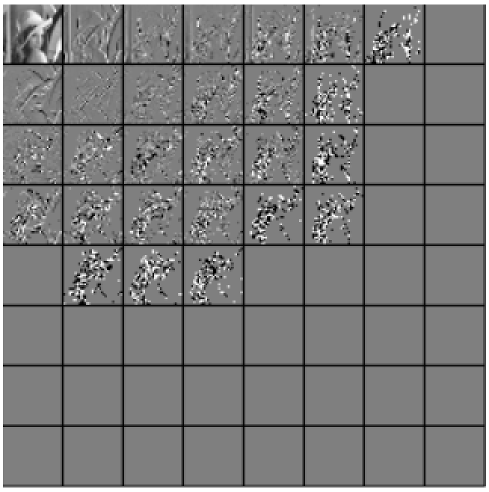
Yes, we can do it. It can be used for 8-bit 16-bit video games and cartoons. It doesn't need to have much more details. Also, some movies can be converted the cartoons by using this method.

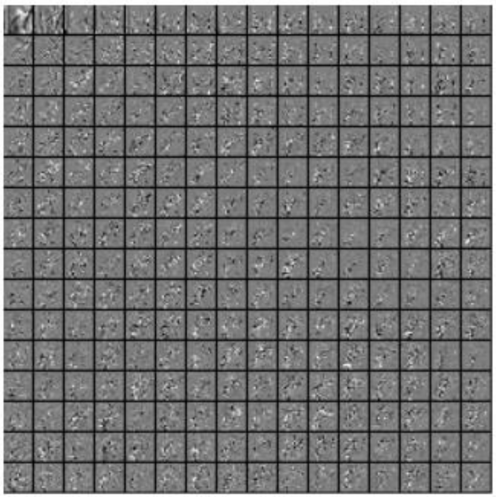
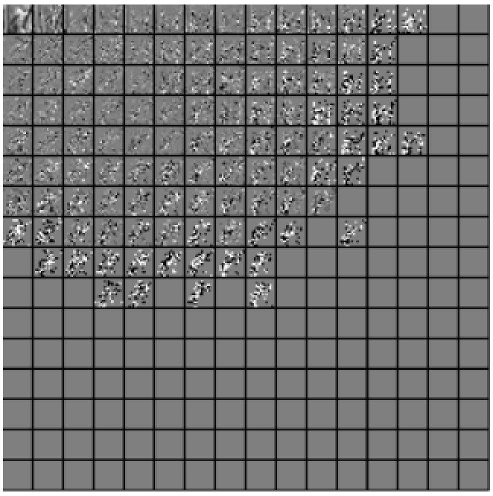
DCT

Select the Lena256B image. Select PCM compression for all DCT coefficients. Pick c = 0.75 as the exponent power of the generalized Gaussian distribution.

a) Study the block sizes of 2x2, 4x4 and 8x8, 16x16. Explain what you observe in the "DCT: Original Coefficients" window. Plot both the un-coded and coded versions of the DCT coefficients, side by side for the four block size choices, as in the example below.



The most top and left component consists of DC component; and through X and Y axis components consist of higher frequencies.

b) Use again entropy coding, but with the wrong signal model. Assume wrongly that the shape parameter of the generalized Gaussian distribution is a = 2 (hence pure Gaussian), and not a = 0.75. What do you observe? How is coding performance affected?

The quality of the coded images depends on the noise at the uncoded images. When the Gaussian distribution is 2, the last samples at the coded images are too noisy.

JPEG

- Use the Lena256B image and the standard luminance normalization matrix. Note: *JPEG button → Huffman tab → Select FLC, Standard VLC, Optimal VLC in turn*
  JPEG button → Bit rate tab → Bitrate → Select bit rate as 0.5, 0.8, 1.0, 1.5, 2.0, 2.5, 3.0 in turn → Apply
  Write down the Encoded Bit Rate in bpp, Optimized Quality Factor and the corresponding SNR. (FLC: Fixed Length Coding, VLC: Variable Length Coding)

a) Fill the SNR-bit rate tables, one for each entropy coding choice. At the same time, write down the corresponding QF: Quality Factors. How much additional SNR does entropy-coding give?

Bit rate	FLC			Standard VLC		
	Encoded Bit Rate	Quality factor	SNR (dB)	Encoded Bit Rate	Quality factor	SNR
0.5	0,7	2	7,4	0.5	17	15,7
0.8	0,8	4	10,4	0,8	38	18,2
1.0	1	6	12	1	55	19,6
1.5	1,5	13	14,9	1,5	78	22,4
2.0	2	23	16,6	2	87	24,8
2.5	2,5	34	17,8	2,4	91	26,7
3.0	3	48	19	3	94	28,8

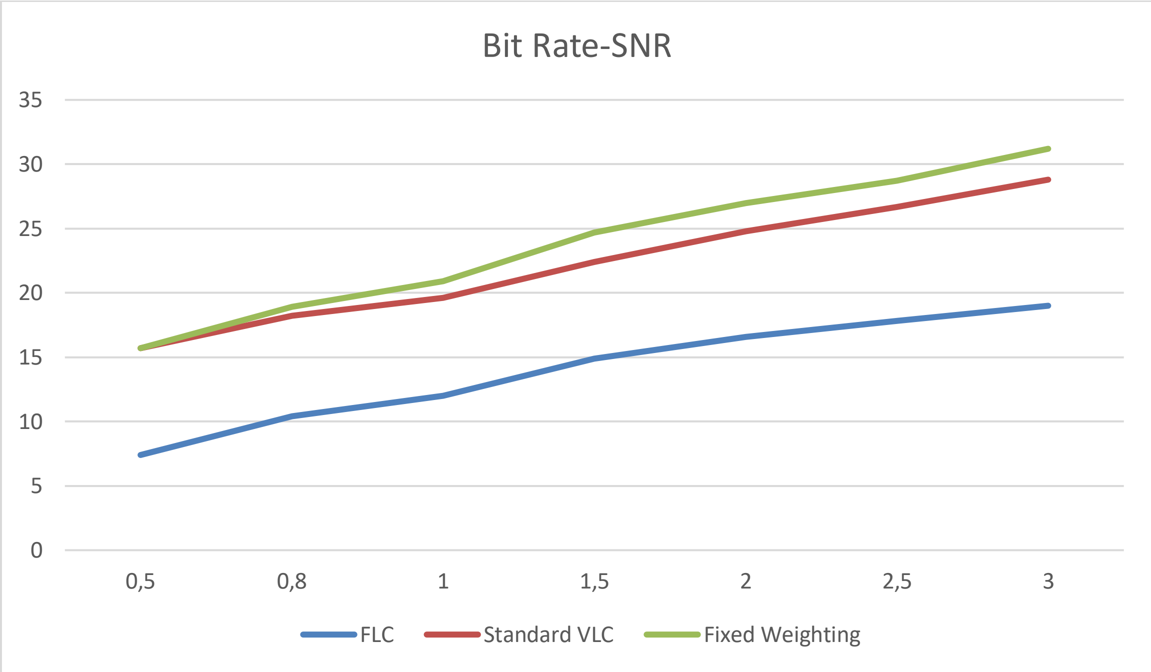
It gives additional 7-8 for SNR values.

b) Compare the resulting SNRs from a “flat normalization matrix” against that of the “standard luminance normalization” and comment.
   Note: *Repeat above selecting: Quant → Choose Flat*

Bit rate	Fixed weighting			Standard weighting (psychovisual)		
	Encoded Bit Rate (b	Quality factor	SNR (dB)	Encoded Bit Rate	Quality factor	SNR
0.5	0,5	41	15,7	0.5	17	15,7
0.8	0,8	66	18,9	0,8	38	18,2
1.0	1	76	20,9	1	55	19,6
1.5	1,5	87	24,7	1,5	78	22,4
2.0	2	91	27	2	87	24,8
2.5	2,4	93	28,7	2,4	91	26,7
3.0	2,9	95	31,2	3	94	28,8

SNR values and quality factors for flat are higher than standard weighting.

Draw the three bit rate-SNR curves on the same plot:



c) Observe the images with flat versus standard normalization matrix at 0.5 bpp. Their SNRs are equal, yet one looks better than the other one. Explain this dilemma.

The human vision system senses a bit more different than the what actually it is. The SNR values are same, the quality factor is higher for flat however the image for standard normalization matrix looks better.