TEL411 – Digital Image Processing

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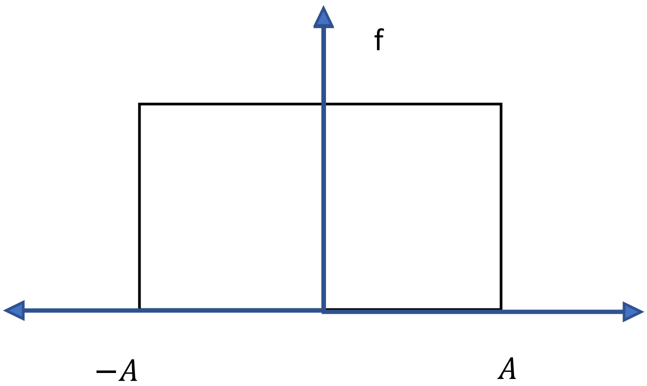
Project

Due date: Friday, January 8, 2021

Part A

Quantization is the process of mapping input values from a large set to output values in a smaller set, often with a finite number of elements. Consider a discrete 1D input signal $f(x)$ that consists of values that belong to the interval $[-A\,, A]$ following a uniform



distribution as depicted above. The goal of a *uniform scalar quantizer* (USQ) is to reduce the number of the values that could be assigned to each element of the input signal f. To design a USQ we need to define the number of the quantization levels $L = 2^R$ which must be of the same length $\Delta = \frac{A-(-A)}{L} = \frac{2A}{L}$.

1. Assume that your input signal exists in the range $[-255, 255]$. Generate a function called "uni_scalar" that works according to the definition of the uniform scalar quantizer given below:

$$Q(x) = \Delta \times \operatorname{sgn}(x) \left\lfloor \frac{|x|}{\Delta} + \frac{1}{2} \right\rfloor$$

where $\mathrm{sgn}(x)$ stands for the sign, x is the input signal and Δ the quantization step. You may use the sign() function.

2. Plot the characteristic functions of the uniform quantizer for $R = 0, \dots, 8$.

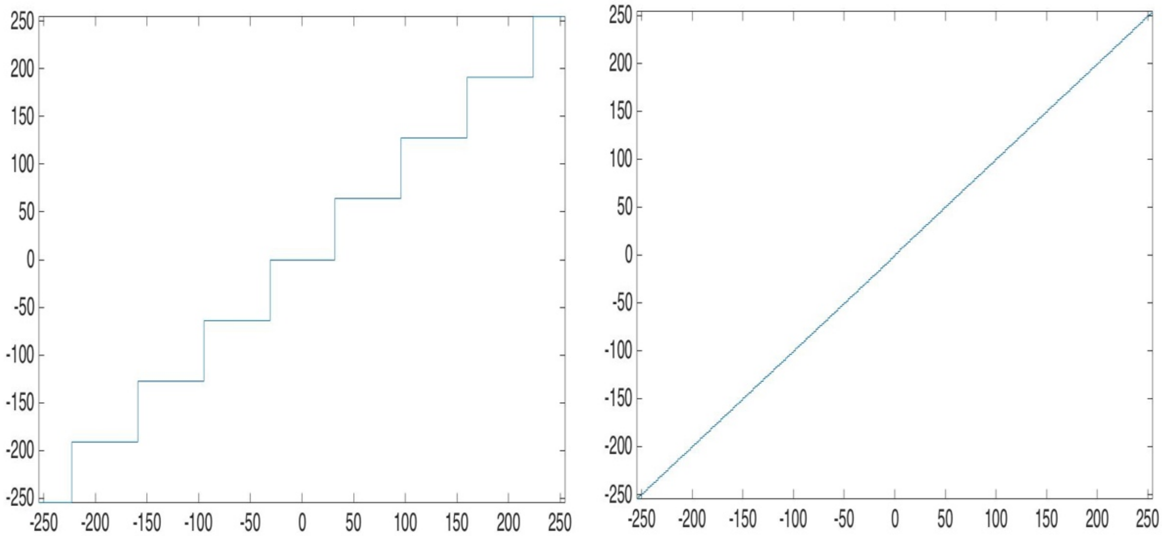


Figure 1. Characteristic function of R=2 (left) and R=7 (right).

3. Quantize the ''lena_gray_512.tif" (eclass Labs/Input_Data) for every possible R value and illustrate your results. (Note: ''lena_gray_512.tif" is an 8-bit gray-scale image).
4. Measure the distortion D due to the quantization using the Mean Square Error (MSE).
5. Plot the rate-distortion curve $D(R)$ and explain your results.

Part B

This section will introduce you to video processing. You will be able to read a video file and display each one frame. In addition, you are asked to report some important information concerning the input video stream and convert one of its RGB frames into a grayscale colormap.

1. Load the "xylophone.mp4" video using the VideoReader() function.

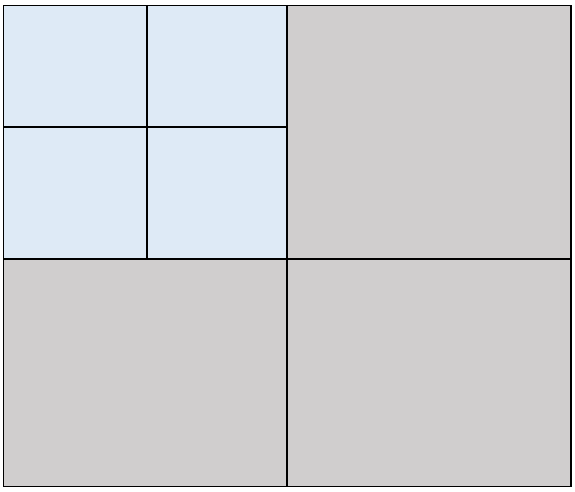
2. Report (i) the number of frames, (ii) the framerate of the video, (iii) the resolution of each frame and (iv) the total duration of this video.
3. Write a small script that illustrated each frame according to the framerate (*Framerate* is the number of individual video frames (images) which are captured per second). You may use the functions hasFrame(), readFrame() and pause().
4. Extract the 50^{th} frame of the "xylophone.mp4" video stream and convert the RGB image to a gray-scale. Illustrate in the same figure window the RGB and gray-scale version of the 50^{th} frame. You may use the function rgb2gray(), subplot().

Part C

The goal of this section is to build a compression system using the Haar transform and the uniform scalar quantizer. You need to decompose an image into 2 Haar levels. Then you will quantize the subbands of these levels using 2 different methods before you recover the input image applying the inverse Haar transform. The goal is to compare these two methods utilizing the entropy and the PSNR metrics.

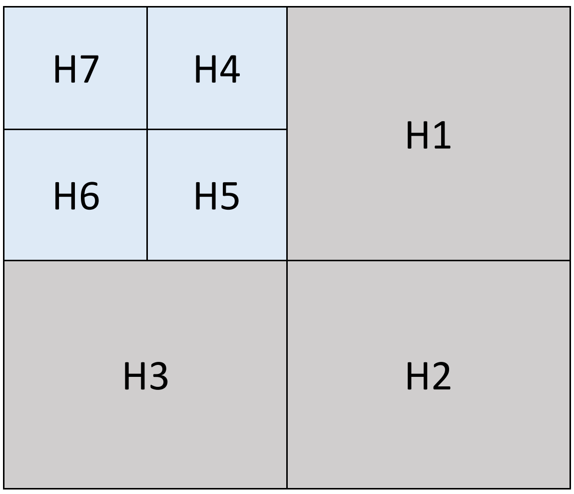
Figure 2. The 50th frame.

1. Use as in input the 50^{th} gray-scale frame of the "xylophone.mp4".
2. Rescale your image into 256x256.
3. Apply the Haar transform to obtain 2 decomposition levels as illustrated below



4. Quantize each subband choosing the same quantization step R=4 (do not quantize the low frequency image).
5. Calculate the entropy in each subband, and the total entropy to obtain the compression ratio for each configuration of the quantization step.

$$H = -\sum p \log_2 p.$$



6. Reconstruct the frame using the inverse Haar transform and measure the distortion using the Peak Signal-to-Noise Ratio (PSNR) metric.
7. Now, quantize each subband choosing different quantization steps (R=3 for the 1st layer and R=5 for the second layer. Do not quantize the low frequency image).
8. Calculate the entropy in each subband, and the total entropy to obtain the compression ratio for each configuration of the quantization step.
9. Reconstruct the frame using the inverse Haar transform and measure the distortion using Peak Signal-to-Noise Ratio (PSNR).
10. Compare the different quantization methods and explain your results.