POLITECNICO DI MILANO

MMSP 2nd Module – Lab2

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Scalar quantizers

EXERCISE 1

Exercise 1 - Problem

1. Generate a 1000-sample realization of $x(n) \sim N(\mu, \sigma)$ with variance 3 and mean 0.

2. Quantize $x(n)$ using:
   1. A scalar mid-rise quantizer with fixed quantization step delta=2 and plot the input-output characteristic.
   2. A scalar mid-tread quantizer with fixed quantization step delta=2 and plot the input-output characteristic.
   3. A scalar mid-tread quantizer with M=4 output levels and plot the input-output characteristic.
   4. cb = [-5, -3, -1, 0, 1, 3, 5] as reproduction levels and th = [-4, -2, -0.5, 0.5, 2, 4] as thresholds and plot the input-output characteristics.

3. For each one of the above quantizers compute the MSE and the SNR.

Exercise 1 - Hints

1. Mid-rise quantizer formula:

$$q(x) = \left(\left\lfloor \frac{x}{\Delta} \right\rfloor + \frac{1}{2}\right) * \Delta$$

2. Mid-tread quantizer formula:

$$q(x) = \left\lfloor \frac{x}{\Delta} + \frac{1}{2} \right\rfloor * \Delta$$

Scalar quantizers

EXERCISE 2

Exercise 2 - Problem

1. Generate a 10000-sample realization of $s_g(n) \sim N(0,2)$ and $s_u(n) \sim U$ with variance 2 and mean 0.

2. Quantize $s_g(n)$ and $s_u(n)$ with M=[4,8,16,32,64,128] levels and uniform quantizer. Plot R-D curve for each number of levels. Plot the theoretical distortion obtained with a uniform scalar quantizer considering the case of the uniform distributed signal.

3. Design an optimum uniform quantizer and a Lloyd-Max quantizer for $s_g(n)$ with the same levels defined in the previous step. Compare the R-D curves obtained with this quantizers with those obtained with uniform quantizer.

Exercise 2 - Hints

1. Use **rand** and **randn** for data generation
2. Use MSE as metric for distortion
3. Use SNR for R-D curves
4. Remember distortion lower bound for Gaussian pdf:

$$\sigma_e^2 = \sigma_x^2 2^{-2R}$$

5. Use **lloyds** and **quantiz** to implement Lloyd-Max

Scalar quantization

EXERCISE 3

Exercise 3 - Problem

1. Suppose that you are sampling the output of a sensor at 10 kHz for 10 seconds. Quantize the output with a uniform quantizer at 10 bit per sample. Assume that the pdf of the signal is gaussian with mean 0 V and variance 4 V^2. What is the bit rate of the quantized signal?

2. What would be a reasonable choice for the quantization step?

3. What is the MSE?

Vector quantization

EXERCISE 4

Exercise 4 - Problem

1. Consider a 2D vector quantizer with codebook y1=(1,2), y2=(1,4), y3=(-1,2), y4=(0,-2). Show optimal assignement regions

2. Quantize the sequence x=(-4:5) using groups of 2 consecutive samples at time

Exercise 4 - Hints

1. Use **voronoi** to show a voronoi tessellation of a 2D space

2. Use **dsp.VectorQuantizerEncoder** and **step** to implement the vector quantizer