GUC Berlin
German University in Cairo
الجامعة الألمانية بالقاهرة

German University in Cairo - GUC
Faculty of Information Engineering & Technology - IET
Department of Communication Engineering
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Students Name: **Students ID:**

COMM901 – Source Coding and Compression

Quiz 3

	Question 1	Question 2	SUM
possible points	14	6	20
achieved points			
		sum counted:	
		percentage:	

<u>Question 1:</u> [14 points – best 14 of the 15 answers are counted]

Mark the correct answer for each question (there is only one correct answer for each question).

(1) What characterizes a quantizer?

a. The output of a quantizer has the same entropy rate as the input.

b. Quantization results in a non-reversible loss of information.

c. A quantizer always produces uncorrelated output samples.

(2) What property has the output signal of a scalar quantizer?

a. The output is a discrete signal with a countable symbol alphabet (but not necessarily a finite symbol alphabet).

b. The output is a discrete signal with a finite symbol alphabet.

c. The output signal may be discrete or continuous.

(3) What is a Lloyd quantizer?

a. A Lloyd quantizer is the scalar quantizer that yields the minimum distortion for a given source and a given number of quantization intervals.

b. The output of a Lloyd quantizer is a discrete signal with a uniform pmf.

c. For a given source, the Lloyd quantizer is the best possible scalar quantizer in rate-distortion sense. That means, there does not exist any other scalar quantizer that yields a smaller distortion at the same rate.

(4) Assume the decision thresholds $\{u_i\}$ for a scalar quantizer are given and we want to derive the optimal reconstruction levels $\{s_i'\}$ for minimizing the MSE distortion. The pdf of the input signal is denoted by $f(s)$. How are the optimal reconstruction levels derived?

a. $s_i' = \frac{\int_{u_i}^{u_{i+1}} s \cdot f(s)\ ds}{\int_{u_i}^{u_{i+1}} f(s)\ ds}$

b. $s_i' = \frac{u_i + u_{i+1}}{2}$

c. $s_i' = u_i + \frac{f(u_{i+1})}{2}$

(5) A Lloyd quantizer can be considered as optimal quantizer for fixed-length coding of the quantization indices. Can we improve a Lloyd quantizer by using variable length codes?

a. No, variable length coding does not improve the quantizer performance, since all quantization indices have the same probability.

b. No, variable length coding does not improve the quantizer performance, since the quantizer output is uncorrelated.

c. Yes, in general, the quantizer performance can be improved by variable length coding (there are some exceptions for special sources).

(6) Assume we want to design a quantizer with 256 quantization intervals, where the quantization indices are transmitted using fixed-length codes (using an 8-bit codeword per index). The reconstruction levels $\{s_i'\}$ are given. How should we set the decision boundaries $\{u_i\}$ for minimizing the distortion of the quantizer?

a. $u_i = \frac{s_{i-1}+s_i}{2}$

b. $u_i = s_i - \frac{1}{2}$

c. $u_i = s_i - \sqrt{(s_i - s_{i-1})^2 + (s_{i+1} - s_i)^2}$

(7) What characterizes an entropy-constrained Lloyd quantizer?

a. An entropy-constrained Lloyd quantizer is the scalar quantizer that yields the best rate-distortion performance for a given operation point (assuming that the quantization indices are coded using optimal entropy coding).

b. An entropy-constrained Lloyd quantizer minimizes the entropy rate of the quantizer output for a given number of quantization intervals.

c. An entropy-constrained Lloyd quantizer minimizes the number of quantization intervals for a given distortion.

(8) What characterizes the best possible scalar quantizer with variable length coding at high rates (for MSE distortion)?

a. All quantization intervals have the same probability.

b. All quantization intervals have the same size.

c. None of the above statements is correct.

(9) Which statement is true regarding the performance of optimal scalar quantizers with variable length coding at high rates for iid sources?

a. For iid sources, the operational distortion-rate curve for optimal scalar quantization is always equal to the distortion-rate function (theoretical limit).

b. Only for Gaussian iid sources, the operational distortion-rate curve for optimal scalar quantization is equal to the distortion-rate function (theoretical limit)

c. For iid sources, the operational distortion-rate curve for optimal scalar quantization is 1.53 dB worse than the distortion-rate function (theoretical limit).

(10) What characterizes a vector quantizer?

a. Multiple input symbols are represented by one quantization index.

b. Multiple quantization indexes are represented by one codeword.

c. Each input symbol is represented by a fixed-length codeword.

(11) What statement is correct for comparing scalar quantization and vector quantization?

a. By vector quantization we can always improve the rate-distortion performance relative to the best scalar quantizer.

b. Vector quantization improves the performance only for sources with memory. For iid sources, the best scalar quantizer has the same efficiency as the best vector quantizer.

c. Vector quantization does not improve the rate-distortion performance relative to scalar quantization, but it has a lower complexity.

(12) Why is vector quantization rarely used in practical applications?

a. The coding efficiency is the same as for scalar quantization.

b. It requires block Huffman coding of quantization indexes, which is very complex.

c. The computational complexity, in particular for the encoding, is much higher than in scalar quantization and a large codebook needs to be stored.

(13) Which of the following statements is true for Lloyd quantizers:

a. The input signal and output (reconstructed) signal are uncorrelated.

b. The input signal and the quantization error are uncorrelated.

c. The output (reconstructed) signal and the quantization error are uncorrelated.

(14) Let N represent the dimension of a vector quantizer. What statement about the performance of the best vector quantizer with dimension N is correct?

a. The vector quantizer performance is independent of N.

b. By doubling the dimension N, the bit rate for the same distortion is halved.

c. For N approaching infinity, the quantizer performance asymptotically approaches the rate-distortion function (theoretical limit).

(15) Assume we have a source with memory and apply scalar quantization and scalar Huffman coding? Can the performance, in general, be improved by replacing the scalar Huffman coding by conditional Huffman coding or block Huffman coding?

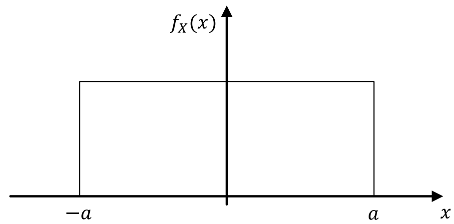
a. Yes, the performance can in general be improved, since there will be also dependencies between successive quantization indexes.

b. No, the performance cannot be improved, since the quantization removes all dependencies between the source symbols.

c. No, the performance cannot be improved, since the quantization error and the input signal are uncorrelated.

Question 2: [6 points]

Given is a continuous-amplitude random process $\boldsymbol{X} = \{X_n\}$ with independent and identically distributed random variables X_n. As illustrated in the figure below, the random variables X_n have a uniform probability density function in an interval $[-a; a]$.



Consider a 1-bit quantizer that consists of two quantization intervals. The decision boundary between the intervals is given by $u_1 = 0$.

(1) Determined the optimal reconstruction levels s_0' and s_1' that minimize the MSE distortion.

Let b be the value of the pdf inside the interval $[-a; a]$. Since the integral is equal to 1, we have

$$\int_{-a}^{a} f_X(x)\ \mathrm{d}x = b \cdot \int_{-a}^{a} \mathrm{d}x = 2ab = 1 \qquad \Longrightarrow \qquad b = \frac{1}{2a} \quad [1]$$

The optimal reconstruction level s_1' is given by the centroid condition

$$s_1' = \frac{\int_0^\infty s \cdot f(s)\ \mathrm{d}s}{\int_0^\infty f(s)\ \mathrm{d}s} = \frac{\frac{1}{2a}\int_0^a s\ \mathrm{d}s}{\frac{1}{2a}\int_0^a \mathrm{d}s} = \frac{\frac{1}{2}(a^2 - 0^2)}{a - 0} = \frac{a}{2} \quad [2]$$

Due to reasons of symmetry, we have for the other reconstruction level

$$s_0' = -\frac{a}{2} \quad [1]$$

(2) Is the resulting quantizer a Lloyd quantizer for the given source?

A Lloyd quantizer fulfils two conditions, the centroid condition and the nearest neighbour condition. The centroid condition is fulfilled, since we used it for deriving the reconstruction levels.

The nearest neighbour condition is also fulfilled, since we have

$$u_1 = \frac{s_0 + s_1}{2} = \frac{-\frac{a}{2} + \frac{a}{2}}{2} = 0 \quad [1]$$

Hence, the developed quantizer is a Lloyd quantizer. [1]