EE5351 – DIGITAL VIDEO CODING

INSTRUCTOR: Dr. K.R. Rao

Summer 2009, Exam 2

Tuesday, 14 July 2009

1:00PM – 2:30 PM (1:30 Hour)

(OPEN ONLY CLASS NOTES)

INSTRUCTIONS:

1. Open ONLY class notes.
2. Calculator is allowed.
3. Please show all the steps in your work.
4. You can work problems in any order.
   At the end please rearrange as 1, 2, and 3 (4–8 are multiple choices).
5. Please print your name and student ID.
6. No cheating, no talking.

Name________________________

Student ID____________________

[25 Points]**[Problem 1]**

Suppose we have a source that can be modeled as a random variable taking values in the interval [-4, 4] with more probability mass near the origin than away from it. We want to quantize this using the companding quantizer which composes of compressor and 3 bit uniform quantizer. The compressor characteristic we will use is given by the following equation

$$c(x) = \begin{cases} 2x & \text{if } -1 \le x \le 1 \\ \frac{2x}{3} + \frac{4}{3} & x > 1 \\ \frac{2x}{3} - \frac{4}{3} & x < -1 \end{cases}$$

The mapping is shown graphically in figure 1. The inverse mapping is given by

$$c^{-1}(x) = \begin{cases} \frac{x}{2} & \text{if } -2 \le x \le 2 \\ \frac{3x}{2} - 2 & x > 2 \\ \frac{3x}{2} + 2 & x < -2 \end{cases}$$

The inverse mapping is shown in figure 2. For this companding quainter , what are the outputs for the following inputs: -0.8, 1.2, 0.5, 0.6,3.2,-0.3. Compare your results with the case when the input is directly quantized with a uniform quantizer with the same number of levels. Comment on your results.

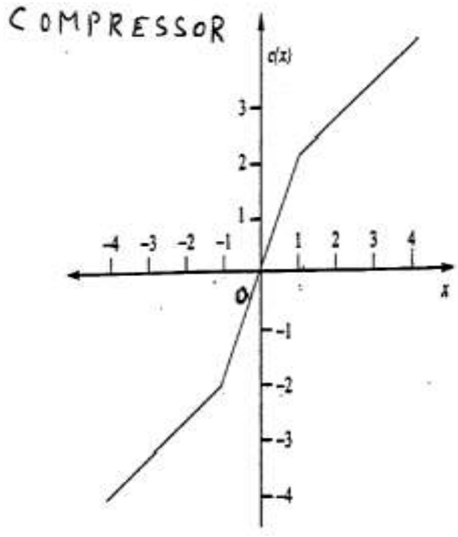


Figure 1

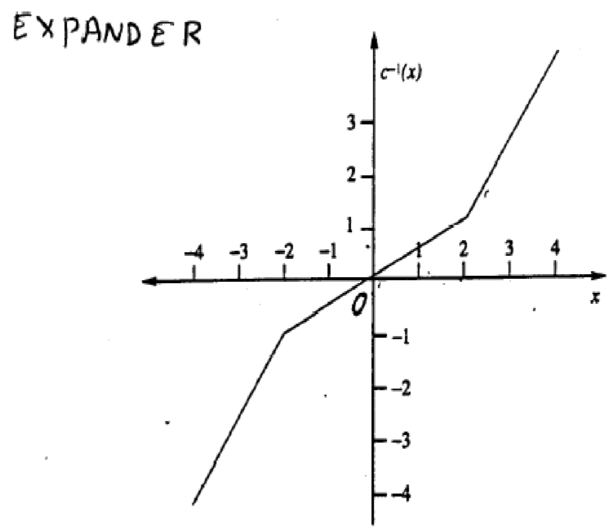


Figure 2

[25 Points]**[Problem 2]**

Using LBG algorithm, design the code book for these training vectors (Choose the threshold ε=0.001

x1= [-0.5, 1];

x2=[0.6,-0.1];

x3=[-0.8,0.6];

x4=[-0.7,-1.2];

x5=[-0.2,-0.9];

x6=[1.1, 0.5];

x7=[-0.6,0.2];

x8=[0.1,1.7];

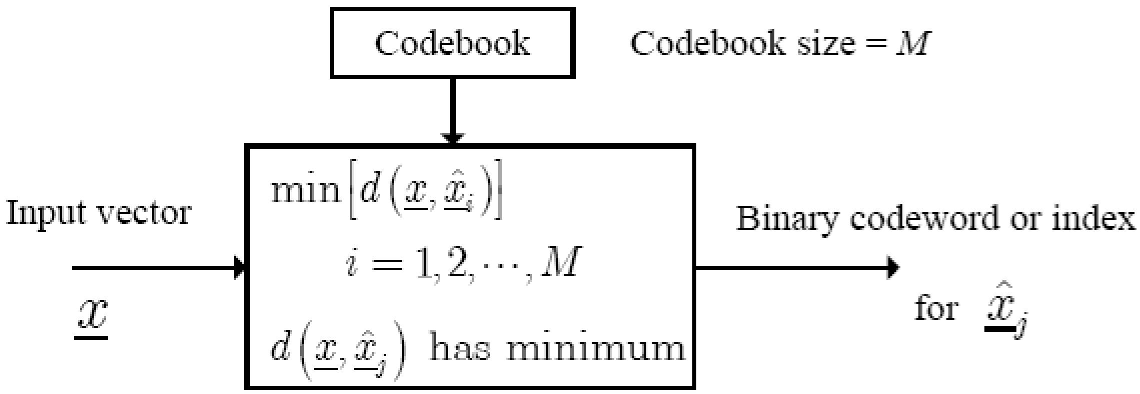
x9=[0.7,-0.3]

x10=[0.3,4.8]

Start with a uniform Quantizer (codebook)

$$(\underline{\hat{x}}_1, \underline{\hat{x}}_2, \underline{\hat{x}}_3, \underline{\hat{x}}_4) = \left(\frac{S_1}{2,2}\right), \left(\frac{S_2}{2,-2}\right), \left(\frac{S_3}{-2,2}\right), \left(\frac{S_4}{-2,-2}\right)$$

[25 Points]**[Problem 3]**
(Vector quantization) VQ codebook contains ***M*** codeword's (codebook size). Each Codeword is fixed length binary coded.



(3.1)[5 Points] How many codebook indices are used for this Quantizer?

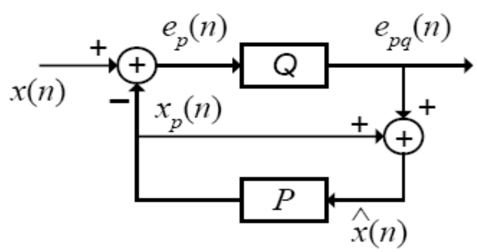
(3.2)[5 Points] Calculate the number of bits needed to transmit each codebook index

(3.3)[5 Points] Given each input vector has *L* pixels (dimension of input vector), find the compression rate of the encoder in bpp (bits per pixel)

(3.4)[10 Points] Explain in detail the splitting algorithm for designing a codebook. What is an empty cell problem and how can this be solved.

[25 Points]**[Problem 4]**
(DPCM with linear-causal K-th order predictor)
(4.1) [9 Points]

Given $\sigma_{pe}^2 = E\left[e_p^2(n)\right]$, prediction error $e_p(n)$ and predicted value $x_p(n)$ are uncorrelated, $x_p(n) = \sum_{i=1}^{K} a_i x(n-i)$, where $x(n)$ is input signal, and a_i are predictor weights. Also $e_p(n)$ has zero mean.



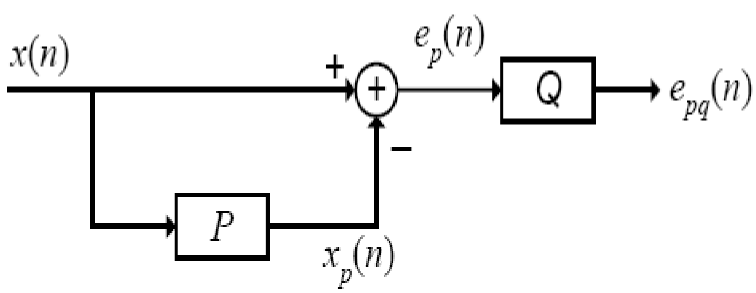
Show that prediction error variance, $\sigma_{pe}^2 = \sigma_x^2 - \underline{a}_{(1\times K)}^T \; \underline{r}_{(K\times 1)}$

where, $\underline{a}_{(K\times 1)} = \left[a_1, a_2, \cdots, a_K\right]^T$,

$\underline{r}_{(K\times 1)} = \left[r_1, r_2, \cdots, r_K\right]^T$

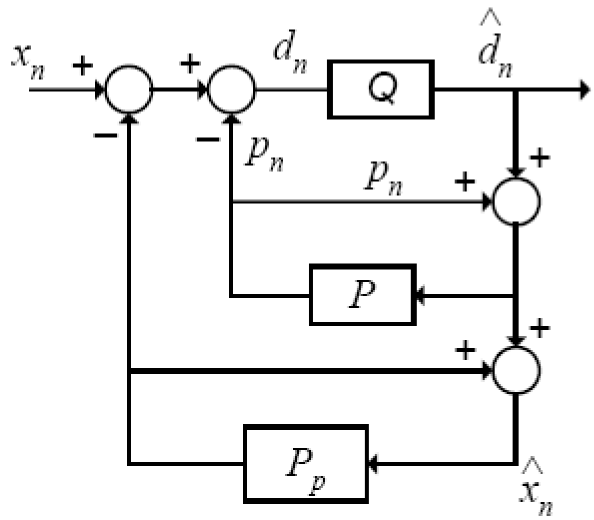
$\left[E\left[x(n)x(n-1)\right], E\left[x(n)x(n-2)\right], \cdots, E\left[x(n)x(n-K)\right]\right]^T$

(4.2)[8 Points] Given a DPCM with feed forward predictor.



Describe its disadvantages. Sketch the corresponding inverse DPCM

(4.3)[8 Points] Given a DPCM structure with pitch predictor (used in speech Coding).



What are its advantages? Sketch the inverse DPCM.