EEE 431 (Fall 2019)

Project 1 (Sunday, November 17, midnight)

This project studies some aspects of quantization.

First, record a piece of speech into Matlab with a certain sampling frequency (greater than the Nyquist rate), and form a vector with the resulting samples. Make sure to take a sufficiently long speech signal (e.g., at least about 1 million samples) for proper statistical analysis. Remove the silence periods from the speech signal, and pass it through a low pass filter with cut-off frequency around 4 kHz. Normalize the resulting sequence to make sure that all the signal amplitudes are in the interval $[-1, 1]$.

Work to do:

Part I:

1. Estimate the probability density function (PDF) of the source samples using a normalized histogram (with a sufficiently high resolution). Also fit a polynomial of a degree of your choice to the PDF estimate to model the source PDF mathematically. Make sure that this function is also normalized (and if there are any negative parts, these are set to zero) so that it can serve as a valid PDF.

   Comment on the nature of the source samples, and your PDF estimates.

2. Assume that uniform quantizers with 16, 64 and 256 levels are used. Determine the corresponding MSE distortion values, and the resulting signal to quantization noise ratios (SQNRs).

3. Design the optimal non-uniform quantizers with 16, 64 and 256 levels that minimize the MSE distortion using the Lloyd-Max quantizer design algorithm. Determine the corresponding MSE distortion values, and the resulting signal to quantization noise ratios (SQNRs). Comment on your results.

4. Record another piece of speech, remove the silence periods, low-pass filter and normalize it to the interval $[-1, 1]$. Apply the quantizers of the previous two parts to this speech signal, and estimate the resulting squared errors. How do these compare with the theoretical expectations obtained earlier?

Part II:

We now change the distortion metric to be the mean absolute value, i.e., expected value of the absolute value of the quantization error (instead of the squared error).

Repeat parts 2-4 with this new distortion metric.

Note that you will need to adopt the Lloyd-Max quantizer design steps to this new distortion metric. Due to complete symmetry, the step of finding the new boundaries for given

reconstruction levels does not change. However, for the step of finding the optimal reconstruction levels from given boundaries, you will no longer be computing conditional expectations. Instead you will need to find the reconstruction level that minimizes the expected value of the absolute value (which can be done numerically).

Make sure to comment on the resulting non-uniform quantizer. Are they the same as before?

What would be the mean absolute value distortions if we were to use the non-uniform quantizers of the previous part instead of the newly designed ones? (You can compute these based on the source PDF model, and through simulations, i.e., by applying the previous quantizers and measuring the average of the absolute values of the quantization errors.

Part III:

Estimate the joint PDF of two consecutive samples of the speech source you have recorded (and processed). That is, take samples 1 and 2, 3 and 4, 5 and 6, …, together, and provide a two dimensional histogram (properly normalized) to estimate the joint PDF.

What do you observe? Are the corresponding source samples correlated? Can you think of good quantizer structures that could be well suited to quantize two samples at a time? Do you expect to see significant performance improvements with vector quantization over scalar quantizers?

Reporting Requirements:

Your report should contain all the relevant information about details of your results and detailed comments. The specific format is up to you, but please make sure to properly label each figure, include relevant captions, point to the right results in your explanations, etc. The report should include a title page, brief introduction and outline as well as any references used. The references used should be cited within the report wherever they are used. The report must be typed using an advanced word-processor (e.g. latex, word, etc), and should be submitted as a pdf file on the course moodle site (submission link to be provided).

Please also submit your Matlab codes as well. Submit your code as a single m-file (by copying and pasting all your codes including the Matlab functions all in one file).

One final note: Do your own work for all the parts. Your codes will be checked (using a software) for authenticity.