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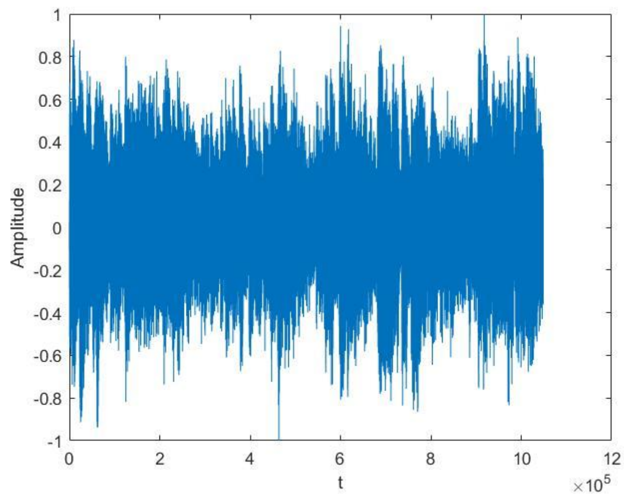
EEE-431

Telecommunications 1

Project 1

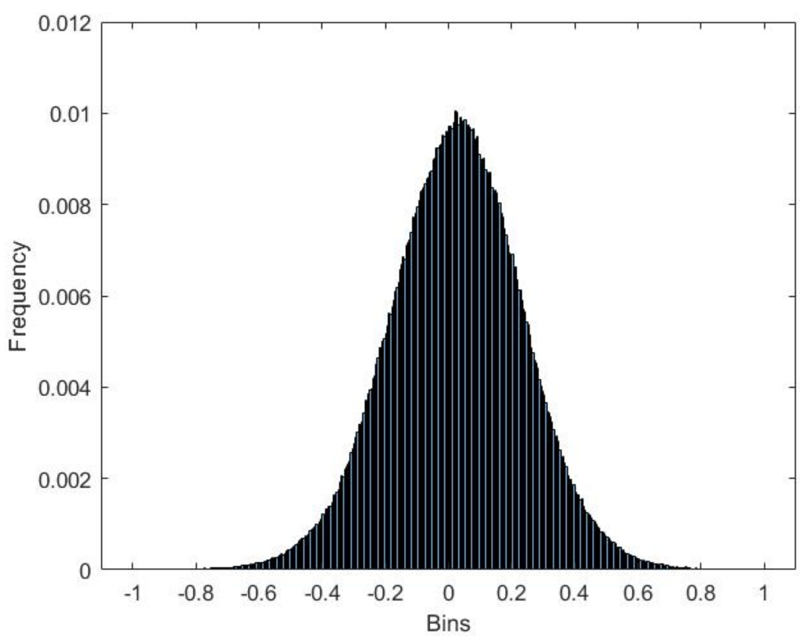
Part 1:

Following is the audio that was used in the quantization



Q.1

Following is the histogram of the audio samples and it can be seen that the samples seem to follow a normal distribution where most of the values are close to zero and higher amplitudes are seen to be less frequent.



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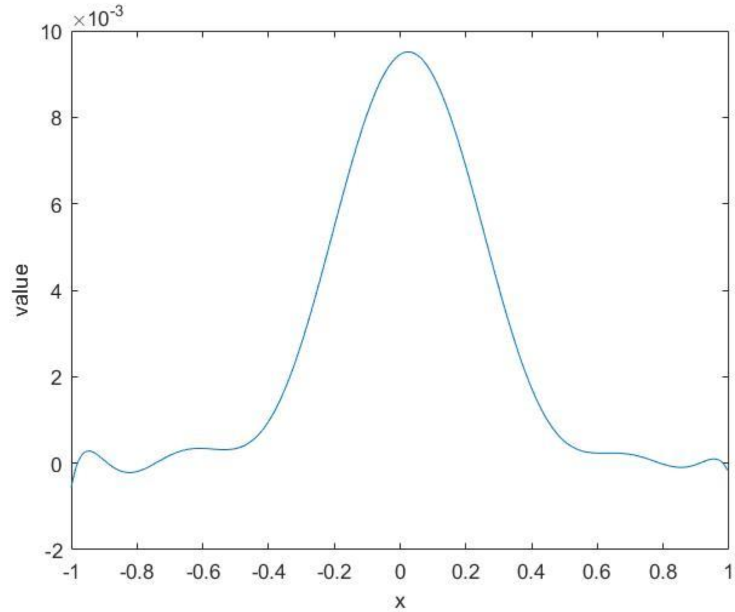
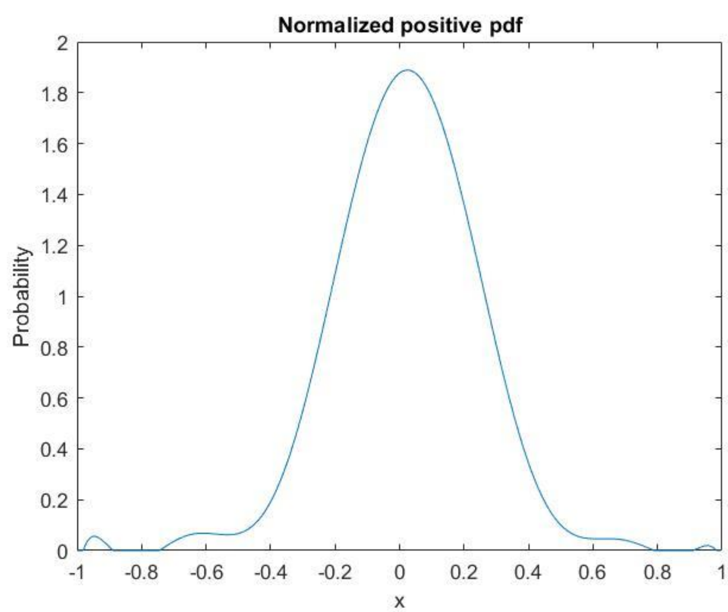
Using the Matlab polyfit function, an approximation to the pdf of the audio samples was generated which can be seen as follows.



However, the approximated pdf is not normalized and also negative at some places. So, the function is half rectified and the pdf is normalized by dividing the coefficients by the integral of the rectified pdf. Following is the new normalized pdf.



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Q.2

Using the MSE distortion measure, following values for distortion and SQNR are obtained using the uniform quantizer.

NonUniformQuantizersAbs | NonUniformQuantizersSq | UniformQuantizersAbs | UniformQuantizersSq

1x3 struct with 9 fields

Fields	N	ai	xi	D_theoretical	D_data	SQNR_theoretical	SQNR_data	D_test	SQNR_test
1	16	1x17 double	1x16 double	0.0013	0.0013	38.1943	34.3048	0.0013	19.9383
2	64	1x65 double	1x64 double	8.1393e-05	8.2384e-05	609.0629	542.5032	8.2188e-05	316.4026
3	256	1x257 doub...	1x256 doub...	5.0863e-06	6.0462e-06	9.7465e+03	7.3920e+03	6.0316e-06	4.3113e+03

Q.3

Using the MSE distortion measure, following values for distortion and SQNR are obtained using the non-uniform quantizer. (denoted by suffix "_theoretical"). 50 iterations were run for optimization of xi and ai values.

NonUniformQuantizersAbs | NonUniformQuantizersSq | UniformQuantizersAbs | UniformQuantizersSq

1x3 struct with 9 fields

Fields	N	ai	xi	D_theoretical	D_data	SQNR_theoretical	SQNR_data	D_test	SQNR_test
1	16	1x17 double	1x16 double	5.6799e-04	0.0013	87.2785	34.3048	4.7982e-04	54.1966
2	64	1x65 double	1x64 double	6.8495e-05	8.2384e-05	723.7620	542.5032	6.9680e-05	373.1999
3	256	1x257 doub...	1x256 doub...	5.0090e-06	6.0462e-06	9.8970e+03	7.3920e+03	5.9775e-06	4.3504e+03

It can be seen that the theoretical distortion values decrease and theoretical SQNR values increase with the increase of N as expected. Moreover, comparing the uniform quantizer to the non-uniform quantizer, we see a considerable increase in SQNR for the non-uniform quantizer. However, we also see that when we increase the quantization level to 256, there is not a considerable difference between uniform and non-uniform quantization since the uniform and non-uniform levels become close to each other.

Q.4

A new audio is used for this part. The results for SQNR and D can be seen in the figures of the previous two parts which are represented by the suffix "_test" (the suffix "_data" corresponds to the values using the original recording).

The metrics follow the same trend as expected by using different values of N and by changing from uniform to non-uniform quantizer. However, there is a decrease in the test audio SQNR compared to the theoretical SQNR. This is because the new audio may follows a slightly different distribution as compared to the distribution the quantizer was trained on which can be seen as follows.

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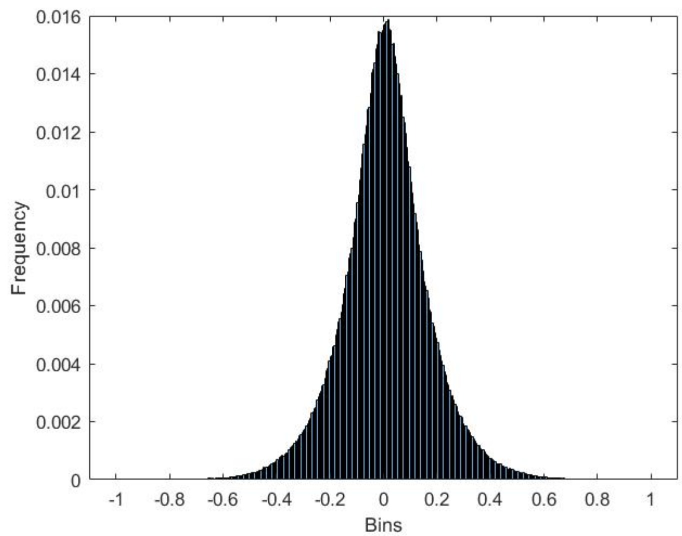

Part 2:

Q.2

Using the mean absolute value as distortion measure, following values for distortion and SQNR are obtained using the uniform quantizer.

NonUniformQuantizersAbs | NonUniformQuantizersSq | UniformQuantizersAbs | UniformQuantizersSq

1x3 struct with 9 fields

Fields	N	ai	xi	D_theoretical	D_data	SQNR_theoretical	SQNR_data	D_test	SQNR_test
1	16	1x17 double	1x16 double	0.0312	0.0313	1.5897	1.4297	0.0313	0.8315
2	64	1x65 double	1x64 double	0.0078	0.0078	6.3447	5.7181	0.0078	3.3321
3	256	1x257 doub...	1x256 doub...	0.0020	0.0020	25.3816	22.8542	0.0020	13.3224

Q.3

Using the mean absolute value as distortion measure, following values for distortion and SQNR are obtained using the non-uniform quantizer. A division of 20 values is used between a_i s for determining x_is. The corresponding values are as follows.

NonUniformQuantizersAbs | NonUniformQuantizersSq | UniformQuantizersAbs | UniformQuantizersSq

1x3 struct with 9 fields

Fields	N	ai	xi	D_theoretical	D_data	SQNR_theoretical	SQNR_data	D_test	SQNR_test
1	16	1x17 double	1x16 double	0.0203	0.0313	2.4458	1.4297	0.0181	1.4334
2	64	1x65 double	1x64 double	0.0069	0.0078	7.1386	5.7181	0.0067	3.8958
3	256	1x257 doub...	1x256 doub...	0.0019	0.0020	26.2077	22.8542	0.0019	13.9184

It can be seen that the same trends are followed as in the part 1. However, the results seems to be close for uniform and non-uniform quantizer.

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For comparison of performance of quantizers in part 1 and part 2, we use the same distortion metric i.e. mean absolute error. The theoretical distortion and SQNR are follows for both of the non-uniform quantizers. (Suffix 1 corresponds to part 1 and vice versa)

NonUniformComparison

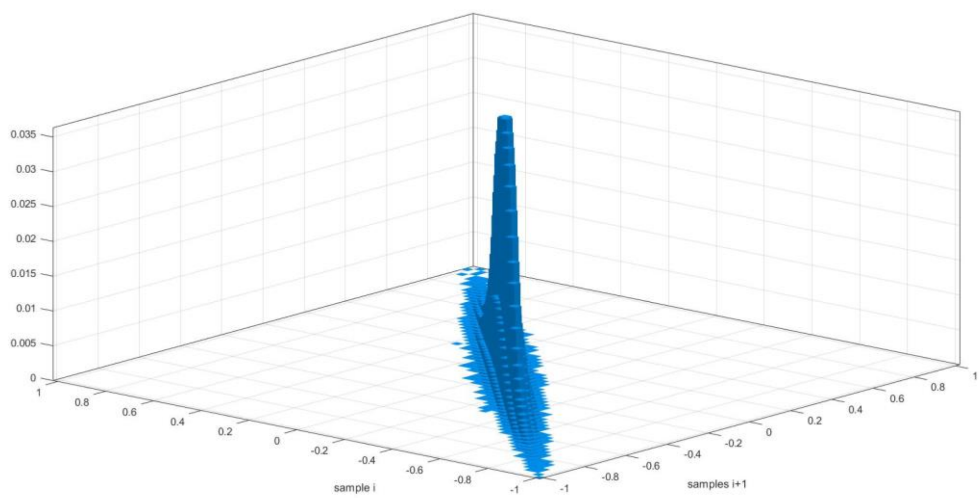
1x3 struct with 5 fields

Fields	N	D_abs2	SQNR_abs2	D_abs1	SQNR_abs1
1	16	1.0207e-04	2.4457	9.9414e-05	2.5110
2	64	3.4970e-05	7.1385	3.6056e-05	6.9234
3	256	9.5251e-06	26.2077	9.7574e-06	25.5840

It can be seen that the mean absolute distortions are close for both the quantizers. However, the quantizer trained using mean squared error as the quantization metric performs slightly better theoretically.

Part 3:

Following is the histogram of the consecutive samples.



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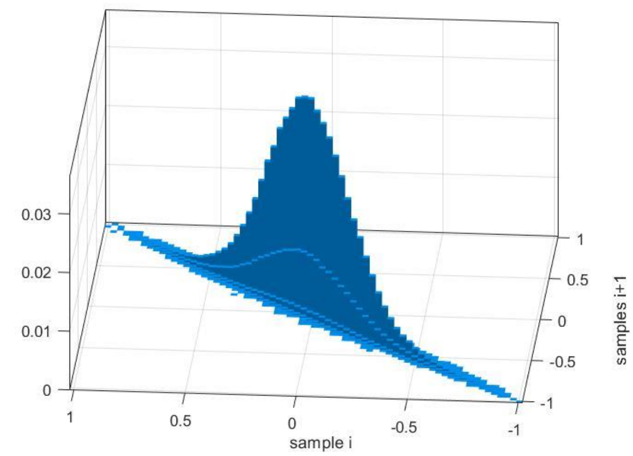

It can be seen that there is strong correlation between the consecutive samples in the audio. Therefore, we may use vector quantization to quantize the data. Since there is a strong correlation between the data, since consecutive samples have very high probability of having similar values. So, smaller and more regions can be assigned where the values are more frequent (i.e along the line $x_1 = x_2$) and we can see significant performance improvements with vector quantization.