Vector Quantization of LPC Parameters in the Presence of Channel Errors

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Summary

Linear predictive coding (LPC) parameters are widely used in various speech coding applications for representing the spectral envelope information of speech. In our earlier paper [1], we have reported on a vector quantizer using line spectral frequencies and shown that it can quantize LPC parameters in 24 bits/frame with an average spectral distortion of 1 dB, less than 2% frames having spectral distortion in the range 2-4 dB and no frame having spectral distortion greater than 4 dB. In this paper, we study the performance of this quantizer in the presence of channel errors and compare it with that of scalar quantizer. We also investigate the use of error correcting codes for improving the performance of the vector quantizer in the presence of channel errors.

Channel errors, if not dealt with properly, can cause a significant degradation in the performance of a vector quantizer. This problem has been addressed recently in a number of studies [2, 3, 4], where algorithms for designing a vector quantizer that is robust in the presence of channel errors were described. In these robust design algorithms, the codebook is reordered (or, the codevector indices are permuted) such that the Hamming distance between any two codevector indices corresponds closely to the Euclidean distance between the corresponding codevectors. Farvardin [3] has used the simulated annealing algorithm to design such a codebook. However, he has observed that when the splitting method [5] is used for the initialization of the vector quantizer design algorithm, the resulting codebook has a "natural" ordering which is as good in the presence of channel errors as that obtained by using the simulated annealing algorithm, especially for sources with memory (i.e., where vector-components are correlated). In our experiments with the LPC vector quantizer, we have made similar observations. Since the naturally-ordered codebook is obtained without additional computational effort and it performs well in the presence of channel errors, we use it in our experiments. Naturally-ordered codevectors in this codebook have the property that the most significant bits of their binary addresses are more sensitive to channel errors than the least significant bits; i.e., a channel error in the most significant bit in the binary address of a codevector causes a larger distortion than that in the least significant bit. In our experiments described in this paper, we use this property to our advantage by protecting the most significant bits using error correcting codes.

Effect of channel errors is studied here on the performance of the the 24 bits/frame vector quantizer and the 34 bits/frame scalar quantizer. Both vector and scalar quantizers use line spectral frequencies for LPC quantization. Results for these quantizers are shown in Tables 1 and 2, respectively, for different bit error rates. It can be seen from these tables that the 24 bits/frame vector quantizer performs as well as the 34 bits/frame scalar quantizer.

In order to improve the performance of the 24 bits/frame vector quantizer in the presence of channel errors, we have investigated the use of a number of error correcting codes. Results for this quantizer using an additional 8 bits/frame for error correction with the (15,11) Hamming code are shown in Table 3. We can see from this table that there is no effect on performance for bit error rates as high as 0.1%. Also, for bit error rates up to 1%, there is very little additional distortion (i.e., the average spectral distortion is still about 1 dB and outliers are few in number). Thus, the performance of the vector quantizer is very good up to bit error rates of 1%.

References

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Table 1: Effect of channel errors on the spectral distortion (SD) for the 24 bits/frame vector quantizer.

Bit error rate (in %)	Av. SD (in dB)	Outliers (in %)	
		2-4 dB	>4 dB
0.0	1.03	1.03	0.00
0.001	1.03	1.04	0.01
0.01	1.03	1.09	0.04
0.05	1.05	1.41	0.30
0.1	1.08	2.00	0.64
0.5	1.28	5.55	3.11
1.0	1.55	9.73	6.76
10.0	4.62	27.68	54.69

Table 2: Effect of channel errors on the spectral distortion (SD) for the 34 bits/frame scalar quantizer.

Bit error rate (in %)	Av. SD (in dB)	Outliers (in %)	
		2-4 dB	>4 dB
0.0	0.92	1.00	0.01
0.001	0.92	1.01	0.03
0.01	0.93	1.09	0.11
0.05	0.95	1.51	0.36
0.1	0.98	1.96	0.80
0.5	1.23	5.56	4.01
1.0	1.56	9.35	8.38
10.0	5.12	23.30	62.25

Table 3: Effect of channel errors on the spectral distortion (SD) for the 24 bits/frame vector quantizer, using 8 bits/frame for error correction.

Bit error rate (in %)	Av. SD (in dB)	Outliers (in %)	
		2-4 dB	>4 dB
0.0	1.03	1.03	0.00
0.001	1.03	1.03	0.00
0.01	1.03	1.03	0.00
0.05	1.03	1.03	0.00
0.1	1.03	1.03	0.00
0.5	1.04	1.18	0.16
1.0	1.06	1.39	0.50
10.0	3.11	17.39	31.23