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Parameter coding for CELP: Channel Error Considerations

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This paper discusses the coding of the parameters for a CELP speech coder operating at 4.8 kb/s. A major consideration is operabililty in an environment with channel errors such as present in mobile satellite or digital cellular systems. The high quality of CELP at 4.8 kb/s is in part due to efficient coding of the synthesis parameters. This compactness of the representation means that even isolated errors can cause severe reproduction distortion. Moreover, in the presence of channel errors, severe distortion can propagate well beyond the point at which an error occurs.

This paper briefly reviews the coding strategy employed for a CELP coder operating at 4.8 kb/s. The parameters used are a line spectral frequency (LSF) representation of the LPC parameters, combined pitch filter lag and coeffiecient coding, waveform index, and waveform gain. Frame-to-frame coding with and adaptive sep size is employed for the odd-numbered LSF parameters. The even-numbered LSF parameters are coded with respect to the neighboring odd-numbered LSF parameters. In addition, every second frame is interpolated from the surrounding frames using one of 8 possible interpolated LSF vectors. The waveform gain is also coded differentially frame-to-frame.

A number of modifications to prevent error propagation are considered. The focus is on changes to the coding strategies rather than explicit error protection in the form of added redundancy . A system reset feature was investigated, but finally rejected as being unreliable. The main improvements in the presence of channel errors are achieved by modifying the frame-to-frame DPCM coding of the waveform gain and the ADPCM coding used for the LSF parameters. Leakage is applied to the waveform gain coding to effectively control error propagation. A number of changes are necessary to the LSF coding procedures. A leakage factor is introduced to the ADPCM frame-to-frame coding of the odd-numbered LSF parameters. In addition, the multiplicative factors used to adapt the step sizes are reduced to prevent wild fluctuations due to errors. Finally, the presence of errors is detected from cross-overs of the LSF parameters. Under these circumstances, the resulting distortion is reduced by an ad hoc procedure to force the LSF parameters to be well-ordered. Upon detection of cross-overs, a "correction" is also applied to the adaptive step size.

The final configuration was tested at various channel error rates. Performance is acceptable with random errors up to an error rate of 10^{-3}. The effect of errors is well localized. Only a very small loss of speech quality is in evidence due to the modifications in the absence of channel errors. The coder was also tested with clustered errors generated by a mobile satellite channel (average rate 10^{-3}). Computer simulations show that the modified CELP coder is more tolerant to clustered channel errors than to random errors of the same average rate.