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Study on power envelope subtraction based on modulation transfer function

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In the real noisy reverberant environment, the quality of the sound and the intelligibility of the speech are degraded because the significant features of the speech are drastically smeared due to the reverberation and background noise. Thus restoration of the original signal from a noisy reverberant signal is a very important issue concerning the various speech signal processing systems, such as speech-emphasize for transmission systems, hearing aid systems and the preprocessing for speech recognition systems.

There have already been many famous methods for noise suppression and dereverberation. For example, the spectral subtraction method, the Kalman filtering method, the minimum-phase inverse filtering method and the multiple input/output inverse theorem method. All these methods can only reduce the noise or reverberation separately and they cannot work well in noisy reverberant environment.

Recently, a method for restoring the power envelope from the noisy reverberant speech has been previously proposed by the authors. This method is based on the concept of modulation transfer function (MTF) and does not require the impulse responses and noise conditions in the room acoustics to be measured. The proposed method consists of two parts: power envelope subtraction process and power envelope dereverberation process.

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This method suppresses the effects of reverberation and noise on the power envelopes by restoring the smeared MTF. However, this has a problem that the power envelope subtraction process can only reduce the mean of noise power envelope without removing the fluctuations of them and these fluctuations will be emphasized during the dereverberation process.

In this paper, we improve an MTF-based power envelope subtraction by incorporating Kalman filter to solve the problem. Because Kalman filter has the features below:

- Kalman filter uses two moments of the noise. The first moment of noise is the mean value of the noise, the second moment of noise is the variance of the noise and the variance of the noise stands for the fluctuations.
- Kalman filter can be used for stationary and non-stationary signals.
- Kalman filter can be used in time-variant and time-invariant systems.
- Kalman filter can overcome the musical tone problem and obtain the good speech quality of reducing the processing distortion of speech signal.
- Kalman filter not only takes advantage of the characteristics of the signal and noise, but also uses the production model of speech, ie, autoregressive model which is an effective model for human speech production system.

The most important reason for choosing Kalman filter is for the first feature of the Kalman filter. We also use the linear prediction method to estimate the parameters for Kalman filter based on the fifth feature.

We have carried out simulations in three kinds of noise conditions, they are white noise, pink noise and factory noise, the white noise and pink noise are stationary noise while the factory noise is non-stationary noise. We also carried out simulations in noisy reverberant conditions to evaluate the improved method. We use the improved power envelope subtraction method in the same three kinds of noise conditions and the same dereverberation mehtod in the same reverberant environment with the previous method. Evaluation results showed that the improved method can effectively reduce the mean as well as fluctuations of noise on the power envelope and there are much improvements in correlation and SER in both noisy environment and noisy reverberant environment compared to the previous method.