RESOLUTION OF CONVOLVED SIGNALS IN BIOMEDICAL APPLICATIONS*

Bengt Mandersson

This thesis deals with the design of pulse shaping filters with finite impulse response (FIR) applied to the resolution of convolved signals. The thesis consists of three parts: I. Design of FIT Filters for Deconvolution; II. Least Squares Filters Using Bandpassing Subfilters; III. Digital Filtering of Ultrasonic Echo Signals.

The application of the pulse shaping technique to deconvolution problems yield filters with "inverse" properties relative to the input signals. This means e.g. that the magnitudes of the spectra of the filter impulse responses must be high where the magnitudes of the input signal spectra are low. This filtering technique is consequently sensitive to noise and to variations of the input signal waveforms. When designing such filters, the trade-off between noise sensitivity and pulse shaping performance must be taken into account. It is then of great importance to have methods for determining filters that are robust in the sense that they are as insensitive as possible to noise and to variations of the input waveforms.

Pulse shaping filters applied to deconvolution problems are often determined by minimizing the mean squared difference between the filter response to a specified input and some desired pulse shape (least squares filters). However, the solution can be sensitive to the detailed structure of the desired pulse. In many applications it is not always obvious what desired pulse shape to select in order to obtain the most suitable filter. Part I defines

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"soft" versions of pulse shaping filters. These are also based on minimizing squared differences between the filter responses and desired pulses but with the modification that regions are inserted where the differences do not affect the solution. Both amplitude and temporal regions are examined.

The number of adjustable parameters in the design of FIR filters is quite high. Iterative solution schemes using a steepest descent algorithm are most easy to implement, since they do not need so much computer storage space and the amount of computation in each iteration is low. But the inverse filter technique leads to ill-conditioned minimization problems. Part II describes how the rate of convergence for the steepest descent algorithm can be increased by configuring the FIR filters as sets of bandpass subfilters in parallel. The computations are done in the frequency domain and an FFT routine is used to determine the DFT of the signals. This not only reduces the amount of computation but also suitably relates the temporal properties of the filter to its frequency characteristics.

In the ultrasonic pulse echo method axial resolution is strongly dependent on the durations of the impulse responses of the ultrasonic transducers. These impulse responses normally have narrow bandpass characteristics. Owing to this it is difficult to derive inverse filters suitable for ultrasonic signals. In Part III, the weighted least squares pulse shaping filter defined in Part I is applied to the ultrasonic signals in order to decrease the duration of the received ultrasonic pulses. The weighted least squares filter is found to be suitable for ultrasonic signals and improved resolution is achieved using this filter. This filter is used both to filter received echoes and to preshape emitted ultrasonic pulses.