N91-13345

Design of QMF (Quadrature Mirror Filter) in Spatial Domain & Edge Encoding

Paul P. Wang
Duke University
Department of Electrical Engineering
Durham, N.C. 27706

(Mr. Fred Huck NASA Research Principle Investigation)

SUMMARY

Simoncelli and Adelson [1] have extended the one-dimensional QMF filter to two dimensions with hexagon symmetry and three dimensional spatio-temporal extensions with rhombic - duodecahedray symmetry. Jain and Crochiere presented an excellent QMF design technique in the time domain [2]. We propose here to extend the design of a two dimensional QMF over a rectangular lattice in the spatial domain based primarily on the extension of the idea of Jain and Crochiere. In addition, the design will investigate the use of 2-D Z-transformations. The basic block diagram of a two-dimensional QMF is shown in Figure 1.

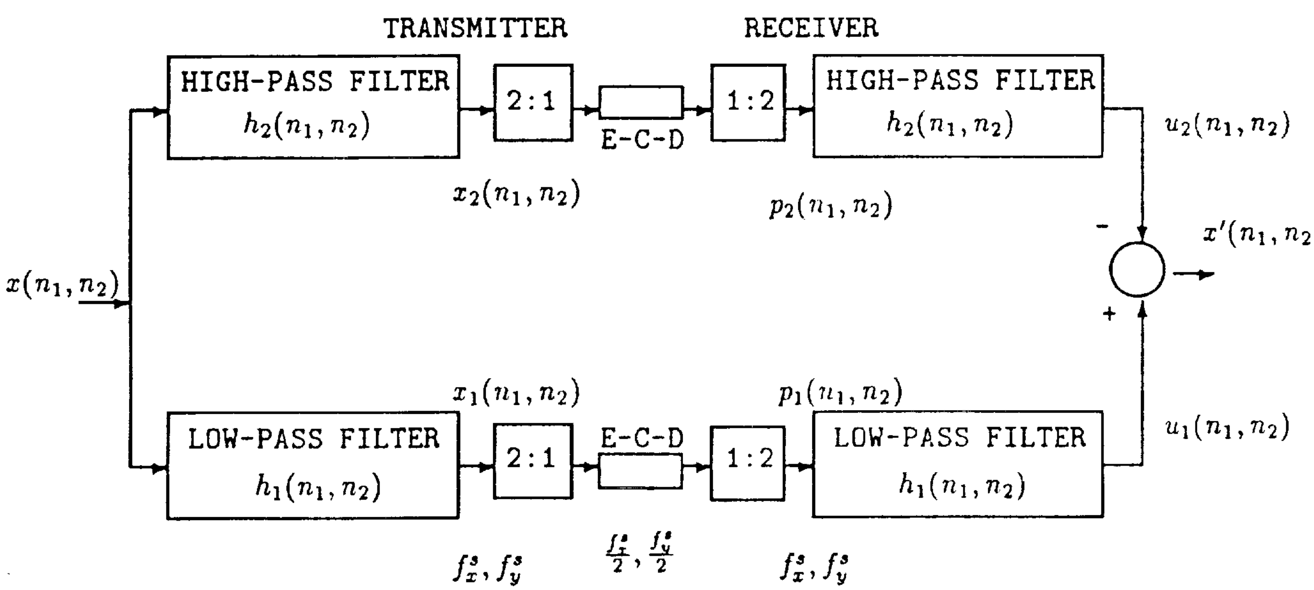

Figure 1: Two dimensional quadrature mirror filters in a two-band subband coder.

Each of the blocks E-C-D denotes the cascade of an encoder, channel and decoder. The cancellation property requires $h_1(n_1, n_2)$ and $h_2(n_1, n_2)$ to have certain well-known properties. It

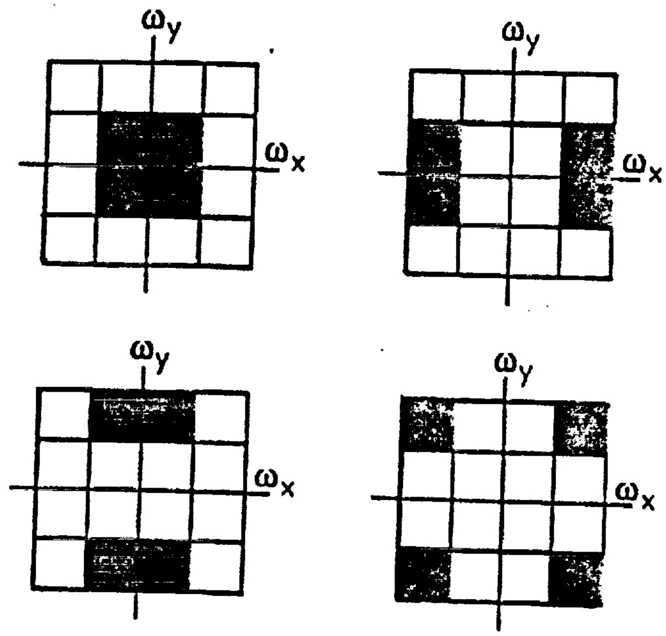

Figure 2: Idealized partition of the frequency domain by separable application of two-band one-dimensional QMFs.

is also known that the ripple balance condition must be satisfied for a perfect reconstruction. We minimize a weighted sum $E_r + \alpha E_{sb}$, where α is the weight-factor, E_r is the passband ripple energy and E_{sb} is the stop-band residual energy. The user can specify the stopband frequencies $\omega_{sb}^x, \omega_{sb}^y$, the weight-factor α and of course the number of taps N. There is every expectation that the convergence to the optimum is stable and thus does not require manual intervention (from repeated trials with different start-up guesses; also note that this feature is very important in the Kalman filter and it is also the feature that the learning phase of the neural network is trying to achieve).

We will generalize the iterative solution of Crochiere and Rabiner [3] which involves the eigenvectors of matrices with a dimensionality equal to one half the number of the filter taps on both horizontal and vertical axes respectively.

Since this proposed QMF is intended for the applications in image processing, all the important and interesting engineering issues will be addressed throughout the development phase.

Most applications of QMF's are multidimensional and involve separable filters. A two-dimensional example is illustrated in Figure 2.

The frequency spectrum is split into low-pass, horizontal high-pass, vertical high-pass and diagonal band high-pass sub-bands, which contains mixed orientations. We believe this method of decomposition can be improved. The boundary need not necessarily be straight lines. So far, the argument for splitting this way has not been persuasive. In order to reach a better solution, one would have to begin with the analysis of the problem at hand. In other words, for a class of pictures sharing the common characteristics, we make a characterization via Fourier transformation to allow us to quantitatively express such features which would be representatively of the class in the frequency domain. Finally, one determines the boundaries as the results of optimizing some meaningful criteria.

The second part of our proposal is related to the first part, the design of a two-dimensional QMF. The motivation of the second part of the proposal is trying to achieve an extremely high data compression ratio. We believe that is is entirely possible to achieve dramatic results when pattern recognition techniques are employed.

Suppose we have established a new boundary splitting the frequency spectrum into regions different from that of Figure 2. The low frequency region (around the origin) will be encoded using conventional methods. It might require some minor modification, but major modification is not envisioned at this point. It is the high frequency encoding that we anticipate to make significant contribution. In the high frequency spectra, we propose to perform encoding for the purpose of data compression in the spatial domain. It is well known that the high frequency spectrum is related to the "edges" in the spatial domain. The coding of "edges" via pattern recognition techniques is believed to yield extremely high compression ratios. There are several approaches to this problem, most of them fairly well established in the research community of pattern recognition.

The most serious problem in the coding of the "edges" is the uncertainty, small perturbations and errors in the "edge" primitives. This problem can be solved through analytical means. Any departure from the standard masks or primitives must be accounted for and a decision must be made in order to complete the inference process. There are many approaches in pattern recognition field and some of them are quite promising. Once the above major obstacle is overcome, then the high compression ratio can be obtained by taking advantage of the "relationship" of different levels (represented by symbols, such as non-terminal vocabularies etc.) in the overall hierarchical structure.

The final goal of this second part of the proposed research is the demonstration of extremely high data compression ratios using NASA pictures.

References

[1] Eero P. Simoncelli and Edward H. Adelson. "Non-separable Extensions of Quadrature Mirror Filters to Multiple Dimensions." M.I.T. Media Laboratory Vision Science Technical Report 119. To appear in the Proceedings of IEEE Special Issue on Multidimensional Signal Processing. 1990.

[2] Vijay K. Jain and Ronald E. Crochiere "Quadrature Mirror Filter Design in the Time Domain". IEEE Transactions on Acoustics, Speech and Signal Processing. Vol ASSP-32 No. 2. April 1984 pp.353-361.

[3] R.E. Crochiere and L.R. Rabiner Multirate Digital Signal Processing. Signal Processing Series, Prentice-Hall, Englewood Cliffs, NJ 1983.