Chapter 6

Summary and Conclusions

A brief summary of the research work conducted and the important conclusions thereon are highlighted in this chapter. The scope for further work in this field as an extension of the present study, has also been discussed.
6.1 Summary of the Work and the important Conclusions

The work presented in this thesis mainly concentrates on two important inter-related topics in time-frequency analysis.

The first topic of interest has been the methods for signal coding and compression. A new compression scheme has been developed for pseudo-periodic signals in which the Pitch-Synchronous Wavelet Transform technique is uniquely combined with the popular Linear Predictive Coding technique. The local periods of the signal under consideration are estimated and using the period information, the signal is represented in Pitch-Synchronous form. After normalizing the PS data, the PSWT is computed. The LPC parameters are estimated for the PSWT coefficients corresponding to each level of decomposition. The predictor coefficients are suitably encoded and packed with other relevant information for transmission to the remote location where it is decoded for reconstructing the original signal. Case studies on typical pseudo-periodic signals have been carried out and the performance of the scheme has been evaluated using standard measures. The PSWT based LPC technique results in better compression and higher reconstruction quality.

It has been observed that the predictive coding of PSWT coefficients has greater potential in signal compression compared to the ordinary DWT based methods. The method has been validated with different classes of practical signals like ECG, human voice and musical instrument tones. The various parameters for the compression such as the type of wavelet, order of prediction, level of decomposition, etc. were optimized for each of these classes. The UDWT based methods are found superior in period estimation of signals like ECG and musical instrument tones, compared to the autocorrelation based methods. The period normalization is found to have improved the beat-to-beat correlation, contributing to better compression.

The effectiveness of the method is largely dependent on the accuracy with which
the local periods are estimated. The noise contamination in the signals is found to reduce the efficiency of compression. Another shortcoming of this method is that the compression is computationally intensive.

The second topic of consideration has been the computational issues of Discrete Wavelet Transform. The most popular algorithm for DWT computation employs the 'pyramid structure' developed by S.G. Mallat. It basically follows a sequential structure. For a number of applications, this structure is found to be inefficient in terms of the number of computations. As a better choice in such cases, a novel Parallel Multiple Subsequence structure has been developed by uniquely combining the noble identities in multirate systems with the principle of polyphase splitting. The input data and wavelet/scaling filter sequences are divided into a level-dependent number of parallel subsequences resulting in a highly parallel environment especially at higher levels. The complexity involved while employing this PMS structure for DWT computation has been analyzed in detail and compared with that of the pyramid structure. The PMS structure could eliminate all the irrelevant computations that are to be carried out while using the pyramid structure. The PMS structure being parallel, it is found better for directly computing the transform coefficients at any arbitrary selected level of decomposition without going through the intermediate levels. The efficiency of the PMS structure has been shown to be more in the case of lower levels of decomposition and is dependent on the length of wavelet also. The scheme is still better for computations using the Haar wavelet.

Both 1D and 2D computational structures have been derived. Typical signal processing applications have been presented as case studies wherein the PMS structure is identified to be advantageous, both computationally and algorithmically. Case studies include the PSWT computation and the edge detection in biomedical images. This structure is shown to be better for PSWT and Block DWT computation. For 2D ap-
Applications it has the added advantage that the data transposition operation has been reduced to the minimum.

6.2 Scope for Further Investigations

The PSWT based compression schemes are highly dependent on the accuracy of local period estimation. The methods for period estimation are found to be dependent on the signal characteristics and none of them are found universally acceptable. Even though lot of research has been carried out in this field, accuracy demands are still not met. A signal dependent adaptive period estimator is necessary to enhance the compression scheme.

The PSWT based compression scheme is applicable only for the pseudo-periodic regions present in the signal. Practical signals comprise of other regions also, which have to be separately dealt with in a real-time processing environment. This necessitates the use of a signal adaptive segmentation scheme at the preprocessing end.

The PSWT based feature enhancement technique proposed in this thesis is based on simple thresholding of PSWT coefficients. Application of energy dependent hard/soft thresholding can be attempted for signal enhancement by eliminating the instrument dependent noise part without any loss in the instrument tonal quality.

The compression scheme has concentrated on optimization of the variants used for signal coding only. Since majority of the PSWT coefficients of pseudo-periodic signals are insignificant, especially for noise free signals, dynamic bit allocation can be attempted thereby achieving higher levels of compression. The possibility of totally avoiding the insignificant coefficients also can be attempted. This will be of special importance in the case of signals where a good number of samples are insignificant. For example, in the case of ECG, the diagnostic information contained is in general localized to the QRS complex. Moreover by sending the residue part along with other information, the signal quality can be further enhanced, eventhough at the cost of compression.
Chapter 6. Summary and Conclusions

The PMS structure developed in this thesis has been validated for 1D and 2D DWT computations. It is expected to give still better performance with Wavelet Packet Transform computation, which can also be taken up as an extension of this work.