Abstract

The main objective of this thesis is to propose a novel signal decomposition approach which is truly intrinsic and adaptive to the given input signal and is able to decompose instantaneous signals into non-overlapping bands using analytic signal matched filter bank. The analytic signal matched filter bank in consideration is a M-band uniformly decimated, multirate filter bank, obtained by combining the signal matched analysis filter bank and signal matched synthesis filter bank with analytic signals procedure. The proposed approach is utilized to decompose a signal for given statistics as well as given data case scenario. The adaptive nature of our algorithm enables us to track time varying signal characteristics and can be utilized for variety of signal processing and signal analysis applications including coding and denoising. We have demonstrated the application and efficacy of the proposed algorithm by denoising and performing TFA on sample from biomedical signal processing and speech signal processing.

It is easily seen that output of an LTI system, with random input, can be written as a superposition of damped exponentials having random amplitudes and phases. Hence we infer that if the system parameters are slowly varying with time then it manifest in terms of slowly varying coefficients and phases. Translated in terms of poles, they correspond to the natural frequencies of a system, the output, for a random input signal, vary in amplitude and phase around these frequencies. This forms the basis for our proposed signal decomposition scheme. Given any signal, that we wish to decompose, we assume that it is output of a system with random input. One of the most appropriate decomposition of this signal, which could throw light on the system as well as its input, would be in terms of a bank of bandpass filters around the natural frequencies. Since (i) the decomposition involves bank of filters, multi-rate filter-banks are natural choice for the purpose; (ii) the

analytic representation is the most convenient form for band pass signal representation we explore analytic form of multi-rate filter banks; (iii) our objective, as mentioned earlier, is to explore signal decomposition scheme which is purely intrinsic to the signal and also adaptive, designing the multi-rate filter bank in signal matched fashion, seemed a natural way to go; (iv) finally, the down sampling operation in the analysis side spreads the spectra in the entire band it is more logical to carry out orthogonalization/decoupling, across the channels, on the synthesis side rather than analysis side , if we want different channels to carry different band information. This fact is clearly highlighted by observing overlapping obtained in earlier proposed signal matched filter bank scheme[1] where the goal was to obtain optimum coding gain.

We have also defined a Hilbert space framework to provide a geometrical interpretation of the proposed algorithm. We present a time as well as order recursive, least squares algorithm for the proposed algorithm ASMFB for the given data case.

Further more, we demonstrate applications of our proposed algorithm for the analysis of real-time non-stationary signals. Since ECG signals are integral part of any scheme for diagnosis and analysis of heart diseases, we have applied ASMFB algorithm for real- time classification of abnormalities such as PVC in ECG data as it arrives. The proposed algorithm decomposes a given ECG signal into decorrelated non-overlapping bands, which follow AM-FM character such that each band has only one harmonic component of the original signal. The proposed method for classification of ECG signal, into normal and abnormal, is purely based on ASMFB algorithm for feature extraction and uses SVM as a classifier.

Experimental results on publicly available database demonstrate that the proposed feature sets effectively characterize the ECG signals and are suitable for classification between different classes of ECG abnormalities with a classification accuracy of 99%. We have also demonstrated efficacy of the proposed algorithm for pre-processing of these non-stationary ECG signals by removing artifacts and noises in the corrupted ECG signal.

The thesis also presents a spin-off arising from the developed theory. The non-linear dynamical system analysis of denoised ECG signal obtained after using proposed algorithm has been presented. The proposed phase space analysis based technique has shown to be effective in detecting cardiac arrhythmia in critically ill patients and hence may aid in the diagnosis of heart disease in intensive care units.