CHAPTER 1

INTRODUCTION

1.1. INTRODUCTION

Given a time series, one can readily see how the energy is distributed over time. By performing Fourier transform to obtain the spectrum, one can see how the energy is distributed in frequency. However, as most signals encountered in practical situations are nonstationary, a joint representation of the signal in time and frequency is required. Time-frequency distributions (TFDs) characterize a signal in time and frequency simultaneously and provide more revealing picture of the signal's characteristics. However, these time-frequency representations perform prominently for certain classes of signals, because of their resolution tradeoffs and cross terms. Therefore, TFDs that track the instantaneous frequency and truly represent the signal have been extensively investigated. Extending the analysis domain beyond time and frequency gives a redundant representation of the signal. Possible dimensions of interest can be shear in frequency, shear in time, scale and rotation. Such multi-dimensional analysis may results in a compact representation, but is computationally inefficient. Hence, adaptive signal decompositions employing finite size bases are gaining importance. Recently, computationally tractable estimation procedures for obtaining the signal's projection onto a non-finite size dictionary have been proposed. This generalization of the existing representations leads to an efficient way of representing large classes of signals in subspaces spanned by operators like, shear in frequency, rotation, scale, etc. .

Specifying the signal's characteristics to be synthesized in joint time-frequency plane circumvents the problems associated with the conventional time-domain or frequency-domain approaches leading to a more efficient way of synthesizing time-varying signals. Short-time Fourier transform and Wigner-based synthesis have been paid much attention in the TFDs in time-variant filtering, since TFD-based signal synthesis removes the constraints of stationarity. The properties of the continuous-time TFDs are well understood. However, the discretization of these distributions is not straightforward unlike the Fourier transform. Many definitions are given to sample these distributions with each one of them having their own advantages and disadvantages. Eventhough, an attempt has been made to define discrete TFDs that closely follow their continuous counterparts, the computational viewpoint is still the Fourier transform interpretation of the generalized autocorrelation function. As WVD is the most widely used TFD, many algorithms have been proposed to compute it. Recently, time-recursive approach has been used to compute the short-time Fourier transform because of its localized communication and regularity. But the implementation of TFDs using the time-recursive approach has not yet been considered. We positively try to answer the many challenging issues concerning with the analysis of nonstationary signals, synthesis of a time-variant signals and implementation issues of GTFDs. Thus, our objective lies in:

1. Devising an algorithm to analyze a non-stationary signal called chirp transform with chirp rate and shift in time as parameters and analyze different signals in the transform-domain with applications in system identification and spectral estimation, and provide motivation to tile the time-frequency (t-f) plane.

2. Modeling the t-f plane, given a spectrogram, as a mixture of normal pdfs, estimate the number chirplets, their orientation and location, and analyze the mapping rules which synthesize the signal from the mixture components. We present the view point of chirplet decomposition, which can be interpreted as an adaptive signal representation method.

3. Extending the architecture of short-time Fourier transform (STFT) to generalized TFDs (GTFDs). We propose an algorithm to compute Wigner-Ville distribution (WVD) and GTFDs having real symmetric kernels and devise a scheme to compute running-windowed GTFDs (RWGTFDs) using the time-recursive approach.

1.2. CONTENTS OF THE THESIS

The remaining chapters of the thesis are organized as follows:

1. Chapter 2 reviews the existing methodology to depict the signal in time and frequency; and the construction of adaptive signal representations. Various time-frequency, time-scale and signal decomposition algorithms are reviewed and it forms the necessary background to understand the remaining chapters.

2. Chapter 3 deals with the synthesis of signals from time-frequency distributions. A review of Wigner-based and spectrogram-based signal synthesis algorithms is carried out. The descritization issues of TFDs and the implementation aspects of WVD, spectrogram and GTFDs are considered in this chapter.

3. Chapter 4 presents the analysis of nonstationary signals using chirp transform employing chirps as the expansion set. Various properties of the chirp transform and its applications in spectral estimation and system identification are dealt with.

4. Chapter 5 presents a unified approach to signal analysis/synthesis based on chirplets. The estimation of chirplets and their parameters by modeling the t-f plane as a mixture of normal densities computed using incremental variant of EM algorithm is considered. A view point of chirplet decomposition is presented that can be considered as an adaptive signal representation.

5. Chapter 6 envisages the usage of time-recursive approach in computing GTFDs. A pre-processor for avoiding buffering time in computing discrete Fourier transform using time-recursive approach has been addressed in this chapter. An algorithm for computing WVD has also been proposed in this chapter. It also deals with the algorithm for computing the running-windowed GTFDs having real-valued symmetric kernels.

6. Chapter 7 gives the conclusions drawn from this work and recommends the lines for future work.