Analysis and decomposition of frequency modulated multicomponent signals

PhD Thesis in Mathematical Models for Engineering
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Abstract

Frequency modulated (FM) signals are studied in many research fields, including seismology, astrophysics, biology, acoustics, animal echolocation, radar and sonar. They are referred as multicomponent signals (MCS), as they are generally composed of multiple waveforms, with specific time-dependent frequencies, known as instantaneous frequencies (IFs).

In many applications, the extraction of signal characteristics (i.e. amplitudes and IFs) is required, that is why MCS decomposition is an important topic in signal processing. It consists of the recovery of each individual mode and it is often performed by IFs separation. The task becomes very challenging if signal modes overlap in the TF domain, i.e. they interfere with each other, at the so-called non-separability region and, for this reason, a general solution to MCS decomposition is not available yet. As a matter of fact, existing methods for overlapping modes decomposition all have the same limitations: they are parametric —i.e. they adapt only to the assumed signal class, or they rely on signal-dependent and parametric TF representations— otherwise, they are interpolation techniques—i.e. they almost ignore information corrupted by interference and recover IF curve by some fitting procedures, resulting in high computational cost and bad performances against noise.

This thesis aims at overcoming these drawbacks, providing efficient tools for dealing with MCS with interfering modes. An extended state-of-the-art revision is provided, as well as the mathematical tools and main definitions needed to introduce the topic. Then, the problem is addressed following two main strategies: the former is an iterative approach that aims at enhancing MCS'

resolution in the TF domain; the latter is a transform-based approach, that combines TF analysis and Radon Transform for separating individual modes.

As main advantage, methods derived from both the iterative and the transform-based approaches are non-parametric, as they do not require specific assumptions on the signal class. As confirmed by the experimental results, the proposed approach provides a contribution to solve a challenging problem in TF analysis of FM-MCS, with a consequent improvement of the state of the-art.