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Convex Optimization approach to signals with fast varying instantaneous frequency

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Abstract

Motivated by the limitation of analyzing oscillatory signals composed of multiple components with fast-varying instantaneous frequency, we approach the time-frequency analysis problem by optimization. Based on the proposed adaptive harmonic model, the time-frequency representation of a signal is obtained by directly minimizing a functional, which involves few properties an "ideal time-frequency representation" should satisfy, for example, the signal reconstruction and concentrative time frequency representation. FISTA (Fast Iterative Shrinkage-Thresholding Algorithm) is applied to achieve an efficient numerical approximation of the functional. We coin the algorithm as *Time-frequency bY COnvex OptimizatioN* (Tycoon). The numerical results confirm the potential of the Tycoon algorithm.

Keywords: Time-frequency analysis, Convex optimization, FISTA, Instantaneous frequency, Chirp factor

1. Introduction

Extracting proper features from the collected dataset is the first step toward data analysis. Take an oscillatory signal as an example. We might ask how many oscillatory components inside the signal, how fast each component oscillates, how strong each component is, etc. Traditionally, Fourier transform is commonly applied to answer this question. However, it has been well known for a long time that when the signal is not composed of harmonic functions, then Fourier transform might not perform correctly. Specifically, when the signal satisfies $f(t) = \sum_{k=1}^{K} A_k(t)\cos(2\pi\phi_k(t))$, where $K \in \mathbb{N}$, $A_k(t) > 0$ and $\phi_k'(t) > 0$ but $A_k(t)$ and $\phi_k'(t)$ are not constants, the momentary behavior of the oscillation cannot be captured by the Fourier transform. A lot of efforts have been made in the past few decades to handle this problem. Time-frequency (TF) analysis based on different principals [21] has attracted a lot of attention in the field and

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