A software companion for compressively sensed time-frequency processing of sparse nonstationary signals

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Abstract

Compressive sensing is a computational framework for acquisition and processing of sparse signals at sampling rates below the rates mandated by the Nyquist sampling theorem. In this paper, we present seven MATLAB functions for compressive sensing based time-frequency processing of sparse nonstationary signals. These functions are developed to reproduce figures in our companion review paper.
Keywords: Compressive sensing, time-frequency analysis, nonstationary signals.

1. Motivation and significance

Compressive sensing has been a very active research area for the past ten years. Its main idea is to decrease a number of step during acquisition and compression of signals by combining these two processes into a single step [1], [2]. The main advantage of compressive sensing is that it enables us to acquire signals/images at sampling rates below rates mandated by the Nyquist sampling theorem, but signals under consideration have to be sparse in time or other signal domains [1].

Compressively sampling non-stationary signals is not always trivial, as those signals are typically not sparse in time or frequency domains [3], [4], [5]. Furthermore, such compressively sampled nonstationary signals need to be processed using advanced signal processing techniques such as time-frequency representations [6], [7].

In our companion review paper [8], we reviewed several algorithms dealing with compressive sensing and time-frequency processing of nonstationary signals. In this paper, we briefly describe MATLAB functions developed to produce all seven figures from the companion paper. These figures represent various test cases where compressive sensing and time-frequency analysis can be combined to provide a framework for the analysis of nonstationary sparse signals.

These developed functions expand our previous efforts to disseminate software solutions that provide implementations of advanced signal processing algorithms in various applications [9], [10]. Hence, current functions along with previous software releases aim to increase the implementation of these algorithms in practical applications. This is a significant contributions, as it is a well known fact that many signal processing solutions have never been translated to practice due to difficulties encountered during the algorithmic software implementation.

As mentioned before, these functions were developed as standalone MATLAB functions and can be run independently of other functions. A typical user will download the function into their working MATLAB directory and run functions as any other MATLAB functions. However, these functions do not require any inputs, and their outputs are figures shown in the companion paper.

Lastly, it should be mentioned that these functions implement previously proposed algorithms (e.g., [11], [12], [13], [14]) and no new algorithms were proposed in the companion paper.

2. Software description

Each developed function is a stand-alone function that can be run independently in a MATLAB environment. No additional functions are needed. It should be mentioned that for function *figure1* additional data is needed, which is also shared via the ZIP file.

It should be pointed out that parts of codes were borrowed from the l_1-magic toolbox [15] developed by Professor Candes and his collaborators. However, those parts are clearly labeled, and no ownership is claimed.

2.1. Software Architecture

No particular software architecture is used here, as each function is a stand-alone function.

2.2. Software Functionalities

The main functionality of the software is to reproduce figures from the companion paper. However, other researchers will be able to use the software and adopt it for their own examples.

3. Impact

The proposed software package represents an excellent tool for researchers and engineers to recreate examples shown in the companion review paper. Moreover, the researchers working in the compressive sensing field will be able to reuse the existing functions in other applications with different problem set-ups. In other words, signal processing practitioners will be able to apply these techniques in diverse applications from medical signal processing to communications applications. Particularly, the idea of using the ambiguity domain to produce sparse time-frequency representations can be further explored to cope with the cross-terms in time-frequency representations. Thereby, researchers working in this field can modify the software functions in order to include certain foreknowledge about the desired components locations in the ambiguity domain. Functions developed for the separation of stationary and non-stationary signals can be also reused in various scenarios occurring in communication channels. In our examples, we illustrated the case with overlapping radar data. However, similar challenging situations also occur in wireless communications, where signals of interest are stationary, while disturbance components can be highly nonstationary signals. In those cases, researchers can adopt the provided functions to eliminate the disturbance and obtain an incomplete representation that needs to be recovered using the described approach. Furthermore, the proposed package also enables signal processing practitioners, especially at early stages such as upper-year undergraduate students or early-stage graduate students, to understand the nuisances of algorithmic implementations using modern software packages such as MATLAB.

Furthermore, we anticipate that the considered functions can be used in diverse signal processing applications from compressive sensing of nonstationary signals to estimation of instantaneous frequencies of highly complex nonstationary signals corrupted by measurement noise.

The developed functions could be also of interest for the practitioners outside the signal processing community. In other words, these functions can be used as a framework for the implementation of missing data reconstruction in certain economic and financial time series analysis, where it is commonly assumed that the discrete Fourier transform is a suitable tool for data representation.

4. Conclusions

In this paper, we presented a set of MATLAB functions that is useful for implementing algorithms considered in the companion review paper. These algorithms were based on the ideas of compressive sensing and time-frequency processing of nonstationary signals. In particular, these proposed functions represent an initial draft of the future comprehensive MATLAB toolbox for compressive sensing of nonstationary signals that will be able to also provide a set of functions for time-frequency processing of such signals.

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Nr.	Code metadata description	Please fill in this column
C1	Current code version	V1.0
C2	Permanent link to code/repository used for this code version	`https://pitt.box.com/s/lvnh5dxzauiy6hyy2pd5t5zul0719ht3`
C3	Legal Code License	Apache License 2.0
C4	Code versioning system used	None
C5	Software code languages, tools, and services used	MATLAB
C6	None	
C7	If available Link to developer documentation/manual	None
C8	Support email for questions	irenao@ac.me

Table 1: Code metadata (mandatory)

Current code version

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