Readme document for Multisensor Time-Frequency Signal Processing (MTFSP) MATLAB Package [1]

The additional material in this file is provided by Prof. B. Boashash and Dr. A. Aissa-El-Bey to assist the reader to better understand the supplementary material of the paper [1]. The MTFSP MATLAB package can be obtained using the permanent GitHub link in [2]. Further information on the package and extra illustrative examples can be found in [3].
The MATLAB scripts listed below, supplied within the MTFSP MATLAB package, are used to produce results and supporting figures illustrated in the paper:

MATLAB Scripts:

Demo_MTFD_example.m

- Description: This script produces the results that are depicted in Figs. 7 and 8 of the paper.
- Process: It generates three synthetic signals: a sinusoidal frequency modulation (FM) swaying between 0.1 and 0.4 Hz with a frequency of 3.8 Hz, a linear frequency modulation (LFM) signal changing from 0.4 to 0.1 Hz, and a tone of 0.3 Hz. Two multisensor time-frequency distributions (MTFDs) are computed for the generated signals are computed using the multisensor Wigner-Ville distribution (MWVD) and the multisensor Smoothed Pseudo-MWVD (SP-MWVD), as depicted in Figs. 7 and 8 respectively.

Demo_BSS_instantaneous_mix.m

- Description: This script produces the results that are depicted in Figs. 11 and 12 of the paper.
- Process: It generates three synthetic signals, where two of them are crossing LFM signals interchangeably changing from 0 to 0.5, Hz and the third is a tone of 0.3 Hz, as depicted in the first row of Fig. 11. The generated signals are mixed using an instantaneous noisy uniform linear array (ULA) model, to be received on six sensors with an SNR of 30 dB (Fig. 12). The received mixtures are whitened, and their MTFD is computed for the selection of auto and cross-terms. Finally, the un-mixing matrix is estimated, using a joint diagonalization/joint off-diagonalization (JD/JOD) algorithm, and estimated sources are classified using their time-frequency correlation with the original signals, as depicted in the second row of Fig. 11.

Demo_BSS_convolutive_mix.m

- Description: This script produces the results that are depicted in Figs. 13 and 14 of the paper.
- Process: It generates two synthetic signals: linear and quadratic FM signals interchangeably changing from 0 to 0.5 Hz, as depicted in the first row of Fig. 13. The generated signals are passed through a noisy convolutive invariant model, to be received on four sensors with an SNR of 40 dB (Fig. 14). The received mixtures are

whitened, and their MTFD is computed for the selection of auto-terms. Finally, the un-mixing matrix is estimated, using a joint block diagonalization (JBD) algorithm, and estimated filtered sources are classified using their time-frequency correlation with the original signals, as depicted in the last three rows of Fig. 13.

Demo_BSS_convolutive_sound.m

- Description: This script produces the results that are depicted in Figs. 15, 16 and 17 of the paper.
- Process: In this demo car start-up and the seagull sounds, found in *Soundtracks* folder, are selected, as illustrated in the first row of Figs. 15 and 16. The selected sounds are passed through a noisy convolutive invariant filter, describing the mixing model, to be received on three sensors, as shown in Fig. 17. The received mixtures are then whitened and their MTFD is computed for the selection of auto-terms. Finally, the un-mixing matrix is estimated, using a JBD, and estimated filtered sources are classified using their time-frequency correlation with the original signals, as depicted in the last three rows of Figs. 15 and 16.

Demo_MultiComponent_Signal.m

- Description: This script produces the results that are depicted in Fig. 18 of the paper.
- Process: It generates a synthetic signals comprised of: a sinusoidal FM signal swaying between 0.025 and 0.175 Hz with a frequency of 2 Hz, an LFM signal changing from 0.2 to 0.45 Hz, and a quadratic FM signal changing from 0.45 to 0.2 Hz. After that, it computes the Smoothed Pseudo Wigner-Ville distribution of the generated signal and plots it, as depicted in Fig. 18.

Demo_UBSS_instantaneous_mix_1.m

- Description: This script produces the results that are depicted in Fig. 21 of the paper.
- Process: In generates four disjoint, in the time-frequency sense, source signals, where the first signal is comprised of two crossing LFMs interchangeably changing from 0 to 0.2 Hz. The second signal is a tone of 0.25 Hz, while the third and fourth source signals are two parallel LFMs changing from 0.3 to 0.4 Hz and from 0.4 to 0.5 Hz respectively, as depicted in the first row of Fig. 21. The generated signals are then mixed using an instantaneous noisy ULA model, to be received on three sensors with an SNR of 30 dB. The received mixtures are whitened, and their MTFD is computed for the selection of auto-terms. Finally, the un-mixing matrix is estimated, using a clustering method, and estimated sources are classified using their time-frequency correlation with the original signals, as depicted in the second row of Fig. 21.

Demo_UBSS_instantaneous_mix_2.m

- Description: This script produces the results that are depicted in Figs. 22 and 23 of the paper.
- Process: In generates four intersecting, in the time-frequency sense, source signals using crossing LFMs. The first two signals are crossing LFMs interchangeably changing from 0.05 to 0.2 Hz, while the third and fourth signals are LFMs

interchangeably changing from 0.3 to 0.45 Hz, as depicted in the first row of Fig. 22. The generated signals are then mixed using an instantaneous noisy ULA model, to be received on three sensors with an SNR of 40 dB (Fig. 23). The received mixtures are whitened, and their MTFD is computed for the selection of auto-terms. After that, the un-mixing matrix is estimated using two methods, clustering and subspace projection, to illustrate the effect of time-frequency intersections. Finally, estimated sources are classified using their time-frequency correlation with the original signals, as depicted in the second and third rows of Fig. 22.

DOA_estimation.m

- Description: This script produces data that will used later by *Demo_DOA_Results.m*.
- Process: In generates two synthetic crossing LFMs interchangeably changing from 0 to 0.5 Hz. The generated signals are mixed using an instantaneous ULA model, to be received on eight sensors at 10° and 30° arriving angles. The received signals are plugged into two nested loops. The first loop (outer loop) chooses the required SNR from a range starting from -10 dB up to 15 dB with an increment of 5 dB (5 iterations). The second nested loop (inner loop) contaminates the received signal using the defined SNR, and estimates its direction of arrival (DOA) using conventional DOA methods (MUSIC and ESPRIT) and extended DOA methods (TF-MUSIC and TF-ESPRIT). The inner loop contains 3000 iterations requiring the whole script to run for a total of 15000 iterations. Finally, averaged MUSIC and TF-MUSIC spectrums along with the estimated DOAs are saved in every SNR iteration to be used by *Demo_DOA_Results.m*.

Demo_DOA_Results.m

- Description: This script produces the results that are depicted in Figs. 25-28 of the paper.
- Process: It loads the DOA results, can be found in *DOA Data* folder, and plots the averaged MUSIC and TF-MUSIC spectrums along with histograms for the estimated DOAs for every SNR value, as depicted in Figs. 25-27. In addition, it calculates and plots the normalized mean square error (Fig. 28) and displays the Mean Probability of Detection for every DOA method.

Demo_BSS_EEG.m

- Description: This script produces the results that are depicted in Figs. 29 and 30 of the paper.
- Process: Clean multichannel EEG is combined with synthetic multichannel EEG artifacts, both data can be found in *EEG Data* folder, as depicted in Fig. 29. The multichannel contaminated signals are whitened, and their MTFD is computed for the selection of auto and cross-terms. After that, two independent sources are estimated using JD/JOD, and artifactual components are identified using a maximum likelihood detector that utilizes an independent template, can be found in *EEG Data* folder. Finally, clean multichannel EEG is estimated and compared with the original clean EEG, as depicted in Fig. 30.

Additional Folders:

- *Supporting functions*: It contains all the functions and sub-functions used in the scripts described above. It is divided into six subfolders namely: BSS, Channel Models, DOA, Graphics, MTFD, and Signal Models, containing functions related to their folder name.
- *Soundtracks*: It contains, six different, one second, soundtracks sampled at 11025 Hz, namely: *bird.wav*, *bird_chirp.wav*, *car_x.wav*, *dolphin.wav*, *jet_doppler2.wav* and *seagull2.wav*. The six soundtracks correspond to the following real sounds: bird song, bird chirping, car start-up, dolphin whistle, flying jet aircraft, and a seagull with ocean noises in the background. The original full length soundtracks can be obtained from here.
- *DOA Data*: It is divided into 5 subfolders containing the averaged MUSIC and TF-MUSIC spectrums along with estimated DOAs for every defined SNR value.
- *EEG Data*: A five seconds segment of clean multichannel EEG was extracted from a publicly available database that can be found here. The extracted EEG segment is down-sampled to 100 Hz and saved as *EEG.mat*. In addition, synthetic multichannel EEG artifacts are stored in *Artifact.mat* along with an artifact template, *Template.mat*, to be used in the maximum likelihood detector.

References

[1] B. Boashash and A. Aissa-El-Bey, "Multisensor Time-Frequency Signal Processing: A tutorial review with illustrations in selected application areas," *Digital Signal Processing*, 2017.

[2] B. Boashash and A. Aissa-El-Bey, "Download Link for MTFSP MATLAB Package," GitHub, 2017. [Online]. Available: https://github.com/Prof-Boualem-Boashash/MTFSP-1.0-software-package-. [Accessed 3 January 2017].

[3] B. Boashash and A. Aissa-El-Bey, "Multisensor time-frequency signal processing software Matlab package: An analysis tool for multichannel non-stationary data," *SoftwareX*, 2017.