Detection of Trumpet Signals Using Molecular Gabor Dictionaries and Matching Pursuit Algorithm

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Abstract. In this paper we consider the construction of a molecular Gabor dictionaries appropriate for trumpet audio signals. Motivated by improving the efficient in detection and segmentation the sounds applying Matching Pursuit algorithm (MP) and Gabor dictionaries. We generate a molecular Gabor dictionary by grouping atoms to sparse representation the trumpet sounds choosing the best 10 atoms with provide 99% energy upon specific interval of time (harmonic). This technique demonstrates than we can use the same molecule (10 atoms) to find sparse decomposition of trumpet sounds with the minimum number of MP iterations. The reported method showed its effectiveness in terms of good sound detection for different signal to noise ratio (SNR) and approximation capability with low computational complexity.

Keywords. Gabor atoms, matching pursuit, sounds segmentation and detection musical sounds.

1 Introduction

The recognizing of sounds has been huge analyzed through different techniques to find the patterns to represent music sounds. Humans are able to detect and recognize an individual sound from complex acoustic environments. The methods to represent audio signals can be classified into two categories: the orthogonal basis expansion and the over complete representation [1]. Whit over complete representation, we implement Matching Pursuit algorithm (MP) that decomposes any signal into a linear expansion of waveforms that are selected from a redundant dictionary of functions [2] and extracting high-level signal features as harmonic components. However, the complexity of the algorithm limits its implementation for signal of long duration. MPTK has showed its effectiveness introducing a new implementation witch reduce the complexity of the algorithm MP [4].

We have used MPTK to find a sparse representation of heart sounds applying proposed segmentation algorithms to detect specific harmonics at phonocardiogram signals achieving a good detection rate [5], [6].

One of the aims of this paper is study the sparse representation of trumpet sounds to detect harmonic at the trumpet pitches and testing its performance with different SNR using MP and proposed molecular Gabor dictionary improving the performance of MP algorithm by reducing the number of Gabor atoms into the dictionary.

Due to the harmonics similarity in a certain pitch and the waveform we selected the trumpet sounds like the best candidate to test the performance of the molecular Gabor dictionary in the detection of harmonic components occurring at various time scales, see Fig. 1.

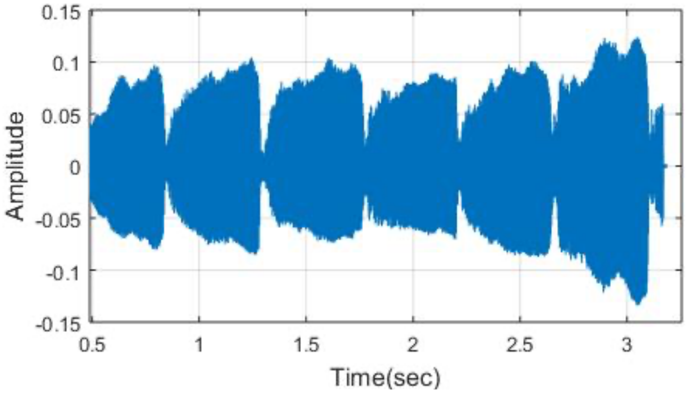

Fig 1. Harmonics trumpet sounds, 3 (sec), 11025 Fs.

2 Matching Pursuit Algorithm

Matching Pursuit (MP) is an iterative algorithm that decomposes a signal $x(t)$ into a sparse linear combination of waveform that belongs to a redundant dictionary of functions called atoms [2]. This decomposition is performed by projecting the signal $x(t)$ over redundant dictionary of functions $D = \{g(t)\}$. So The MP is algorithm that each iteration selects the optimal $g(t)$ which match the structure of signal $x(t)$.

The signal $x(t)$ can be reconstructed from the sum of M number of atoms and residual term $r(t)$ as in (1).

$$x(t) = \sum_{m=1}^{M} a_m * g(t)_m + r(t) \quad (1)$$

where a_m and g_m are ponderation factor and $m-th$ optimal respectively.

3 Gabor Dictionary

The MP requires a good selection of dictionary to represent the $x(t)$ signal like a sparse combination of waveforms belong to the dictionary. Of course the selection of the dictionary depends of the properties of the processed signal. The benefits of using MP has been huge studied and showed advantage with different dictionaries in function the signal properties. Gabor dictionary has showed its potential for audio signal processing, [3]. Gabor atoms are obtained by dilating, translating, and modulating of Gaussian window which is generally real-valued, positive and of unit norm $\int |w(t)|^2 dt = 1$, as in (2).

$$g(t) = \frac{1}{\sqrt{s}} w(\frac{t-u}{s}) e^{i2\pi\varepsilon(t-u)} \tag{2}$$

Where s is used to control the width of waveform envelope, the time displacement u is used to specify the temporal location of the waveform and ε is the frequency [3].

4 Molecular Gabor dictionary.

4.1 Creating a Gabor molecule

We observed that the harmonics of the pitches in trumpet sounds are similar as far as waveform refers, which allow creating a Gabor molecule on specific interval of the time and project this molecule on the trumpet audio signal $x(t)$. We proposed using the MP algorithm and Gabor dictionary on a specific harmonic or main component $x_\delta(t)$ to find a sparse representation with target threshold fixed in 99 % of absorption energy, see Algorithm I.

Algorithm I. Standard Matching Pursuit

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$\boldsymbol{input}: x(t); D = \{g_\gamma(t)\}$
$\boldsymbol{output}: \alpha_m, g_\gamma(t)$
$s(t) = x_\delta(t)$
$R = s(t)$
$\boldsymbol{repeat}$
    $g_{\gamma m} = \arg\max\ | < R, g_\gamma > |$
    $\alpha_m =< R, g_{\gamma m} >$
    $yfit = \alpha_m * g_{\gamma m}$
    $R = R - yfit$
$\boldsymbol{until}\ target\ umbral\ |yfit|^2 \geq .99$ has been reached
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To guaranty the 99 % of absorption energy we created a redundant Gabor dictionary $D = \{g_\gamma(t)\}$ with 23400 atoms. The 99 % of absorption energy was reached with 10 atoms $g_\gamma(t)$ selected from algorithm I, see TABLE I.

The signal $x_\delta(t)$ can be reconstructed from the sum of $M = 10$ atoms selected as in (3), see Fig. 2.

$$x_\delta(t) = \sum_{m=1}^{10} a_m * g(t)_m \tag{3}$$

The sparse representation of $x_\delta(t)$ correspond with our Gabor molecule, which we used to detect each harmonic components occurring in different intervals of time at $x(t)$, see Fig. 3.

TABLE 1. PARAMETERS OF MP ALGORITH 1.

Number of atoms in dictionary	Number of iterations MP	Processing time	Harmonic detected	Reconstruction (%)
23400	10	13 (sec)	1	99

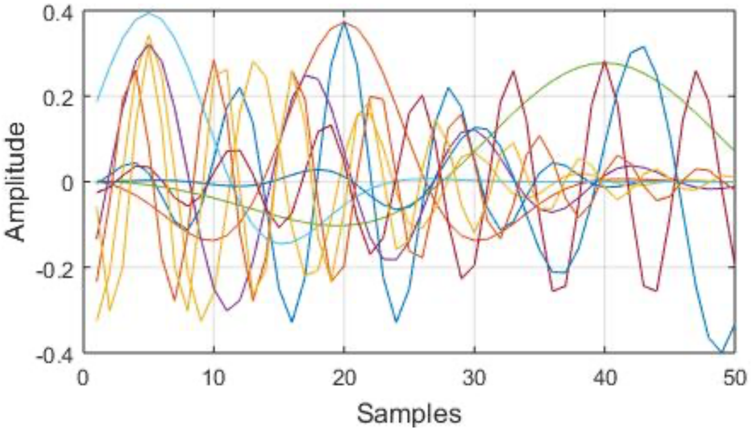

Fig. 2. Gabor atoms which approximate a specific harmonic component at a trumpet pitch.

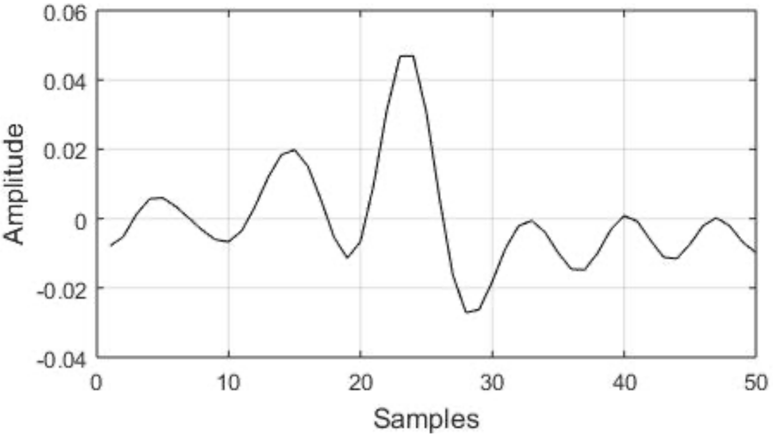

Fig. 3. Gabor molecule composed by 10 atoms which approximate the specific harmonic with 99% of absorption energy.

4.2 Creating molecular Gabor dictionary

To minimize the number of atoms in the dictionary and reducing the complexity computational of MP, we propose creating a molecular Gabor dictionary $D = \{M_\varphi(t)\}$ where $M_\varphi(t) = x_\delta(t)$ corresponds to the sum the $M = 10$ atoms selected from algorithm I, i.e., $M_\varphi(t)$ represent the sum of the optimal atoms which approximate a random harmonic component from $x(t)$ called molecule. The construction of molecular Gabor dictionary proposes that each $M_\varphi(t)$ is located at the position s_β where $x(t)$ shows the peaks of maximum energy $s_\beta = \max[x(t)]$, see Fig. 4.

The number of molecules $M_\varphi(t)$ into molecular Gabor dictionary is defined by the number of peaks β.

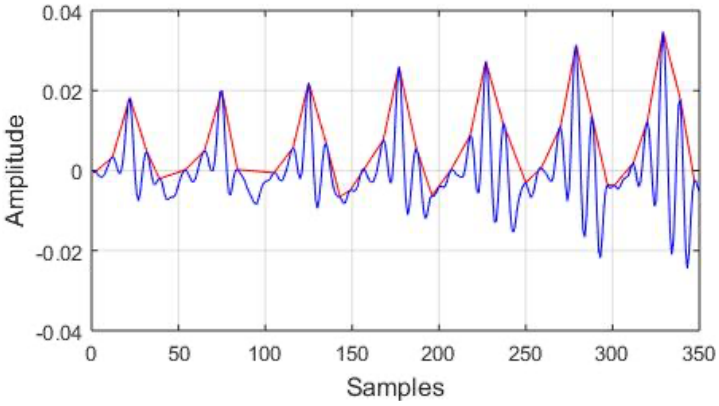

Fig. 4. Peaks of maximum energy at trumpet pitches.

This method is based in creating a Gabor molecule on the region of certain harmonic to detect each harmonic in the signal $x(t)$ using MP algorithm, see Fig. 5.

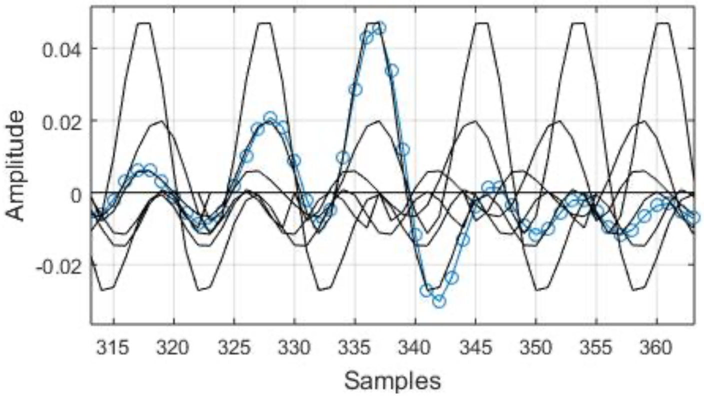

Fig. 5. Gabor molecules locate in position s_β from a specific harmonic $x_\delta(t)$.

The proposed method allows creating a molecular dictionary locate at peak of maximum energy, this approach minimize the number of molecules in the dictionary, i.e., $\varphi = \beta$ achieving a good detection at the harmonic components from $x(t)$.

5 Results

To achieve a gain of energy 99% on the harmonic components selected we need a dictionary with 23400 Gabor atoms locate at time axis with different parameters combinations $s, u\ \epsilon$. With proposed method we require creating molecules on the peaks of maximum energy s_β. The 10 atoms which approximate the main component in specific interval of time $x_\delta(t)$ can be used to approximate the complete signal $x(t)$ minimizing the number of iteration of MP algorithm and reducing the pursuit of optimal molecule where the number iterations of MP corresponds with the number of harmonics of the signal $x(t)$ achieving the 91% of detection, see TABLE II.

TABLE II: DETECTION OF 900 HARMONIC AT TRUMPET PITCHES.

Number of atoms in dictionary	Number of iterations MP	Length of $x(t)$	Harmonic detected	Detection (%)
4907	981	3.18 (sec)	900	91

5.1 Detection of basic components with different SNR

The capability of detection was evaluated with different SNR achieved a 90 % of detection for 70,60,50,40 SNR. The method shows a good performance for 30 SNR detecting 80 % of harmonics in the trumpet pitches.

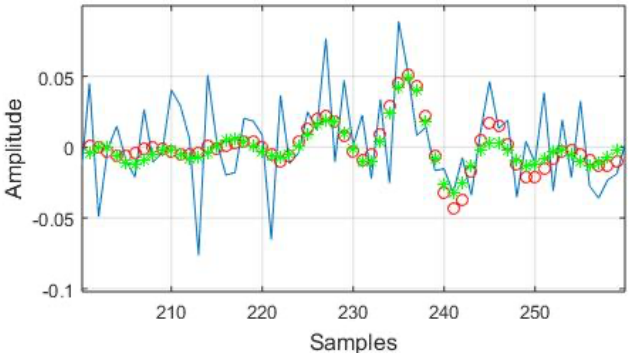

Fig. 6. Detection on specific harmonic $x_\delta(t)$ whit 30 SNR using MP and molecular Gabor dictionary.

6 Conclusions

The proposed method detects the essential features of trumpet pitches by modeling basic components. Due to proposed molecular Gabor dictionary we reduced the iteration of MP algorithm and achieved 80% of detection of harmonics of trumpet pitches for 30db SNR. The peaks of maximum energy allow reducing the number of molecules in the dictionary without depend of Short Time Fourier Transform (STFT) creating molecules at each harmonic components. We applied MP and Molecular Gabor dictionary with a single-channel mixture of multiple trumpet pitches with sampling rate $Fs = 11025$. All the simulations carried out in the present work were performed under Matlab.

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