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CLASSIFICATION ENVIRONMENTAL SOUND WITH WAVELET

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Abstract
Sound signals can deliver important information about the environment. Therefore, recognition and assessment of these signals are very useful for surveillance purposes. Reaching new methods that have highest accuracy and lowest calculating time is ideal. Generally, wavelet method is used in environmental sound classification. In this paper, we propose both continuous and discrete wavelet transform. Firstly, three features are extracted from signal through calculating its scalogram, and secondly, we decompose signals with daubechies mother wavelet in 4 level and calculate B-spline coefficient and then extract three features from them. Finally, we evaluate this method on 80 sound segment from two airplane collected from a public database. It takes 1.3s for calculating the 0.2 seconds of sound segment. In the end combining these methods help reach a higher accuracy percentage compared to the previous works.

Keywords: *wavelet transform, B-spline function, sound classification.*

1. Introduction

Separation of sound from different sources play significant role in auditory analysis and content recognition. The majority of works in sound classification use time-frequency feature extracted from spectral method Such as wavelet coefficient [1]. One of crucial phases in developing systems for classification sound signal is to choose special features of signal that ensure separability between them. Then, accedes to extract these features and create a feature vector and classify these signals [2]. Existing works, in this area are to study features extracted from wavelet coefficient [3]. In this new method at first we study scalogram feature that is in continue domain then we decomposition signal with daubechies6 wavelet family (db6) at 4 level and consider the features in approximate at level 4^{th} (A4). We propose wavelet-base features for discrimination of signals, because this method have trade off between time and frequency resolution. This paper is organized as follows: First, we analyze previous works in continuous wavelet transform (CWT) domain on scalogram, then use discrete wavelet transform (DWT) and decomposition signal with (db6) wavelet family and continue our methods on A4, in which analyze B-spline method on A4, and finally we discuss the result and outlook.

2. Theoretical Background

Classification based on wavelet method is useful in environmental sound because its calculation is easier. Therefore wavelet feature is main objective of this paper for discrimination of sound signals. Although we only will deal with 2 kinds of airplanes, this is a general approach that can in principle be applied to similar kinds of sound signals. Data used in this work is from a public database [4]. And all of the signals were sampled by 44100 Hz.

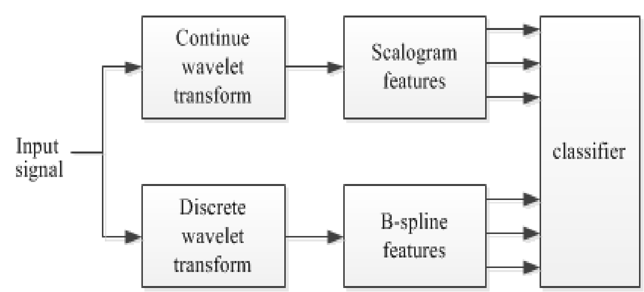

Fig. 1. Block diagram of the proposed method

2.1 Wavelet Transform

Wavelet is an affective way for analysis of non-stationary signals. Generally one advantage of wavelet is the ability of perform local analysis. It is able to reveal signal aspects such as trends, crackles, density of energy, break down point, etc. it also perform a multiresolution analysis. Indeed by using an approach called multiresolution analysis it is possible to analyze a signal at different ferequencies with different resolutions. The wavelet

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transform calculates the correlation between the signal and a wavelet function $\psi(t)$. The similarity between the signal and the analyzing wavelet function is computed separately for different time intervals a wavelet function is a small wave which must be oscillatory in some way to discremenate between different frequencies. The continuous wavelet transform is defined as, [5].

$$X_{WT}(\tau, s) = \frac{1}{\sqrt{|s|}} \int_{-\infty}^{+\infty} x(t)\psi^{*}(\frac{t-\tau}{s})dt \qquad (1)$$

The transformed signal $X_{WT}(\tau, s)$ is a function of the shift parameter τ and the scale parameter s. and ψ is the mother wavelet at which $*$ sign indicates that the complex conjugate. The mother wavelet is contracted and expanded by changing the scale parameter s.
The variation in scale s not only changes the central frequency f_c of the wavelet, but also the window length. Therefore the scale s is used instead of the frequency for representing the results of the wavelet analysis. The translation parameter τ specifies the location of the wavelet in time, by changing τ the wavelet can be shifted over the signal.
In literature, most of the time scalogram is used for presenting the result of CWT. in which percentage of energy for each wavelet coefficient is obvious. Note that in scalogram large scales correspond to low frequencies and small scales to high frequencies.
The CWT performs a multiresolution analysis which makes it possible to analyze a signal at different frequencies with different resolutions. For high frequencies (low scales), which last a short period of time, a good time resolution is desired. Whereas For low frequencies (high scales) a good frequency resolution is more important.

The discrete wavelet transform (DWT) uses filter banks for the construction of the multiresolution time-frequency plane. The low-pass and high-pass filtering branches of the filter bank retrieve respectively the approximations and details of the signal x(k) [6].
A discrete wavelet transform (DWT) daubechies type at 4 level used in this paper is obvious in fig. 2.

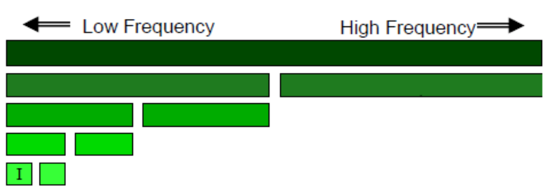

Fig. 2. The proposed wavelet decomposition,
(I) is the approximate at level 4 (A4).

2.2 B-spline Function

An intense activity in wavelet design has led to the construction of a large variety of wavelet bases, the most important requirements are orthogonality and compact support, high number of vanishing moments, symmetry and regularity, explicit analytical form, and an optimal time-frequency localization, etc.
One of the key mathematical properties of wavelets is that they behave like multiscale differentiators. Thus, there is a correspondence between a wavelet with vanishing moments and the differentiation operator. The derivative like behaviour of wavelets was investigated by several researchers including T. Blu, M. Unser, D. Van De Ville. Fractional B-spline Functions were proposed in 2000, by Thierry Blu and Michael Unser [7]. The primary motivation for considering fractional B-splines instead of conventional ones was that the enlarged family happens to be closed under fractional differentiation. The uniform first order causal B-spline function is defined as [8]:

$$\beta_{+}^{0}(x) = x_{+}^{0} - (x-1)_{+}^{0} = \Delta_{+}^{1} x_{+}^{0} \qquad (2)$$

$$\hat{\beta}_{+}^{0}(\omega) = \frac{1-e^{-j\omega}}{j\omega} \qquad (3)$$

Where $x_{+}^{\alpha} = \max\{0, x\}^{\alpha}$ is the one-sided power function, $\Delta_{+} = \delta(x) - \delta(x-1) \xleftrightarrow{f} 1 - e^{-j\omega}$ is the finite difference operator and $\partial \xleftrightarrow{f} j\omega$ is the derivative operator. The k-th order function is defined by convolving the k-1 order function with the first one:

$$\beta_{+}^{k}(x) = \beta_{+}^{k-1} * \beta^{0}(x) \qquad (4)$$

3. Feature Extraction Method

Firstly, the scalogram features of the signals are surveyed. Then the signal is decomposed into 4 levels to analyze approximate with B-spline method. It is worth saying that applying this approach will improve the precision compared to the previous works.

3.1 Scalogram Features

These methods were considered in previous works [9]:

Scale Distribution Width (SDW): Scale distribution width is the difference between the scales, at which the CWT of the signal reaches its half of maximum energy per scale. The energy per scale in this sense is the averaged energy for a particular scale, over all the shift values (in the frame). The idea behind using this feature is to represent the organization of signal around a dominant scale.

Dominant Scale (DS): this is the scales at which the energy of CWT coefficients are maximum.

Time Variance of Dominant Scale (TVDS): Time variance of dominant scale is the standard deviation of values of dominant scale at each sample.

The process of averaging and its features calculation is demonstrated in fig.3.

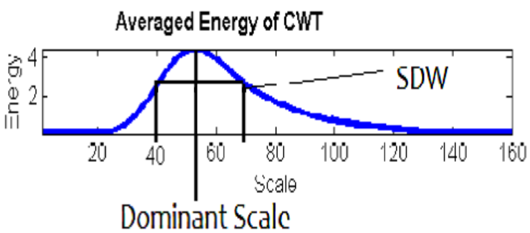

Fig. 3. Demonstrate of how SDW and dominant Scales are calculated [9]

scalogram of the mentioned signals is obvious in Fig.4., and we can investigate the features.

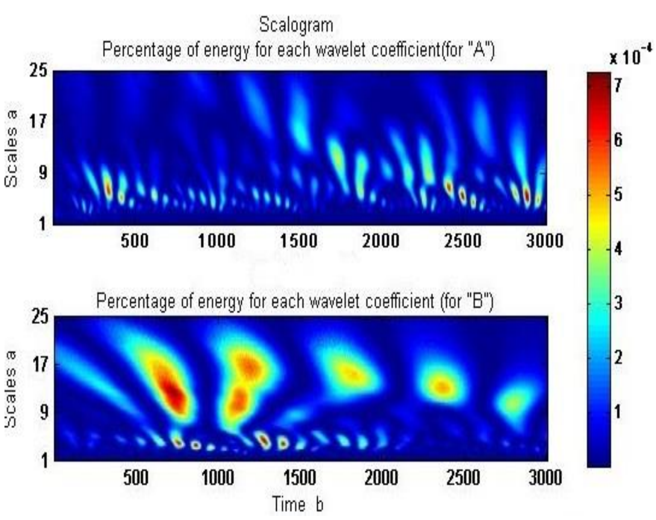

Fig. 4. Scalogram of the sound signals, “A” is the airplane A, And “B” is the airplane B

In order to continue, DWT is studied on the signals. In this step, signals are decomposed by daubechies6 (db6) wavelet family at 4 levels and features are extracted from them.

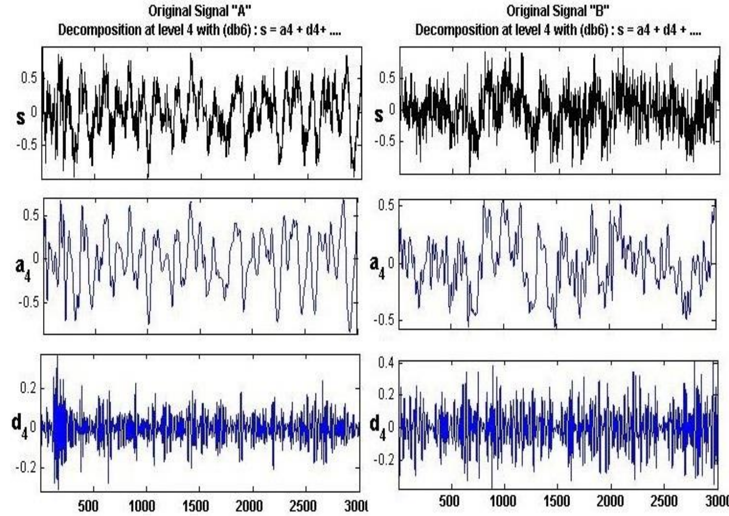

Fig. 5. Decomposed signals to A4 and D4. Signal Decomposed with daubechies6 wavelet (db6) at level 4, only D4 and A4 is shown.

3.2 B-Spline features

As mentioned, we investigate B-spline feature on the A4. At first we achieve B-spline coefficient that is shown in fig.6.

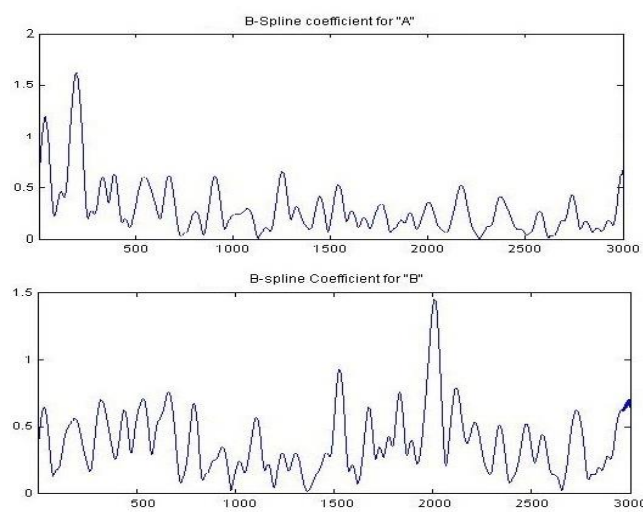

Fig. 6. B-spline coefficient of A4 at two airplane Sound signal

Root Mean Square of coefficient (RMSC): RMS is statistical measure of the magnitude of a varying quantity, and the RMS of a set of values is the square root of the arithmetic mean of the squares of the function that defines the continuous waveform. The RMS for a function over all the time is [10]:

$$f_{rms} = \lim \sqrt{\frac{1}{T} \int_0^T \left[f(t) \right]^2 dt} \qquad (5)$$

Similarly, it is used to calculate the RMS of B-spline coefficient.

Dominant coefficient (DC): Similar to former state, this is the scale at which the amplitude of coefficient is maximum.

Time variance of dominant coefficient (TVDC): TVDC is the standard deviation of values of dominant scale at each sample.

4. Classification and Evaluation Method

Table 1. is obvious the results for selected feature set. In this part of research, 80 sound segments of 2 kinds of airplane have been evaluated. Segments are collected from a public source [4]. And accuracy percent of each feature was calculated and was shown. Finally it is obvious that a complex set of tree features has best accuracy percentage and is very profitable.

Table 1. Result of sound signal classification

Feature Set		*Accuracy Pre.*
Scalogram Features	SDW	47.50%
	DS	78.30%
	TVDS	52.40%
B-spline Features	RMSC	83.70%
	DC	43.80%
	TVDC	42.20%
Combine	SDW+DS+RMSC	92.40%

It should be said that For each segment the signal was split into the overlapping frames of 0.2 seconds, and calculations done by matlab software with system configuration of "CPU core i7 and 8GB DDR3 RAM", and process duration in (SDW+DS+RMSC) was 1.3s.

5. Conclusions

Various spectral and time-frequency features exist in the literature for sound classification, this work has proposes six simple wavelet features in continuous a discrete wavelet domain for capturing important signal traits for classifying airplane sounds. We test this features on 80 sound segments from two different type airplane in different resolution from a public database. Some deal, this method takes long time for process and classification, but has good accuracy percentage and is useful to use for high precise conclusion. For the future actions, local maxima line can be extracted from B-spline wavelet and study this feature on the sound segments.

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