IOSR Journal of VLSI and Signal Processing (IOSR-JVSP)
Volume 6, Issue 2, Ver. I (Mar. -Apr. 2016), PP 21-24
e-ISSN: 2319 – 4200, p-ISSN No. : 2319 – 4197
www.iosrjournals.org

A Detection and Identification Method for Airtarget Acoustic Signal Characterization

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Abstract: *Detection and classification of Airtargets (ATs) commonly performed using radar. ATs become essential demand for detection and classification However; Acoustic signal application is one of the famous techniques that used to detect low flying ATs passively. Peak of Power Spectral Density (PSD) and corresponding frequency are considered as main features of ATs recognition. The represented method for ATs detection and classification using Discrete Cosine Transform (DCT) to extract ATs features. It has many advantages for being used more than radar traditional techniques. It's characterized by simplicity, low cost and low CPU processing. It has been tested using recorded real AT acoustic signals. They are used for testing requirements to achieve reality of the test. These real ATs are characterized by (PSD), frequency, Mean, Median, Entropy and Variance. All of these features have been extracted using DCT method. It proofed that it's more effective than Discrete Fourier Transform for ATs classification.*

Keywords: *Airtargets (ATs), discrete cosine transform (DCT), Standard Deviation, Power Spectral Density (PSD), Entropy, Euclidean distance.*

I. Introduction

Air defense systems based on active radar are the most usable systems at many countries. It uses electromagnetic wave for AT detection and ranging. It became conventional tool for long and short range AT detection and classification. Small ATs as UAV and drones have been a large threats for air defense system, also due to huge advancements and continuous development of smart weapons, active radar became an easily target to be detected, localized and destroyed. It has been necessary to develop a nonconventional technique for ATs detection. ATs detection and classification passively will be more effective. Many researchers tried to detect ATs by applying the passive concept by using ATs acoustic wave. It can be used for detection, and classification.

All of The acoustic signals that being heard from musical device, mechanical machine, and speech are acoustic signals. It has different techniques for being detected and recognized. The speech recognition has many methods to acquire feature extraction. [1]. Cepstral Analysis and Mel-frequency Cepstral Coefficients (MFCC) are famous methods and have wide usage for speech recognition. They depend on getting the PSD for extracting the envelop speech features using DCT [2].

In this paper DCT is being used as a proposed method for extracting ATs features using its acoustic signal. DCT has a widely usage in engineering science especially at image and audio coding and compression. It is an orthogonal transformation as discrete Fourier Transform (DFT). It transforms the signal to its frequency spectrum [5]. It has many advantages than DFT. Its coefficients are real values only otherwise DFT coefficients values are real and imaginary part, simplicity of implementation and low processing time. Due to all of these advantages it has been recommended for this application.

II. Euclidean Distance Measurements

A widely usage of Euclidean Distance at many application in different fields as in science, economics and image recognition is very useful to measure the distance between vectors [9]. It can be used at ATs detection and classification application.

When Euclidean Distance is being used for measuring distance between two vectors contain different measurement scale the Weight Euclidean Distance WED measurements should be used. If there are two vectors X and Y each one has size N as at our application. The VSFL has a vector for each AT of order 1x8 which gives Mean, Median, Variance, Standard Deviation, Entropy, Frequency and Squared Amplitude. Due to the different scale of vector items WED should be applied. WED d_{ew} can be expressed mathematically as following:

$D_{ew}(X,Y) = \sqrt{\sum_{i=1}^{N} v_i\, d_i}$	(1)
$d_i^{\,2} = (y_i - x_i)^2$	(2)

Where d_i^2 is the squared difference between the two vectors and v_i is the inverse of the i^{th} Variance.

III. VSFL Construction

The VSFL is to be constructed from ATs acoustic signal characteristics. It constructed form many features for each AT. Many features should be included at the VSFL to get high accuracy with low false alarm so can't depend on one parameter only. Power Spectral Density (PSD), Frequency, Mean, Median, Mode, Variance, Standard deviation and Entropy are the features of ATs that being used at VSFL construction. The dominant frequency at the PSD is being treated as a main characteristic feature for the given acoustic signal to start the classification algorithm. Many steps are being executed for constructing the VSFL for the ATs as shown at Fig (1).

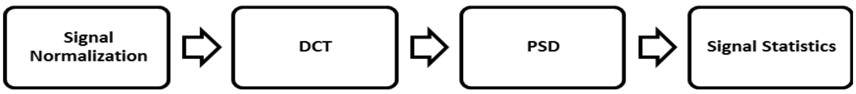

Figure (1): steps of VSFL construction

1. Signal normalization.

It can be achieved by dividing the signal amplitude y by its modulus. It can be expressed mathematically at equation (3).

$y_{normalized} = \frac{y}{\lvert y \rvert_{max}}$	(2)

Where $y_{normalized}$ is the normalized value of acoustic signal.

Normalization for acoustic signal is being used to overcome the problem of the strength variation for acoustic signal. It achieves even it was recorded from the same source. Strength variation problem is related to many factors as how far is the Target form microphones, the speed of the AT, weather temperature, humidity and wind noise [4].

2. DCT

Applying DCT to the normalized acoustic signal is the second step to calculate the PSD. It expresses a finite sequence data points in terms of a sum of cosine function oscillating at different frequencies [6]. It is expressed as following:

$$y(x) = \mathrm{w(k)} \sum_{n=1}^{N} \mathrm{x(n)} \cos\left(\frac{\pi}{2N}(2\mathrm{n}-1)(\mathrm{k}-1)\right) \quad (3)$$

Where

$$\mathrm{w(k)} = \begin{cases} \frac{1}{\sqrt{N}} & k = 1 \\ \sqrt{\frac{2}{N}} & 2 \le k \le N \end{cases}$$

N	Is the Number of samples.
x(n)	Is the discrete input signal.
y(x)	Is the output signal in frequency domain.

3. Power Spectral Density.

Third step calculates the PSD of the acoustic signal by getting the squared amplitude of DCT coefficients [7]. The max amplitude and the corresponding frequency store in VSFL. Figures (2, 3) show the PSD verses the frequency.

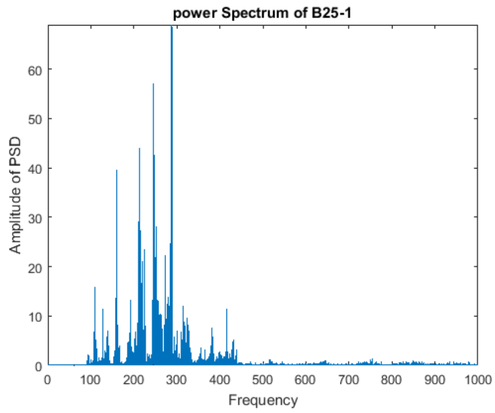

Figure (2): The squared coefficients (PSD) of DCT for aircraft B-25

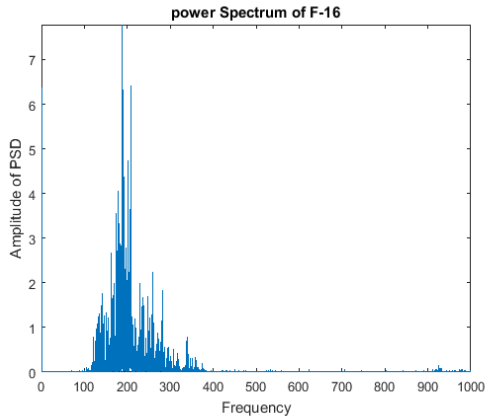

Figure (3): The squared coefficients (PSD) of DCT for aircraft F-16.

4. Signal statistics.

At fourth step signal statistics is being realized on the PSD coefficients of the AT acoustic signal to extract more features for AT and being store at VSFL. Mean, Median, Mode, Variance, Standard deviation and Entropy can be calculated. Table (1) shows statistics on B-25 and F-35 aircraft acoustic signals. Now the VSFL has been constructed from the eight features. It can be expressed as eight dimensional VSFL.

Table (1): DCT coefficient Statistics for B-25 and F-16 aircrafts

Parameters	**B-25**	**F-16**
Mean	0.10184	0.024434
Mode	2.6533e-11	9.3349e-13
Median	0.012316	0.0047052
Standard deviation	0.92379	0.14114
Variance	0.8534	0.019919
Entropy	4.5788	3.4524
Dominant frequency	288.0066	188.4155
Squared amplitude	68.96717	7.781544

Figures (2) and (3) and table (1) show a discrepancy at the extracted features between the two ATs. It can be detected easily and being used with a simple classifier to achieve the classification process with low rate of false alarm.

IV. Recording System Of Acoustic Signal.

The recording system captures the ATs acoustic signal from the field at run time. It is constructed with a sensitive dynamic microphone 10-50mV/Pa, 20-20,000 Hz audio amplifier and computer software classification algorithm to capture the characteristic features to be compared with the pre-constructed vector space. The classification software will determine which one of the ATs at VSFL is the closest one to the unknown signal.

V. Classification Algorithm

It depends mainly on calculating the WED between the unknown acoustic signal characteristic features vector and the features of all vectors at the VSFL [8]. The algorithm starts to calculate the WED between features of the unknown acoustic signal and the feature VSFL from first vector features to the end. All results are being saved in array called WED Array. It contains on two parameters, WED and the ATs index that being compared with. It is being sorted in ascending order according to the WED. The first element in the array refers to the minimum WED between the captured acoustic signal and the stored features of different ATs.

VI. Results

The Dominant frequency of PSD, squared PSD amplitude, Mean, Median, Mode, Variance, Standard deviation and Entropy succeeded to construct the VSFL to be used at ATs detection and classification. It succeeded to detect and classify the captured air targets acoustic signal. The results has been compared with another algorithm used DFT for detect and classify ATs using the same criteria. The results were matched. Using DCT was for replacing DFT in many applications to classifying weapons and ATs using acoustic signal. It reduces the processing time and reached to the same accuracy of using DFT for classification ATs. It reduces the CPU processing time and overcome its speed limitation.

VII. Conclusion

The constructed a system can be used for air defense systems ATs detection and classification according to acoustic signal. It is useful to get information about ATs passively without being detectable. It can be used instead of active radar to detect and classify the small UAV which has small cross sectional area at short range with very low altitude.

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