Acoustic Signal based Feature extraction for Vehicular Classification

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***Abstract*— Acoustic signal classification consists of extracting the features from a sound, and of using these features to identify classes the sound is liable to fit.. Different types of noise coming from different vehicles mix in the environment and identifying a particular vehicle is a challenging one. Feature Extraction is done to identify the characteristic of the vehicle. The characteristic of each vehicle will be used to detect its presence and classify its type. Six different features of the vehicle acoustic signals are calculated and then further utilized as input to the classification system. These features include Signal Energy, Energy Entropy, Zero-Crossing Rate, Spectral Roll-Off, Spectral Centroid and Spectral Flux. All these features are extracted from each and every acoustic signal of the vehicles.**

Keywords- Vehicle acoustic signal, Feature Extraction, Short Time Energy, Entropy, Zero-Crossing Rate, Spectral Rolloff, Spectral Centroid, Spectral Flux

I. INTRODUCTION

The key target of the feature extraction and selection is to get the most effective features from the variety of features. In general the data size of the signal wave or image is ample. For example, a digital image contains several thousand of data, a acoustic waveform of electrocardiogram or a waveform of copter (or tank or other target) may also contain several thousand of data. The data of a satellite remote sensing image is huge, so recognition and classification of these data is incredible [1, 2].

Acoustic sensors, such as a microphone array, can collect an acoustic signal to identify the type and localize the position of a working ground vehicle. Acoustic sensors can be used in sensor networks for applications such as traffic monitoring and battlefield surveillance [3, 4]. They become more and more attractive because they can be rapidly deployed and low cost [5, 6]. One of the research areas in acoustic sensor processing is identification of the type of the vehicle [7], which can help to improve the performance of tracking. The main approaches in acoustic vehicle classification mainly use signal processing and pattern recognition techniques. Many acoustic features can be extracted to classify working ground vehicles. The commonly-used features are Signal Energy, Energy Entropy, Zero-Crossing Rate, Spectral Roll-Off, Spectral Centroid and Spectral Flux.

The remainder of this paper is organized as follows. Section 2 gives the details about significance of the feature extraction in signal processing. Section 3 describes about the features extracted, experimentation and results. Conclusion follows in Section 4.

II. SIGNIFICANCE OF FEATURE EXTRACTION

Figure 1 shows the diagram of the sequence of operations in signal processing. Feature extraction is the most important step for object recognition. The objective of feature extraction is to extract meaningful features from acoustic signals so that they can be classified according to their source.

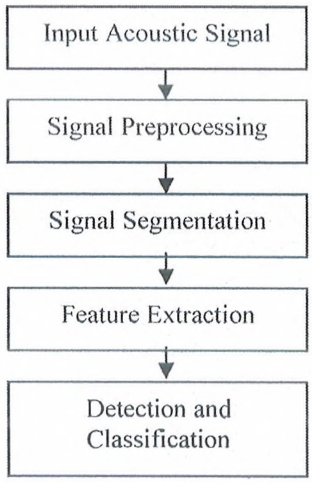

Figure 1. Flow diagram for Signal Processing

Feature extraction takes the high dimensional characteristic information into the low dimensional characteristic by the method of mapping or transformation. However, getting more features does not always mean better as the number of characteristic parameters is not proportional to recognition rate.

The feature selection process chooses valuable features from extractive, and deletes worthless features by some kinds of the regulation of classification. Due to this, the dimensionality of the feature space will be compressed strangely. The capability of the feature extraction and the rationality of the feature selection will influence the

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recognition rate. Next section discusses the list of features that are extracted from the input acoustic signal.

III. EXPERIMENTATION AND RESULTS

Feature extraction is the most important step in audio classification. The discussed six features are calculated for all the 10 signals shown in Annexure I. For each of the feature sequences, a simple statistic ie, the standard deviation value is calculated. Those statistic values are the final feature values that characterize the input audio signal. The features considered here are [8, 9, 10],

i) Short-time Energy
ii) Entropy
iii) Spectral Flux
iv) Spectral Centroid
v) Spectral Rolloff
vi) Zero-crossing rate

i) **Short-Time Energy (E):** The short-time energy of a frame is defined as the sum of squares of the signal samples normalized by the frame length. This is shown in the equation 1.

$$E = \left(\frac{1}{N} \sum_{n-0}^{N-1} x(n) \right) ------(1)$$

ii) **Entropy:** The entropy is the measure of information content, which is interpreted as the average uncertainty of information source. It is calculated as the summation of the products of the probability of outcome multiplied by the log of the inverse of the outcome probability, taking into considerations of all possible outcomes {1, 2, …, n} in the event $\{x^1, x^2, \ldots, x^n\}$, where 'n' is the number of frames; p(i) is the probability distribution, considering all histogram counts. It is formulated as (2).

$$E(x) = -\sum_{i=1}^{k} p(i) \log_2(p(i)) ------(2)$$

iii) **Spectral Flux:** Spectral Flux is a measure of how quickly the power spectrum of a signal is changing. The Spectral Flux method of onset detection measures the change in magnitude of the power of the entire spectrum across consequent spectrums. If there is a transient or a sudden attack, the change in energy will be denoted by a jump in the difference of energy between consequent spectrums. Shown in equation 3.

$$SF(n) = \sum_{k=-N/2}^{(N/2)-1} H(|X(n,k)| - |X(n-1,k)|) --(3)$$

It is important to note that after taking the difference in the spectrums, a positive difference value indicates a rise in energy while a negative difference value indicates a dip in energy.

iv) **Spectral Centroid:** The Spectral Centroid is a measure used in digital signal processing to characterize a spectrum. It indicates where the "center of mass" of the spectrum is. Perceptually, it has a robust connection with the impression of "brightness" of a sound. It is calculated as the weighted mean of the frequencies present in the signal, with their magnitudes as the weight:

$$Centroid = \frac{\sum_{n=0}^{N-1} f(n)x(n)}{\sum_{n=0}^{N-1} x(n)} ------(4)$$

where x(n) represents the magnitude of bin number n, and f(n) represents the center frequency of that bin.

v) **Spectral Rolloff (R):** This feature measures the frequency below which a specific amount of the spectrum magnitude resides. It measures the "skewness" of the spectral shape. The Rolloff point is calculated as,

$$SR = \max_m \left\{ \sum_{k=0}^{m} |X_t[k]| \le TH. \sum_{k=0}^{N-1} |X_t[k]| \right\} --(5)$$

where the threshold, TH, takes values between 0.85 and 0.99.

vi) **Zero-crossing rate:** The zero-crossing rate is the rate of sign-changes along a signal, i.e., the rate at which the signal changes from positive to negative or back. This feature has been used heavily in both speech recognition and music information retrieval and is defined formally as,

$$zcr = \frac{1}{T-1} \sum_{t-1}^{T-1} \amalg\{s_t s_{t-1} < 0\} ------(6)$$

where 's' is a signal of length 'T' and the indicator function is 1 if its argument 'A' is true and 0 otherwise.

Below table I and table II shows the feature values and time elapsed to calculate for all the 10 acoustic signals.

TABLE I. FEATURE VALUES FOR 10 SIGNALS

Signals	Short Time Energy	Entropy	ZCR	Centroid	Roll Off	Flux
Signal 1	0.0723	0.1754	0.0506	0.0562	0.0231	2.7858
Signal 2	0.0186	0.1335	0.0595	0.0488	0.0463	3.7177
Signal 3	0.0125	0.0357	0.0126	0.0102	0.0231	2.4175
Signal 4	0.08	0.1021	0.0214	0.0175	0.0463	1.1708
Signal 5	0.0318	0.1735	0.0199	0.0255	0.0231	1.6348
Signal 6	0.0743	0.0476	0.0367	0.0259	0.0463	2.7233
Signal 7	0.0381	0.1744	0.0065	0.0152	0.0116	0.8164
Signal 8	0.0419	0.0356	0.0032	0.0148	0.0116	0.1667
Signal 9	0.0173	0.0473	0.0088	0.0115	0.0231	1.5424
Signal 10	0.0277	0.1891	0.0206	0.0195	0.0116	2.5335

TABLE II. TIME ELAPSED TO CALCULATE THE FEATURE VALUES FOR 10 SIGNALS

Signals	Short Time Energy	Entropy	ZCR	Centroid	Roll Off	Flux
Signal 1	0.256274	0.263876	0.26299	0.340549	0.321249	0.560742
Signal 2	0.09992	0.100553	0.101612	0.114935	0.105902	0.261436
Signal 3	0.106958	0.062942	0.061365	0.06866	0.064562	0.090057
Signal 4	0.129357	0.074548	0.087715	0.110957	0.08849	0.197344
Signal 5	0.518841	0.416309	0.419753	0.46601	0.432826	0.66763
Signal 6	0.291019	0.169409	0.170486	0.224215	0.177422	0.488405
Signal 7	0.96466	0.894537	0.892899	0.990018	0.86047	0.987858
Signal 8	0.938364	0.922724	0.921545	0.988411	0.867896	0.989557
Signal 9	0.544324	0.182127	0.18141	0.196841	0.188928	0.279407
Signal 10	0.83293	0.838741	0.844865	0.920647	0.878769	0.910937

The above features are extracted from the signals and are given as inputs to the classification system. The above table shows the feature values for all 10 signals and time elapsed to calculate these features.

IV. CONCLUSIONS

The objective of this paper is to calculate the acoustic signal features which are used in the vehicular classification and it focuses feature extraction of the acoustic signal. Feature extraction is the key step for acoustic target recognition. Six different features of the acoustic signals calculated are Signal Energy, Energy Entropy, Zero-Crossing Rate, Spectral Roll-Off, Spectral Centroid and Spectral Flux. These features are extracted for all the signals and for each of the feature sequences the simple statistic standard deviation is calculated. This step leads to the identification of one statistic values for each feature sequence. These statistic values are the final feature values that characterize the input audio signal and it can be used in the classification system.

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ANNEXURE I

Acoustic Signals taken for Study