

Digital Watermarking Technique in Vehicle Identification using Wireless Sensor Networks

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Abstract—Wireless Sensor networks (WSN) is an emerging technology and have great potential to be employed in critical situations like battlefields and commercial applications such as building, traffic surveillance, habitat monitoring and smart homes and many more scenarios. This paper discusses about digital watermarking technique in vehicle acoustic signals for vehicle identification using Wireless Sensor Networks. Vehicle identification means, identifying the category of the vehicle. The assumed category here may be friend or foe. The Digital Watermarking technique has been introduced to make the vehicle acoustic signals authenticated. The vehicle acoustic signals belong to the friend category are authenticated using digital watermarking technique and the signals are embedded into digital watermarking technique to represent it uniquely. Here the step by step process of embedding the digital watermarking technique is discussed along with the results. Once the embedding of the digital watermarking technique is done, the resultant signals are further used for vehicle identification or classification.

Keywords- Wireless sensor networks, vehicle acoustic signal, digital watermarking, vehicle identification

I. INTRODUCTION

Vehicle Identification in Wireless Sensor network (WSN) is an important application in Battlefield surveillance. The development of wireless sensor networks was originally motivated by military applications like battlefield surveillance. However, Wireless Sensor Networks are also used in many areas such as industrial, civilian, Health, Habitat Monitoring, Environmental, Military, Home and Office application areas [3]. The Wireless Sensor Networks comprise of relatively inexpensive sensor nodes capable of collecting, processing, storing and transferring information from one node to another. These nodes are able to autonomously form a network through which sensor readings can be propagated. Since the sensor nodes have some intelligence, data can be processed as it flows through the network. Sensing devices will be able to monitor a wide variety of ambient conditions: temperature, pressure, humidity, soil makeup, vehicular movement, noise levels, lighting conditions, the presence or absence of certain kinds of objects, mechanical stress levels on attached objects and so on [7]. These devices will also be equipped with significant processing, memory and wireless communication capabilities. Emerging low-level and low-power wireless communication protocols will enable us to network these

sensors and it will add a new dimension to the capabilities of sensors. Sensors will be able to coordinate among themselves on a higher-level sensing task. Research on vehicle detection or identification using magnetic fields, images, and sounds have been conducted. Magnetic fields are able to detect the movement of vehicles successfully [8], but it is not appropriate for vehicle identification purposes. Magnetic sensors use the direction and magnitude of external magnetic fields for detection and classification that means the vehicle to be detected and classified must pass through the sensor. In conclusion, magnetic sensors are more appropriate when used with infrastructure support. Visual image processing is widely applied in vehicle identification. This approach, however, may not be suitable for sensor networks because a large volume of data needs to be processed and occupy more memory space as the sensor has only limited built in memory. Finally, vehicle identification using sound is the most promising approach. So the vehicle acoustic signals as a wav file can be used for vehicle identification. Vehicle identification identifies the category of the vehicle as friend or foe. The Digital Watermarking technique has been introduced to make the vehicle acoustic signals authenticated. Digital watermarking is the process of embedding information into a digital signal [10,2,9]. The vehicle acoustic signals belonging to the friend category are embedded with digital watermarking to represent it uniquely. The remaining of this paper is organized as follows. Section II describes the vehicle acoustic signals and its analysis. Section III gives the proposed method for embedding digital watermark into the vehicle acoustic signals. Section IV discusses the experimental results. Section V concludes the paper.

II. VEHICLE ACOUSTIC SIGNAL ANALYSIS

In this study, the acoustic signals are used as a source for vehicle identification. These acoustic signals are captured by the acoustic sensors mounted in the field as well as on the vehicle. The acoustic sensor in the Smart Dust sensor node is a condenser type microphone. The schematic for a typical condenser acoustic sensor [4] is shown in figure 1. It includes a stretched metal diaphragm that forms one plate of a capacitor. A metal disk placed close to the diaphragm acts as a backplate. A stable DC voltage is applied to the plates through a high resistance to keep electrical charges on the plates. When a sound field excites the diaphragm, the capacitances between the two plates vary according to the

variation in the sound pressure. The change in the capacitance generates an AC output proportional to the sound pressure, which is an ultra low-frequency pressure variation. A high-frequency voltage (carrier) is applied across the plates and the acoustic sensor output signal is the modulated carrier. The Figure 2 shows a typical vehicle acoustic signal waveforms.

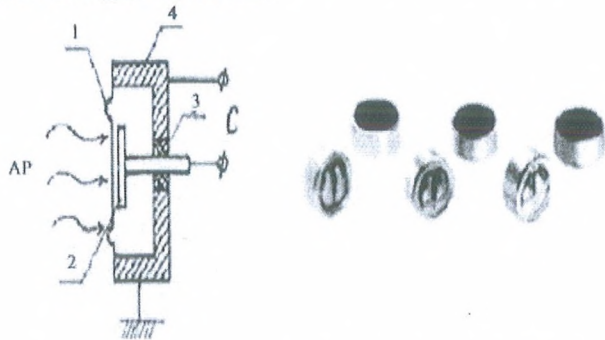


Figure 1. Condenser Microphone. AP-the acoustic pressure C-the variable capacitance; 1-the metal diaphragm; 2-the metal disk; 3-the insulator; 4-the case.

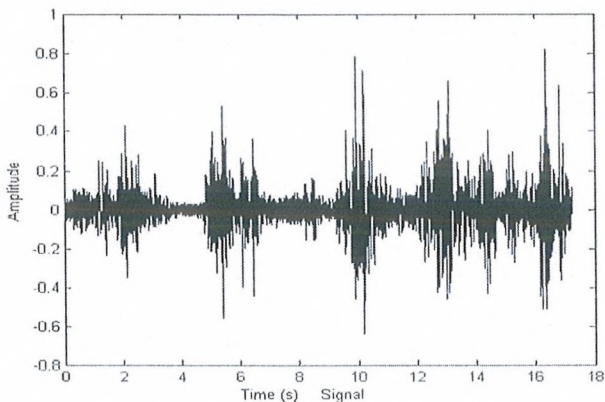


Figure 2. Waveforms of Acoustic Signals Emitted from a Truck

The acoustic signature is made up of a number of individual elements [6]. These include:

- Machinery noise: noise generated by a ships engines, propeller shafts, fuel pumps, air conditioning systems, etc.
- Cavitation noise: noise generated by the creation of gas bubbles by the turning of a ship's propellers.
- Hydrodynamic noise: noise generated by the movement of water displaced by the hull of a moving vessel. These emissions depend on a hull's dimensions, the installed machinery and ship's displacement. Therefore different vehicle classes will have different combinations of acoustic signals that together form a unique signature. Let X be the signal measured to make the signature to which the testing signals can be compared. Let Y be the sound of a vehicle to be identified. Sound data, X (or Y), are captured and divided into multiple sound frames, N (or P, respectively), where a sound frame, X_i (or Y_i) is a basic unit of this analysis [11].

Each sound frame, X_i (or Y_i), will be pre-processed in the following steps includes pre-processing by filtering noise, PSNR and MSE comparison and removing DC value which may be caused by the sensor device and environment. In Frequency Analysis, spectral analysis and FFT is done. Normalization is applied to the frequency spectrum to reduce the amplitude variation, and finally identification of the vehicle characteristic is done by calculating average and moving average. The following steps are applied to each X_i , which is the sound frame of each signal.

A. Pre-processing

The first and foremost step involved in pre-processing of the signal includes de-noising and removing DC (Direct Current) value.

De-noising:

Basically datasets are contaminated with noise, either because of the data acquisition process, or because of naturally occurring phenomena. A first pre-processing step in analysing such datasets is de-noising, that is, estimating the unknown signal of interest from the available noisy data. There are several different approaches to de-noise the signals. Here there are three different filtering methods have been used to remove the noise from the vehicle signal. Those are Median Filter, Wiener Filter and 1 D Digital Filter.

1) Median Filter

The Median filter is the simplest filter that relies on median of the data instead of mean. The median of the set is more robust with respect to the presence of noise. It is observed that after sufficient iterations, every signal converges to a root signal. Equation 1 shows the formula for median filter.

$$\text{Medianfilter}(x_1 \dots x_N) = \text{Median}(\|x_1\|_2, \dots, \|x_N\|_2) \quad (1)$$

Wiener Filter

The Wiener Filter performs two-dimensional adaptive noise-removal filtering and it estimates the local mean and variance for the signal. Its purpose is to reduce the amount of noise present in a signal by comparison with an estimation of the desired noiseless signal. The goal of the Wiener filter is to filter out noise that has corrupted a signal. It is based on a statistical approach. The input to the Wiener filter is assumed to be a signal, $s(t)$, corrupted by additive noise, $n(t)$. The output, $S'(t)$ is calculated by means of a filter, $g(t)$, using the convolution equation 2.

$$S'(t) = g(t) * (s(t) + n(t)) \quad (2)$$

where $s(t)$ is the original signal (to be estimated) $n(t)$ is the noise $S'(t)$ is the estimated signal $g(t)$ is the Wiener filter's impulse response.

2) 1 D Digital Filter

It uses digital filter for the data sequence which works for both real and complex inputs. Equation 3 shows the formula for 1D digital filter.

$$y(n) = b(1)*x(n) + b(2)*x(n-1) + \dots + b(nb+1)*x(n-nb) - a(2)*y(n-1) - \dots - a(na+1)*y(n-na) \quad \text{--- (3)}$$

where 'n-1' is the filter order, which handles both Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters, 'na' is the feedback filter order and 'nb' is the feed forward filter order.

3) Comparison of Filters

The performances of the filters are compared using Peak signal-to-noise ratio (PSNR) and Mean Squared Error (MSE). PSNR is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale. The signal in this case is the original data, and the noise is the error introduced by compression. When comparing compression codecs, it is used as an approximation to human perception of reconstruction quality, therefore in some cases one reconstruction may appear to be closer to the original than another, even though it has a lower PSNR. A higher PSNR would normally indicate that the reconstruction is of higher quality.

The range of validity of this metric is most easily defined via the mean squared error (MSE) which for two m×n monochrome signal X and Y, where one of the signal is considered a noisy approximation of the other. Equations 4 and 5 are used to calculate MSE and PSNR respectively.

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \|X(i, j) - Y(i, j)\|^2 \quad \text{--- (4)}$$

$$PSNR = 10 \cdot \log_{10} \left(\frac{MAX_x^2}{MSE} \right) \quad \text{--- (5)}$$

The performances of the three filters are compared for ten acoustic signals.

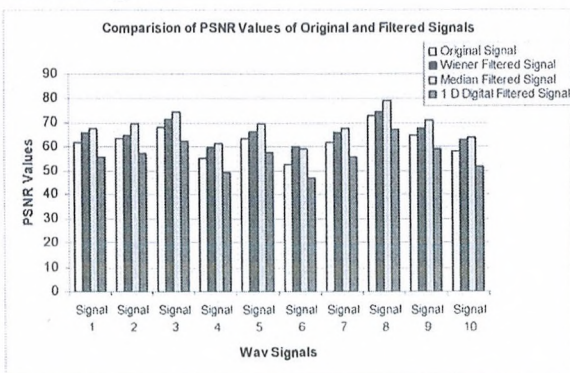


Figure 3. Comparison of PSNR values of acoustic signals

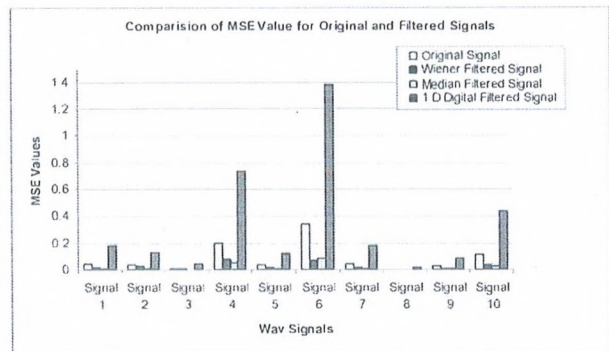


Figure 4. Comparison of MSE values of acoustic signals

From the figure 3 and figure 4, it can be observed that median filter is the most suited one compared to other filters in removing noise from acoustic signals. The MSE value should be low and the PSNR value should be high for the efficient performance. So the acoustic signals filtered through median filter are further used for embedding digital watermarking technique.

III. PROPOSED METHOD FOR EMBEDDING DIGITAL WATERMARK

Digital watermarking technology allows users to embed data into digital contents such as text, still images, video and audio data [1]. In this paper, the signals belong to friend category are inserted with digital watermark. The signals that belong to different category don't have this digital watermark. The insertion of watermarking into acoustic signals is represented as below:

$$X' = E_k(X, W) \quad \text{--- (6)}$$

where X is the pre-processed original signal, W is the watermark information being embedded, k is the user's insertion key (Watermark Parameter), and E represents the watermark insertion function, X' is the resultant signal. The different types of watermarks used [1,2,10] are classified as shown in figure 5.

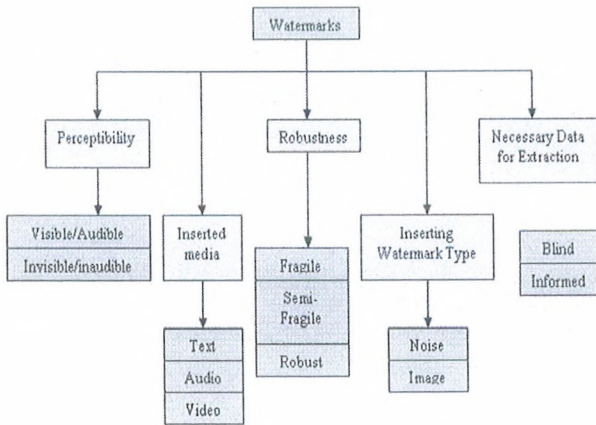


Figure 5. Types of Watermark

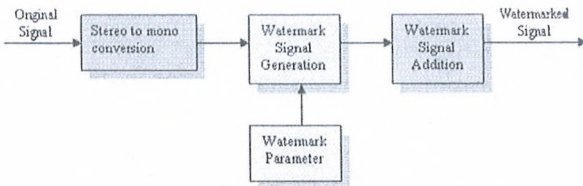


Figure 6. Proposed Watermark Insertion Process

In this study, the inserted watermark type is noise and the inserted media is audio acoustic signal. The proposed insertion process is shown in figure 6. In this proposed watermark insertion process there are four stages. Original signal is nothing but a vehicle acoustic signal captured by the acoustic sensors mounted in the field. This signal is included into stereo to mono conversion. A separate watermark signal is generated by using the watermark parameter. This generated watermark signal is added to the original signal in order to make it unique. The figure 7 (a) and (b) shows the original and digital watermark inserted acoustic signals. After inserting watermark technique the signal is treated as that of the friend vehicles.

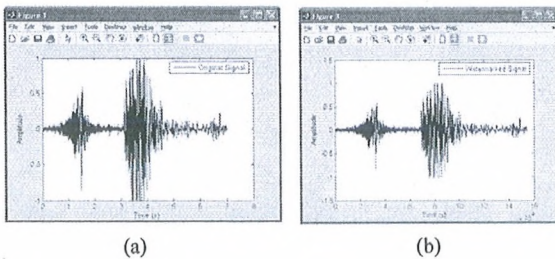


Figure 7. (a) Before embedding Digital watermark (b) After embedding Digital Watermark

IV. EXPERIMENTATION AND RESULTS

Acoustic signals that belong to 10 vehicles are taken into consideration shows in Annexure I. Watermarking is embedded for all the 10 signals. After embedding, PSNR (Peak-signal-to-noise-ratio) and MSE (Mean Square Error) are compared for both original and watermark embedded signals. Here, the watermark is noise, the figure 8 and figure 9 show the PSNR and MSE values for both the original signal and the watermarked signal. It is clearly shown that there is no difference after adding the watermark. So this approach will not affect the nature of the signal captured through the sensors.

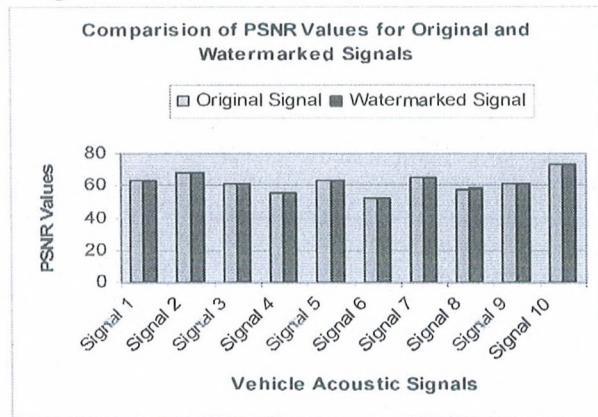


Figure 8. Comparison of PSNR values for Original and Watermarked signals

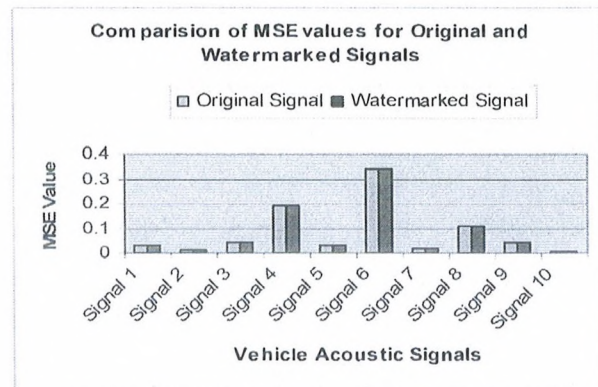


Figure 9. Comparison of MSE values for Original and Watermarked

V. CONCLUSIONS

This paper discusses about embedding digital watermarking technique in vehicle acoustic signals for vehicle identification. Vehicle identification means, identifying the category of the vehicle. The assumed category here may be friend or foe. The Digital Watermarking technique has been introduced to make the vehicle acoustic signals authenticated. The vehicle acoustic signals belong to the friend category are authenticated using digital watermarking technique. This process of embedding

the digital watermarking technique into acoustic signals shows that there is not much disturbance in the signal. Comparatively, the graphs shows that there is only a minimum peak signal to noise ration is decreased and mean square error is increased in the watermarked signal. Once the embedding of the digital watermarking technique is done, the resultant signals are further used for vehicle identification

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ANNEXURE I

Acoustic Signals taken for Study

