Initial Evaluation of Low Power Vehicle Detection System utilizing Discrete Wavelet Transform

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***Abstract*—Vehicle detection is one of the fundamental tasks in the intelligent transportation system (ITS). We have developed an acoustic vehicle detection system which successfully detected the vehicle and direction of travel with an F-measure of 0.92. However, the power consumption of the system is high, which puts power restrictions on deployment. We therefore propose a low power vehicle detection system, which is a combination of the acoustic vehicle detection system presented in our previous work and a newly developed ultra low power vehicle detector(ULP-VD). Initial experimental evaluations reveal that the ULP-VD successfully detected vehicles with a precision of 0.94 and recall of 0.95.**

***Index Terms*—ITS (intelligent transport system), DWT (discrete wavelet transform), Logistic Regression, Vehicle Detection.**

I. Introduction

Vehicle detection is one of the fundamental tasks in the intelligent transportation system (ITS). We are developing an acoustic vehicle detection system using microphones installed at a sidewalk [1, 2]. Our system detects vehicles using the sound generated from tires during vehicle running. Because sound waves are diffracted over obstacles, we can deploy microphones in a low height configuration, which drastically reduces roadwork cost in terms of road closure as well as safety installation. Experimental evaluations revealed that our vehicle detection method successfully detected vehicles with an F-measure of 0.92.

The acoustic vehicle detection system, however, consumes much power requiring a power cable or a big battery for 24/7 operation. The system relies on a sound map that is generated with much computation including image processing and convolutional integral, putting difficulties on power reduction. Power saving is one of the most important tasks to apply the vehicle detection system to an environment with limited power resources.

We therefore propose a low power vehicle detection system, which is a combination of a high performance vehicle detector (HP-VD) and a newly developed ultra low power vehicle detector (ULP-VD). The experiment results reveal that our ULP-VD successfully detected vehicles with a precision, recall of 0.94, 0.95, respctively.

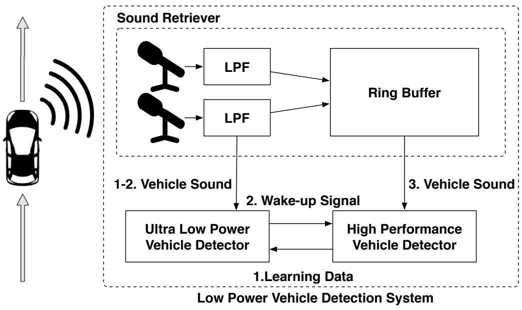

Fig. 1. Overview of low power vehicle detection system

II. Low Power Vehicle Detection System

A. Overview

Fig. 1 shows an overview of a low power vehicle detection system, which consists of three blocks: a sound retriever, HP-VD, and ULP-VD. Average power consumption is successfully reduced by employing wake-up scheme: the HP-VD is activated only when vehicles are detected by the ULP-VD. We implement the ULP-VD on an ultra low power MCU such as MSP430 to reduce power consumption because the ULP-VD is always activated.

The sound retriever consists of two microphones followed by low-pass filters (LPFs) and a ring buffer. The LPF reduces influences of environmental noise. The main component of vehicle passing sound is no more than 2.0 kHz [3]. The cut-off frequency of the LPF is therefore set to 2.5 kHz with a 0.5 kHz margin. Low-pass-filtered sound signals are then stored in the ring buffer.

The ULP-VD retrieves sound signals from one microphone of the sound retriever. The sound data is divided with a time-window. The windowed data is analyzed using discrete Wavelet transform (DWT) to detect vehicles. The ULP-VD wakes HP-VD when a vehicle is detected.

In the following subsections, we describe the ULP-VD because the HP-VD has been presented in our previous papers.

B. Ultra Low Power Vehicle Detector

Fig. 2 shows an overview of the ULP-VD, which consists of three components: a discrete Wavelet transform (DWT) block, logistic regression block, and thresholding block. We employ

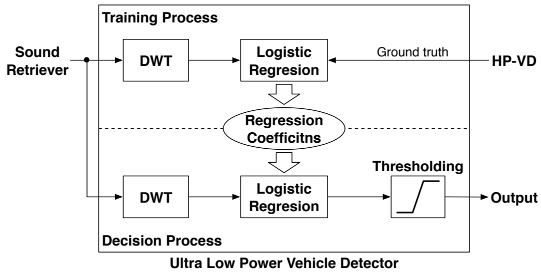

Fig. 2. Overview of ultra low power vehicle detector

machine learning using logistic regression, which consists of training and decision processes.

In a training process, the DWT block analyzes time-frequency components of sound signals and extract feature values. The feature values are then passed to logistic regression as training data to create a regression model; regression coefficients are calculated. Ground truth, i.e., labels for training is derived a high performance vehicle detector (HP-VD), as shown in Fig. 1.

In a decision process, feature values are again extracted from DWT analysis results. Logistic regression block calculates probability of existence of vehicles with the regression coefficients derived in the training process. We finally apply a threshold to the probability to determine if the vehicle is passing in front of microphones.

III. Initial Evaluation

As an initial evaluation, we conducted experiments to evaluate basic performance of the ULP-VD. Figure 3 shows experiment instruments. A target road has two lanes, one lane in each direction. Two microphones were installed approximately two meters away from the road center separated by 50 centimeters at a height of one meter. We recorded vehicle sound for approximately 30 minutes using a Sony HDR-MV1 recorder with AZDEN SGM-990 microphones. The sound was recorded with a sampling frequency of 48 kHz and with a word length of 16 bits. Video monitoring the target road was also recorded as ground truth data. Although we installed the two microphones for HP-VD, one of the microphones was used for ULP-VD evaluations in this paper.

Table I shows the experimental results of precision, recall and F-measure. We can confirm that the ULP-VD successfully

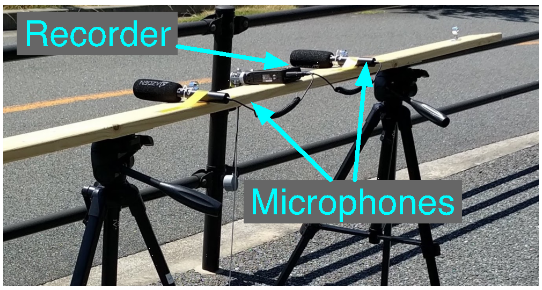

Fig. 3. Experiment instruments

TABLE I
Evaluation Results

TPs	FNs	FPs
735	37	45
Precision		0.94
Recall		0.95
F-measure		0.95

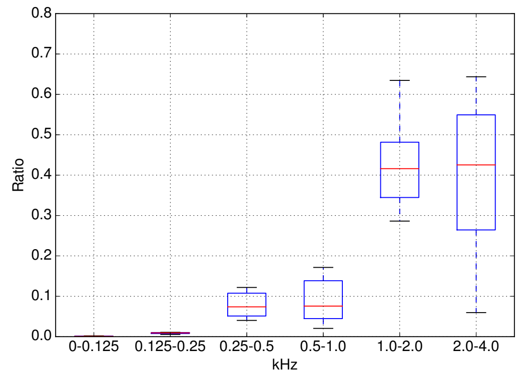

Fig. 4. Influence of each frequency component on vehicle judgment (using feature values obtained by 5 decomposition level Haar wavelet transform for the time-window of 128, 256, 512, 1024, 2048, 4096)

detected vehicles with a precision of 0.94 and recall of 0.95. Figure 4 shows the influence of each frequency component on vehicle detection. The importance of the frequency component of 1.0 kHz to 4.0 kHz was high, and this trend was confirmed in other decomposition levels and time-window.

IV. Conclusion

This paper presents a low power vehicle detection system. The ULP-VD using the discrete Wavelet transform (DWT) and logistic regression was newly developed, which can be implemented on a low power MCU. We conducted experiments in our university to evaluate the basic performance of the ULP-VD. Initial experimental evaluations reveal that the ULP-VD successfully detected vehicles with a precision of 0.94 and recall of 0.95.

Acknowledgment

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