Blind Vehicle's Sound Detecting Technique for Advanced Safety-Driving System

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***Abstract*—Automobile makers have been developed and commercialized safety-driving systems to reduce the number of traffic accidents, especially with cameras or radars. This paper presents a new vehicle detecting system in a blind spot, which identifies the diffracted sound emitted from the blind vehicles behind obstacle. We show that our system works efficiently in a noisy real environment.**

I. INTRODUCTION

In recent years, automobile makers make a lot of efforts to develop safety-driving systems in order to reduce the number of traffic accidents. Some makers have commercialized the system of detecting approaching vehicles with cameras or radars [1]. However, nearly 40% of all vehicle crashes in Japan occur in a blind spot [2], and these systems are difficult to deal with vehicles in a blind spot.

This paper describes a new vehicle detecting system in a blind spot. Our system detects the diffracted sound, which is emitted from vehicles in a blind spot. In a real environment vehicle's sound is corrupted with ambient noise, and it is very challenging to detect specific sound in a noisy environment [3], [4].

We introduce a new concept of phase time trajectory (PTT). PPT represents an inherent feature of sound and makes it possible to identify vehicle's sound (engine sound and siren sound) corrupted with ambient noise (background noise, wind noise, and rain noise).

II. BLIND VEHICLE DETECTING SYSTEM

Our blind vehicle detecting system sets on a vehicle to detect the other vehicles in a blind spot. Fig. 1(a) shows the conditions of detecting a blind vehicle. In this case, there is a wall between two vehicles and it is incapable of identifying the other vehicle's existence with cameras or the drivers' eyes.

Fig 2 shows the block diagram of our system. Firstly, the system transforms sound waveform of the detected vehicle into the time-frequency domain's signals, and calculates phase time trajectory (PTT). Here, PTT is a time varying of sound's phase, and the feature of PTT is different between vehicle's sound and ambient noise. Secondly, only the vehicle's sound is extracted by using the feature of PTT. We explain the detailed technique in the next section. Finally, the direction of detected vehicle is calculated with a conventional cross-correlation method [3]. We calculate the vehicle's direction from the time delay between two microphones of the extracted vehicle's sound. Fig. 1(b) shows that our system detects the blind vehicle's direction successfully. In this case, engine sound of the blind vehicle is detected from the corrupted

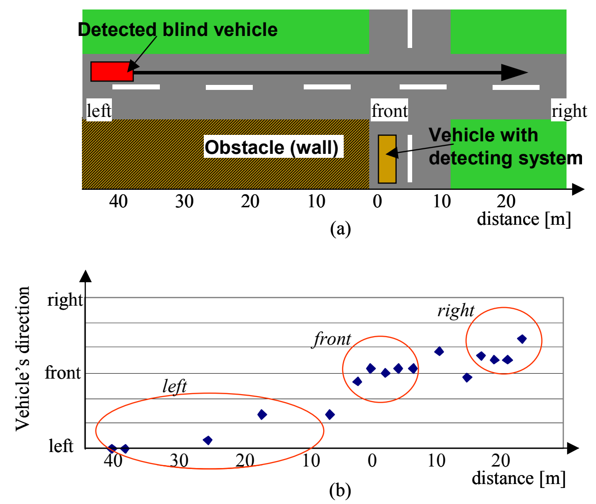

Fig. 1. Conditions of detecting blind vehicle (Fig. 1(a)), and resulting detecting vehicle's direction in a real environment (Fig. 1(b)). Engine sound of the blind vehicle is detected from the corrupted sound with wind noise (Wind velocity is 6m/s).

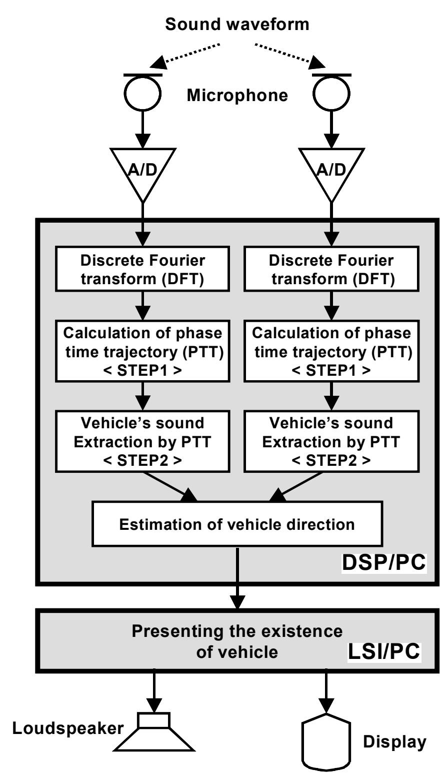

Fig. 2. The block diagram of blind vehicle detecting system.

sound with wind noise, and wind noise is non-stationary.

III. VEHICLE'S SOUND DETECTION

We propose a new sound extracting method based on phase time trajectory (PTT) to deal with moving sound sources corrupted with non-stationary noise, and dealing with this condition is very challenging.

PTT is defined as a time varying of the phase, which is the displacement from the phase of a specific reference of sinusoidal wave of analyzed frequency. The feature of PTT of a specific sound does not change in the time-frequency region, and PTT is independent of amplitude. Therefore, our extracting technique can deal with non-stationary noise. And also, we can identify the difference of PTT between vehicle's sound and ambient noise using short period of sound, and it is applicable to detecting the moving vehicles on real-time.

Our sound extracting method consists of two steps. Firstly, PPT is calculated as

$$\varphi(f,t) = \text{mod}_{2\pi}\,(\theta(f,t) - 2\pi f t)\,, \qquad (1)$$

where $\theta(f,t)$ [rad] is the phase calculated from frame-by-frame discrete Fourier transform (DFT), and f [Hz] and t [sec] denotes frequency and the analysis time of short-time discrete Fourier transform, respectively. Fig. 3 shows the examples of PTT of vehicle's sounds (engine sound and siren sound), and is almost constant over time. On the other hand, PTT of the ambient noise (background noise, wind noise, and rain noise) is fluctuated over time in Fig. 4. Secondly, vehicle's sound is extracted by identifying the time-frequency regions of PPT, which is constant over time as follows:

$$\sigma(f,t) = \frac{1}{T}\int_0^T \sqrt{(\varphi(f,\tau) - \overline{\varphi}(f,\tau))^2}\,d\tau \le A\,, \qquad (2)$$

where $\overline{\varphi}(f,t)$ is the mean value of $\varphi(f,t)$ over T duration. Fig. 5 shows the vehicle's sound extracting results, and engine sound of the blind vehicle is detected from the corrupted sound with wind noise (Wind velocity is 6m/s).

IV. CONCLUSION

In order to detect the blind vehicles, we identify the diffracted sound emitted from the blind vehicles. In a real environment, the vehicle's sound is corrupted with ambient noise. This paper shows that our system with the concept of phase time trajectory (PTT) works efficiently to detect the blind vehicle's sound in a noisy environment.

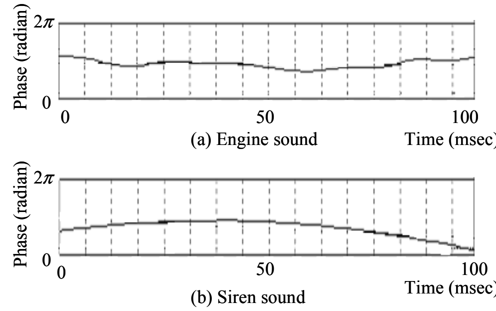

Fig. 3. Phase time trajectory (PTT) of vehicle's sound. (a) PTT of engine sound and (b) PTT of siren sound. are described.

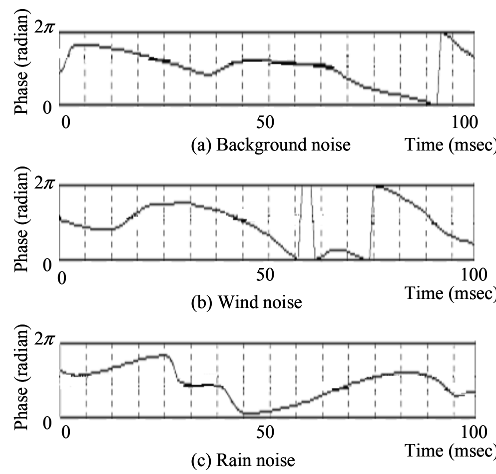

Fig. 4. Phase time trajectory (PTM) of ambient noise. (a) PTT of background noise, (b) PTT of wind noise, and (c) PTT of rain noise are described.

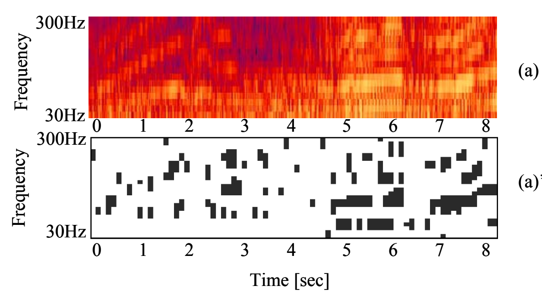

Fig. 5. Spectrogram and vehicle's sound extracting results of engine sound corrupted with wind noise. (a) is spectrogram and (a)' is extracting results of engine sound.

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