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Development of an Autonomous Vehicle Equipped with a Broadband Ultrasonic Sensor (Thermophone) for Engineering Verification of the Bats Jamming Avoidance Behavior

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1 Introduction

Bats grasp their spatial environment by echolocation, through which they emit ultrasonic pulses and listen to echoes from their surroundings. Based on previous behavioral studies, it has been reported that bats avoid acoustic jamming during group flight with conspecifics by increasing the difference in the terminal frequency (TF) of the downward frequency modulated (FM) pulse they emit (i.e., frequency adjustment behavior) [1, 2]. In this study, a thermophone [3], a thermoacoustic transducer capable of emitting broadband ultrasonic pulses similar to those emitted by bats, was mounted onto an autonomous vehicle. The purpose was to implement a mathematical model of the bats frequency adjustment behavior in a robot. The effectiveness of the model was verified and evaluated.

2 System configuration for a thermophone-equipped autonomous vehicle

2.1 Ultrasonic Sensing System

Figure 1A shows the autonomous vehicle used in this study, equipped with a thermophone and two MEMS microphones (SPU0410LR5H-QB; Knowles, Itasca, IL, USA). A small computer (Raspberry Pi® 4, Cambridge, UK) and field programable gate array board (EDX-302; HuMANDATA Ltd., Osaka, Japan) were used to control the system via cross-correlation processing of the emitted pulse and echoes. GoPiGo3 (Dexter Industries, Stafford, VA, USA) provided driving control. The transmitted signal from the thermophone mimics the FM pulse of bats [4]; we confirmed that the signal could be emitted from the thermophone (Figures 1B and C).

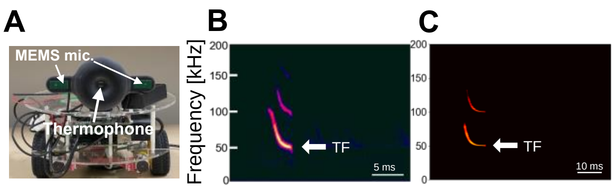

Figure 1: (A) Picture of an autonomous vehicle. Spectrograms of frequency modulated (FM) pulses emitted by bats (B) and the thermophone (C).

2.2 Frequency adjustment algorithm

In bat-mimetic FM pulses, it has been reported that if the TFs differ by about 1 kHz, the correlation between signals decreases significantly, which enhances the ability to avoid acoustic jamming [1]. Based on the bats frequency adjustment behavior observed in group flight experiments [2], we constructed an algorithm that changes the TF of its own ultrasonic pulses according to the frequency of receiving TFs lower than its own. Specifically, the TF of the next emitted pulse is determined from the integral value of the received signal spectrum below its own TF using our model [5], which was inspired by the capacitor charge–discharge model.

3 Method

The running area (1.5 m × 1.5 m) was surrounded by obstacles (plastic poles; diameter: 120 mm). Four immobile vehicles generating jamming signals (55–95 kHz, bat-mimetic FM pulses) were placed at four corners (Figure 2). The running vehicle operated under three conditions: no jamming (Condition 1) and jamming without and with the frequency adjustment algorithm in the running vehicle (Conditions 2 and 3, respectively). Each condition was tested 10 times, and the results were evaluated based on the error of the point at which the running vehicle was localized.

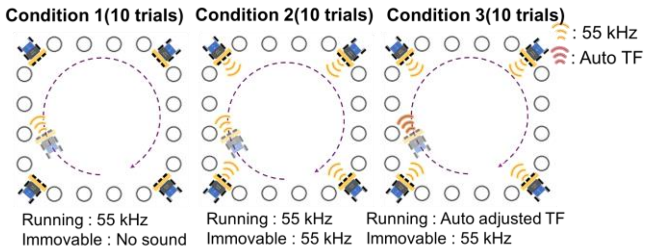

Figure 2: Obstacle avoidance drive with three jamming conditions for the autonomous vehicle.

4 Result

In Condition 3, with the frequency adjustment algorithm, it was confirmed that the running vehicle changed its own TF according to the integral value of the received signal spectrum below its own TF (Figure 3). Figure 4A is an example of a spectrogram of the received signal by the running vehicle when the immobile vehicles emitted a jamming pulse with the same TF as that of the running vehicle in Condition 2. The cross-correlation results of its own pulse and the jamming pulse showed a high correlation due to the jamming pulse from the immobile vehicle. As a result, the running vehicle was confused by its own echoes, resulting in incorrect localization at a point where there was no obstacle. On the other hand, in Condition 3, where the frequency adjustment algorithm was implemented, a small difference in the TF effectively removed the correlation peaks with the jamming pulses from the immobile vehicle (Figure 4B). As a result, the localization error was reduced under Condition 3, compared with that of Condition 2, in which the frequency adjustment algorithm was not implemented. The localization performance was similar to that of Condition 1, a no-jamming environment. These results demonstrate that the bats frequency adjustment behavior can also be useful in engineering systems.

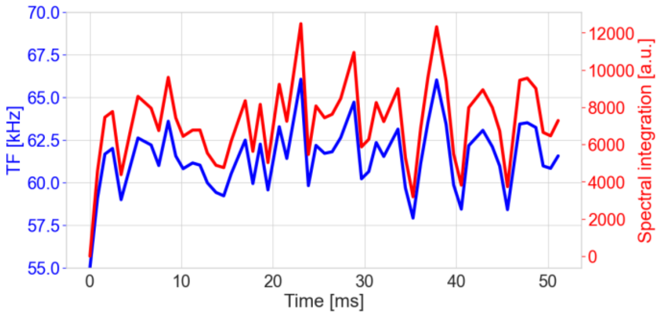

Figure 3: Temporal changes in the TFs and the spectral integration of signals received by the autonomous vehicle.

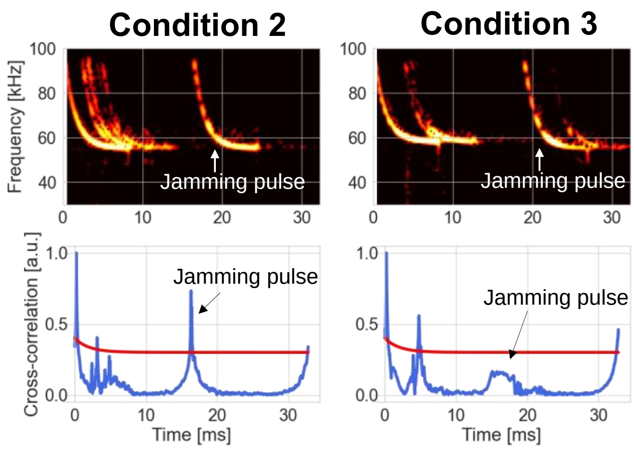

Figure 4: Spectrograms (top) and cross-correlation (bottom) of the received signals without (Condition 2) and with (Condition 3) the frequency adjusted algorithm.

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References

[1] Hase, K, Miyamoto, T, Kobaysi, I. K, Hiryu, S, "Bats enhance their call identities to solve the cocktail party problem", *Communications Biology*, VoL1, pp.39, 2018.

[2] Hase, K, Kadoya, Y, Maitani, Y, Miyamoto, T, Kobayasi, I. K, Hiryu, S, "Rapid frequency control of sonar sounds by the FM bat, Miniopterus fuliginosus, in response to spectral overlap", *Behavioual Processes*, VoL128, pp.126-133, 2016.

[3] Nishioka, T, Teshima, Y, Mano, T, Sakai, K, Asada, T, Matsukawa, M, Ohta, T, Hiryu, S, "Ultrasound radiation from a three-layer thermoacoustic transformation device", *Ultrasonics*, VoL57, pp.84-89, 2015.

[4] Parsons, S., Jones, G, "Acoustic identification of twelve species of echolocating bat by discriminant function analysis and artificial neural networkds", *Journal of Experimental Biology*, VoL203, pp.2641-656, 2000.

[5] Hase, K, Oka, S, Sugihara S, Sumiya, H, Miyazaki, T, Kobayasi, I. K, Hiryu, S, "Simulation of echolocation behavior by group flying bats based on the response to artificial jamming sounds", *Japanese Society for Mathematical Biology*, 2021.