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Indoor Positioning in Large-scale Area using Multiple Acoustical Transponder Units

複数の音響トランスポンダユニットを用いる大規模空間における屋内測位

Hirokazu Iwaya‡, Koichi Mizutani, Tadashi Ebihara, and Naoto Wakatsuki
(Univ. Tsukuba)
岩谷洋和 [1‡]，水谷孝一 [1,2]，海老原格 [1,2] 若槻尚斗 [1,2]
([1] 筑波大院・シス情工, [2] 筑波大・シス情系)

1. Introduction

Indoor positioning is one of the topics of the great interest to realize indoor navigation or robot automation in a large-scale area such as shopping mall, inside building, or factory. Commonly, indoor positioning is achieved by measuring multiple distances among anchors of known positions and a terminal of unknown position using any modulated signals such as acoustical waves, infrared, or radio waves. In addition, to measure distances, ultrasounds are often used and they perform cost-effective accurate positioning whose errors are typically within 0.1 m [1-6]. However, there are two problems such as clock synchronization among devices and coverage area limit due to ultrasound attenuation in the air.

To cope with these problems, we proposed a transponder-based indoor positioning method using audible sound [7-8]. The proposed method has two advantages in following points, (i) it does not require clock synchronization among anchors (transponders) and terminal, (ii) it is suitable for the large-scale area since audible sound can cover a wide area. In the past, we designed acoustical transponder-based positioning method and evaluated performance using three transponders as one unit. The performance showed the error of 0.1 m in an anechoic chamber and a large room.

However, in the case of deployment of multiple transponder units in the large-scale area, the relationship of coverage positioning area and positioning accuracy had not yet been investigated. Therefore, the purpose of this study is to evaluate positioning performance in a large-scale area using audible sound and two transponder units.

2. Acoustical Positioning using Transponder Units in the Large-scale Area

2.1 System Overview

Figure 1 shows an overview of the experiment environment using transponder units. To achieve positioning of a terminal, multiple transponders as positioning units are installed on a ceiling in an indoor room. The terminal and each transponder consist of

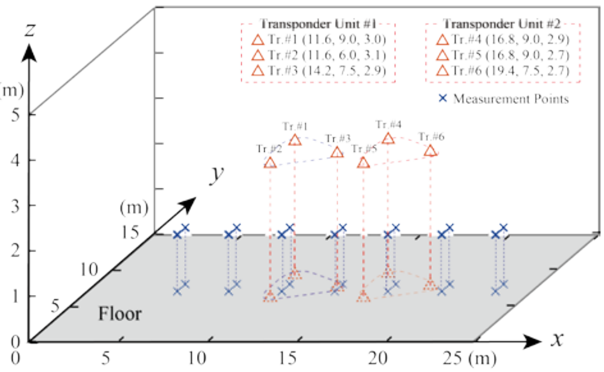

Fig. 1 Overview of experiment environment.

a pair of loudspeaker and microphone. The detail of the processing method for the positioning of the terminal is described in our previous studies [7- 8]. First, the terminal transmits a request signal to the transponders. When the transponders receive the request signal, after a constant delay time, they transmit response signals to the terminal. Then, the terminal receives response signals from the transponders. To perform positioning of the terminal, the terminal measures round-trip time-of-flights (TOFs) among the terminal and multiple transponders using the cross-correlation functions between the received response signals and the reference signals. Eventually, the terminal estimates own position by using multiple TOFs, position of the transponders, and trilateration method.

2.2 Coverage Positioning Area in a Large Room

In the case of the positioning of the terminal using multiple transponder units in a large room, the coverage positioning area and the positioning accuracy must be clarified. To confirm the coverage positioning area using transponder units, we assume three transponders as one transponder unit. In the following section, a basic positioning experiment was carried out using two transponder units in a gymnasium.

3. Experiment

The experimental system was set up in a gymnasium of 25 m (W) × 15 m (D) × 10 m (H) size.

A loud-speaker (P650K, Fostex), a microphone (c9767, DB Products Limited), an A-D/D-A converter (USB- 6221, National Instruments) and a personal computer (PC) were used as the terminal and the transponders. Calculation of the transmitting signal and processing of the received signal were performed on a measurement software (LabVIEW, National Instruments). The acoustical parameters, such as TOFs and position of the terminal were calculated by a software (MATLAB) on PC. We used a chirp signal (carrier frequency of 100 Hz to 20 kHz, signal length of 1 s) as the measurement signal. The sampling frequency of the A-D/D-A converter was 50 kHz. By using the above parameters, the positioning was performed by changing the position of the terminal for 14 patterns. In each position, the positioning was performed for 10 times.

Figures 2(a) and **(b)** show positioning results using each TOF from the transponder unit. The obtained results suggest that the errors of estimated terminal position were small in the near case of distance between the terminal and transponders. On the other hand, the errors of estimated terminal position were large in the far case of distance between the terminal and transponders.

Figures 3(a)-(c) show the error of the estimated terminal position and the actual terminal position on the *y*-axis. As shown in these figures, the errors of the terminal position become large. Assuming indoor navigation in the large-scale area, the error of the estimated terminal position was desired within 0.5 m. Therefore, the transponder unit should be located about 9.0- 12.0 m interval when the situation using a signal individually. As shown in **Fig. 3(c)**, the acoustical positioning using two transponder units achieved the error of 0.5 m in the range of 15 m by using nearer transponder unit information. As the experiment result, it was found that the acoustical positioning can cover more than 10 m area with sufficient accuracy. However, this experiment result was obtained in an ideal condition. In the actual environment, when the terminal receives multiple signals from transponders, the quality of TOFs might be deteriorated. If a handover method such as adopting TOFs from near transponder unit would be established, the acoustical positioning method can cover a large-scale area with sufficient positioning accuracy.

4. Conclusion

In this paper, a positioning performance in a large-scale area using audible sound and two transponder units was evaluated. The basic positioning experiment was carried out using a chirp signal in a gymnasium. It was found that in the ideal environment, acoustical positioning can achieve sufficient positioning using nearer TOFs information. Positioning experiments using multiple transponder units and implementing handover method for the large-scale area are our future works.

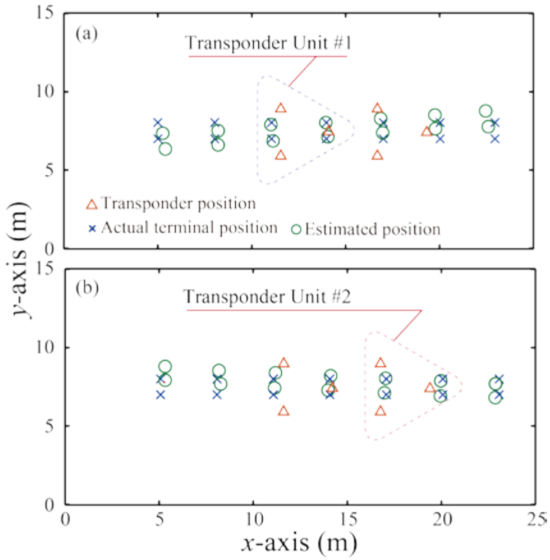

Fig. 2 Positioning result using TOFs from (a) transponder unit #1 and (b) #2.

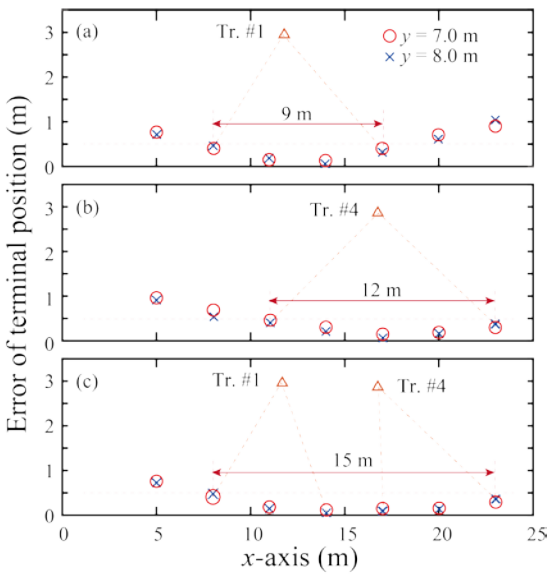

Fig. 3 Error of terminal position obtained from TOFs of (a) Transponder unit #1, (b) Transponder unit #2, and (c) using nearer (a) or (b) versus actual terminal position on *y*-axis.

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