POSITIONING SYSTEM FOR MOBILE TERMINALS USING A MICROPHONE ARRAY NETWORK AS AN INTUITIVE INTERFACE

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ABSTRACT

Physical positions are quite useful to realize an intuitive interface for communication among mobile terminals. We propose the placement of a microphone array on mobile terminals and the use of a network as an intuitive interface. The mobile terminals can obtain their relative positions by emitting a sound, which facilitates estimation of the directions of arrival (DOAs) among them. We produced a prototype using a tablet PC, 16 microphones, and an FPGA board. Then, we implemented two applications, exploiting the positioning system to elucidate its wider possibilities.

Index Terms—Microphone array, mobile terminal, network, sound source localization

1. INTRODUCTION

These days, mobile terminals such as smart phones and tablet PCs are rapidly coming into widespread use. Many network application programs operate on mobile terminals. However, they cannot exploit their positional relation—their relative directions and distances—because sensors on mobile terminals, network equipment such as Wi-Fi, and global positioning systems (GPS) cannot provide accurate position information at close range.

We propose implementation of a microphone array on a mobile terminal and communication of its positional information in a network. By emitting a sound from a terminal and localizing the sound source, a positional relationship is obtainable [1, 2], thereby enabling direction of arrival (DOA) estimation. In our proposal, a mobile terminal is able to recognize relative positions with the DOA (Fig. 1). It is possible to obtain the positional relations by exchanging the DOAs through a network.

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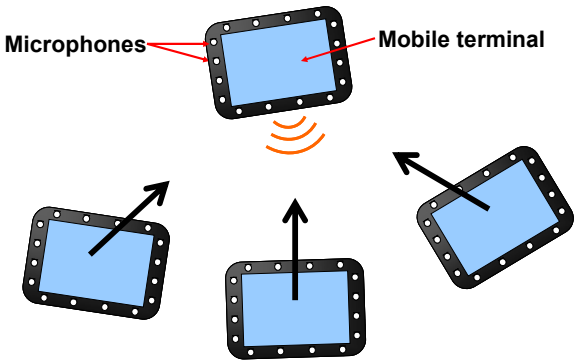


Fig. 1. Direction of arrival (DOA) estimation using a microphone array on a mobile terminal.

2. APPROACH

Positional relations among terminals are resolved using the following procedure. 1) A terminal emits a sound and broadcasts its name to other terminals. 2) While the terminal is emitting the sound, the other terminals estimate the DOA using the multiple signal classification (MUSIC) algorithm [3]. 3) Another terminal emits a sound in turn and obtains the DOAs from all terminals. 4) Their positional relations are obtainable by exchanging and calibrating the DOAs.

3. PROTOTYPE IMPLEMENTATION

As presented in Fig. 2, we made a prototype using a tablet PC (TW317A5; Onkyo Corp.), 16 microphones, and an FPGA board (SZ410 Suzaku; Atmark Techno Inc.) to evaluate the proposed system. The microphone array, formed on the tablet PC, connects to the FPGA board. The microphone interval is set to 5 cm. The DOA estimation module is implemented on the FPGA as hardware. The DOA result is fed to the tablet PC through a USB. When estimating DOAs, 500Hz sine wave is emitted for 3 seconds from the tablet PC.

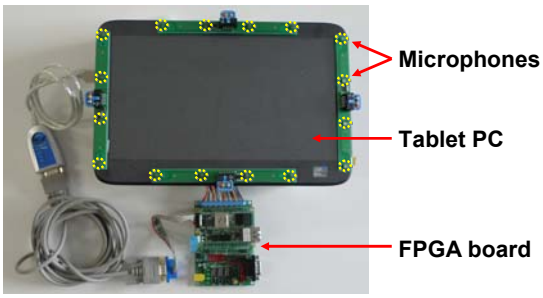
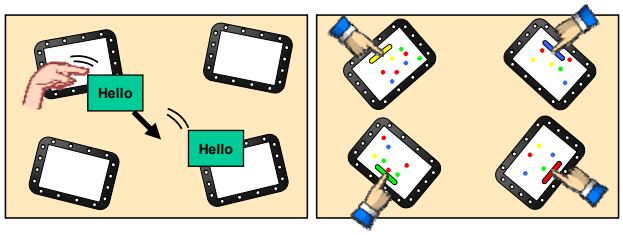


Fig. 2. Prototype.



(a) Intuitive messenger (b) Multiplayer hockey game

Fig. 3. Two applications.

4. APPLICATIONS

We implemented two application programs to exhibit the proposed system and its feasibility as an intuitive interface.

4.1. Intuitive messenger

Email and instant messaging services, which are often used to exchange messages among mobile terminals, require an email address and some specification of the destination every time they are used, even if a receiver is immediately in front of a sender. Our messaging application requires no such complicated routine. It works well on a table with several devices, allowing the intuitive exchange of messages using positional relations. In our messenger application, messages are sent by dragging them toward the destination, as illustrated in Fig. 3(a). This can make it easier to append another message or forward it to another destination.

4.2. Multiplayer hockey game

Messenger applications merely use angle information. However, a multiplayer hockey game requires angle and distance information. In this application example, four players hit multiple balls to opponents (Fig. 3(b)). The balls must be delayed by a certain time according to the distance separating terminals. The distance information is calculable using 12 angles obtained by sound-source localization.

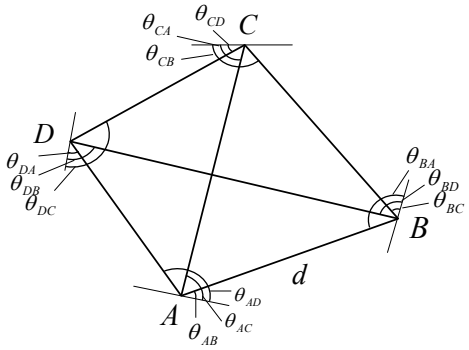


Fig. 4. Estimating distances using angles.

In Fig. 4, if a length of AB is known as d, then length AC is obtainable using the following equation.

$$AC = \frac{d \sin(\theta_{BA} - \theta_{BC})}{\sin(\theta_{CB} - \theta_{CA})}$$

Furthermore, the other lengths are obtainable from d and 12 angles. In general, d must be defined as a constant value. However, if all terminals have a unity timer, i.e. if all are synchronized with a single timer, then the distance is related to the time difference between emitting and arriving sounds, irrespective of the number of players. Under this condition, the group of terminals can act as a huge microphone array for hands-free high-performance sound acquisition [1, 2].

5. SUMMARY

Positioning systems such as GPS can localize a mobile terminal at coarse resolution, but they can not provide an accurate positional relation at close range. We proposed implementation of a microphone array on a mobile terminal, which achieved a close-range positioning system by emitting sound and calculating a DOA. The prototype was implemented using a tablet PC, 16 microphones, and an FPGA board. We also demonstrated applications, exhibiting the utility of microphone arrays as an intuitive interface.

REFERENCES

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