EyeSound: Single-Modal Mobile Navigation Using Directionally Annotated Music

Shingo Yamano[1] Takamitsu Hamajo[1] Shunsuke Takahashi[1]
[1]Kanazawa Institute of Technology
Ishikawa, Japan
syamano@acm.org, {tkmthmj, hs.sin5591}@gmail.com

Keita Higuchi[2]
[2]The University of Tokyo
Tokyo, Japan
khiguchi@acm.org

ABSTRACT

In this paper, we propose a mobile navigation system that uses only auditory information, i.e., music, to guide the user. The sophistication of mobile devices has introduced the use of contextual information in mobile navigation, such as the location and the direction of motion of a pedestrian. Typically in such systems, a map on the screen of the mobile device is required to show the current position and the destination. However, this restricts the movements of the pedestrian, because users must hold the device to observe the screen. We have, therefore, implemented a mobile navigation system that guides the pedestrian in a non-restricting manner by adding direction information to music. By measuring the resolution of the direction that the user can perceive, the phase of the musical sound is changed to guide the pedestrian. Using this system, we have verified the effectiveness of the proposed mobile navigation system.

Categories and Subject Descriptors

H.5.2 [**INFORMATION INTERFACES AND PRESENTATION**]: User Interfaces—*Auditory (non-speech) feedback*

General Terms

Human Factors

Keywords

mobile navigation, single-modal, eyes and hands free interaction

1. INTRODUCTION

The mobile computing environment has significantly changed because of the widespread use of multi-functionality and the downsizing of mobile devices. As a result, listening to music and Web browsing while on the move has become commonplace. Most mobile devices use the global positioning system (GPS), an accelerometer, and an electronic compass. Consequently, context-aware computing that can predict the user's location and movements by using these resources has evolved[1].

Typical mobile navigation systems superimpose the current location and the destination on a map displayed on the mobile device screen. However, such systems restrict a user's movements because they require the screen to be observed and the device to be held. Furthermore, when users access the navigation system while listening to music on the same device, they are unable to pay attention to their surroundings. Therefore, many new non-restricting mobile navigation systems have been proposed. Tsukada et al. developed ActiveBelt, which a belt-type wearable device that provides navigational guidance[2]. Imamura et al. proposed HAPMAP, which indicates the proper direction of motion through haptic feedback and involves the use of a handrail-type mobile device[3]. Simon et al. developed AudioGPS, which instructs users by mapping the direction of movement onto a sound source[4]. Further, Jeff et al. have proposed SWAN, which uses a voice-guided navigation system[5].

We propose a mobile navigation system that allows the user to have unrestricted movements by adding direction information to a music source. Unlike conventional systems, this system does not require the screen to be observed and the device to be held. With the proposed system, users can reach their destination by moving according to the direction information that is added to the music by changing the phase of the musical sound. Also, we investigates the resolution of the direction that users can perceive with the proposed system.

2. MOBILE NAVIGATION USING DIRECTIONALLY ANNOTATED MUSIC

Our proposed mobile navigation system operates by changing the phase of the musical sound. We verified the usefulness of this system by comparing it with other systems. Figure 1 shows a comparison of the conventional and proposed systems. The former restricts the user's movements because it guides the user via a screen display, whereas the latter guides the user simply through auditory information, i.e., the users only need to move in the direction of the music source.

Navigation systems proposed by other studies, such as Matt et al.'s ONTRACK[6] and Steven et al.'s gpsTunes[7], guide the user by controlling the volume of music. Brewster's study explains how much multitasking humans can perform while listening to music[8].

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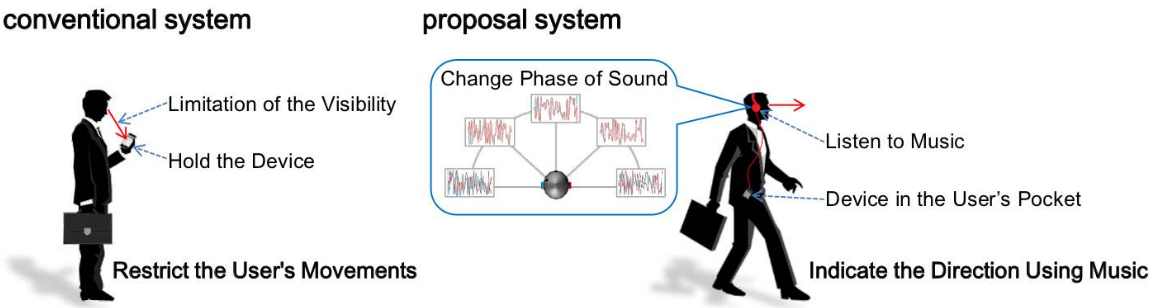
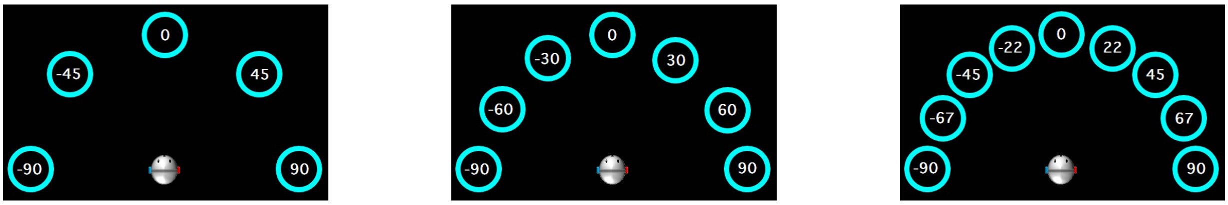


Figure 1: Comparison of the conventional and proposal systems: (Left) The problems with conventional system. (Right) Description of the proposal system.



(a) 5-Way (b) 7-Way (c) 9-Way

Figure 2: Layouts of the indication direction: Cyan circles are the music source position, the gray object is the listener. A music is played from a arbitrary circle toward the listener.

2.1 Advantage of Phase Control

Phase control enables the addition of arbitrary direction information to music. We perceive time lag and phase differences in sounds entering the left and right ears with the help of sound reflected to the occiput and the special shape of our ears. We can estimate the location of the music source from these perceived differences. Thus, by changing the phase of the sound entering the left and right ears, a user can be guided to move in the desired diagonal direction.

3. EXPERIMENTATION ON DIRECTIONAL RESOLUTION

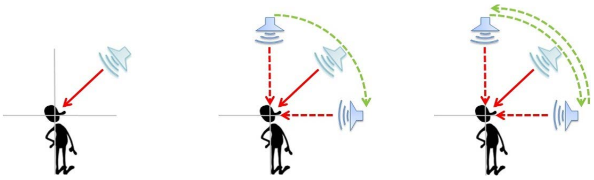
Directional resolution is the ability to perceive the direction from which a sound is coming. If the source of the music changes position, its phase will also change. Therefore, if we can perceive the direction of the sound in detail, indication direction increases.

3.1 Experimental Objective

This experiment is designed to investigate the recognition rate in perceiving the direction of a sound. In addition, we incorporate a method with a high recognition rate to the current system.

3.2 Experimental Description

The experimental program was implemented as an Android application. Figure 2 represent the positional relation between the music source and the listener. The numbers in the circles represent the angle between the position of the front and the music source. The positional relation of the music source defined the position using polar coordinates as $(r,\ \theta)$. The user at $(0,\ 0)$ is located at the reference position, and $(r,\ 0)$ gives position of music source number 0. Experiments were conducted indoors with 15 test subjects.



(a) fixation (b) one-way (c) two-way

Figure 3: Directional indication method of diagonal: (a) A music is played from the fixed position of the music source. (b)(c) A music is played with periodically changing the position of music source.

We verified indication directions for the three directions 5, 7, and 9. For the diagonal directions, in addition to the basic method (fixation) using only once to change the phase, we verified two expansion methods (one-way and two-way) using a periodic phase change in the music source (Figure 3). $(r,\ \theta_c)$ is the current position of the music source, and θ_x is the angle between the current position of the music source and its next position. In the case of one-way, the music source moves to $(r,\ \theta_c + \theta_x)$ from $(r,\ \theta_c - \theta_x)$. In the case of two-way, the music source oscillates from $(r,\ \theta_c - \theta_x)$ to $(r,\ \theta_c + \theta_x)$ and back. This repeats until the test subject turns.

The methods used in this experiment are discussed below. Test subjects wear the headphones to hear the sound, which is modified using the phase control. In the experimental program (Figure 2), test subjects push the button that corresponds to direction from which the music is heard. The number of test subjects push the button is in 5-way is 15 times, in 7-way 21 times, in 9-way 27 times. Our experiment consists of nine methods (three indication directions for each of the three diagonal direction methods).

3.3 Results

The experimental results are shown in Tables 1,2, and 3. They show that the 90 (r, $\frac{1}{2}\pi$) and -90 (r, $-\frac{1}{2}\pi$) indicator positions were higher the recognition rates than any angles. The indication of diagonal direction showed that the expansion methods (one-way and two-way) had a higher recognition rate than the basic method (fixation). Also, we found that an increase in the number of indication directions led to a lower recognition rate in the diagonal direction. Two diagonal expansion methods of the 5-ways showed a higher recognition rate than the other methods. Based on these results, we consider incorporating two diagonal expansion methods into the current navigation system.

Table 1: Evaluation result of the 5-way

angle	fixation	one-way	two-way
90	80.0	97.8	95.6
45	48.9	82.2	80.0
0	71.1	80.0	91.1
-45	60.0	80.0	77.8
-90	86.7	93.3	93.3

Table 2: Evaluation result of the 7-way

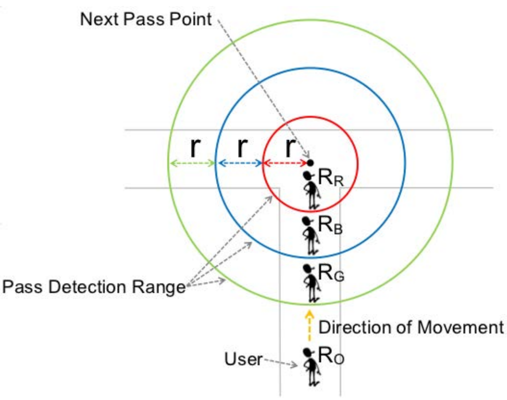
angle	fixation	one-way	two-way
90	88.9	97.8	88.9
60	57.8	68.9	75.6
30	46.7	57.8	48.9
0	75.6	88.9	91.1
-30	46.7	57.8	51.1
-60	60.0	71.1	73.3
-90	73.3	97.8	86.7

Table 3: Evaluation result of the 9-way

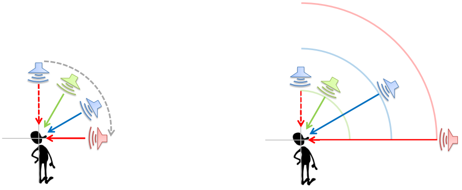
angle	fixation	one-way	two-way
90	93.3	95.6	88.9
67	42.2	62.2	57.8
45	24.4	37.8	44.4
22	17.8	26.7	40.0
0	62.2	84.4	64.4
-22	44.4	40.0	40.0
-45	22.2	35.6	35.6
-67	33.3	62.2	66.7
-90	73.3	86.7	91.1

4. DIRECTIONAL INDICATION METHOD

In addition to the two methods incorporated into the current navigation system, we propose two directional indication methods. Next Pass Point is the next turning point, and Pass Detection Range is a range intended to reduce the error in location information obtained by the GPS (Figure 4 (a)). The radius of the smallest red range is r, and the center of the range is the Next Pass Point. Also, the Pass Detection Range is prepared every r from the Next Pass Point, and the phase of the musical sound gradually changes as the user passes through these ranges from R_o to R_R. These methods use a graded change in the position of the music source in order to improve the recognition rate without hindering the user listening to music.



(a) Pass Detection Range



(b) Method1 (c) Method2

Figure 4: Directional indication method: (a) To change the position of the music source when the users enter inside of the range. (b)(c) The position of the music source is gradually changed to correspond to Pass Detection Range.

4.1 Method1

We define θ as the angle between the direction of movement and the indication direction. The position of the music source is moved $\frac{1}{3}\theta$ towards the indication direction every time the user passes through the Pass Detection Range from outside (Figure 4 (a)(b)).

4.2 Method2

In addition to method 1, the position of the music source is moved farther away depending on the Pass Detection Range (Figure 4 (a)(c)). It is gradually moved r towards the indication direction every time the music source moves $\frac{1}{3}\theta$.

5. IMPLEMENTATION OF MOBILE NAVIGATION USING OUR METHOD

This application was implemented as an Android application. The phase change of the musical sound is controlled by OpenAL. Map and route information were obtained from the Android Maps API and Google Maps API, respectively. First, the user selects music, their destination, and the radius of the Pass Detection Range, and the application then calculates the route to the user's destination. Second, the user goes to the Next Pass Point (Figure 5 (a)), and if they are inside the Pass Detection Range, the phase of the musical sound changes to the next indication direction (Figure 5 (b)). If the user turns correctly within this range, the phase of the musical sound is modified to the original phase (Fig-

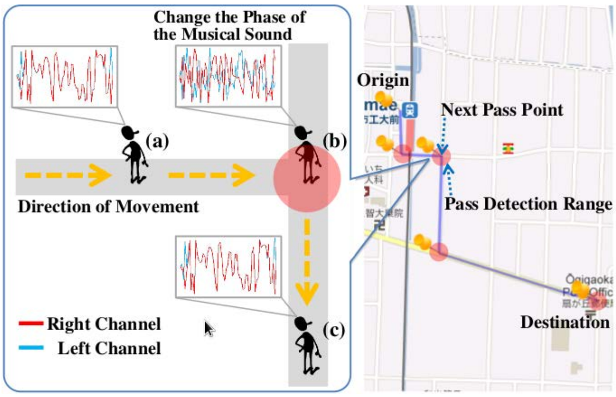


Figure 5: The positional relationship between the user and the timing of the phase change: The phase of the musical sound is changed to next direction when the position of the user is inside of the red range.

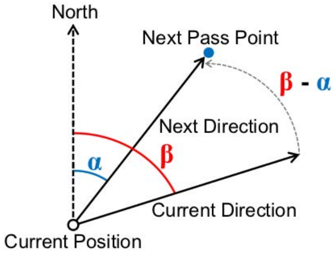


Figure 6: Calculation method of the next direction: The next direction is calculated by using the values obtained by GPS and electronic compass.

ure 5 (c)). The user repeats this process until they arrive at the destination. Finally, the user is notified of his arrival at the destination by the music stopping.

The method of calculating the next indication direction uses the difference in azimuthal angles $\beta-\alpha$ (Figure 6). The longitude and latitude of the current position is defined as (c_long, c_lat). Similarly, the Next Pass Point is defined as (n_long, n_lat). α is calculated as $\arctan\{(n\_long - c\_long, n\_lat - c\_lat) * 180/\pi\}$, where the coordinates of the current position and the Next Pass Point are obtained from the GPS. The β angle is taken from an electronic compass.

6. DISCUSSION

This paper reported a method for mobile navigation and its implementation using a phase control. Here, we discuss some current constraints and our future plans.

6.1 Backward Indication

The proposed system does not have a backward indication method because this is the wrong direction of movement. Therefore, if users select the wrong direction, we consider it necessary to use a different sound from that used for normal indication.

6.2 Advantage of a Single-Modal System

The existing mobile navigation system using eyes, hands, and ears is multi-modal. By contrast, the proposed mobile navigation system is single-modal, as it only uses the ears. The operation of mobile navigation becomes easier by changing from multi-modal to single-modal system, although this decreases the amount of information available. However, we believe that single-modal is better in the mobile environment. For example, a conventional navigation system has an advantage in dealing with more information, such as detailed information to the destination, but when users lose their way they must compare real geographic information to the map on the screen of the mobile device. In contrast, in the case of a mobile navigation system using only auditory information, users simply move in the direction of the sound.

7. CONCLUSION

This paper identified the problems with conventional navigation methods. These problems meant user's movements were restricted, because they must hold the device in order to observe the screen while using mobile navigation. To overcome these problems, we proposed a mobile navigation system that uses phase changes of musical sound. Our system does not restrict user's movements because it is based solely on auditory information, which is the direction of the music source as perceived by the user. Further work will mainly consist of implementing and evaluating a mobile navigation system using the proposed directional indication methods and the experimental results for directional resolution.

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