**An Empirical Study of Verbal Map Guidelines for Visually-impaired people to Enhance Daily Mobility**

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**Synopsis**

This study was conducted to revise verbal map guidelines for a pedestrian navigation system. The guidelines show rules for describing features in a town to enhance everyday mobility.

This report presents a review of earlier studies and explains the concept of an audio augmented reality (AR) application for visually-impaired people. Then, field experiments are conducted to assess methods to encourage visually-impaired people to use audio guidance through courses and to advance hearing research. Outlines, results, and consideration of the experiments are presented. Finally, verbal map guidelines are revised.

This study assessed a system necessary for a navigation system for visually-impaired people to enhance everyday mobility. The system can be managed continuously by sharing feature information from users with other users according to guidelines.

**KEYWORDS:** Visually-impaired people, Verbal map, Navigation system, Field experiment

1. Research Background and Objectives

1.1 Background

A typical smartphone has a global positioning system (GPS) function and a web access function. Furthermore, augmented reality (AR) applications of smartphones have become commonplace. Such phones can display appropriate information for a location on a screen. However, visually-impaired people cannot see a screen and cannot use AR applications. Therefore, they must ask sighted people to take them to a place to which they have never walked before.

A navigation system must be designed as soon as possible for practical use by visually-impaired people to enhance everyday mobility. Therefore, earlier studies developed systems using Radio Frequency Identification (RFID) tags which make up for GPS and a “verbal map” that explains feature information to visually-impaired people using audio guidance. Timing of the explanations of elements and contents on the verbal map in a general street were defined in earlier studies. In addition, verbal map guidelines were created to show rules for recording feature information.

However, the use of RFID tags has not spread. Therefore, it is necessary to develop a navigation system that is independent of the RFID tag, i.e., which presents no problem even if the position identification precision is low. In addition, elements and contents that should be described on "the verbal map" exist, which are not yet treated in the guidelines.

1.2 Research objectives

This study clarifies the “verbal map” in a complicated place that has no verbal map guidelines. A revised edition of the guidelines shall be created by adding results of this study to guidelines of earlier studies.

2. Research approach

The study flow is presented in Figure 1. Previous studies have clarified the usefulness of position identification techniques using RFID and GPS and “the verbal map” in streets and large-scale institutions. Verbal map guidelines for use with general street information have been proposed in earlier studies.

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Field experiments are conducted to simulate an audio AR application through a course that includes many elements that were not subjects of the previous studies. In this experiment, subjects that are shot in the previous guidelines are complemented. Then the guidelines are revised.

An audio AR cooperation application can probably be used in the future. The user can expect to share features provided by an audio AR application on a web site. Using this, in a continuous system, users can maintain and update the latest town information. Furthermore, the navigation system can be practical for visually-impaired people to enhance their own everyday mobility.

3. System used for the experiment

(1) Audio navigation

First, it is assumed that a visually-impaired person would like to walk to the first place, for example, a friend's house. When a visually-impaired person walks to a destination from a certain spot, that person needs information about the walking space in addition to directions on how to progress through it. Moreover, the feature information that can be used to discern signs is necessary to determine where the person is or where the person should turn. The message the person can imagine for the whole space is the "verbal map."(3)

In a navigation system, messages corresponding to the present location specified by GPS are given to a visually-impaired person according to a spot where the person walks. The person hears the message, and checks and judges the related features and signs. Then the person walks by accepting the walk space where the person is presently. Then, after walking, the person arrives at the destination.

This study makes use of an audio AR application as such a navigation system. Furthermore, an audio AR cooperation application can probably be produced for future use with this system.

(2) Audio AR application

The progress of a navigation system for visually-impaired people is of paramount importance. It is ineffective to build the system independently. Furthermore, the widening use of RFID tags used in earlier studies is not good. Therefore, to put a navigation system into practical use for visually-impaired people to enhance daily mobility, a best policy for visually-impaired people is probably to download an audio AR application with a smartphone and use a navigation system.

The navigation system for visually-impaired people to enhance daily mobility comprises 3 systems in a function side, as shown in Figure 2.
1) Navigation system  
A visually-impaired person hears a message and arrives at the destination from the present location (guidance).

2) Feature description data input system  
A visually-impaired person inputs and records the feature information as a message.

3) Data sharing system  
A visually-impaired person updates the town information by sharing the feature information related to a web site.

![Diagram of systems and applications]

Figure 2  Relation between systems and applications.

A part of an audio AR application is 1) the navigation system and 2) the feature description data input system. An audio AR application can reproduce messages corresponding to the present location in the field performing a town walk. Additionally, it can record audio guidance about features to be recorded as a memory of the person visiting that spot.

A part of an audio AR cooperation application is 2) the feature description data input system and 3) the data sharing system. An audio AR cooperation application can edit an audio guidance inputted as preparations to use an audio AR application. Additionally, it can share and update the guidance on a web site.

4. Experiment outline  
In the field experiment, visually-impaired people use audio guidance while walking. Hearing research was conducted with several test subjects.

1) Advance preparation  
Messages are created through an experimental course according to the guidance. Furthermore, an audio file is recorded on a music player. When the experiment starts, visually-impaired people put on a bone conduction headphone and a microphone for recording experiment conditions. A bone conduction headphone enables a person to walk while hearing surrounding environmental sounds.

2) Walking experiment  
Looking at the action of visually-impaired people through a course, the music player is operated, passing messages according to a point to a bone conduction headphone by radio. Hearing the messages, visually-impaired people decide the direction of movement according to their own judgment and aim at the destination. A visually-impaired person walks together with a guide helper for safety as needed. However, the user decides the direction of movement. The condition of a walking experiment is recorded with the environmental sound and the utterance by a video camera, as shown in Figure 3.

3) Hearing research  
After doing the walking experiment, a hearing experiment is conducted in a room. Evaluation of messages is heard, with a mental state through the course and features and signs that visually-impaired people typically use in everyday life.
5. Experiment

(1) Experiment challenges

The purpose of the experiment is to complement subjects which are shot in the previous guidelines and to revise the guidelines. The points that are lacking (challenge) in the guidelines are the following 4.

(Challenge 1) Guidance to a pinpoint (vast space → narrow space)

When visually-impaired people are guided from a vast space to a narrow space, such as a narrow feature and a street, they tend to pass a space where they can go ahead. Thereby, they become lost. Necessary feature information is clarified under such a situation.

(Challenge 2) Guidance to the pinpoint (similar features are close to one another)

When similar features are closely arranged in the short section, visually-impaired people cannot choose a suitable feature easily. Therefore, necessary feature information must be clarified in such a space.

(Challenge 3) Special passage

In previous studies, necessary feature information at a passage where visually-impaired people often walk outdoors in everyday life is clear. However, in a special passage where a person might have little walking experience, such as stairs or a roofed passage, necessary feature information is not so clear.

(Challenge 4) Signs

Because visually-impaired people specify the present location, the corners where they should turn and so on, the signs they can determine are clarified.

As the course of the field experiment, we (sighted people) set up a route that includes points that can complement four Challenge points. Specifically, the course extends from the front of the main gate in the whole study common educational building area in the Osaka City University to the B classroom on the fourth floor the whole study common educational building area. We experimented with 28 visually-impaired people (20 completely blind people and 8 weakly sighted people). Characteristics of a point through the course and challenges of the guidelines corresponding to it are presented in Table 1.

There is no corresponding point for Challenge 4. The signs visually-impaired people use in everyday life were known to them after doing the walking experiment.
Table 1  Relations between points and challenges

<table>
<thead>
<tr>
<th>Point</th>
<th>Characteristic</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Passage in the garden of the brick pavement with the curb stone on both sides</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>b</td>
<td>Piloti</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>Courtyard where 4 types of pavement such as textured paving blocks are spread linearly</td>
<td>2 3 4</td>
</tr>
<tr>
<td>d</td>
<td>Grand stairs of the tiling where there is a landing on the way, a handrail in the center, and tiered platforms of the tree on both sides</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>e</td>
<td>Roofed passage</td>
<td></td>
</tr>
<tr>
<td>f</td>
<td>Door of the same kind in the passage in succession</td>
<td></td>
</tr>
</tbody>
</table>

※ Point a is taken as the passage where visually-impaired people often walk outdoors in everyday life.

(2) Results of the experiment

The results of the experiment for every challenge are shown below.

(Challenge 1)
For guidance from a vast space to a nan-ow space, an open space with a little feature guided by going along with them hand and white canes is chosen, such as a wall, a curb stone and a textured paving block. There is a stone paving like a textured paving block in the open space. The stone paving is explained using information about the pavement. Visually-impaired people can apparently use it effectively as a key by exploring it with a white cane.

(Challenge 2)
In this experiment, a door of the same kind is used in the passage in succession. Consequently, it is the opinion that it is plain for visually-impaired people to have it explained concretely using a number such as “the x-th door from this side”.

(Challenge 3)
Through the course, a piloti, grand stairs, a roofed passage are explained as a special passage with a little walk experience. Therefore, in a special passage to go straight with a little walk experience, if there is no information about a concrete distance how many meters distance must be walked to the terminal, then visually-impaired people become uneasy during walking.

When they pass stairs, they would like to know the width of stairs and the existence of a handrail and a landing because the stair width is easy to imagine and assess. Furthermore, visually-impaired people use handrails in everyday life. However, if there is information about a handrail of stairs that is passed for the first time, then they can walk in comfort. Regarding landing, if they know of the existence and the number of landings, they understand whether they have finished passing the stairs. Therefore, their information is described for a safe and reliable walk. In addition, if there are stairs of special pavement or form, then they should be described.

A visually-impaired person does not understand a term itself like a piloti or a roofed passage. However, they are spaces that are difficult to explain in the form of a “verbal map”. Therefore, it is necessary for visually-impaired people to learn the name and meanings of terms in advance.

(Challenge 4)
The results of the hearing research for signs for visually-impaired people to use in everyday life are shown in Table 2, in which the signs are classified by the degree of an obstacle (completely blind or weakly sighted) and what stimuli they distinguish the sign according to. Consequently, many visually-impaired people use the material of a wall, which is distinguishable by a difference in touch, a convenience store that is distinguishable by the noise of people nearby and an opening-and-closing sound of an automatic door and a restaurant, which is distinguishable by the noise of people and the peculiar smell of food and drink.
Table 2  Signs for visually-impaired people used in everyday life

<table>
<thead>
<tr>
<th>Hearing</th>
<th>Sound</th>
<th>Completely blind</th>
<th>Weakly sighted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Convenience store</td>
<td>4 people</td>
<td>Convenience store</td>
</tr>
<tr>
<td></td>
<td>Restaurant</td>
<td>4 people</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vending machine</td>
<td>2 people</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Supermarket</td>
<td>2 people</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Iron plate</td>
<td>1 person</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pachinko parlor</td>
<td>1 person</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fountain</td>
<td>1 person</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manhole</td>
<td>1 person</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kindergarten and school</td>
<td>1 person</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Restaurant</td>
<td>4 people</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hearing Sound</td>
<td>6 people</td>
<td>Telegraph pole</td>
</tr>
<tr>
<td></td>
<td>Hand</td>
<td>3 people</td>
<td>Guardrail</td>
</tr>
<tr>
<td></td>
<td>White cane</td>
<td>1 person</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sight Light and darkness†</td>
<td></td>
<td>Convenience store</td>
</tr>
<tr>
<td></td>
<td>Sight Sound</td>
<td></td>
<td>Bus stop</td>
</tr>
</tbody>
</table>

※ This shows features that weakly sighted people said that they can use as a sign by contrast of color and light and darkness.

As the place of a sign, the guidance aside from features at a corner of a way is not necessary. However, visually-impaired people can confirm whether the place shown by the present location and a message are in agreement. Therefore, even if nothing exists at a corner, information about signs is effective.

6. Verbal map guidelines

Results of field experiments, previous studies, and a literature review suggest a revised edition of the verbal map guidelines. The composition of the guidelines is shown in Figure 4. They are the "subject" and the "grammar". The "subject" is a content related to what kind of features should be described as a message. The "grammar" is a rule to describe features according to what kind of vocabulary and order should be used.

![Guidelines diagram](image)

Figure 4  Composition divisions of the verbal map guidelines.

The composition of detailed guidelines can enable classification into subjects, priorities, syntax, and vocabulary:

**<a-1> Subject**

Feature information necessary for visually-impaired people. Table 3 shows necessary feature and attribute information.

**<a-2> Priority**

Where there are multiple features that might exist with complicated topography, priority is shown to judge which feature information is most necessary. For example, information about dangerous objects such as a waterway, a ditch, and a step with a possibility of leading to big accidents such as a falling should be
assigned priority. In contrast, priority of the information about pavements and slopes where people can walk in comfort is low.

<b-1> Syntax

The order of feature information is shown to describe the ease of imagining a walk space while visually-impaired people hear a message. For example, they are “A feature is explained from this side to the inside.”, “A feature is explained to a clockwise rotation from the left.” and “When the same kind of feature continues, it is explained as a x-th feature.”

<b-2> Vocabulary

Standardized expressions are used for visually-impaired people to understand them easily. For example, it is difficult for visually-impaired people with congenital blindness to imagine a word using a Chinese reading of a kanji. Therefore, even if it is the same word, for example, a planting, the Japanese reading is used, such as "Uekomi", rather than the Chinese reading such as "Shokusai". The expression "winding" is easy to imagine as a shape for sighted people. However, it should not be used because visually-impaired people cannot imagine such shapes well.

An example of the contents of the verbal map guideline is presented in Table 4, which describes what kind of information should be described for subjects such as landmarks and information about distance and time. According to the guidelines of such contents, a message is created in actual walking space.

Table 3 Features and attribute information

<table>
<thead>
<tr>
<th>Feature</th>
<th>Attribute information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passage</td>
<td>Width, Pavement, Shape, Distance, Name</td>
</tr>
<tr>
<td>Stairs&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Width, Pavement, Shape, Handrail, Landing</td>
</tr>
<tr>
<td>Open space</td>
<td>Size, Pavement, Shape, Name</td>
</tr>
<tr>
<td>Crossing</td>
<td>Signal, Traffic lane</td>
</tr>
<tr>
<td>Institution</td>
<td>Position, Entrance, Name</td>
</tr>
<tr>
<td>Dangerous object</td>
<td>Waterway, Ditch, Step</td>
</tr>
<tr>
<td>Textured paving block&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Position, Starting and Terminal point, Turning point</td>
</tr>
<tr>
<td>Sign</td>
<td>Hearing, Smell Touch, (Sight)</td>
</tr>
</tbody>
</table>

<sup>1</sup> Stairs are walking spaces used for vertical movement, such as stairs, an escalator, a slope, and an elevator.

<sup>2</sup> Dangerous objects are features presenting the danger of falling. When a dangerous object is in a walking space, the kind and position of the dangerous object must be shown.

Table 4 Example of verbal map guidelines

Example 1: Subject <a-1> Landmark

We describe features without mobility and features that are distinguished by the sense of touch, hearing and smell by stopping as a sign.

- Sense of touch: a wall with a different feeling, a mailbox, a telegraph pole, and so on
- Sense of hearing: a convenience store, a vending machine, a supermarket, a fountain, and so on
- Sense of smell: a restaurant (coffee shop, etc.)

Example 2: Subject <a-1> Information about distance and time

We explain concretely how many meters there are to the next walk space in the walk space with depth. We explain the remaining distance concretely on the way, when there are 100 meters or more of distance.
7. Practical Example

The purpose of a practical example is to create a message through an actual course as a concrete example of application and inspection of the verbal map guidelines created through the field experiment, etc. In this case, experiments were conducted with 2 visually-impaired people (1 completely blind person and 1 weakly sighted person). Contents through the course setting and application of the guidelines are described in this chapter.

The course is a route of the city area covered in a situation in which a visually-impaired person (completely blind person) is passing in everyday life together with a guide helper. Concretely, the course is from the Nankai Nanba Station 3rd floor north wicket to the Osaka visually-impaired person welfare center. The outline through the course is presented in Figure 5. A spot is shown below for which the way of thinking of the guidelines, the application example of the contents of the guidelines and creating a message. In addition, the following geographical numbers are the geographical numbers shown in Figure 5.

![Figure 5 Example of guidelines application (Sketch of the course)](image)

(1) Building with the fountain to hear the sound of water from 2 places

Way of thinking of the guidelines>

Signs that are necessary for visually-impaired people are explained. A sign used for them is a feature that can identify the place using tactile or audio information. Particularly, it is necessary to describe signs that are distinguishable by the sense of hearing more carefully and in greater detail.

Contents of the guidelines>

Features without mobility and those which are distinguishable by tactile, olfactory, and audio senses by stopping as a sign are explained. For example, a convenience store, a vending machine, a supermarket, a fountain and so on are distinguishable by hearing, a restaurant (coffee shop, etc.) is distinguishable using the sense of smell, and a wall can be sensed by touch, as are a mailbox, a telegraph pole and so on.

Creating a message>

“It is in front of the xx building soon. There is a fountain in the building. Please go straight on then.”

(2) The crossing where there is an audio signal of a push button and which crosses a road with many traffic lanes

Way of thinking of the guidelines>

Features necessary for safe and reliable walking at a crossing are explained.

Contents of the guidelines>

The existence of a signal is explained (the existence of an audio signal and the position if there is a signal.), in terms of the crossing characteristics (name, kind and number of traffic lanes).

Creating a message>

“It is a crossing with an audio signal soon. The xx line passes north and south, and the yy market is east. The xx line is a road of 5 traffic lanes of the one-way for north. Please cross a pedestrian crossing, go straight on and go into the yy market.”

(3) Long road on the city outskirts where distance without features must be explained

Way of thinking of the guidelines>

Features that are necessary for a safe and reliable walking along a single route having no features are explained. When going straight, some unease is felt whether visually-impaired people can walk through the right course or whether the application is operating when long silence continues.

Contents of the guidelines>
The distance in meters to the next walk space is explained. We explain the remaining distance concretely when there is 100 meters or greater distance.

<Creating a message>
“There is a crossing soon. Please come out of the xx market, go into a thin street with the sidewalk divided into both sides in the white line and go straight on 450 meters”.
※ In fact, for a 450 meters straight passage, no message is passed. Try a long-time long silence daringly.
(4) Slope of stone pavement with stairs on the way

<Way of thinking of the guidelines>
Information necessary to walk on the stairs safely and reliably is explained. Particularly, because the stairs present the danger of leading to big accidents such as a falling, it is necessary to explain information whenever stairs are involved.

<Contents of the guidelines>
The width of stairs, the existence of a landing are explained (the number, and the existence of a landing) and the existence of a handrail. We explain the position of a handrail if it exists. Additionally, information about pavement is explained when the pavement changes in front of and behind stairs.

<Creating a message>
“There is a slope of a stone pavement soon. Stairs are in the middle of the slope. There are 3 landings on the stairs. 3 poles stand on the stairs. The slope continues after that. Please go up the slope and go straight on the narrow street in flat asphalt.”

8. Conclusion

This study provided the following results.
1) The verbal map guidelines produced from field experiments which simulate an audio AR application were revised. Results show that creation of the navigation message is enabled in every place throughout the city area.
2) A message was created through a course that a visually-impaired person is using in everyday life by application of the revised edition of the verbal map guidelines.

According to these results, the verbal map guidelines for visually-impaired people to enhance daily mobility are created. They are necessary to produce a practical navigation system. Visually-impaired people and people supporting them can create messages in places where they actually walk.

Future studies will evaluate the operability of an audio AR application and the validity of the message composition considering the GPS error, not by simulations such as field experiments, having visually-impaired people use the system with a smartphone.

In the near future, if system users can identify messages created for using the guidelines, other visually-impaired people will be able to walk at the first place and the system will be continuously manageable.

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References