The 29th Annual International Technology and Persons with Disabilities Conference (CSUN2014) (2014)

# Roles of Navigation System in Walking with Long Cane and Guide Dog

Takeshi Kurata[1, 2] Yoshikazu Seki[1]
Masakatsu Kourogi[1] Jun Ishikawa[3]

[1]AIST, Japan [2] University of Tsukuba
[3] University of Shizuoka, Japan
E-mail: t.kurata@aist.go.jp

## Introduction

- Owing to the popularity of smartphones, a variety of navigation applications for sighted pedestrians has been developed.
  - If such applications could be equipped with interfaces suitable for visually impaired pedestrians, it would become popular also among them.

# Introduction

- 'Walk' comprises O & M (Orientation and Mobility).
  - Orientation: geographical navigation and the spatial recognition
  - Mobility: road-condition understanding, body control, obstacle avoidance, etc.

O & M



# Walking with cane or with guide dog, using talking navigation

| | Orientation Support | Mobility Support | |
|---|---|---|---|
| Talking navigation | ✓ High | Low | *Route guidance<br>*POI notification<br>*Map search |
| Cane | N/A | ✓ High | *Detecting road conditions |
| Guide dog | Low | ✓ High | *Orientation to some extent<br>*Mobility to greater extent |

# Motivation

Long Cane or Guide Dog
+
Navigation system

→ More practical and popular

↓ Sensor/Guidance Log

Quantitative evaluation on O&M skills for training



# Walking with cane or with guide dog, using talking navigation

- Qualitative understanding of relationship between a navigation system and a cane or guide dog: OK
- What remains are
  - How and to what degree we can obtain sensor log by the navigation system and other wearable devices to evaluate O & M skills of trainees
  - How to provide trainees/trainers with feedback after walking

# What this presentation is about

- Preliminary subjective experiment on how such combinations works
- Exploration of the applications of sensor log such as evaluation indices and intuitive ways of feedback



# Walking experiment: Devices

- Talking GPS:
  - Trekker Breeze (made by HUMANWARE and localized in Japanese by EXTRA)
  - Audio assistance with regard to the distance and direction to the next stop,
    whether the destination
    is along the route or off it,
    and landmarks


Trekker Breeze

## Walking experiment: Devices

In addition to the talking GPS, the subjects were also equipped with the following devices:

- EEG (Electroencephalogram, Brain Wave):
  - B3 Band made by B-Bridge
- Heart rate, GPS:
  - RS 800 CX N GPS made by POLAR
- PDR (Pedestrian Dead Reckoning, relative positioning):
  - GALAXY S II made by SAMSUNG



## Walking experiment: Subjects

- Five subjects were completely blind and one has extremely low vision.
- Four subjects were walking with a cane and two subjects were walking with a guide dog.

Walking with a cane

Walking with a guide dog

# Walking experiment: Routes

- Multiple routes were established
  - Subjects would not remember a specific route
- The distance of each route was set at approximately 210 to 250m
  - To provide a uniform degree of exercise stress

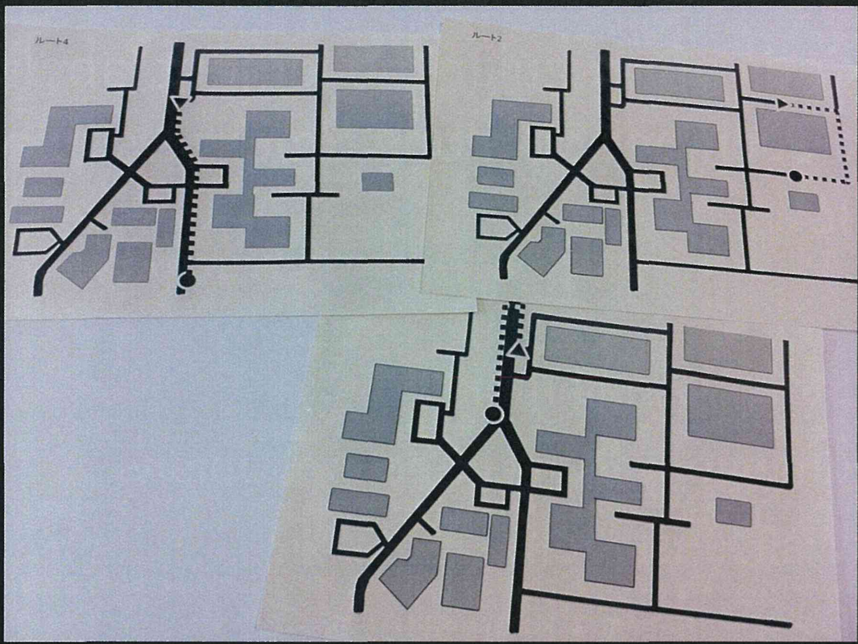
11

# Walking experiment: Procedures

- Aims of the experiment and what to do were explained to the subjects, and their consent was received.
- Operation of the talking GPS was practiced, and the wearable devices were attached.
- Trials were repeated 2–3 times for each subject.
  1. Prior understanding of the established routes using tactile maps with a supplementary oral explanation on the subject's questions
  2. Walking while using the talking GPS with a cane or with a guide dog
  3. Interview
- Tactile Trajectories were provided afterward.

12

# Tactile maps for step 1



Buildings [polygons], Road [solid line], Established route [dotted line], Starting point [Solid triangle], Finish point [Solid circle]



# Label: Walking mode

Three kinds of walking-mode labels were put to each period along timeline subjectively as follows:

(A) walk with confidence

(B) walk without confidence

(C) situation understanding

## Label: Irregular movement

Five kinds of irregular-movement labels were put to each period along timeline subjectively as follows:

1. Stop walking rapidly
2. Change walking direction rapidly
3. Walk unsteadily
4. Decrease walking speed
5. Touch obstacles



## Results: Accuracy & Efficiency

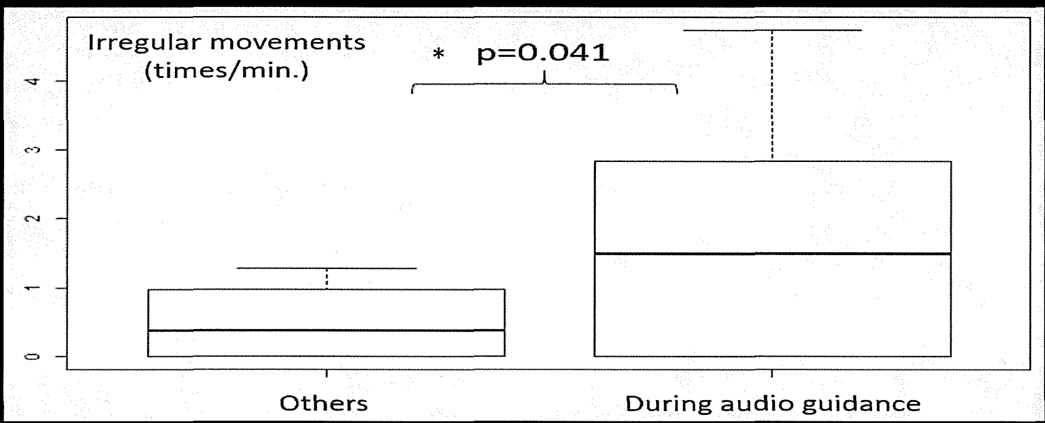
- Accuracy: the percentage of time period in which the subject stayed on the established route
  - (A) walk with confidence: 100%
  - (B) walk without confidence: 71%
- Efficiency: No critical problem
  - Walking speed with a cane: 3km/h
  - Walking speed with a guide dog: 4km/h

# Results: Safety

Frequency of Irregular movements (times/min.)

- During audio guidance: 1.6
- Others (during no audio guidance): 0.5

Note: In 40% of walking time, the audio guidance was provided.

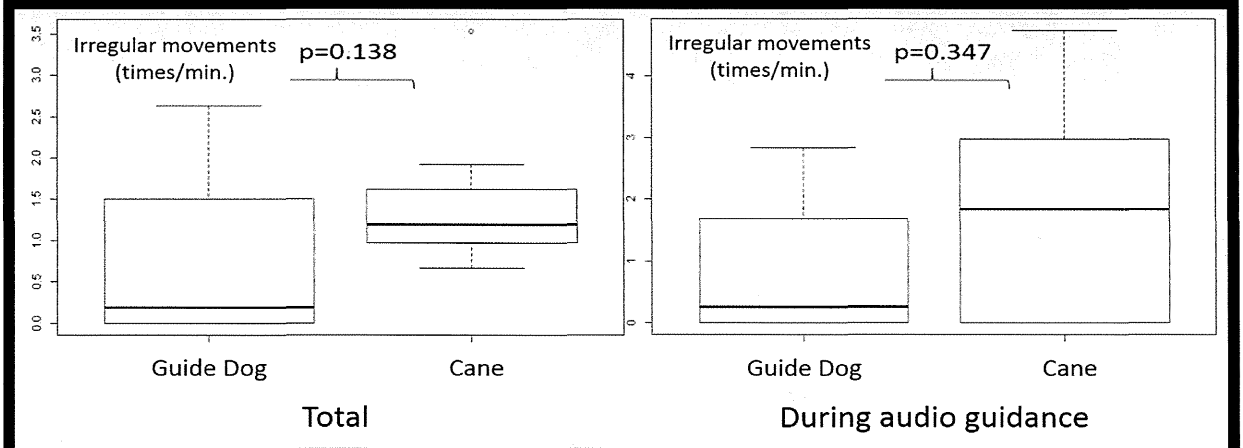



Wilcoxon signed-rank test



# Results: Safety

- No significant difference between walking with a cane and with a guide dog
- Some tendency of more irregular movements in walking with a cane




Mann-Whitney U test

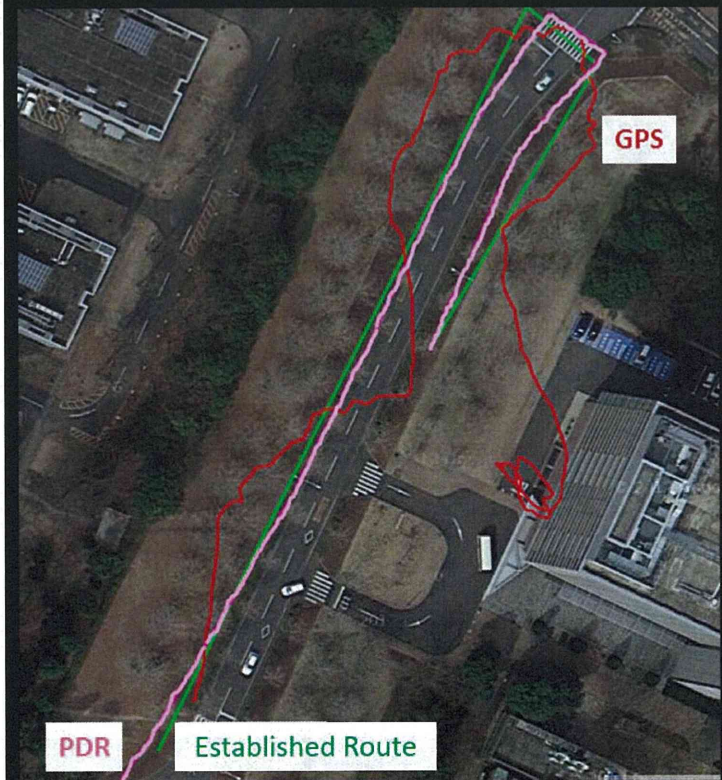
# Results: Brain wave & Heart rate

- Brain wave:
  - The concentration index: (B) > (A)
    - 100% (11/11 trials)
  - The relaxation index: (A) > (B)
    - 82% (9/11 trials)

  Notes: 11 trials included both modes of (A) walk with confidence and (B) walk without confidence.
- Heart rate: No particular results were obtained regarding the heart rate.



# Results: Positioning



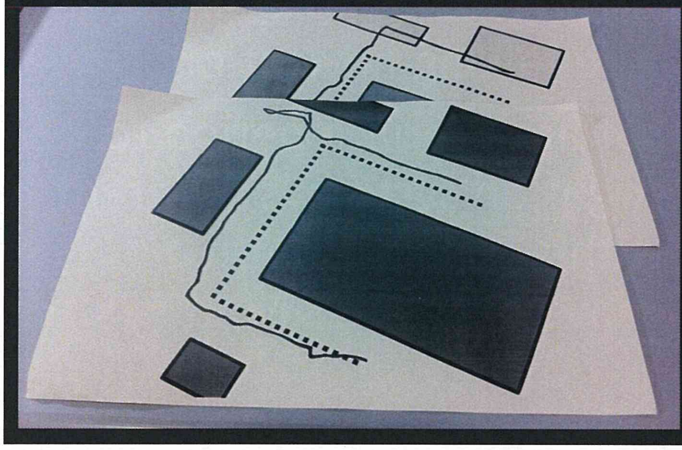

Evaluation of the accuracy of PDR.

- positioning error: 3 m
- Error of estimated walking speed: 20%

[Green] Established route
[Red] Walking path measured on the GPS
[Pink] Walking path measured on the PDR

# Results: Tactile trajectory

- Subjects were shown "tactile trajectories", which are tactile maps with his own trajectories.
- From the interview, we learned that the subject could instinctively confirm veering, and local and global deviation by using the tactile trajectory.



Tactile trajectory shows the buildings, the established route, and the walking trajectory, as measured by PDR or GPS.



# Discussions: Evaluation indices

The following six indices potentially can be measured by what we used in the experiments.

(1a) Accuracy (Micro): Local veering

(1b) Accuracy (Macro): Deviation from the route in total

(2) Safety: Frequency of irregular movement especially during or shortly after audio guidance

(3a) Efficiency (Micro): Walking steps and walking speed

(3b) Efficiency (Macro): Time to finish walking along the established route

(4) Anxiety: Stress level during walking

# Discussions: Comparison between Cane and Guide dog

- The cognitive load for mobility seems to be relatively low for walking with a guide dog as compared to walking with a cane.
- Pedestrians with a guide dog have more spare cognitively to manage the talking navigation.
- There is a possibility that appropriate period to start using a talking navigation system is different between pedestrians with a cane and with a guide dog even if they have similar O&M performance.



# Conclusions (E-mail: t.kurata@aist.go.jp)

| | Orientation Support | Mobility Support | Cognitive Load when using talking navigation |
|---|---|---|---|
| Talking navigation | ✓ High | Low (Negative Contribution) | |
| Cane | N/A | ✓ High | Relatively High |
| Guide dog | Low | ✓ High | ✓ Relatively Low |

Long Cane or Guide Dog
+
Navigation system

→ More practical and popular

↓ Sensor/Guidance Log

Evaluation Indices
Tactile Trajectories

→ Feedback to Trainees & Trainers

# Thank You!!

Takeshi Kurata
AIST, Japan
E-mail: t.kurata@aist.go.jp

**Title**

Smartphone-based Talking Navigation System for Walking Training

**Authors**

Keisuke Okuno, AIST, Japan, E-mail: k.okuno@aist.go.jp, Phone: +81-29-861-1566 (Presenter and contact person)

Takeshi Kurata, AIST, Japan, E-mail: t.kurata@aist.go.jp, Phone: +81-29-861-5789

Yoshikazu Seki, AIST, Japan, E-mail: yoshikazu-seki@aist.go.jp, Phone: +81-29-861-6716

Masakatsu Kourogi, AIST, Japan, E-mail: m.kourogi@aist.go.jp, Phone: +81-29-861-2264

Jun Ishikawa, University of Shizuoka, Japan, E-mail: ishikawa@u-shizuoka-ken.ac.jp, Phone: +81-54-264-5325

**Abstract**

We report on a development of smartphone-based talking navigation system, tactile map/trajectory creation system, and analysis of irregular motions in experiments with visually impaired pedestrians.

Section 1. Introduction

A variety of navigation applications for sighted pedestrians has been developed, as the popularity of smartphones grows. If such a device could be equipped with interfaces suitable for visually impaired pedestrians, it would become popular also among them, as it would provide them with increased senses of their surroundings [1].

Walking is known to comprise O & M (Orientation and Mobility) [2]. We have been advancing the research in order to assist both trainers and trainees on walking training and to realize quantitative evaluation on O and M skills for the training [3]. In the research, we deepened the qualitative understanding of relationship between the navigation system and a cane or guide dog. We also found out that obtained sensor logs by the navigation system and other wearable devices would quantitatively represent improvements of O & M skills. The evaluation indices included accuracy, safety, efficiency and anxiety.

However, in the last experiments [3], a specialized talking navigation system was used and participants of the experiments needed to carry several other devices for measuring sensor values and for recording them. It is possible to have a smartphone-based navigation system that have all functions other than to measure EEG and heart rate. The smartphone can have functions such as positioning, route guidance, distance/direction/landmark notification, and logging positions/motions and the guidance during walking.

Thus, in this paper, we report a development of a smartphone-based navigation system. We also report a map/trajectory creation system with which trainees can understand routes in advance and their accuracy of walking trajectories taken in experiments against desired routes. In addition, we discuss about analysis of irregular motions observed in the last experiments [3].

## Section 2. Smartphone-based Talking Navigation System

First we introduce a smartphone-based talking navigation system, quipped with function to measure positions and motions during walking, with audio guidance and logging ability.

Hardware consists of a smartphone with 9 axis sensors (acceleration/gyroscope/electronic compass) such as Nexus 5 by SAMSUNG, and QZSS (Quasi-Zenith Satellite System) receiver by CORE CORPORATION. This enables audio navigation based on measurement of relative positioning by PDR [4], absolute positioning by GPS and high precision absolute positioning by QZSS. The talking navigation system is designed to work without, if needed, QZSS, considering limited operational time of a QZSS satellite.

Software is developed considering distribution and promotion of the software in the future. We adopted Free Open Source Software for Geospatial (FOSS4G) for development of the talking navigation system and map/trajectory creation system that will be explained in the next section. The OpenStreetMap (OSM) [5] is used to describe map information as much as possible.

Map and routes data are stored in a database using PostgreSQL and PostGIS [6]. A route search engine, pgRouting [7] working with the database, is used by the smartphone to search route from current and starting position to a goal. The OpenLayers [8], which is the map displaying library utilizing javascript and MapServer [9] that is a WebGIS engine, realizes displaying map information on the screen.

A TTS (Text to Speech) engine for Android, DocumentTalker, developed by the Create System Development Corp is used. Audio guidance is realized by the TTS using text, which is created based on result of route search gained through the pgRouting. Positioning program integrates date of PDR, GPS and QZSS to calculate position. All the calculation related to PDR is also performed on the smartphone.

## Section 3. Tactile Map and Trajectory Creation System

In the experiment [3], tactile maps were used so that participants were able to understand the routes in advance. Tactile trajectories were shared with participants after each trials, in order to provide them with feedback of accuracy and degree of deviation of their taken routes. Based on interviews in the last experiment [3], we consider the feedback with tactile trajectory as an important and valuable method that helps participants to understand their performance instinctively.

Now, we briefly explain how tactile map and trajectory creation system works. OSM data, such as roads and buildings, is created by using JOSM (Java OpenStreetMapEditor) [10]. Then, Maperitive [11] is used for drawing bitmap images, based on the OSM data and positioning data from such as GPS and PDR. Finally, we create a tactile map/trajectory from the bitmap image printed on a paper with foaming agent, by using PIAF (a 3D copy machine by Amedia Corporation). It is important that this tactile trajectory creation system would enable us to provide an instant feedback to participants. It is because that tactile trajectory can be created only after obtaining trajectory data from an experiment, while tactile map can be prepared in advance.

## Section4. Irregular Walking Motions during the Talking Navigation

Using the result from the last experiment [3], we analyzed relationship between number of observed irregular walking motions and timing of audio guidance made by the talking navigation system. In the last experiment, we found that percentage of audio guidance made was 40% against entire walking time period.

We manually counted number of the irregular motions by observing recorded videos. We defined five irregular motions as “Sudden change of direction while walking”, “Sudden stop”, “Staggering”, “Sudden change in speed”, and “making contacts with obstacle”.

As a result, frequency of irregular motions occurred during audio guidance was 1.6 times per minute, and 0.5 times per minute otherwise. We found a statistically significant difference between two cases, $p=0.041$, by using Wilcoxon signed-rank test.

The interview in the last experiment [3] shows that the cognitive load for mobility is relatively low for walking with a guide dog as compared to walking with a cane. It leads to a hypothesis that pedestrian with a guide dog have more spare cognitively to manage the talking navigation.

However, there was no statistically significant difference found between walking with a guide dog and walking with a cane. Mann-Whitney U test between pedestrian with a guide dog and with a cane on entire walking time period is $p=0.138$, and the test on time period having audio guidance is $p=0.347$. There is a tendency that participant walking with a guide dog has lower frequency of having irregular motions, but we need further experiments with increased number of trials to make any conclusion.

## Section 5. Discussion and Conclusion

In this paper, we reported a development of smartphone-based navigation system and map/trajectory creation system for walking training of visually impaired pedestrians. We also discussed about relationship between number of observed irregular walking motions and timing of audio guidance made by the talking navigation system.

From a discussion in section 4, we can hypothesis that there are strong relationship between audio guidance and irregular motions, and we have learned that it is important to consider content of audio guidance and timing when to provide audio guidance, and how these relate to quality of walking training. A remaining problem is to detect irregular motions automatically. If it is realized, the analysis of relationship between audio guidance and irregular motions would be done more efficiently.

We are designing evaluation indices such as accuracy (micro & macro), safety and efficiency (micro & macro), and a method to calculate scores of the indices automatically as well as methods to provide feedbacks of walking performance, including tactile map with his own trajectory. Then, we plan to conduct further experiment using all the system explained in the paper.

**謝 辞**

本研究は，厚労省科研「白杖歩行・盲導犬歩行・同行援護歩行に対応したマルチモーダル情報処理技術に基づく訓練と評価の循環支援」プロジェクトの一環として行われた．

**References**

[1] T. Kurata, M. Kourogi, T. Ishikawa, Y. Kameda, K. Aoki, and J. Ishikawa: "Indoor-Outdoor Navigation System for Visually-Impaired Pedestrians: Preliminary Evaluation of Position Measurement and Obstacle Display", ISWC2011, pp.123-124, 2011.

[2] B. B. Blasch, W. R. Wiener and R. L. Welsh, Foundations of Orientation and Mobility 2nd Ed., 1977.

[3] T. Kurata, Y. Seki, M. Kourogi, and J. Ishikawa: “Role of Navigation System in Walking with Long Cane and Guide Dog”, CSUN2014, 2014

[4] M. Kourogi and T. Kurata, “Personal Positioning Based on Walking Locomotion Analysis with Self-Contained Sensors and a Wearable Camera”, ISMAR2003, pp.103-112, 2003.

[5] OpenStreetMap: http://www.openstreetmap.org/

[6] PostGIS: http://www.postgis.net/

[7] pgRouting: http://pgrouting.org/

[8] OpenLayers: http://openlayers.org/

[9] MapServer: http://mapserver.org/

[10] JOSM: http://josm.openstreetmap.de/

[11]Maperitive: http://maperitive.net/