Smartphone-based Talking Navigation System for Walking Training

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Introduction

• Navigation(GPS) apps with Smartphone
  – Popular for sighted pedestrians.

• For Visually Impaired Pedestrians?

➢ Suitable Interfaces ?
  ✓ Optimized Audio Guidance

➢ Seamless navigation indoor/outdoor?
  ✓ GPS would not work indoor
Motivation

Traditional

Long Cane or Guide Dog

Digital age

Navigation system

+ enables

Sensor/Guidance Log

Quantitative evaluation on O&M skills for Training & Feedback

O: Orientation, M: Mobility
In CSUN2014

- Walking experiment with visually impaired persons
  - using Special Purpose Talking Navigation Device

- Quantitative and Qualitative Analysis of Log(Data)
  - Efficiency / Accuracy / Safety

- Pre-journey learning and training & Feedback Tool
  - Tactile Map / Trajectory
Remaining Problem in CSUN2014

• Special Purpose Talking Navigation Device
  – High Cost, Lack of flexibility in development

• Quantitative Analysis of Log(Data)
  – Manual analysis
  – More analysis in detail required

• Tactile Map/Trajectory Generation System
  – Many manual steps required -> NO prompt feedback
In CSUN2015: Progress Report

1. **Quick overview of csun2014**
2. **Quantitative Analysis of Safety Index (Irreg. mov.)**
   - Statistical analysis
   - Automated Detection of Irregular movements (for self-feedback purpose)
3. **Smartphone-base Talking Navigation**
   - Low cost, Flexibility with android OS
   - Seamless navigation indoor/outdoor by PDR/BLE/GPS/QZSS
   - Confirmation mode with POR (point of reference)
4. **Pre-journey learning and training & Feedback Tool**
   - Semi-automated tactile maps/trajectory generation sys.
   - Immediate feedback
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Experiment (CSUN2014): Devices

- **Talking GPS:**
  - Trekker Breeze (made by HUMANWARE and localized in Japanese by EXTRA)

- **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
    (Smartphone: GALAXY S II by SAMSUNG)
Experiment (CSUN2014): Subjects, Route

• Subjects:
  – Cane: 3 completely blind, 1 extremely low vision.

• Route:
  – # of routes: 4
  – Distance: 210-250m
Results (CSUN2014) : Positioning

Evaluation:
- 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
# Qualitative Analysis (CSUN2014)

<table>
<thead>
<tr>
<th></th>
<th>Orientation Support</th>
<th>Mobility Support</th>
<th>Cognitive Load with talking navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talking navigation</td>
<td><img src="#" alt="High" /></td>
<td><img src="#" alt="Low (Negative Contribution)" /></td>
<td></td>
</tr>
<tr>
<td>Cane</td>
<td>N/A</td>
<td><img src="#" alt="High" /></td>
<td>Relatively High</td>
</tr>
<tr>
<td>Guide dog</td>
<td>Low</td>
<td><img src="#" alt="High" /></td>
<td><img src="#" alt="Relatively Low" /></td>
</tr>
</tbody>
</table>

**Cognitive Load**

- **Cane = High >> Cane + Navi = Very High (Relatively High)**
- **Dog = Low >> Dog + Navi = Easily Acceptable (Relatively Low)**
Quantitative Evaluation (CSUN2014)

- **Accuracy**: Time Ratio being off the route
  - Walking with Confidence: 0%
  - Walking w/o Confidence: 29%

- **Efficiency**: Time to complete the routes
  - w/ White Cane (2 subjects): ≈ 3km/h
  - w/ Guide Dog (2 subjects): ≈ 4km/h
  - Note: Calculated with those who had the same condition in routes and trials

- **Safety**: Frequency of irregular movement
  - During and shortly after audio guidance: 2.8 times/min
  - Otherwise: 0.6 times/min
  - Note: Audio guidance was made 40% of the time

CSUN2015: redefine & statistical analysis
In CSUN2015: Progress Report

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Detection of Irregular Movements
- safety measurement-

• Definition (5 kinds)
  • 「Rapid Change in Walking Direction」
  • 「Rapid Stop」
  • 「Rapid Change in Walking Speed (Increase/Decrease)」
  • 「Walking Unsteadily」
  • 「Touch obstacles」 -> irreg. movements to avoid obstacles

Irregular Movements independent from Audio guidance
Safety: Irregular Movements (by Human eyes with video)

- Statistically significant Difference
  - During vs. NO Audio Guidance (Overall):
  - During vs. NO Audio Guidance (w/ White Cane)

Wilcoxon signed-rank test

NO vs. during Audio Guidance
Guide Dog + White Cane (Total)

NO vs. during Audio Guidance
Guide Dog

NO vs. during Audio Guidance
White Cane

\[ *p = 0.01343 \]
\[ p = 0.2 \]
\[ *p = 0.0355 \]
Safety: Irregular Movements (cont.)

• No statistical significant difference
  – w/ White Cane VS. w/ Guide Dog

Mann-Whitney U test

Guide Dog vs. White Cane (Overall)

Guide Dog vs. White Cane (During NO audio guidance)

Guide Dog vs. White Cane (During audio guidance)
Automated Detection Method
-Irreg. Mov. (safety measure)-

• Input:
  – Positioning Data from PDR, GPS

• Calculate 2\textsuperscript{nd} order time deviation of Location Info of the Subjects (Acceleration)

• Adjust threshold value based on AVG and DIV of the Acceleration of the subjects

\[
(\text{Threshold}) = \text{AVG}(|\text{Acc}|) + A \times \text{DIV}(|\text{Acc}|)
\]

Note: A is adjusted based on FP and FN
A Result of the Detection

Detection Rate: 88% (92/104)
- False Positive: 18% (20/116)
- False Negative: 12% (12/104)

note: need to consider change in direction as well for detecting the Unsteady Walk

Image: an example of the result
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Smartphone-based Talking Navigation (HW)

- Smartphone-based: (low cost, flexible development)
  - Walking Behavior, Positioning, Logs of the audio guidance and etc
  - QZSS (Quasi Zenith Satellite System): high cost, limited time of use
    Talking Navigation is available with and without QZSS

- Talking Navigation based on Positioning:
  - Absolute Positioning: GPS, High precision by QZSS, BLE (Bluetooth Low Energy)
  - Relative Positioning: PDR (Pedestrian Dead Reckoning)

PDR (10-axis sensor) + GPS + QZSS + BLE

Nexus 6

FLEAZF5, smartphone with QZSS

Seamless Navigation Indoor / Outdoor
Smartphone-based Talking Navigation \((SW)\)

- For easy access and promotion
  - FOSS4G (Free Open Source Software for Geospatial)
  - OpenStreetMap (OSM), as much as possible

### Smartphone

- Positioning Program \((QZSS, GPS, PDR)\)
- Audio Guidance Program
- Basic Navigation Program
- Map Displaying Program: (OpenLayers) (JavaScript)

### Server

- Route Search Engine: (pgRouting)
- Data Conversion: (osm2pgrouting)
- WebGIS Engine: (MapServer) (PHP, MapScript)
- Database: (PostGIS/PostgreSQL)
POR Confirmation Mode

• **POI vs. POR?**
  – **POI:** Point Of Interest
    • Facilities (i.e. restraint) and geographical point (i.e. park)
  – **POR:** Point Of Reference (EO Guidage CSUN2014)
    • Points easy to sense the existence, for confirming routes (Steps, Stairs, Sloop, Door, Sound/Noise, Scent/Odor)

• **Guidance Mode:** Talking Navigation

• **POR Confirmation Mode:** (a quiz mode)
  – Check if subjects are on an expected route (Skill check)
  – A user can be a sensing device (Correct positioning)
    • A navigation system should never break: it should only become an MP3 player. By Jacques Lemordant (INRIA)
Example: EO Guidage (csun2014)
GUIDINO by Medeo Group (csun2015)

- Hybrid BLE and Wi-Fi positioning
- For visually impaired persons
- Navigation with POR

BLE on roof

(POR) Entrance with Voice Guidance
Seamless Indoor-Outdoor Navigation with POR, PDR, BLE, GPS/QZSS

1. Outdoor: PDR/GPS/QZSS and POR
2. Door(entrance): BLE / POR
3. POR: toilet
4. Indoor: PDR/BLE (relative/absolute positioning)
5. Door(exit): BLE / POR
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Tactile Maps

- Pre-journey learning and training-

- Road [solid line]
- Buildings [polygons]
- Established route [dotted line]
- Starting point [Solid triangle] / Finish point [Solid circle]
Tactile Trajectory (for Feedback)

- Tactile maps with subjects’ own trajectories.
- Subjects instinctively confirm (by Interview)
  - veering
  - local and global deviation

- Buildings [polygons]
- Established route [dotted line]
- Walking trajectory measured by PDR or GPS [solid line]
Tactile Map/Trajectory Generation Sys

- For Immediate feedback of training
- Print by a semi-automated system (working on it)

(1) Script to integrate Map and Trajectory data using Maperitive

(2) Script to output png for Tactile Trajectory using output of (1) and Maperitive

(3) Generate Tactile Map/Trajectory by using PIAF
Conclusion

• **Safety Index (Statistical analysis):**
  – Audio Guidance causes more Irregular movements
  – Cane users are affected by audio guidance (high cognitive load)

• **Automated Detection of Irregular Movements (for self-feedback):**
  – 88% detected (FP=18%, FN=12%), compared to manual result

• **Smartphone-base Talking Navigation:**
  – Low cost, Flexibility with android OS
  – Seamless navigation indoor/outdoor by PDR/BLE/GPS/QZSS
  – Confirmation mode with POR (skill check & human as a sensor)

• **Semi-automated tactile maps/trajectory generation system:**
  – For immediate feedback after training
Future work

• Subject experiment for seamless indoor/outdoor navigation with longer routes.
• Evaluate contribution of POR confirmation mode.
• Different optimization of audio guidance for white cane and guide dog users
• Automated Evaluation of other Indices.
• POR infrastructure shared on the cloud