A Wearable Wireless RFID System for Accessible Shopping Environments

Sreekar Krishna, Vineeth Balasubramanian, Narayanan Chatapuram Krishnan, Colin Juillard, Terri Hedgpeth, Sethuraman Panchanathan

Center for Cognitive Ubiquitous Computing, Arizona State University
Motivation

- Imagine an individual who is blind at a grocery store

Options available today

- Be bothersome
  - Ask a store assistant for every single item, its details, its nutritional value, etc, etc

- Be the pest
  - In every aisle, ask the customer there for a particular item and its details

- Be the nag
  - Call a friend and ask him/her to come down with you every time

- Bonus solution: Be super-smart
  - Teach the dog to shop
Relevant Earlier Work – I

- **RoboCart, Utah State University**
  - A motor driven robotic cart guide
  - Utilizes RFID technology,
  - Multiple sensors provide navigational assistance

**Issues**

- Moves at .5 mph!
- SONAR navigation too jerky, unreliable due to specular reflections and cross talk.
- Requires preloaded grocery list
- Tags fixed to shelves, not products – can lead to trouble when products are restocked.
- Shopper is guided by the robot...!
GroZi, University of California San Diego
- Hand-held low resolution camera with a memory device
- Product images downloaded at home
- At store, sweep camera on every side of aisle
- System matches captured images to stored images
- Shopper is notified when there is a match

Issues
- Object detection & recognition from images in real-time - is an unsolved problem!
- Delivery of information not timely & error rate too high
- Requires pre-loaded grocery list
Trinetra, Carnegie Mellon University
- Cell phone with text-to-speech software and a Bluetooth enabled barcode reader.
- Shopper can quietly scan the UPC labels from products
- Corresponding product info is downloaded to cell phone from the online UPC database (www.upcdatabase.com).
- A commendable effort toward a assistive shopping device.

Issues
- High cognitive load imposed on the shopper (how to find barcode on product)
- No method for identifying shelf /aisle information.
Objectives

- Accessible Shopping Environment
  - Provide means for independent shopping
  - Provide uninterrupted access to large databases of information in shopping environments

- Don’t impede user movement
- Don’t usurp decision-making, leave it to user

- Leverage potential emerging technologies
  - EPC (Electronic Product Code)
  - RFID (Radio Frequency Identification)

Center for Cognitive Ubiquitous Computing, Arizona State University
Proposed System Architecture

Component 1: User wearable devices
- Wearable RFID Reader
- PDA with speech
  - Bluetooth

Component 2: Store server with a relational database
- Store Database
  - Wi-Fi
Components: User Devices

- **RFID Reader**
  - High-frequency RFID reader, M1 module, by SkyeTek Inc
  - Form factor: 1.5” x 1.5” x 0.125”
  - Voltage: 1.8 – 5.0 V
  - Power: 500 mW at 5 V
  - Can work with industry standard RFID tags like ISO15693, ISO14443A and ECMA-319
  - RS-232 communication
Components: User Devices

- **Bluetooth Module**
  - Mitsumi WML C40AH
  - Form factor: 0.5” x 1” x 0.0625”
  - Achieves 10 m of reliable bidirectional communication link

- **PDA with Speech Software**
  - Dell Axim X51V
  - Windows Mobile 5.0 OS
  - MobileSpeak speech software
Components: Store Server

- Relational Database
  - Implemented on Microsoft SQL Server 2005 Express
  - Entity Relationship Diagram

Center for Cognitive Ubiquitous Computing, Arizona State University
• **Interface between user device and database**
  - Implemented as Web Services on Microsoft ASP.NET 2.0
  - Equipped with intelligence to retrieve requested data, and check for related data.
  - Functions exposed on Web Services in turn call stored procedures/queries on database.
Parameters of testing

- Tag detection ability of the RFID reader under different conditions.
- The overall system delay- $T_d$, time taken by the device, from point of tag scan to the time when data is available to the user on the PDA as a synthesized voice.
Parameters considered in the experiment

- Distance from the tag to reader
- Orientation of the tag with respect to the reader.
- Material on which the tag is placed.
- Type/Geometry of the tag.
- Whether external antenna was used with reader.
System Evaluation: RFID Reader-Tag

- Experimental Setup
## Tags and materials used

<table>
<thead>
<tr>
<th>Tag #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tag-It HF-I, Texas Instruments, 2.25in x 2.25in, ISO15693 compliant</td>
</tr>
<tr>
<td>2</td>
<td>Tag-It HF-I, Texas Instruments, 1.5in x 1in, ISO15693 compliant</td>
</tr>
<tr>
<td>3</td>
<td>ICode SL1, Philips, 1 in diameter, Proprietary data format</td>
</tr>
<tr>
<td>4</td>
<td>ISO15693 compliant access-control card, 3.5in x 2 in</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material #</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wood</td>
</tr>
<tr>
<td>2</td>
<td>Plastic</td>
</tr>
<tr>
<td>3</td>
<td>Cardboard</td>
</tr>
<tr>
<td>4</td>
<td>Glass</td>
</tr>
<tr>
<td>5</td>
<td>Ceramic</td>
</tr>
</tbody>
</table>
System Evaluation: RFID Reader-Tag

- Detection Distance-Orientation Maps

TI Tag-It HF-I, 2.25in x 2.25in.

TI Tag-It HF-I, 1.5in x 1in.

ICodeSL1, Phillips, 1in diameter.

Access-control card, 3.5in x 2in.

Center for Cognitive Ubiquitous Computing, Arizona State University
Conclusions

- Tag 1 with a form factor of 1.5” by 1.5” provided best detection in terms of maximum possible radial distance and angular variation.

- Maximum distance of detection = 3 inches
  - Tag 1, tag perpendicular to reader

- Detection probability gradually falls towards 0 as the orientation changes from 90° to either 0° or 180°

- With an external antenna:
  - Maximum distance increased to 6 inches
  - Detection region is approx 2.5 times larger
System Evaluation: Time Delay

- Time delay:  
  - \( T_d = T_c + T_t \)

- Two components
  - \( T_c \): Time taken to send RDIF info from the reader to PDA
    - RFID tag = 20 characters
    - Serial port operates at 9600 bits/sec
    - Bits per character = 10 (8 data + 1 start + 1 stop)
    - Delay time = \( 20 \times \frac{10}{9600} = 20.8 \text{ ms} \)
  
  - \( T_t \): Time taken for the RFID tag info to be sent to the database, database retrieval and response read out to the user
    - This was measured using 5 user subjects with 10 trials for each subject
System Evaluation: Time Delay

- Average median performance of 5 users = 159.7 ms
- Total System delay = 159.7 + 20.8 = 180.5 ms
Ongoing work

- Usability studies

- Use proximity sensors/active RFID readers for aisle/section detection

- Identify external antennas with suitable form factor to increase range of RFID reader

- Adopt dead reckoning systems for user localization

Center for Cognitive Ubiquitous Computing, Arizona State University
Questions?