Indoor Localisation and Tracking of Misplaced Objects

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## NCSR Demokritos HMFM Team

<table>
<thead>
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<th>Main Responsibilities</th>
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<tr>
<td>Stelios C. A. Thomopoulos, PhD</td>
<td>Project Coordinator and Technical Development</td>
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<tr>
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<td>Development &amp; Architecture Design Coordination, Back-End development</td>
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<td>George Vastianos, MSc</td>
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<td>Localisation algorithms design</td>
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<td>Olga Segou, Dipl. -Ing, PhD candidate</td>
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<tr>
<td>John Goufas, MSc</td>
<td>Back-End programming</td>
</tr>
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Presentation Layout

- Objectives
- Overview of Achievements so far
- Object Mapping and Tracking Solution for Indoor Environments
  - Development Storyline and System Description
  - Personal Medicine Assistant Integration and Trials
  - Demonstration Scenario
- The Way Ahead
- Publications
Objectives

- **Indoor Localisation Technologies (M1-M12)**
  - Feasibility Study and Experimenting with available indoor localisation technologies and solutions

- **Misplaced Object Mapping and Tracking (M3-M14)**
  - To deliver specifications regarding the indoor “misplaced object in home” mapping mechanism and the corresponding tracking service

- **Ambient and Multi-Modal UIs for Indoor Mapping and Misplaced Object Tracking (M6-M23)**
  - provide specifications for interfacing the audio, visual and haptic UI components provided by WP3 with the guidance and routing information models provided, while also a reasoning component for ambient routing presentation will be specified.

- Results are provided to WP4 for pilot implementation.
Achievements so Far (i)

- A study on existing indoor localisation solutions was conducted, together with an analysis for HMFM suitability
  - RFID passive technology most suitable in terms of ergonomics, cost and intrusiveness
- Embedded in the design the users feedback on object tracking solution and privacy concerns:
  - Interviews with elderly clients of the Caritas village and younger members of Finnish Federation of the Visually Impaired (FFVI)
  - Interviews with blind people (between 60 and 78) members of ONCE (Spanish Blind Organisation) and elderly (between 65 and 80) from an Elderly People’s Spanish Centre.
- A variety of experiments were run using RFID technology in order to test related technology potentials and evaluate the feasibility of an RFID-based indoor localisation system for HMFM.
Achievements so Far (ii)

- An indoor object mapping and tracking system has been developed based on passive RFID technology
  - Efficient and cost-effective solution thanks to the NCSRD in-house development of Multiplexer Unit
  - Improved accuracy thanks to the combined cell-id and fingerprinting algorithms
  - Deployed and tested in NCSRD LocTrack Laboratory
- Integration with Personal Medicine Assistant and Graphic/Audio/Touch User Interfaces
  - Robotiker’s Homelab Trial
User interviews (i)

The following key points are derived after examining the results:

- Misplacing objects in their personal space happens often or sometimes for the vast majority of interviewees.
- A related assistive service for locating misplaced object would be either necessary or at least useful again for most interviewees (75%).
- It is evident from most answers that simplicity in terms of UIs is a key for the success of such a service.
- Navigation in a user’s own house is in general not necessary; for the minority in need of navigation, a proximity-based sound alarm would be preferable.
- House room accuracy is not enough for almost all interviewees. For the majority the exact location is needed or at least a specific area or part of a room.
User interviews (ii)

- Privacy questions were not answered by the older half of interviewee’s pool (70+). Apparently the notion of privacy needs to be better explained or included into the questions with a more simple way.
- The people who answered the privacy questions in general have faith on the current legal framework and would trust a service which would make use of their location information in order to locate their misplaced objects.
RFID Experiments

• The goal of the measurements is to offer documented results regarding the feasibility and applicability of an RFID-based system for indoor localization of everyday objects of visually impaired persons, such as their medication packages.

• The evaluation of the proposed approach, besides feasibility, is in terms of accuracy and robustness.

• To provide initial results regarding localization algorithms and techniques which will be further investigated in following experimental work, together with alternative candidate techniques.
RFID Experiments

A total of 7 experiments were conducted:

- Basic RSSI measurements for the creation of fingerprints database and localization algorithms testing based on circular polarization antennas.
- Basic RSSI measurements for the creation of fingerprints database and localization algorithms testing based on linear polarization antennas.
- RSSI measurements for the comparison between circular and linear polarization antennas in a wide range of transmitting power levels (part 1: circular and part 2: linear polarization polarization).
- RSSI measurements for the detection of maximum working range of the circular polarization antenna.
- RSSI measurements for the detection of maximum working range of the linear polarization antenna.
- Additional RSSI measurements on 9 grid points & 2 additional height levels for testing how the localization algorithms will react in case that the RFID tags (in a real environment) placed on a height different than the average 0.8m.
Range measurements results for all antenna-tag combinations

<table>
<thead>
<tr>
<th>Transmit Power: 30dBm (max power)</th>
<th>Antenna #1 (Built-in) Laird Technologies S8658WPR</th>
<th>Antenna #2 (External) Mobilemark BP6-868</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tag group A (large) - Allien Squiggle tags</td>
<td>24.5m</td>
<td>5m</td>
</tr>
<tr>
<td>Tag group B (small) - Avery Runway tags</td>
<td>3.5m</td>
<td>2m</td>
</tr>
</tbody>
</table>
Coverage Results for Tag of type “A” at coordinates (6.5, 3.5) (corner of room) for transmitting power equal to 30dBm (scaled)
Coverage Results (ii)

Coverage Results for Tag of type “A” at coordinates (6.5, 3.5) (corner of room) for transmitting power equal to 26.5dBm (scaled)
Coverage Results (iii)

Coverage Results for Tag of type “A” at coordinates (6.5, 3.5) (corner of room) for transmitting power equal to 23dBm (scaled)
Coverage Results (iv)

Coverage Results for Tag of type “A” at coordinates (4, 2.5) (center of room) for transmitting power equal to 30dBm (scaled)
Experiments Conclusions

- An RFID-based system has been tested in order to verify its applicability for developing a localization system for objects like medication packages, in indoor environments.

- From the presented experimental results, it can be deducted that the optimal combination of equipment is antenna #1 (built in) together with tags of group A.

- Furthermore, the reading range of the equipment is considered to be satisfactory.

- Coverage and localization accuracy in a typical indoor environment indicate that the localization of objects in indoor environments is feasible using the proposed approach.
RFID shortcomings

- Large number of scattered waves of significant power levels may arrive to the receiver and compromise the localization procedure.
- This phenomenon becomes more severe in the case where there are metallic objects within the room, or in the neighborhood of the tag.
- Possible ways to overcome this problem is to use reference tags in spots where it is known that there are large metallic objects, or use more dense fingerprinting in order to identify and mitigate the effects of multipath propagation in localization accuracy.
Object Mapping and Indoor Tracking System Architecture

- RFID Localisation Module
  - RFID H/W Management
  - Location Determination Algorithms
- Object Tracking Information Management Server
  - HMI Dialogue Management
  - Tracking Handler & Reasoning Engine
  - Indoor Mapping and Location Information
- RFID Localisation Module

User Interfaces: ia, ib, ic, id, ie
Indoor Mapping and Reasoning

- An extensible and hierarchical information model, supporting standard geodata structure (polygons, lines, points).
- This can be easily interfaced with a variety of GIS applications, following a well known standard, e.g. KML.
- The ontology supports a variety of parameters, interfacing indoor mapped entities with a wide range of potential personalised services (e.g. unbotrusive daily activities monitoring, home ”logistics”)
- The model is technology-independent: entities can be related to different types of tags and sensors, while different abstraction levels are supported, depending on the accuracy of underlying technology.
RFID hardware
The Multiplexer Unit

- In-house development of NCSRD
- Connects the RFID reader with up to eight antennas
- Enables building single reader RFID cells, replacing the need for expensive multiple RFID readers setup
- Makes easier the installation and offers mechanical protection and stability to the integrated circuit boards
Localisation Algorithms

- A well known Scene-Analysis algorithm, based on fingerprinting the RSSI (Received Signal Strength Indication) over the localization area and then perform localization using Euclidean norms in signal space.

- Simple Cell-ID algorithm, where the position of the Reader is assumed to be identical with the position of the Tag corresponding to the maximum RSSI measurement.

- An algorithm combining the above two algorithms: the cell-id algorithm is firstly used to limit the area where fingerprinting analysis occurs.
Test Site 1: NCSR Demokritos LocTrack Laboratory
Test Site 2: Robotiker Homelab
## Localisation Algorithm Results

<table>
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<tr>
<th></th>
<th>Fingerprint</th>
<th>Cell-ID</th>
<th>Combined</th>
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<tr>
<td><strong>Average accuracy</strong></td>
<td>1.3m</td>
<td>0.79m</td>
<td>0.91m</td>
</tr>
<tr>
<td><strong>Median accuracy</strong></td>
<td>1.6m</td>
<td>0.56m</td>
<td>0.79m</td>
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<tr>
<td><strong>67th percentile of accuracy</strong></td>
<td>1.4m</td>
<td>0.79m</td>
<td>0.9m</td>
</tr>
<tr>
<td><strong>95th percentile of accuracy</strong></td>
<td>2.3m</td>
<td>1.25m</td>
<td>1.83m</td>
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Invalid measurements correspond to failed localisation - power equal to 30dBm
Personal Medicine Assistant Integration and Demo Scenario

- Using Axis2 (SOAP standard implementation), Indoor Mapping and Tracking was integrated with the Personal Medicine Assistant application through a standardised Web Service interface.

- Demo Scenario:
  - The User registers the NFC/RFID enabled package of medicine “X” to the system
  - The Personal Medicine Assistant reminds the User that it is time to take medicine “X”
  - The User realises that he doesn’t remember where the medicine is so he presses the button requesting from the system to find the specific medicine
  - A message appears on the screen suggesting:
    - the estimated current location of the specific package in case the last scan succeeded in locating the package in the area
    - the last know position in case the package cannot be currently found in the area
The Way Ahead

- System validation and optimisation of localisation algorithms
- Considering and supporting additional multi-modal User Interfaces
- Evaluation and user acceptance
- *To be discussed in the consortium meeting: Demonstration of pilot system*
Publications

Journals


Conference Proceedings

Thank you