A Real-time Indoor Tracking System by Fusing Inertial Sensor, Radio Signal and Floor Plan.

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6 October, 2016
Outline

- Proposed Indoor Positioning System
  - Inertial Sensor Component.
  - Radio Information Component.
  - Floor Plan Information Component.
  - Data Fusion Component.
- Implementation
  - Inertial Measurement Unit (IMU) process.
  - Ranging process.
  - Particle Filter.
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- Preliminary Results
- Conclusions
Proposed Indoor Positioning System

- Inertial Sensor Component (ISC)
  - IMUs → Move Detection
  - IMUs → Motion Vector
  - IMUs → Map Constraints
  - IMUs → Ranging

- Floor Plan Component (FPC)
  - Map Floor → Map Constraints
  - Map Floor → Data Fusion Component (DFC)

- Radio Inf. Component (RC)
  - Power → Ranging
  - Ranges → Particle Filter
  - Ranges → Location

- Data Fusion Component (DFC)
  - Map Likelihood → Particle Filter

- Position Monitoring
Inertial Sensor Component

**Accelerometer:**
- Linear acceleration.

**Gyroscope**
- Angular rotation velocity

**Magnetometer**
- Azimuth value

Radio Information Component

Signal Power \rightarrow NLR \rightarrow Ranges

Non-Linear Regression Model [1]

\hat{d}_i = \alpha_i \cdot e^{\beta_i \cdot \text{RSS}_i}

Floor Plan Information Component

Map Constraints
Map Floor
Map Likelihood

Define “allowed” zones

Data Fusion Component

Bayesian Filter

- Represents a PDF as a set of samples (particles).
- Model of how state changes in time.
- Model of what observations you should see.
- Belief of the current state given all the observation so far.
Implementation
Ranging I
Implementation

Ranging II

Non-Linear Regression Model

\[ \hat{d}_i = \alpha_i \cdot e^{\beta_i \cdot \text{RSS}_i} \]
Implementation
Inertial Measurement Unit I

Accelerometer

Step Recognition

\[ \hat{a}_{z,t} > \text{Threshold} \quad \&\& \quad \hat{a}_{z,t-1} < \hat{a}_{z,t} \quad \&\& \quad \hat{a}_{x,t} < \hat{a}_{z,t} \quad \&\& \quad \hat{a}_{y,t} < \hat{a}_{z,t} \]
Implementation
Inertial Measurement Unit II

Magnetometer, Accelerometer

Heading Orientation

OffsetX: Inclination X axis Magnetic North
Azimuth: Magnetic North and Y axis

\[ \theta = (\text{OffsetX} - \text{Azimuth}). \]

\[ st = \text{stride length}. \]
Implementation
Particle Filter

Particle Propagation

Particle Correction And Resampling

System State

Motion Vector
\[ X = \hat{st} \cdot \cos(\theta) \]
\[ Y = \hat{st} \cdot \sin(\theta) \]

Likelihood

RSS observation
- Ranging
- Constraints

Floor Plan

System State

\[ x_k = \sum_{i=1}^{N_s} w_k^i x_k^i \]

Particle Correction

Resampling

\[ w_k^i = \hat{w}_k^i / \sum_{n=1}^{N_s} \hat{w}_n^i \]
Experiments

**EXPERIMENT 1**
- University of Bern.
- Target area: 336 m² (3 floors)
- 12 Check Points

**EXPERIMENT 2**
- University of Geneva.
- Target area: 192 m²
- 9 Check Points
Results

(a) Particle Filter vs PDR, Scenario 1

(b) Particle Filter vs PDR, Scenario 2

<table>
<thead>
<tr>
<th>Tracking Approach</th>
<th>Mean error</th>
<th>S.D</th>
<th>90% Acc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle Filter Scenario 1</td>
<td>1.7m</td>
<td>1.0m</td>
<td>3.2m</td>
</tr>
<tr>
<td>Particle Filter Scenario 2</td>
<td>1.9m</td>
<td>1.27m</td>
<td>4.3m</td>
</tr>
<tr>
<td>PDR Scenario 1</td>
<td>6.2m</td>
<td>2.9m</td>
<td>10.5m</td>
</tr>
<tr>
<td>PDR Scenario 2</td>
<td>5.1m</td>
<td>4.25m</td>
<td>15.7m</td>
</tr>
</tbody>
</table>
Conclusions

- Tested complex scenario. Room entrance prone to error.
- Proposed Ranging-PF assisted approach higher accuracy, stable than PDR.
- PF outperforms PDR around 72.6% with 90% accuracy.
- Use RSSI-based ranging information to recalibrate PDR to deal with accumulative errors.
- RSSI-based ranging information requires ANs position.
- Remarks from competition
  - Outdated AP locations/MAC information provided
  - Large scenarios (50000 m²) take long survey period
  - Ranging or fingerprinting?
Questions?

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