A Novel Backtracking Particle Filter for Pattern Matching Indoor Localization

Widyawan, Martin Klepal
Stéphane Beauregard, Dirk Pesch

Centre for Adaptive Wireless Systems
Cork Institute of Technology
Ireland
Outline

• Motivation
• Indoor Localization
• Algorithm
• Result
• Conclusion
Motivation

- Improving pattern matching localization with Particle Filter and Map Filtering
- Propose novel variant Particle Filter called Backtracking Particle Filter algorithm and evaluate with RSSI Localization
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Indoor Localization

• The pattern matching indoor location works in two phases:
  – Calibration phase (database of RSSI values/fingerprint)
  – Online Tracking
• Fingerprint can be created manually or by using indoor propagation model
• This paper use empirical approach called the Multi-Wall Model
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Particle Filter and Map Filtering

**Prediction stage:**

\[
p(x_t | Z_{t-1}) = \int p(x_t | x_{t-1}) p(x_{t-1} | Z_{t-1}) dx_{t-1}
\]

motion model  \quad \text{posterior distribution at } t-1

**Update Stage:**

\[
p(x_t | Z_t) = \frac{p(z_t | x_t) p(x_t | Z_{t-1})}{p(z_t | Z_{t-1})}
\]

**Particle Filter:**

\[
p(x_t | Z_t) \approx \sum_{i=1}^{N} w_i \delta(x_t - x_i)
\]

Map filtering illustration

A typical likelihood function of WLAN AP
Backtracking Particle Filter

- Backtracking Particle Filter is a technique to refine state estimates based on particle trajectory histories.
- If some particles $x^i_t$ are not valid at some time $t$, the previous state estimates back to $x^i_{t-k}$ can be refined by removing the invalid particle trajectories.
- This is based on assumption that an invalid particle is the result of a particle that follows an invalid trajectory or path.
- Therefore, recalculation of the previous state estimation $x^i_{t-k}$ without invalid trajectories will produce better estimates.
BPF Illustration

= Estimated Object State
= Ground Truth
= Likelihood filter

invalid particles

= backtracking invalid trajectories

= Backtracking Estimated State
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Simulation

- Simulations were run in floor-plan 2,500m²
- The fingerprint database was estimated using the Multi Wall Model
- A nominal walking behavior was generated by advancing the current location of a simulated user along a ground truth path at a rate of 1 m/s at each simulation time step (1 second)
- Noisy RSSI scan measurements were generated for each simulation time step by adding Gaussian noise with standard deviation of 5 dBm to the nominal, noise-free RSSI values for current position from fingerprint DB
### Result

<table>
<thead>
<tr>
<th></th>
<th>NN</th>
<th>KF</th>
<th>PF</th>
<th>BPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>without MF</td>
<td>μ= 4.37, σ= 4.66</td>
<td>μ=3.57, σ=2.90</td>
<td>μ= 1.82, σ= 1.50</td>
<td>μ= 1.62, σ= 0.97</td>
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<tr>
<td>with MF</td>
<td></td>
<td>μ= 1.67, σ= 1.40</td>
<td>μ= 1.34, σ= 0.80</td>
<td></td>
</tr>
</tbody>
</table>

NN = Nearest Neighbour  
KF = Kalman Filter  
PF = Particle Filter  
BPF = Backtracking Particle Filter
Trajectories

- Nearest Neighbour & KF
- PF & BPF without Map Filter
PF & BPF with Map Filtering
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Conclusion

• Backtracking Particle Filter algorithm is proposed and evaluated with pattern matching localization

• BPF with building constraint information yields excellent positioning performance (1.34 m mean 2D error), enhancement up to 25% compare to PF only (1.82 m mean 2D error)

• This result show that BPF can be performed via the elimination of trajectory error based on likelihood function.