Bluetooth based Indoor Localization using Triplet Embeddings
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Motivation:
- Localize people within a building using low-cost IoT Bluetooth receivers, from RSSI information and location of the receivers.

In this work:
- We propose a model-free positioning algorithm based on Triplet Embeddings
- We leverage the missing information using RSSI information
- We do not use the RSSI values directly, but ordinal information in RSSI values

Setup

![Image of owl installation for a nursing unit at USC's Keck hospital](Image)

Figure 1: Owl installation for a nursing unit at USC’s Keck hospital. The black circles show owl positions, placed in rooms shaded in light gray. The yellow circles show owls that we use as sender devices (one at a time) to validate our algorithm.

Assumptions

We assume that higher RSSIs imply smaller distances between source and receiver:

\[ r_j > r_k \Rightarrow D_{ik} > D_{jk}, \quad \forall j \neq k. \tag{1} \]

where \( s \) is the sender device (source) and \( j, k \) are receivers.

Algorithm

**Algorithm 1**: Estimate sender position from sensor positions and RSSIs

**Input**: \( X \subseteq \mathbb{R}^2 \): Known receiver positions

**Input**: \( r \in \mathbb{R}^2 \): RSSIs

**Result**: \( \tilde{x} \): Estimated sender position

1. \( D = \text{distances}(X) \);
2. // Obtain triplets and compute the embedding
3. \( S, y = \text{triplets}(D, r, g) \);
4. \( \hat{Z} = \text{embedding}(S, y, f) \);
5. \( \hat{Z} = [\hat{x}, \hat{y}] \)
6. // Find the best affine transformation for the receiver positions.
7. \( \Pi = \text{Procrustes}(\hat{X}, X) \);
8. // Apply affine transformation and return
9. if \( \Pi(\tilde{x}) \in \text{conv}(X) \) then
10. return \( \Pi(\tilde{x}) \);
11. else
12. return null;

Results

<table>
<thead>
<tr>
<th>Owl</th>
<th>Error [m] for ( g_1(x) )</th>
<th>Error [m] for ( g_2(x) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.767 ± 2.446</td>
<td>3.358 ± 2.118</td>
</tr>
<tr>
<td>B</td>
<td>5.456 ± 2.595</td>
<td>5.779 ± 2.306</td>
</tr>
<tr>
<td>C</td>
<td>3.244 ± 2.114</td>
<td>4.149 ± 1.117</td>
</tr>
</tbody>
</table>

**Figure 4**: Box plot of the error as a function of number of receivers for a sent packet for two clipping functions \( g_1 \) and \( g_2 \). The sender is device A from Figures 1.

Conclusions

- We propose a model-free algorithm for indoor localization that uses the ordinal information of the RSSI values
- We test an algorithm in a real-world setting: A heavy-traffic nursing unit within USC’s Keck hospital
- We are able to localize different sources with an average error of 4m
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References