Accurate Extraction of Face-to-Face Proximity Using Smartphones and Bluetooth

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Motivation
Whether digital communication facilitates or impedes face-to-face interactions.

- Digital communication: texting, social networking...
- Face-to-face interactions: two or more individuals within a certain distance that could afford such interactions
- Self-reporting (i.e., subjects are asked about their social interaction proximity) is unreliable since the accuracy depends upon the recency and salience of the interactions.
- Look for an accurate estimator of the proximity which face-to-face interaction requires

Contribution
We demonstrate the viability of using Bluetooth RSSI with appropriate smoothing for the purposes of face-to-face proximity estimation and evaluate the accuracy across several real-world scenarios.

- We study the relationship between the value of Bluetooth RSSI and distance based on empirical measurements and compare the results with the theoretical ones using the radio propagation model.
- We discuss the construction of a data collection platform using Bluetooth on Android-based smartphones.
- We explore the energy efficiency of Bluetooth compared with WiFi and GPS via experimental measurements.

RSSI-based position techniques comparison:

<table>
<thead>
<tr>
<th></th>
<th>Bluetooth</th>
<th>WiFi</th>
<th>GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HW costs</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Coverage</td>
<td>Medium</td>
<td>High (Indoor)</td>
<td>High (Outdoor)</td>
</tr>
<tr>
<td>Power Usage</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Accuracy</td>
<td>1-4m</td>
<td>3-30m</td>
<td>5-50m</td>
</tr>
</tbody>
</table>

Accuracy requirement: 1-1.2m
Ubiquity: most modern smartphones support Bluetooth

Bluetooth RSSI vs. Distance

According to the radio propagation model and power level, Figure (a) presents indoor, outdoor, and theoretical results for Bluetooth across a variety of distances (0-5 meters). The inside results were relatively close to the theoretical values. However, the results outside the building were somehow farther away from the theoretical reference.

- In Figure(b), the influence of possible factors (antenna orientation, obstacles, etc.) are analyzed. We also analyzed the similar factors outdoors. We found the most important environment issue came from the backpack.

Conclusions and Future Work
- Validate the usage of Bluetooth as a tool for face-to-face proximity detection.
- Explore the relationship between Bluetooth RSSI values and distances for indoors and outdoors settings.
- Analyze the impacts of different settings.

For our future work, we intend to further explore real-world scenarios including small scale experiments with five to ten phones. We further intend to improve our threshold algorithms with data mining and include considerations for atmospheric pressure and night.

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