Investigation of Seamless Indoor and Outdoor Positioning Integrating Wi-Fi and GNSS

Esmond Mok (HKPolyU)
Guenter Retscher (TU Wien)
Linyuan Xia (Wuhan University)

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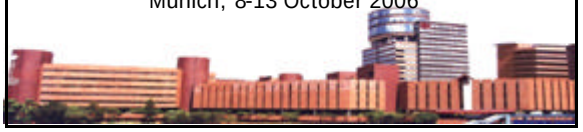


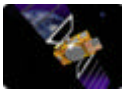
CONTENT

Modern/Emerging Positioning Technologies

Space-Based Positioning:


GPS

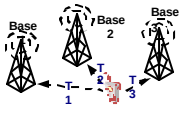

GLONASS


GALILEO

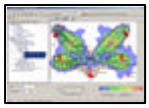

BD

Ground- Based Positioning:


UWB



Cellular Wireless Network




Wi-Fi

Development Trend of Positioning Technology

Seamless Indoor and Outdoor Positioning by integrating range measurements from space and ground measurement sources

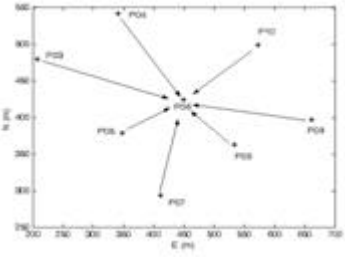
- GPS, GLONASS, GALILEO, BD
- Cellular Wireless Network
- UWB
- Wi-Fi Positioning

Processing Model for Integrating Range Measurements from Space and Ground Measurement Sources:

- GPS, GLONASS, GALILEO (Pseudorange)
- Cellular Wireless Network (TOA/TDOA)
- Ultrawide Band (TOA/TDOA)
- Wi-Fi Positioning (RSS)

[GNSS 2005, 8-10 December 2005, Hong Kong]

Simulation Studies



Range Data:
Pseudorange
TOA/TDOA

Wi-Fi:
Signal Strength
(RSS)

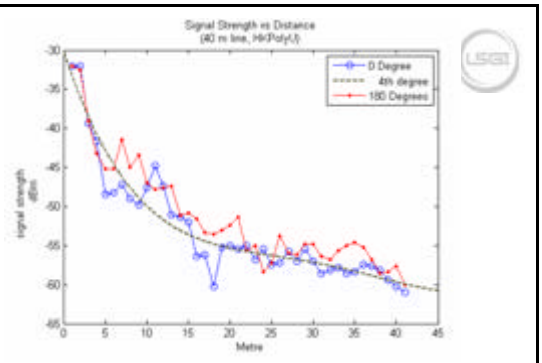
Questions:

The communication range of Wi-Fi signals can be more than 100 metres; but what is the **effective range** for RSS-to-distance conversion, and **accuracy achievement** of the distance converted from RSS ?

Hong Kong Polytechnic University Podium indoor-outdoor transition area

Access Point

40-m baseline observation at 1-m intervals



Test result of signal strength vs. distance over a 40 metre baseline in HKPolyU

Observations

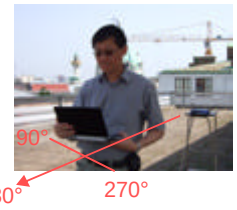
- In the area under test, the RSS varies around -30 and -60 dBm
- Overall, the Wi-Fi signals collected at the 0° and the 180° directions have similar trends, with small differences in RSS

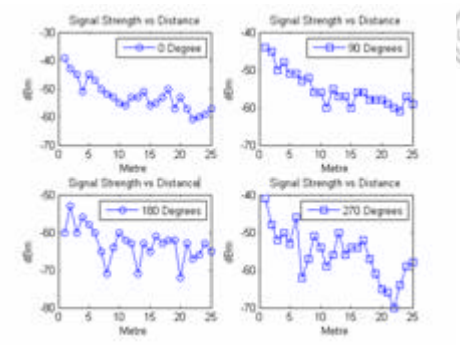
Observations

- It is noted that the discrepancy of RSS between the two directions can be as big as 10 dBm at around 7 and 17 metre points
- Obvious change of RSS in relation to distance can be found between 0 and 20 metre points, and after 20m, RSS fluctuates between -53 and -60 dBm
- A curve fitting using 20m range data would provide reasonably good RSS-to-distance conversion model, if the discrepancies around 7 and 17 metre points are removed

Field test carried out at the TU Vienna

Observations made along this baseline at 1-m intervals and in 4 directions





25 metre baseline test at TU Vienna: Plot of data collected in the directions 0°, 90°, 180° and 270°

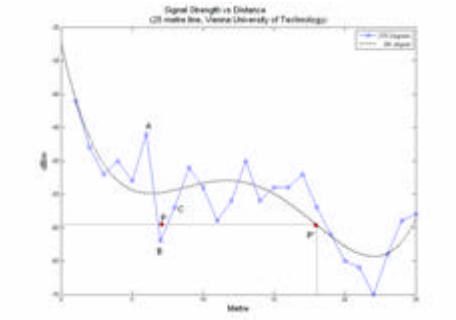
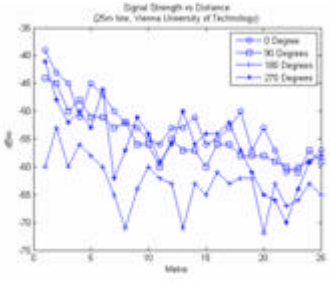


Illustration of incorrect SS to distance conversion based on curve fitting

RSS-to-Distance Estimation Algorithm

- A calibration baseline established at the centre of RSS-to-Distance conversion area (20m radius), RSS signal observations at 1-m intervals and in 4 directions

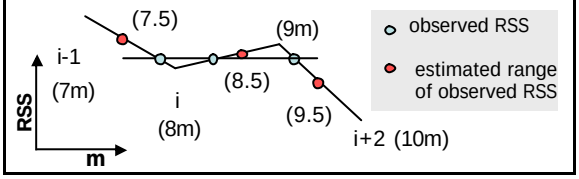
- The RSS pattern of the baseline over the four directions are obtained after this calibration

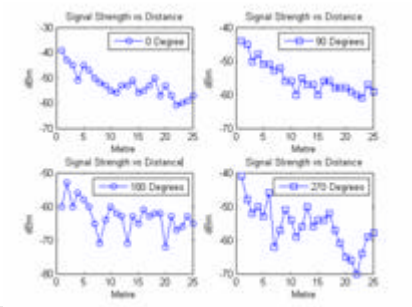


- Let the signal strengths observed at a point in the RSS-to-Distance conversion area be:

$$a_0, a_{90}, a_{180}, a_{270}$$

- A series of interval tests is then carried out using each direction's RSS calibration pattern





interval searching can be efficiently performed with the aid of a computer program

Scenario 1: The mean of
interval test result of SS at 0°
interval test result of SS at 90°
interval test result of SS at 180°
interval test result of SS at 270°

Scenario 2: The mean of
interval test result using mean SS of 0°, 90°
interval test result using mean SS of 0°, 180°
interval test result using mean SS of 0°, 270°
interval test result using mean SS of 90°, 180°
interval test results using mean SS of 90°, 270°
interval test results using mean SS of 180°, 270°

Scenario 3: The mean of
interval test result using mean SS of 0°, 90°, 180°
interval test result using mean SS of 0°, 90°, 270°
interval test result using mean SS of 0°, 180°, 270°
interval test result using mean SS of 90°, 180°, 270°

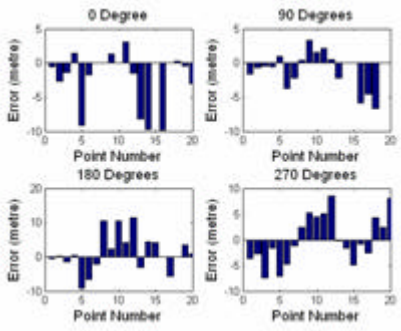
Scenario 4: The mean of
interval test using mean SS of 0°, 90°, 180°, 270°

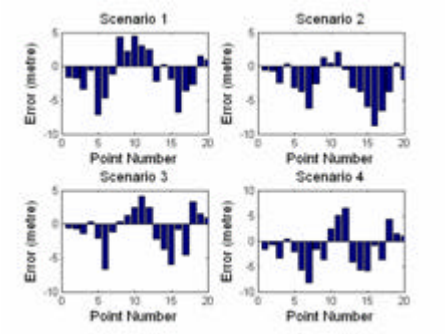
Different mean combinations of signal strength data used for interval searching

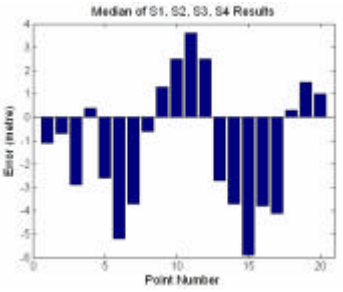
Points randomly observed inside the RSS-to-distance conversion area

True Distance	0 Degree Error (metre)	90 Degrees Error (metre)	180 Degrees Error (metre)	270 Degrees Error (metre)	S1 Error (metre)	S2 Error (metre)	S3 Error (metre)	S4 Error (metre)	Median of S1, S2, S3 S4 Error (metre)
1.4	-0.6	-1.6	-0.6	-3.6	-1.6	-0.6	-0.6	-1.6	-1.1
2.3	-2.7	-0.7	0.3	-2.7	-1.7	-0.7	-0.7	-0.7	-0.7
3.6	-1.4	-0.4	-1.4	-7.4	-3.4	-2.4	-1.4	-3.4	-2.9
3.4	1.4	-0.6	0.4	-1.6	-0.6	0.4	0.4	0.4	0.4
4.9	-9.1	0.9	-9.1	-7.1	-7.1	-3.1	-2.1	-2.1	-2.6
6.3	-1.7	-3.7	-6.7	-4.7	-4.7	-3.7	-6.7	-5.7	-5.2
10.8	NS	-2.2	-2.2	-1.2	-1.2	-6.2	-1.2	-8.2	-3.7
13.4	NS	0.4	10.4	2.4	4.4	-2.6	0.4	-1.6	-0.6
16.3	1.3	3.3	2.3	5.3	2.3	1.3	1.3	-3.7	1.3
15.5	NS	1.5	10.5	4.5	4.5	0.5	2.5	2.5	2.5
17.1	3.1	2.1	4.1	5.1	3.1	2.1	4.1	5.1	3.6
13.5	-1.5	0.5	11.5	8.5	2.5	-0.5	2.5	6.5	2.5
10.8	-8.2	-2.2	-3.2	-0.2	-2.2	-3.2	-2.2	-4.2	-2.7
9.3	-9.7	NS	4.3	-1.7	0.3	-3.7	-3.7	-5.7	-3.7
7.1	NS	NS	4.1	-4.9	-1.9	-5.9	-5.9	-5.9	-5.9
4.2	-9.8	-5.8	NS	-0.8	-6.8	-8.8	-0.8	-0.8	-3.8
8.4	NS	-4.6	-5.6	-2.6	-3.6	-6.6	-4.6	-3.6	-4.1
8.3	0.3	-6.7	NS	4.3	-2.7	-3.7	3.3	4.3	0.3
14.5	-0.5	NS	3.5	2.5	1.5	0.5	1.5	1.5	1.5
13.0	-3.0	0.0	1.0	8.0	1.0	2.0	1.0	1.0	1.0

Error threshold : 5 m







Concluding Remarks

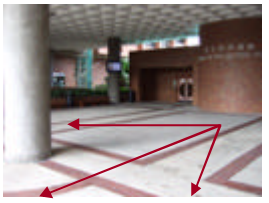
- For the radio signal strength (RSS) of the WiFi data to be successfully incoporated into the integrated processing model, an algorithm for converting the WiFi signal to the corresponding distance is essential.
- Field tests were carried out in the Hong Kong Polytechnic University and Vienna University of Technology. Results have shown that RSS quality may vary significantly depending on radio interference and multipath effects of the environment

- For areas with less environmental interference, a least squares polynomial fitting may be able to establish a reasonable signal strength to distance conversion relationship
- For site conditions where signal strength is susceptible to radio intereference and multipath effects, it is unlikely that polynomial fitting will provide correct solution to the RSS-to-distance conversion.

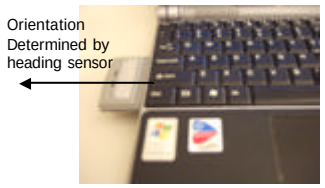
- An algorithm has been proposed by making full use of the signal strength propagation characteristics under real site conditions to estimate distance
- This algorithm has been verified in an unfavourable site condition and has proven to be successful with 90 % success rate in a 20 m radius area with the accuracy threshold set to 5 m.

- Future investigation focus will be

(i) improvement of the conversion accuracy by increasing the number of calibration baseline in the RSS-to-distance conversion area



(ii) Wi-Fi card and heading sensor integration, and investigation of a RSS interpolation model according to orientation and antenna characteristics



Right now, simultaneous output of 4 directions' RSS is not available

Acknowledgment:
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THANK YOU