Statistical Sensor Fusion of Ultra Wide Band Ranging and Real Time Kinematic Navigation

M. W. A. Khan, R. Piché and E. S. Lohan.
Tampere University of Technology, Finland
Objective

The goal is to improve RTK GPS positioning solution by augmenting Ultra-Wide Band (UWB) ranging.
Introduction
Global Positioning System (GPS) tracking’s precision is not sufficient for mobile robots

<table>
<thead>
<tr>
<th>Source of error</th>
<th>RMS range error (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite clock and ephemeris</td>
<td>≈ 3 m</td>
</tr>
<tr>
<td>Atmospheric</td>
<td>≈ 5 m</td>
</tr>
<tr>
<td>Receiver noise and multipath</td>
<td>≈ 1 m</td>
</tr>
<tr>
<td>UERE</td>
<td>≈ 6 m</td>
</tr>
</tbody>
</table>
Real Time Kinematic (RTK) GPS working principle

- **Base station (BS) at known point**
- **BS transmits raw data to rover through radio**
- **Rover calculate its position through difference of measurements**

Accuracy: ~ 2–5 cm
Configuration used for RTK GPS positioning
Hardware used for RTK GPS

Yaun10 USB receiver
ANN-MS ublox active GPS antenna
Sample testing result of RTK GPS positioning solution
Ultra-Wide Band (UWB) is based on radio pulses

UWB signal has 500MHz absolute bandwidth or 20% fraction bandwidth

Spoonphone and UWB tags
UWB uses two-way time-of-flight method for ranging

Range = c * [(Total Transaction Time – Processing time) / 2].

Source sends message

Target receives message and sends reply after processing

Source receives the reply message and calculates range
UWB Hardware and testing

Figure: Dynamic line-of-sight error measurement (red *), linear regression line (continuous line) and 95% credibility interval limits (dashed line).
Kalman filter short description

Two stage recursive filter

Three basic components of kalman filter

- State Vector
- Dynamic Model
- Measurement Model
Methodology and Material
Fusion of RTK GPS and UWB gives a better system
UWB and RTK GPS Fusion Configuration used in Paper
UWB and RTK GPS Fusion Process Flow

- **BeSpoon Phone**
  - Range data
  - Calculate Position in Local Coordinate System
  - Position in Local Coordinate
  - Kalman Filter for UWB and RTK GPS Fusion
  - Position in local coordinate after UWB+RTK GPS Fusion

- **RTK GPS**
  - Position in Geodetic Coordinate
  - Geodetic to Local Coordinate position conversion
  - Position in Local Coordinate
Aerial view of testing area
Front view of testing area
Testing and Results
Measurement result with 6 UWB tags

Track is divided into three sub-tracks for better analysis.

<table>
<thead>
<tr>
<th>Sub-Track</th>
<th>RTK GPS</th>
<th>UWB</th>
<th>UWB + RTK GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.910</td>
<td>0.133</td>
<td>0.304</td>
</tr>
<tr>
<td>2</td>
<td>0.234</td>
<td>0.122</td>
<td>0.070</td>
</tr>
<tr>
<td>3</td>
<td>0.065</td>
<td>0.063</td>
<td>0.053</td>
</tr>
</tbody>
</table>
Comparison of fusion results with and without cycle slip of sub track 2

<table>
<thead>
<tr>
<th>Cycle Slip</th>
<th>UWB +RTK GPS</th>
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</thead>
<tbody>
<tr>
<td>Without</td>
<td>0.070</td>
</tr>
<tr>
<td>With</td>
<td>0.071</td>
</tr>
</tbody>
</table>
Testing and Results

Result with different types of tag’s placement scenarios

<table>
<thead>
<tr>
<th>Sub-Track</th>
<th>6 Tags</th>
<th>4 Tags</th>
</tr>
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RMS ERROR (m)
Conclusion

• The fusion of UWB and RTK GPS compensates the shortcomings of both and yields better performance than possible from any individual system.

• The number of tags and their placement has impact on overall results as well.

• Moreover UWB has centimeter level of positioning accuracy comparable to RTK GPS, so UWB can also be used as replacement of RTK GPS.