Performance of Precise Point Positioning using Current Triple-frequency GPS Measurements in Australia

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Outline

1. Introduction to triple-frequency PPP
2. Aims of research
3. Mathematical models
4. Methodology
5. Results & Conclusion
Introduction to Triple-frequency PPP

• NRTK is not suited for precise positioning service on a wide-area or global scale

• PPP requires a long convergence time (e.g. several tens of minutes), not suitable for real-time applications

• Using triple-frequency GPS can speed up convergence time as shown by Laurichesse (2012, 2015, 2016)

• The data used is limited due to the limited number of GPS Block IIF satellites and ground infrastructure limitations
Aims at research

• To provide an insight into the current performance of triple-frequency GPS PPP in Australia

Number of triple-frequency GNSS satellites in view for a given location

Source: reproduced from Laurichesse (2016)
Mathematical models

- Single-differenced-between-satellite method has been used

- Three main steps for dealing with triple-frequency PPP:
  
  - Hatch Melbourne Wubbena Extra Wide-lane
  - Phase Wide-lane Ambiguity Resolution
  - Narrow-lane Ambiguity Resolution
  - L1 & L2 with support from extra wide-lane
  - L2 & L5
  - L1
## Mathematical models

<table>
<thead>
<tr>
<th>Steps</th>
<th>Wavelengths (m)</th>
<th>Noise levels of combinations</th>
<th>Parameters</th>
<th>Possible advantages for Triple-frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dual</td>
<td>Triple</td>
<td>Dual</td>
<td>Triple</td>
</tr>
<tr>
<td><strong>EWL</strong></td>
<td>Not applied</td>
<td>5.86</td>
<td>Not applied</td>
<td>0.7σ_p</td>
</tr>
</tbody>
</table>
| **WL** | 0.86 | 3.40 | 0.7σ_p | 110σ_L | N_{WL} | U+ T+ N_{WL} | -WL ambiguities can be fixed in about two minutes  
-Providing decimetre-level positioning accuracy |
| **NL** | 0.107 | 0.108 | 2.99σ_p 2.99σ_L | 110σ_L 2.54σ_L | U+ T+ N_{NL} | U+ T+ N_{NL} | -An optimal combination for phase measurements with a low noise level  
-Using the support of WL and EWL to create a new form “code measurement” |

*U*: user positions; *T*: troposphere delays; *N*: Ambiguities
Methodology – Static test

- The research used real observations collected from eight Australian CORS stations over one week period in 2016
- Triple- and dual- frequency PPP results were compared for both float and fixed ambiguities
- The proposed algorithms in Laurichesse (2012, 2015, 2016), Li et al. (2013), Geng and Bock (2013) have been implemented
- A modified version of RTKLIB and Matlab-based GPS PPP data processing software have been developed.
Methodology – Static test

8 GNSS CORS stations from the Australian Regional GNSS Network (Source: Google Earth)

Visibility of the GPS Block IIF satellites transmitting L5 signal at the ALIC station on DOY 215 2016
Results

- **Float** solution for dual- and triple-PPP approaches

![Graph showing float solution for dual- and triple-PPP approaches](image)

10 cm: 2F&3F ~ 22 min
Results

- **Fixed** solution for dual- and triple- PPP approaches

![Graphs showing RMS comparison]
Results

**Ambiguity fixing rate**

AFR > 95%, after 20min
## Results

- Positioning convergence time with combined results from eight selected stations

<table>
<thead>
<tr>
<th>Horizontal RMS threshold</th>
<th>Convergence time (minutes)</th>
<th>Vertical RMS threshold</th>
<th>Convergence time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dual float</td>
<td>Dual fixed</td>
<td>Triple float</td>
</tr>
<tr>
<td>&lt; 5cm</td>
<td>N/A</td>
<td>22</td>
<td>N/A</td>
</tr>
<tr>
<td>&lt; 10cm</td>
<td>25</td>
<td>15</td>
<td>23</td>
</tr>
<tr>
<td>&lt; 15cm</td>
<td>15</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

*N/A: Data collected is not enough to reach accuracy levels.*
Conclusion

• Dual- and triple- frequency PPP GPS performance in Australia has been demonstrated

• Triple-frequency GPS satellites:
  – strengthen the PPP positioning model,
  – improve the float ambiguity positioning accuracy & shorten solution convergence time by an average of 5 minutes compared to dual-frequency PPP
  – Increase the ambiguity fixing success rate by 10%

• **Future work:** Adding multi-constellation and multi-frequency GNSS to the PPP model, expanding with kinematic mode
THANK FOR LISTENING
References

- Laurichesse, D 2015, Handling the Biases for Improved Triple-Frequency PPP Convergence, *GPSWorld*.