Comparative Analysis of Multi-constellation GNSS Precise Point Positioning (PPP) in Kinematic Mode

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Overview

- Introduction
- Case Study
- Some Conclusion Remarks
Introduction

Until a few decades ago, carrier phase-based measurement should be carried out by using at least two geodetic-grade GNSS receivers simultaneously tracking common satellites to produce very precise and accurate positions.
Introduction

In addition to this, all the collected raw GNSS data should be processed with scientific or commercial GNSS processing software to obtain coordinates.

Although this approach provides high accurate positioning, it needs reference station(s) data and also requires time consuming, costly and exhausting field and office studies.
Furthermore, the GNSS processing software mostly requires **license fee** and **expert technical person with advanced GNSS knowledge and experience** to obtain accurate results.
Introduction

New approaches and algorithms have been developed to overcome the above-mentioned drawbacks faced in conventional differential method by using a single receiver, aiming to make positioning more easily and quickly with high accuracy.

As a result of the developments in satellite and receiver systems and studies, a technique called as Precise Point Positioning (PPP) has been started to widely use in the surveying community since its introduction in 1997.
Introduction

Although the PPP technique was initially applied to GPS observations, the availability of precise products for other satellite system (i.e. GLONASS, Galileo, BeiDou and QZSS) in addition to the GPS emerges the multi-constellation PPP approach.
Introduction

Multi-constellation GNSS PPP offers more accurate and reliable positioning while reducing the convergence time especially when the positioning is conducted in areas where especially not enough numbers of GPS satellites are visible or blocked/sheltered as well limited satellites and/or poor geometry are faced.
Introduction

The main such data producer, International GNSS Service (IGS), initiated the IGS Multi-GNSS-EXperiment (MGEX) Project for track, collate and analyze all available GNSS signals.
Introduction

MGEX network was established in 2012 and since then;
- multi-constellation precise ephemerides and clock products
- combined multi-GNSS Broadcast Ephemeris,
- Earth orientation parameters
- multi-GNSS biases covering up to five global or regional navigation satellite systems (i.e. GPS, GLONASS, Galileo, BeiDou, QZSS) have been routinely produced and distributed.
Introduction

All MGEX stations routinely track the GPS signals as well as at least one of the Galileo, BeiDou or QZSS while most of the stations support also GLONASS.
Case Study

The aim of this study is to make an accuracy assessment of multi-constellation GNSS PPP kinematic applications.

For this purpose, a kinematic test was carried out at Obruk Dam Lake, in Çorum, Turkey on June, 2017.
Case Study

The kinematic data was collected for approximately 6 hours at 1-second interval from all visible GPS, GLONASS, Galileo and BeiDou satellites in view.
Case Study

In this experiment, **Trimble R10** multi-frequency multi-constellation GNSS receivers with internal antenna were used.

The R10 receiver track the following satellites:

- GPS (L1C/A, L1C, L2C, L2E, L5)
- GLONASS (L1C/A, L1P, L2C/A, L2P, L3)
- Galileo (E1, E5a, E5B)
- BeiDou (COMPASS) (B1, B2)
- QZSS, WAAS, MSAS, EGNOS, GAGAN.
- SBAS
- Trimble CenterPoint RTX,
- OmniSTAR HP, XP, G2, VBS positioning
Case Study

The PPP-derived coordinates of each measurement epoch were determined by processing of the collected data by using GrafNav GNSS Post-Processing Software by applying five different solution scenarios:

- **Scenario 1**- GPS-only,
- **Scenario 2**- GPS+GLONASS,
- **Scenario 3**- GPS+GLONASS+BeiDou,
- **Scenario 4**- GPS+GLONASS+Galileo,
- **Scenario 5**- GPS+GLONASS+ Galileo+BeiDou.
Case Study

The PPP-derived coordinates were calculated by applying *Multi-Pass* processing with the GrafNav software.

In this approach, the collected data is processed **three times sequentially, forward, reverse and forward** again.
Case Study

Within this study, one of the IGS Analysis Centers, Center for Orbit Determination in Europe (CODE)’s products with COM ID were used to estimate the PPP-derived coordinates.

The necessary precise satellite orbits and clock corrections data were retrieved from the related web site.

ftp://ftp.aiub.unibe.ch
Case Study

The collected data were processed by following above mentioned 5 different scenarios and PPP-derived coordinates were calculated.
With the aim of make an accuracy assessment of the multi-constellation GNSS PPP, it should be established the reference trajectory (or known coordinates).

The known coordinates of each measurement epoch with cm-level accuracy were computed by processing of the GNSS data both collected on the vessel and at the reference station with GrafNav GNSS Post-Processing Software with the Post Processing Kinematic (or Post Processed Kinematic) (PPK) carrier phase-based differential method.
Case Study

The calculated PPP coordinates using CODE’s precise satellite orbit and clock (with COM ID) data were compared to the reference coordinates epoch-by-epoch. Differences in the position and ellipsoidal heights are given in the following figure.
Case Study

East

North

Up

Differences (cm) vs UTC Time (HH:MM)
## Statistical Analysis of the Kinematic PPP Solutions (Using CODE Product)

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>2D Position (cm)</th>
<th></th>
<th>Height (cm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min.</td>
<td>Max.</td>
<td>Mean</td>
<td>Min.</td>
</tr>
<tr>
<td>Scenario 1 (G)</td>
<td>0</td>
<td>22</td>
<td>6</td>
<td>-20</td>
</tr>
<tr>
<td>Scenario 2 (G+R)</td>
<td>0</td>
<td>28</td>
<td>6</td>
<td>-20</td>
</tr>
<tr>
<td>Scenario 3 (G+R+C)</td>
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<td>16</td>
<td>4</td>
<td>-26</td>
</tr>
<tr>
<td>Scenario 4 (G+R+E)</td>
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<td>15</td>
<td>5</td>
<td>-21</td>
</tr>
<tr>
<td>Scenario 5 (G+R+E+C)</td>
<td>0</td>
<td>16</td>
<td>4</td>
<td>-24</td>
</tr>
</tbody>
</table>

*G* refers to GPS; *R* refers to GLONASS; *C* refers to BeiDou and *E* refers to Galileo
Conclusion

The finding reveals that, the PPP is a viable alternative technique to the conventional carrier-phase-based differential technique in terms of accuracy, easy-of-use and operation cost.

According to the obtained results, this technique can be used in many surveying applications that required cm-dm level high accurate position information.
Conclusion

The results of this study show that;

*comparing with single system PPP*, multi-constellation GNSS PPP can significantly improve the positioning performance, optimize the spatial geometry, improve the availability and continuity of positioning and shorten the convergence time.

This is more important when the positioning is conducted in observation environment where the GNSS signal is blocked or sheltered.
Thank you very much for your interest and attention…

Contributions, Questions???

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