Performance Analysis of QZSS Centimeter Level Augmentation Services (CLAS)

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Outline

• Quasi – Zenith Satellite System
• Motivations and Objectives
• Centimeter Level Augmentation Service
  • L6D Message Structure
  • Subtypes in L6 Message
• CLAS Message Analysis
• CLAS Aiding Precise Point Positioning
• Conclusions
• Future Work
Quasi – Zenith Satellite System (QZSS)

• Region Navigation Satellite System
• 1 geostationary equatorial orbit (GEO) satellite and 3 Quasi-Zenith orbit (QZO) satellites are included in QZSS.
• East Asia and Australia area
• L1, L2, L5, L6 Signal
• Centimeter Level Augmentation Service (CLAS)
Centimeter Level Augmentation Service

• CLAS supports RTK-PPP real time users. It is designed to improve positioning to centimeter level.

State Space Representation (SSR)
Observation Networks & Station
Augmentation Data Generation & Transition

QZSS Satellite
L6 Signal
Observation Space Representation (OSR)

Land Survey  IT Construction  IT Agriculture
Motivations

• QZSS signal can be received in Taiwan anytime in a day and has a very good performance in elevation.
• The elevation of each satellite is above 60° for 12 hours per day.
Objectives

• Taiwan locates at the edge of CLAS service boundary.
• A preliminary evaluations of the PPP method with CLAS service are provided.
• Satellite Data from IGS station and CLAS data from QZSS website are used.
L6D Message Structure

- L6D Message Structure
  - 2000 bps
  - 6 subframes in 30 seconds
  - Each subframe takes 5 seconds

Header
Reed-Solomon Code
Data Part
Data Part
\[ \vdots \]
Reed-Solomon Code

2000 bits

Subtype \( N_1 \)
\( n_1 \) bits

Subtype \( N_2 \)
\( n_2 \) bits

\[ \vdots \]

Subtype \( N_k \)
\( n_k \) bits
L6D Message Structure

- Corrections contained in 11 Subtypes will be transmitted in 6 subframes.
- Network ID is used to identify specific local correction messages.

<table>
<thead>
<tr>
<th>Subframe</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtype</td>
<td>1~9,11</td>
<td>3,6,8,9,11</td>
<td>3,6,8,9,11</td>
<td>3,6,8,9,11</td>
<td>3,6,8,9,11</td>
<td>3,6,8,9,11</td>
</tr>
<tr>
<td>Network ID</td>
<td>12,2</td>
<td>3,4,14</td>
<td>5,6,15,16</td>
<td>7,8,17,18</td>
<td>9,10,19</td>
<td>11,1</td>
</tr>
</tbody>
</table>
CLAS Network

- Formed by 19 Networks.
- Each Network is formed by several grid points. There are 231 grid points in total. Grid points indicate the position of an observation station.
- These stations are set to collect local data and report result for further augmentation production.
Subtypes in L6 Message

• Subtype 1: This subtype indicates the included satellites and signals in the CLAS message.

• Network-independent Subtype: Subtype 2, 3, 4, 5, 7
  • Only the information from subtype 1 is used to decode these subtypes.

<table>
<thead>
<tr>
<th>Message Header</th>
<th>Satellite Mask</th>
<th>Signal Mask</th>
<th>Cell Mask</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data for Satellite/Signal 1</td>
<td>...</td>
<td></td>
<td>Data for Satellite/Signal N</td>
</tr>
</tbody>
</table>
Subtypes in L6 Message

- **Network-Dependent Subtype**: Subtype 6, 8, 9, 11
- Date included in these subtypes will increase/decrease with the quantity of grid points in each Network.

<table>
<thead>
<tr>
<th>Message Header</th>
<th>Network ID</th>
<th>Grid 1 data for Satellite 1</th>
<th>\cdots</th>
<th>Grid 1 data for Satellite ( M )</th>
</tr>
</thead>
<tbody>
<tr>
<td>\vdots</td>
<td></td>
<td>Grid ( N ) data for Satellite 1</td>
<td>\cdots</td>
<td>Grid ( N ) data for Satellite ( M )</td>
</tr>
</tbody>
</table>
## Corrections in L6 Message

√ for General Data, 30 seconds interval; ● for Network Data, 5 seconds interval

<table>
<thead>
<tr>
<th>Correction</th>
<th>Subtype</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell Mask</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orbit Correction</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>GNSS Clock Correction</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Code/Phase Bias</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Ionosphere Slant Delay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Troposphere Delay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Integrity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>TBD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12 seconds interval for General Data, 30 seconds interval; 5 seconds interval for Network Data.
Availability of CLAS

• Date: 2018/11/28
• Time: 0:00~23:59
• Data Size: 164.8 MB
• Location: Nakatane, Japan
• At least 6 GPS Satellites are supported in 95% of a day.
Orbit Correction

• Source: Subtype 2, 11
• Date: 2018/11/28
• Satellite: G06
• User Algorithm:
  \[ r_{\text{correct}} = r_{\text{eph}} - \delta r_{\text{CLAS}} \]
• Radial, Cross, and Along vectors against user position will help calculation.
GNSS Clock Correction

- Source: Subtype 3, 11
- Date: 2018/11/28
- Satellite: G06
- User Algorithm:
  \[ t_{\text{correct}} = t_{\text{broadcast}} - \delta \]
  \[ t_{\text{CLAS}} \]

![Graph showing GNSS clock correction over time](image)
GNSS Code/Phase Bias

- Source: Subtype 4, 5, 6
- Date: 2018/11/28
- Satellite: G06
- User Algorithm:
  \[ \rho_{\text{correct, code/phase}} = \rho_{\text{code/phase}} + \Delta \rho_{\text{CLAS, code/phase}} \]
- Mapping by the line-of-sight vector from user position to the satellite
Ionosphere Slant Delay Correction

- Source: Subtype 8, 9
- Date: 2018/11/28
- Polynomial part and residual part
- Ionosphere slant delay at user position is computed by interpolating the one on reference grids.
Troposphere Delay Correction

• Source: Subtype 9
• Date: 2018/11/28
• Troposphere vertical delay variations are computed by interpolating or extrapolating the data on the reference grid.
• A mapping function is necessary for further application.
CLAS Aiding Precise Point Positioning

- Date: 2018/11/28
- Accuracy level: 1 meter
- Convergence Improvement: 901\textsuperscript{st} epoch to 160\textsuperscript{th} epoch
- Reduction is about 83\% original needed epoch.
CLAS Aiding Precise Point Positioning

Date: 2018/11/28
Accuracy level: 0.3 meter

Date: 2019/03/04
Accuracy level: 0.3 meter

Reduction: 50%
Conclusions

• CLAS binary data decoder considered as a SSR to OSR convertor.
• CLAS user algorithm are completed and can assist positioning methods.
• Combination of PPP and CLAS is implemented.
• Convergence time improvement against result before applying CLAS:
  • About 50% for 0.3 meter accuracy level
  • About 83% for 1 meter accuracy level
Future Work

• Using Software Defined Receiver (SDR), the QZSS L6 can be obtained through acquisition, tracking and demodulation process. We will complete the work and apply CLAS data to local positioning.
Reference


Thank You!

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