Introduction of Positioning Augmentation Center for High Precision Application in Brunei Darussalam

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1. Introduction
   ● Satellite based centimeter class augmentation system
   ● Application Demonstration
2. How does Geospatial Information work in Brunei?
3. Introduction of “Positioning Augmentation Center”
   ● What is “Positioning Augmentation Center”?
   ● Data Generation and Distribution
4. Typical design of Augmentation Data Center
5. Conclusion
1. Introduction

- High precision augmentation system is very much promising technology in coming Multi-GNSS era when more than 100 navigation satellites would be available.
- Application of Centimeter class high precision positioning service is expected to grow rapidly in Asia-Pacific region and contributes economic growth in the region.
- The needs in Brunei have been surveyed and analyzed. Authorization of “Mapping” by the government would be an essential to assure its consistency with “Positioning”. Authorized CORS* is a key to assure consistency within the map and “Positioning”.

* Continuously Operating Reference Station

- Conceptual Design of “Positioning Augmentation Center” using CORS data has been made considering variety of applications.
1. Introduction-CMAS*

Satellite based centimeter class augmentation system (CMAS)

**CMAS using GPS/GNSS multi-constellation, Authorized CORS is distributed through QZSS LEX signal.**

GPS/GNSS multi-constellation

- Orbit/Clock Error
- Signal Bias Error
- Ionospheric Delay Error
- Tropospheric Delay Error

QZSS

- L1/L2 signals
- Coded SSR Message Downlink
- LEX (L6) signal

Authorized CORS (GEONET for Japan)

Observation per second

SSR Server — CMAS (for only Japan, in 2014 currently)

Master Control Station (for Asia-Pacific)

※ This figure shows a case of Application Demonstration since 2011
1. Introduction—Utilization Demonstrations

- Positioning GPS Buoy
- Driving experiment in case of an earthquake disaster
- Air route experiment
- Bulldozer Blade Control System
- Automated System Operation
- QZS
- Navigation for Stamp Rally
- Location Guidance System for visually-impaired person
- Senso-ji Navi experiment

Survey in a forest
1. Introduction-Growing Potential Market of High precision positioning service

Asia-Pacific accounted for over 50% of global LBS shipments in 2016
2. How does Geospatial Information work in Brunei?

- Why Geospatial Information is so important?
  - Geospatial Information is social infrastructure to support daily life of the people
    - Land Development of the nation and local areas
    - Development and Maintenance of Infrastructure
    - Water Environment, Biological System
    - Urban Problems
    - Disaster Mitigation, ....

- How Geospatial Information to be established, maintained, efficiently?
  - standardization
  - Integration on the same basis
  - Information Sharing

“Positioning ” and “Mapping” should be based on the same accuracy and get together for installation and control!
2. How does Geospatial Information work in Brunei?

- Market Survey is done to make a strategic approach for establish “Geospatial Information” infrastructure in Brunei

potential users

government agencies: 31

private industries: 7

possible applications

- positioning accuracy
- map accuracy
- measurement technology

analysis

market survey is done to make a strategic approach for establish “geospatial information” infrastructure in brunei.
2. How does Geospatial Information work in Brunei?

<table>
<thead>
<tr>
<th>Potential Users</th>
<th>Accuracy</th>
<th>Measurement Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positioning</td>
<td>Map</td>
</tr>
<tr>
<td>1 Land Department</td>
<td>cm</td>
<td>Special map</td>
</tr>
<tr>
<td>2 Survey Department</td>
<td>cm~m</td>
<td>Level500 ~200000</td>
</tr>
<tr>
<td>Housing and Development Department , Town and County Planning</td>
<td>cm</td>
<td>Level500 ~2500</td>
</tr>
<tr>
<td>Environment Park and Recreation (JASTRE)</td>
<td>m</td>
<td>Level250 ~5000</td>
</tr>
<tr>
<td>Authority for Building Control and Construction Industry</td>
<td>cm~Decimeter</td>
<td>Special map</td>
</tr>
<tr>
<td>Public Water Department</td>
<td>cm~Decimeter</td>
<td>Level500 ~2500</td>
</tr>
<tr>
<td>Public Works Department</td>
<td>cm~Decimeter</td>
<td>Level500 ~2500</td>
</tr>
</tbody>
</table>
2. How does Geospatial Information work in Brunei?

Required accuracy in the field

- cm
  - cm
  - cm~Decimeter
  - cm~m
  - Decimeter~m
  - m

- cm
  - 6%
  - 17%
  - 7%

- cm~Decimeter
  - 6%

- cm~m
  - 7%

- Decimeter~m
  - 63%
2. How does Geospatial Information work in Brunei?

Measurement technology available in each field (30field)

- SSR-RTK
- D-GNSS
- TS
- MMS
- Airborne LiDAR
- Remote sensing
- UAV
- TSL
- IMU
- Narrow multibeam sonar

High Precision GNSS Technologies
2. How does Geospatial Information work in Brunei?

Map accuracy required in each field (30field)
3. Introduction of “Positioning Augmentation Center”

- **Ranging Signal Broadcasting**
  - **GNSS** (GPS, GLONASS, Galileo, BDS, QZSS, IRNSS)

- **Augmentation Data Broadcasting**
  - **Augmentation Satellites** (GEO, IGSO, MEO/LEO)
    - **Augmentation Data**
      - (Satellite clock error, Satellite orbit error, Ionospheric delay, Others)
  - **Augmentation Satellites Control Stations**
  - **Positioning Augmentation Centers**
    - **Augmentation Data Uplink**

- **Augmentation Data Generation**
  - a) Augmentation data generation
  - b) Monitoring of operation and measures
  - c) Detection of satellite signal anomaly

- **Observables**
  - **Range Reference Points**
  - **User Terminal**
    - **Calculation of Position**
  - **Ranging Signal Receiving**
3. Introduction of “Positioning Augmentation Center”

The latest satellite positioning methods had better be classified in following 3 steps.

1. Correction References
   - Networked Reference Stations (CORS)
   - Single Reference Station

2. Correction Representation Method
   - State Space Representation (SSR)
   - Observation Space Representation (OSR)

3. Position Computing Method
   - RTK-PPP
   - Dual Freq. PPP
   - Single Freq. PPP
   - FKP
   - VRS
   - RTK

Applications
- Civil
- Architecture
- Maintenance
- Mapping
- Oil Plants
- Gas Plants
- Docking
- Vehicles
- Robots
- Drones
- Maritime
- Agriculture
- Construction
- Real-estate Surveying
### 3. Introduction of “Positioning Augmentation Center”

#### Comparison of Centimeter-class Augmentation Generation Methods

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute Positioning</td>
<td>SSR 3 cm</td>
<td>One Way</td>
<td>1695 bps</td>
<td>within 1min</td>
<td>Yes</td>
<td>Adaptable</td>
</tr>
<tr>
<td>Relative Positioning</td>
<td>FKP 3 cm</td>
<td>One Way</td>
<td>1.5Mbps</td>
<td>within 30s</td>
<td>Yes</td>
<td>Adaptable</td>
</tr>
<tr>
<td>VRS</td>
<td>3 cm</td>
<td>Two Way</td>
<td>—</td>
<td>within 30s</td>
<td>Yes</td>
<td>Adaptable only near virtual reference stations</td>
</tr>
<tr>
<td>RTK (Relative Positioning)</td>
<td>3 cm</td>
<td>Two Way</td>
<td>—</td>
<td>within 30s</td>
<td>Yes</td>
<td>Adaptable only near reference stations</td>
</tr>
</tbody>
</table>

[Note] FKP: Flächen Korrektur Parameter (in the German language), VRS: Virtual Reference Station

SSR has advantage in applying to Nation-wide broadcasting cost effectively by;

1. One way data transmission
2. Small data transmission rate
## 3. Introduction of “Positioning Augmentation Center”

<table>
<thead>
<tr>
<th>Data Distribution Methods</th>
<th>Network Evaluation</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Capacity</td>
<td>Coverage</td>
</tr>
<tr>
<td>Ground Network</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One Way</td>
<td>● Radio Broadcasting</td>
<td>△</td>
</tr>
<tr>
<td>Two Ways</td>
<td>● Fixed Line Internet</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>● Mobile Phone</td>
<td>○</td>
</tr>
<tr>
<td>Satellite Network</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One Way</td>
<td>● Broadcasting Type Satellite Usage</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>● Communication Type Satellite Usage</td>
<td>○</td>
</tr>
<tr>
<td>Two Ways</td>
<td>● Communication Type Satellite Usage</td>
<td>○</td>
</tr>
</tbody>
</table>
4. Typical design of Augmentation Data Center

SSR Server developed by SPAC can generate “augmentation data” to correct position error due to ionosphere, troposphere, etc. The data are universally applicable to any positioning method to be chosen for Forest Management or other purposes.

【NOTE】SSR : State Space Representation. Standard Corrections for all types of error factors.
4. Typical design of Augmentation Data Center

(Case study for Brunei)

Data Centre in Brunei

Brunei CORS

SSR Server

Providing Server

RINEX

RTK

RTCM

Ntrip

Ground Network

User

Integrated GIS
MMS
Drone etc.

LIDAR
Remote Sensing etc.

SW tool HW

SW tool HW

User

QZS

*Future alternative to be studied
## Network Coverage for High Precision Services

**Case study for Brunei**

<table>
<thead>
<tr>
<th>Priority</th>
<th>Application</th>
<th>Expected Working Area</th>
<th>Mobile Phone Coverage</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Construction</td>
<td>Urban area</td>
<td>95%</td>
<td>Better coverage in Urban Areas since more development at Urban.</td>
</tr>
<tr>
<td>2</td>
<td>Transport</td>
<td>Urban and Certain Rural Areas</td>
<td>70% (Certain areas no coverage at all)</td>
<td>Old highway infrastructure has better coverage. New highway from Telisai to Lumut has limited coverage.</td>
</tr>
<tr>
<td>3</td>
<td>Mapping</td>
<td>Urban area is the first priority</td>
<td>80%</td>
<td>Better coverage in Urban Areas.</td>
</tr>
<tr>
<td>4</td>
<td>Oil &amp; Gas</td>
<td>Onshore(Coastline/Offshore using their offshore radar reception)</td>
<td>60%</td>
<td>Oil Rigs, Platforms and Jetty Control Post.</td>
</tr>
<tr>
<td>5</td>
<td>Farming</td>
<td>Forest/Certain Rural Areas</td>
<td>40% Very weak</td>
<td>Very low and limited coverage.</td>
</tr>
<tr>
<td>6</td>
<td>Forestry</td>
<td>Certain Forest/Inlands/Onshore</td>
<td>Less than 40% Extremely weak</td>
<td>Very low and limited coverage.</td>
</tr>
</tbody>
</table>
Satellite Network Usage for High Precision Services

‘Centimeter in seconds at anyplace and anytime’

**RTK**
- 10 Kilometer Area from a Reference Station
- RTK Correction Service Area
- Within 10km

**Network RTK**
- Ground-based Transmittable Area
- Cell-Phone Service Area

**RTK-PPP**
- Nation-wide Area Per a Satellite Channel
- QZSS Service Area
- Since 1990s
- RTK to RTK-PPP evolution

Since 1990s
- RTK Correction Service Area within 10km

Since 2000s
- Ground-based Transmittable Area

Since 2010s
- QZSS Application Demonstration started on 27 Dec 2010.
6. Conclusion

- High precision augmentation system is very much promising technology in coming Multi-GNSS era.
- Surveyed results the needs of Geospatial Information in Brunei have suggested that authorization of “Mapping” and “Positioning” is very much important.
- Authorized CORS* is a key to assure consistency between Map and Positioning.
- Conceptual Design of “Positioning Augmentation Center” using CORS has been made considering variety of applications. SSR method has been focused.
- Geospatial Information should be stored, exploited and shared as “Treasure” of commodity.

  - CORS : Continuously Operating Reference Station
  - SSR : State Space Representation
Thank you for your kind attention.

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Complementary Slides
## CMAS major specification

<table>
<thead>
<tr>
<th>Items</th>
<th>Specification</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcasting Target</td>
<td>Stationary and Mobile</td>
<td>• Use dual frequency carrier phase (When using single frequency carrier phase, only TTFF degrades.)</td>
</tr>
<tr>
<td>Position Accuracy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stationary</td>
<td>Horizontal</td>
<td>3 cm RMSE</td>
</tr>
<tr>
<td></td>
<td>Vertical</td>
<td>6 cm RMSE</td>
</tr>
<tr>
<td>Mobile</td>
<td>Horizontal</td>
<td>3 cm RMSE</td>
</tr>
<tr>
<td></td>
<td>Vertical</td>
<td>6 cm RMSE</td>
</tr>
<tr>
<td>Time To First Fix (TTFF)</td>
<td>within 60 s</td>
<td>• Using dual frequency carrier phase</td>
</tr>
<tr>
<td>Transmission Rate of</td>
<td>1695 bps</td>
<td>• QZSS L6 signal</td>
</tr>
<tr>
<td>Augmentation Data</td>
<td></td>
<td>• 1/1000 High-level compression</td>
</tr>
</tbody>
</table>

(*1) : Position accuracy under condition of good visibility and alignment of satellites  
(*2) : Receiver error not considered.
CMAS is original system which derived ISO 18197 in 2015. It can convert position errors due to 6 different causes into one set of augmentation data, pseudorange and carrier-phase, so that the augmentation data volume to be broadcasted becomes far smaller than conventional methods.

**ISO 18197 : Centimeter-class positioning**

Augmentation Data by State Space Representation (SSR)

① GNSS Orbit Correction  
② GNSS Clock Correction  
③ GNSS Code Bias  
④ GNSS Phase Bias  
⑤ Ionospheric Correction  
⑥ Tropospheric Correction

These augmentation data are provided by SSR server.
RTK-PPP covers diverse needs.

RTK-PPP has **all of corrections** to realize centimeter-accuracy. **Partial uses** of corrections enable various needs at terminals.

- **RTK-PPP**
  - Satellite Clock & Orbit
  - Inter-Signal Bias
  - Ionospheric Delay
  - Tropospheric Delay

- **DF-RT-PPP**
  - Satellite Clock & Orbit
  - Inter-Signal Bias

- **SF-RT-PPP**
  - Satellite Clock & Orbit
  - Ionospheric Delay

**Tens of minute convergence & 10 centimeter-class Quality**

- **1 minute to Fix & Centimeter-class Quality**
- **Rapid Fix & Decimeter-class Quality**

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The 6th AOR Workshop on GNSS
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORS</td>
<td>Continuously Operating Reference Station</td>
</tr>
<tr>
<td>G.</td>
<td>Government</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographical Information System</td>
</tr>
<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
</tr>
<tr>
<td>HW</td>
<td>HardWare</td>
</tr>
<tr>
<td>I/F</td>
<td>InterFace</td>
</tr>
<tr>
<td>LIDAR</td>
<td>Laser Imaging Detecting And Ranging</td>
</tr>
<tr>
<td>Ntrip</td>
<td>Networked Transport of RTCM via Internet Protocol (RTCM 10410.1)</td>
</tr>
<tr>
<td>mgn</td>
<td>Managing GNSS Network (SEGAL)</td>
</tr>
<tr>
<td>MMS</td>
<td>Mobile Mapping System</td>
</tr>
<tr>
<td>QZS</td>
<td>Quasi-Zenith Satellite (G. of Japan)</td>
</tr>
<tr>
<td>QZSS</td>
<td>Quasi-Zenith Satellite System (G. of Japan)</td>
</tr>
<tr>
<td>RINEX</td>
<td>Receiver INdependent EXchange Format (RTCM SC-104)</td>
</tr>
<tr>
<td>RTCM</td>
<td>Radio Technical Commission for Maritime services</td>
</tr>
<tr>
<td>RTK</td>
<td>Real-Time Kinematic GNSS data (RTCM 10402.3 and 10403.2)</td>
</tr>
<tr>
<td>SSR</td>
<td>State Space Representation (RTCM 10403.2)</td>
</tr>
<tr>
<td>SW</td>
<td>SoftWare</td>
</tr>
</tbody>
</table>