Multi-constellation Augmentation Service System (MASS)

Primary Results of Wide Area Real-Time Differential GPS Prototype System in China

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World-wide GNSS Augmentation System

- EGNOS
- GAGAN IRNSS
- MSAS QZSS
- China
- SA/WAAS
- WAAS
Multi-constellation Augmentation Service System (MASS)
Positioning and Navigation Performance

Wide Area:
- Duel frequency: < 0.3m (After initialized, RT, K)
- Single frequency: < 1 m (RT, K)
- Value-added service

Local Area:
- Duel frequency: < 0.03m (After initialized, RT, K)
- Single frequency: < 0.3m (RT, K)
- Value-added service
PANDA Software

**PANDA : Positioning And Navigation Data Analyst**

- To derive possible information from GNSS/SLR/VLBI data in real-time and post-mission
- Developed at Wuhan University since 2001
- Current Applications
  - POD of GNSS (COMPASS, GPS, Galileo)
  - POD of LEOs (CHAMP, GRACE, COSMIC, ...)
  - Huge GNSS Network Processing
  - Global Ionosphere Maps (GIM)
  - Satellite Gravity Recovery
  - Combine Solution for Reference Frame Maintaining
  - PPP
  - .....
PANDA Software

Data cleaning based on residuals / update initial values

GNSS RINEX data
- Single station data cleaning
  - Cleaned GNSS data
  - SST ranging data
  - SLR data
  - GNSS/LEO orbit file

GNSS/LEO orbit integrator

Satellite ICs
- Satellite description
- Observed attitude
- Observed acceleration

Estimator
- Least Square Adjustment for high precision post-mission applications
- Square Root Information Filter for kinematic or real-time applications

Ambiguity constraints

Integer ambiguity resolution

Products
- Site deformation
- LEO orbit / trajectory
- GNSS orbits and clocks
- Earth rotation parameters
- Gravity model
- etc

Solution combination products generation
- Products publication

Real-time Products
- Site pos/vel. and clocks
- Zenith Troposphere Delay
- LEO orbit / trajectory
- GNSS orbits and clocks
New Development: Real-Time

- PPP Based Positioning Service System
  - Real-time GPS orbits
  - Real-time GPS Satellite Clock Offsets
  - Precise Point Positioning
Real Time GNSS Platform in Wuhan University

68 real-time GNSS Data world-wide

Analysis Center (IBM BladeCenter)

Real Time Data Source in Guangdong Province

Satellite Communication equipment

Demo terminal and vehicle
Flow Chart of RT GNSS Processing
Post-Simulation System with old GNSS Network Data

- RINEX Data distribution Software
- Regional RT Ionospheric Grids
- CMONOC 26 GNSS Stations
- Single-frequency demo software
Preliminary Results

Test Network

The distribution of the 70 IGS stations for Real time satellite orbit determination (70 stations)
Rinex data are inputted as stream through simulated real-time model
Result of RT-POD (Hourly predicted) vs IGS Finals

Difference between calculated real-time orbits and IGS final products
RT POD Based on IGS RT Data

Method:
Normal Equation Combining with short-arc sliding window observations for RT POD

POD Precision (cm):
- Radial: 4.11
- Cross: 4.03
- Along: 7.27
- Mean: 5.40

<table>
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<tr>
<th></th>
<th>Max (cm)</th>
<th>Min (cm)</th>
<th>average (cm)</th>
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<tr>
<td>Radial</td>
<td>6.0</td>
<td>2.7</td>
<td>4.1</td>
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<td>Cross</td>
<td>6.5</td>
<td>3.1</td>
<td>4.0</td>
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<tr>
<td>Along</td>
<td>10.6</td>
<td>4.6</td>
<td>7.3</td>
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<tr>
<td>Mean</td>
<td>7.5</td>
<td>3.6</td>
<td>5.4</td>
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RT POD Augmentation Based on Regional GNSS Data

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<tr>
<th>Scheme</th>
<th>Predicted orbit</th>
<th>Regional Augment.</th>
<th>Improvement (%)</th>
<th>Predicted orbit</th>
<th>Regional Augment.</th>
<th>Improvement (%)</th>
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<td>1</td>
<td>12.7</td>
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<td>11.7</td>
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<td>2</td>
<td>46.0</td>
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<td>46.5</td>
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<tr>
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<td>6</td>
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<td>88.4</td>
<td>475.4</td>
<td>62.6</td>
<td>86.8</td>
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Result of RT-CLK vs IGS Finals

RMS values of the difference between the calculated Sat-Clock and IGS final products over the period day 198-203 of year 2006

Statistics of the RMS values
Mean RMS = 0.18 nanosecond

CPUT per epoch on IBM T60 notebook
Mean cup time = 0.6s
Handhold Kinematic Test
Results of Handhold Test

(Initialized Time: 20 minutes)
Kinematic PPP Results vs. Post DD

<table>
<thead>
<tr>
<th>RMS(m)</th>
<th>N</th>
<th>E</th>
<th>U</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.206181</td>
<td>0.170222</td>
<td>0.403532</td>
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</table>
Single-Frequency GPS Receiver Kinematic Test
Single Frequency PPP with RT Products

<table>
<thead>
<tr>
<th></th>
<th>N (m)</th>
<th>E (m)</th>
<th>U (m)</th>
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<tr>
<td>ALGO</td>
<td>0.14162</td>
<td>0.128424</td>
<td>0.248683</td>
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<tr>
<td>BJFS</td>
<td>0.275009</td>
<td>0.224492</td>
<td>0.528504</td>
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<td>SHAO</td>
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<td>0.182978</td>
<td>0.475936</td>
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<td>WHU</td>
<td>0.285737</td>
<td>0.143631</td>
<td>0.656127</td>
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Blocking Test for PPP quick recovery

N: 1.52cm
E: 11.6cm
U: 10.3cm
Block Test for PPP quick recovery in Kinematic mode
Block Test for PPP quick recovery in Kinematic mode
What is GNSS Integrity?

1. Tell users how good your GNSS service is?
   -----Performance Evaluation: accuracy, availability, coverage
2. Find Faults and provide alarming to users.
   -----Fault Detection, check to what extent the fault affects the performance.

Why GNSS Integrity is so important?

1. Consumer customers
   man is independent, GNSS device is just an aiding tool for his life to make convenience. So personal
   PND has lower request in GNSS integrity. But we still improve through RAIM,..., so that the performance
   of the products become better and better.....
2. Safety related intelligent system
   In those intelligent control systems, i.e. airplane, intelligent driving, their performance mostly
   depends on the computer’s analysis, not human’s strong brain.

How to realize GNSS Integrity?

1. (inherent) Trace each step in product producing and evaluate it
   SBAS: orbit, sv clock, ionospheric delay, algorithm developed for it, i.e. RAIM
2. (outside checking) redundant monitoring and Alarming
   SBAS: build tracking and checking system to validate the performance.
Thank You For Your Attention!

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