Cost Effective GNSS Positioning Techniques

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INTRODUCTION

- Report focuses on Cost-effective Use of GNSS
- Global Navigation Satellite Systems (GNSS)
  - Initially developed in early 1970's
  - Improve global positioning and navigation from space
- First Commercial Receivers
  - On the market in 1982
  - Large, bulky, expensive (250,000 €)
  - Manually select satellites on first receivers
- Receivers Today
  - Sophisticated, multi-frequency, multi-constellation
  - Geodetic quality receivers – 5,000 € to 12,000 € (surveying, engineering)
  - Still expensive for developing countries
GLOBAL NAVIGATION SATELLITE SYSTEMS

- Primarily used for Positioning, Navigation and Timing Applications

- Positioning
  - Stationary objects
  - Moving platforms

- Overview of Satellite Positioning
  - Satellite positions as a function of time (ephemerides)
  - Range between visible satellites and antenna (from receiver)
  - Range between visible satellites and origin of a coordinate system (ECEF)
  - Remaining unknown is the position vector of the antenna

GLOBAL NAVIGATION SATELLITE SYSTEMS

- Global Constellations
  - Global Positioning System (GPS)
    - 24 operational satellites plus a number of spares
    - Six orbital planes inclined at 55°
    - Fundamental frequencies: \( f_1 = 1575.42 \text{ MHz} \), \( f_2 = 1227.60 \text{ MHz} \)
  - GLONASS
    - 20-22 operational satellites
    - Three orbital planes inclined at 64.8°
    - L1 band uses frequency division multiple access (FDMA). Frequencies centered around 1602.0 MHz
    - 15 L2 frequencies centered around 1246 MHz
GLOBAL NAVIGATION SATELLITE SYSTEMS

- Global Constellations (cont.)
  - GALILEO
    - GIOVE-A and GIOVE-B Galileo In-Orbit Validation Element. Designed for 27 + 3 medium earth orbit (MEO) satellites
    - Three orbital planes inclined at 56°
    - Code division multiple access (CDMA) to transmit up to 10 signals (1164 – 1592 MHz)

- COMPASS / BEIDOU-2
  - Up to 35 satellites
  - Medium earth orbits
  - Frequencies from the E1, E2, E5B AND E6 bands
  - ICD – very soon

GNSS POSITIONING TECHNIQUES FOR SURVEYING

- Absolute Positioning

- Relative or Differential Positioning
GNSS POSITIONING TECHNIQUES FOR SURVEYING

• Error Sources

- Precise Point Positioning
  - Elimination of errors by differencing replaced by precisely modeling many error sources
  - Satellite positions from accurate orbits
  - Accurate satellite clocks

<table>
<thead>
<tr>
<th></th>
<th>Accuracy</th>
<th>Latency</th>
<th>Sample Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Broadcast</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orbits</td>
<td>~100 cm</td>
<td>Real time</td>
<td>Daily</td>
</tr>
<tr>
<td>Sat. clocks</td>
<td>~2.5 ns SDev</td>
<td></td>
<td></td>
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<tr>
<td><strong>Ultra-Rapid</strong></td>
<td></td>
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<tr>
<td>(predicted half)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orbits</td>
<td>~5 cm</td>
<td>Real Time</td>
<td>15 min</td>
</tr>
<tr>
<td>Sat. clocks</td>
<td>1.5 ns SDev</td>
<td></td>
<td></td>
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<tr>
<td><strong>Rapid</strong></td>
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<td></td>
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<tr>
<td>Orbits</td>
<td>2.5 cm</td>
<td>17-41 hours</td>
<td>15 min</td>
</tr>
<tr>
<td>Sat. clocks</td>
<td>~25 ps SDev</td>
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<td></td>
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<tr>
<td><strong>Final</strong></td>
<td></td>
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</tr>
<tr>
<td>Orbits</td>
<td>2.5 cm</td>
<td>12-18 days</td>
<td>15 min</td>
</tr>
<tr>
<td>Sat. clocks</td>
<td>~20 ps SDev</td>
<td></td>
<td>30 s</td>
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</tbody>
</table>
COST-EFFECTIVE GNSS

- Economize Financial and Physical Resources
- Work as Accurately as Necessary
- Two Possibilities to Economize Resources

1) Low-Cost GNSS Receivers
2) Continuously Operating Reference Stations

Continuously Operating Reference Stations (CORS) and resp. Networks

- Expense of reference station spared
- Multiple reference station

Courtesy UNAVCO, CO
COST-EFFECTIVE GNSS

Use Less Expensive Low-Cost GNSS Receivers and Antennas (150 € and up)

<table>
<thead>
<tr>
<th>Receiver class</th>
<th>Used signal</th>
<th>Applications</th>
<th>Accuracy</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>navigation</td>
<td>code or phase-smeared code, 1 frequency</td>
<td>car navigation, location-based services, sailing, mass market</td>
<td>1 to 10 m</td>
<td>5–100 €</td>
</tr>
<tr>
<td>geodetic</td>
<td>code and phase, in general 2 frequencies</td>
<td>surveying, geodesy, geodynamics</td>
<td>0.001 to 0.1 m</td>
<td>10,000–30,000 €</td>
</tr>
</tbody>
</table>

COST-EFFECTIVENESS

- Calculation base:
  - labor costs between 1 € and 70 € / hour
  - geodetic receiver: 20,000 €
  - low-cost receiver + equipment: 2,000 €
  - calculated for three years using

- Variant 1: GNSS CORS network
- Variant 2: Low-Cost GNSS receiver
- Combination of variant 1 and 2
Web-based Positioning Tools

- User submits data to an online service
- Product provides coordinates with a precision of 1.0 cm
- Global (ITRF) and local (ETRS89, GDA, NAD83) reference frame
- AUSPOS, CSRS-PPP, SCOUT, OPUS (Free)
GLOBAL AND REGIONAL REFERENCE STATION NETWORKS
- Examples -

• **Global**
  IGS Tracking Network

• **North America**
  The National CORS Network – United States
  Plate Boundary Observatory – Western United States
  [http://pboweb.unavco.org](http://pboweb.unavco.org)
  The Southern California Integrated GPS Network

THE INTERNATIONAL GNSS SERVICE

• Voluntary Scientific Organization (200 Groups from 80 Countries)

• Many Products Offered
  – Reference Station Data from Global Network (RINEX)
  – GPS and GLONASS Satellite Orbit and Clock Products
  – Earth Rotation Parameters

• Ongoing Projects
  – Clocks
  – Real Time Pilot Project
  – Reference Frames
  – Ionospheric and Tropospheric Working Groups
THE INTERNATIONAL GNSS SERVICE

IGS Tracking Network

Courtesy IGS

For more information on Cost-Effective GNSS:

Cost Effective GNSS Positioning Techniques

http://www.fig.net/pub/figpub/pub49/figpub49.pdf