Cost-effective precise positioning for geospatial applications

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Total Value of GNSS Precise Positioning Technology

Seven billion GNSS devices by 2022 – almost one for every person on the planet.

Global GNSS market size

CAGR: 9%
CAGR: 5%

Who benefits of precision GNSS?

- Geodetic survey
- Earthquake & tsunami alert systems
- Machine Control
- GNSS meteorology
- Precision Agriculture
- Mobile Mapping
- ITS (Intelligent Transportation System)

Centimeter-level positioning

- Relative positioning using differential principles
- Carrier phase based techniques
- A pair of receivers
- Simultaneous tracking
- Baseline constraint

- RTK
  - Single-baseline
  - Limited area 10-20km
Disadvantages

- **High-operational costs for current positioning technology**
  - Expensive geodetic-grade receivers
  - Expensive post-processing software
  - Infrastructure is required
  - Limited applications due to cost issues

\[10000-30000\] €
How to reduce de cost?

• **Hardware**
  – Can we eliminate one receiver?
  – Can we use other type of receivers?

• **Software**
  – Can we use other positioning technique to obtain precise location information?
  – Can we reduce the cost of the processing software?

Q1: Can we eliminate one receiver?

[Diagram of RTK positioning system with descriptions of Reference Stations, Rover, Network RTK Server, and RTK Corrections.]
NetworkRTK: pro and cons

• **Benefits**
  – No need to set up a base station
  – Cost, labor, mobility, efficiency
  – Homogeneous and consistent accuracy over larger areas
  – The same area can be covered with fewer RS
  – Reliability, availability, continuity (365/24/7)

• **Drawbacks**
  – The cost to subscribe to an RTN and to receive corrections
  – Limited wireless data access
  – Interpolation (or extrapolation)

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Different NRTK realizations

• **Area Correction Parameters (FKP)**
  – Flächen-Korrektur Parameter
  – Geo++ in the mid 1990s

• **Virtual Reference Station (VRS)**
  – Terrasat in the late 1990’s
  – Pseudo Reference Station (PRS)

• **Master Auxiliary Concept (MAC)**
  – proposed by Leica and Geo++ in 2001
  – individualized-MAX
### Test methodology

<table>
<thead>
<tr>
<th>DoY</th>
<th>Session</th>
<th>morning</th>
<th>afternoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>251</td>
<td>VRS</td>
<td>VRS</td>
<td></td>
</tr>
<tr>
<td>258</td>
<td>Nearest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>265</td>
<td>Post-Processing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Two observation sessions
- Two NRTK modes
  - Nearest Station (single-base)
  - VRS
- Five time intervals
  - 10, 60, 180, 300, 480 sec
- 10 occupations at each interval
  - Average

### Accuracy test

#### Horizontal Precision vs. Accuracy

**Overview**
- **RTK**
- **VRS**
- **Mean**
- **OPUS**

**Graph Illustrations**
- Center of precision: 2 cm Rx spec 95%
- Center of accuracy: ~1 cm

**Legend**
- OPUS PP Error
Q2: Can we use other type of receivers?

Cost-effective hardware

- **Original Equipment Manufacturer boards**
  - iTrax03 (2005)

- **GPS/GNSS modules**
  - Garmin 12XL (2000)
  - Garmin GPS25 (2010)

- **Navigation-grade receivers**
  - ublox (2009)
  - 100-500 €
  - LEA 6T, **UBX-RXM-RAW**: carrier phase with half cycle ambiguity resolved, code and Doppler obs.
Baseline processing

Low-cost baseline post-processing statistical indicators & error ellipses

<table>
<thead>
<tr>
<th>Baseline name</th>
<th>Length [m]</th>
<th>Duration [H:MM:SS]</th>
<th>Epochs</th>
<th>Precision [mm] North</th>
<th>Precision [mm] East</th>
<th>Precision [mm] Vert</th>
<th>Precision [mm] Horiz</th>
<th>Precision [mm] 3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>FGI0-KAIV</td>
<td>22821,535</td>
<td>1:19:08</td>
<td>4748</td>
<td>8.4</td>
<td>7.1</td>
<td>17.8</td>
<td>11.0</td>
<td>20.9</td>
</tr>
<tr>
<td>FGI0-SMOK</td>
<td>16424,979</td>
<td>0:52:01</td>
<td>3121</td>
<td>4.6</td>
<td>4.0</td>
<td>11.8</td>
<td>6.1</td>
<td>13.2</td>
</tr>
<tr>
<td>SMOK-TIIL</td>
<td>11623,102</td>
<td>0:40:01</td>
<td>2401</td>
<td>5.4</td>
<td>2.0</td>
<td>12.3</td>
<td>5.7</td>
<td>13.5</td>
</tr>
<tr>
<td>FGI0-TIIL</td>
<td>4871,501</td>
<td>0:31:01</td>
<td>1861</td>
<td>1.9</td>
<td>1.3</td>
<td>4.4</td>
<td>2.3</td>
<td>5.0</td>
</tr>
<tr>
<td>OTA9-SMOK</td>
<td>481,253</td>
<td>0:25:01</td>
<td>1501</td>
<td>4.2</td>
<td>3.5</td>
<td>8.3</td>
<td>5.4</td>
<td>10.0</td>
</tr>
</tbody>
</table>
**Geodetic vs. low-cost baselines**

### Table 2. Comparison of the low-cost baseline vectors with respect to the geodetic baselines

<table>
<thead>
<tr>
<th>Baseline name</th>
<th>Baseline length [m]</th>
<th>Baseline error [cm]</th>
<th>Errors in the baseline components [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>FG10-KAIIV</td>
<td>22821,535</td>
<td>1.9</td>
<td>dX 0.7 dY 1.7 dZ -2.6</td>
</tr>
<tr>
<td>FG10-SMOK</td>
<td>16424,979</td>
<td>-4.6</td>
<td>dX 3.3 dY -3.3 dZ 0.1</td>
</tr>
<tr>
<td>SMOK-TIIL</td>
<td>11623,102</td>
<td>-2.2</td>
<td>dX -2.0 dY 2.0 dZ -4.8</td>
</tr>
<tr>
<td>FG10-TIIL</td>
<td>4871,501</td>
<td>2.1</td>
<td>dX -2.3 dY 1.2 dZ -1.2</td>
</tr>
<tr>
<td>OTA9-SMOK</td>
<td>481,253</td>
<td>1.5</td>
<td>dX 0.0 dY 0.1 dZ -3.6</td>
</tr>
</tbody>
</table>

**Q3: Can we use other positioning technique to obtain precise location information?**

- Dual-frequency data from a **single** GNSS receiver
- **Precise orbits** and SVs **clocks**
- Iono-free data combinations (P3, L3)
- Static positioning
  - $\approx 1.0$ cm (horizontal) and $\approx 5.0$ cm (vertical)
- Convergence period
- Post-processing

- OS: OPUS, magicGNSS, RTS-IGS, etc
- CS: CenterPoint RTX, Veripos APEX, Nexteq i-PPP

Source: Andrei (2010)

http://www.insidegnss.com/node/2977
**Test A** (Pulmankivene)
- Cart mapping

**Test B** (Tahtelä)
- Snow-mobile mapping

**Test C** (Ivalojoki)
- Boat navigation

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**FGI-ROAMER MMS**


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**Statistics**

<table>
<thead>
<tr>
<th></th>
<th>North (m)</th>
<th>East (m)</th>
<th>Up  (m)</th>
<th>2D (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-0.035</td>
<td>-0.067</td>
<td>0.293</td>
<td>0.151</td>
</tr>
<tr>
<td>RMS</td>
<td>0.194</td>
<td>0.167</td>
<td>0.837</td>
<td>0.256</td>
</tr>
</tbody>
</table>

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**Multipath**

**Complete loss-of-lock**
For ≈60% of the recorded epochs, 2D positioning errors are less than 10 cm.

Q4: Can we reduce the cost of processing software?

... other open source or freely available
Summary

<table>
<thead>
<tr>
<th>Nr.crt</th>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Can we eliminate one receiver?</td>
<td>NetworkRTK</td>
</tr>
<tr>
<td>2</td>
<td>Can we use other type of receivers?</td>
<td>Navigation-grade phase-enabled receiver</td>
</tr>
<tr>
<td>3</td>
<td>Can we use other positioning technique to obtain precise location info?</td>
<td>Precise Point Positioning</td>
</tr>
<tr>
<td>4</td>
<td>Can we reduce the cost of the processing software?</td>
<td>Open-source</td>
</tr>
</tbody>
</table>
Acknowledgement

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Thank you for Your attention!

http://www.sv.eng.chula.ac.th

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