Monitoring of Rock Fall at Yangtze River with Low-Cost GNSS receiver

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Second workshop of DAAD Thematic Network ”Modern Geodetic Space Techniques for Global Change Monitoring”

24-28 July 2018, Luxembourg
Introduction

<table>
<thead>
<tr>
<th>receiver class</th>
<th>used signal</th>
<th>applications</th>
<th>accuracy</th>
<th>appr. costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>low cost</td>
<td>code or phase-smoothed code, 1 frequency</td>
<td>car navigation, location based services, sailing, mass market</td>
<td>1 to 10 m</td>
<td>100 – 500 €</td>
</tr>
<tr>
<td>geodata acquisition</td>
<td>phase-smoothed code, 1 frequency</td>
<td>infrastructure planning, architecture, GIS applications</td>
<td>0,5 to 3 m</td>
<td>5 000 – 10 000 €</td>
</tr>
<tr>
<td>geodetic</td>
<td>code and phase, in general 2 frequencies</td>
<td>surveying, geodynamics</td>
<td>0,001 to 0,1 m</td>
<td>10 000 € - 30 000 €</td>
</tr>
</tbody>
</table>

Schwieger and Gläser (2005)

Low-Cost GNSS Receiver for Geodetic Applications, e.g. for monitoring, and machine control (Accuracy: mm to cm-level)?

Carrier Phase measurements should be accessible!
Introduction

Test study with u-blox GPS receivers at University of Stuttgart, ETH Zurich und TU Graz

Schwieger (2009), Uni Stuttgart  Lanzendörfer (2007), TU Graz  Limpach (2009), ETH Zürich

The University of Armed Forces Munich with Novatel GNSS receivers (about 1200€)

Low Cost GNSS is suitable for the monitoring applications, length-dependent error (tropospheric, ionospheric) are reduced for short baseline in relative module.

Heunecke et al. (2011), Uni BW München
Geodetic Application: Monitoring

Dominate error for short baseline: Multipath effect

- Reduced by data processing (e.g. temporal and spatial correlations)
- Good antennas are important (e.g. Trimble Bullet III vs. Ublox ANN-MS, see Takasu and Yasuda 2008, Zhang and Schwieger 2013)
- Optimization of antenna shielding (ground plate vs. choke ring)

Originally developed by JPL

Zhang (2016)

self-constructed L1-optimized CR-GP at IIGS with Trimble Bullet III antenna (side view and top view)

- Groove depth: ¼ of wave length
- Diameter: 1.5 of wave length
Comparison of different Shieldings

1) TBIII antenna without shielding + Ublox LEA-6T single-frequency GPS receiver,
2) TBIII antenna with flat GP + Ublox LEA-6T single-frequency GPS receiver,
3) TBIII antenna with CR-GP + Ublox LEA-6T single-frequency GPS receiver,
4) Leica AX1203 GNSS antenna without additional shielding + Leica GX1230 GNSS receiver.
Comparison of different Shieldings

Quality Analysis

- Improvement of the std.: Flat GP: 35 %, CR-GP: ca. 50 %
- TBIII with CR-GP std. ca. 3/5/9 mm (E/N/h) in this reflexion intensive environment
- TBIII with CR-GP comparable with Leica AX 1203 antenna with GX1230 receiver in this test
DAAD-CSC PPP Project

Project: Automatic Multisensor Early Warning System near the Three Gorges Dam

- Funded by China Scholarship Council (CSC) and German Academic Exchange Service (DAAD) within Project Based Personnel Exchange Program (PPP)
- Duration: 2017-2018 (2 years), possible extension for 1 year (2019)
- Partner: - Institute of Engineering Geodesy (IIGS), University of Stuttgart, Project leader: Prof. Volker Schwieger
  - Institute of Surveying Engineering, School of Geodesy and Geomatics (SGG), Wuhan University, Project leader: Prof. Yaming Xu
- Goal: development of cost effective automatic Multisensor Early Warning System
Test Area: Lianyiya Rock Fall

Three Gorges Dam

Lianziya Rock fall

27 km

Xintan Landslide
Introduction and motivation

- Causes of rock fall
  - Active geological structure
  - Change of water level
  - Coal mining
- Three areas according to:
  - Geological structures
  - Topography
  - Characteristics of movement
- Stabilization of area 1 through constructive measures
- Area 3 still active
  - Average horizontal displacement 1.0~4.2 mm/year
  - Average vertical 0.3~2.9 mm/year
- Direct threat to the shipping on Yangtze River and the surrounding towns!
Instruments

• GB-Radar (IBIS-L)
• GNSS (U-blox C94-M8P RTK Application Board, Leica 1200 System)
• TLS (Leica P50)

- 2 Neo-M8P-2 GNSS (GPS, GLONASS, Beidou, QZSS) modules
- 2 GNSS antennas + ground plate
- 2 UHF antennas (~350€)
Monitoring of Rock fall at the Yangtze River near the Three Gorges Dam with U-blox C94-M8P

Measurement

Reference Station (R)

- Leica 1200 System (GPS only)
- Ublox C94-M8P application Board (GPS+Beidou)

Rover Station (M1)

Rover Station (M2)
Test Area

Area 3

Rover M1

Rover M2

@google

Reference

ca. 700 m (line of sight)
Monitoring of Rock fall at the Yangtze River near the Three Gorges Dam with U-blox C94-M8P

Results – Baseline (Post-Processing)

<table>
<thead>
<tr>
<th>Date</th>
<th>Session</th>
<th>Reference Station</th>
<th>Rover Station</th>
<th>Baseline [m]</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>09 March, 2018</td>
<td>1 (9:20-11:20)</td>
<td>Leica (R)</td>
<td>Ublox(M1)</td>
<td>423.3217</td>
<td>-534.7675</td>
<td>205.4940</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leica (R)</td>
<td>Leica (M2)</td>
<td>401.0503</td>
<td>-546.9636</td>
<td>211.8549</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 (14:00-16:00)</td>
<td>Leica (R)</td>
<td>Leica (M1)</td>
<td>423.3213</td>
<td>-534.7696</td>
<td>205.5032</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leica (R)</td>
<td>Ublox(M2)</td>
<td>401.0518</td>
<td>-546.9635</td>
<td>211.8593</td>
<td></td>
</tr>
<tr>
<td>10 March, 2018</td>
<td>3 (10:15-12:15)</td>
<td>Ublox (R)</td>
<td>Ublox(M1)</td>
<td>423.3161</td>
<td>-534.7708</td>
<td>205.5010</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ublox (R)</td>
<td>Leica (M2)</td>
<td>401.0419</td>
<td>-546.9685</td>
<td>211.8532</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 (14:14-16:14)</td>
<td>Ublox (R)</td>
<td>Leica (M1)</td>
<td>423.3129</td>
<td>-534.7727</td>
<td>205.5002</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Ublox (R)</td>
<td>Ublox(M2)</td>
<td>401.0430</td>
<td>-546.9649</td>
<td>211.8572</td>
<td></td>
</tr>
</tbody>
</table>

The difference of the Baselines is under 1 cm in all the coordinate components
## Monitoring of Rock Fall at the Yangtze River near the Three Gorges Dam with U-blox C94-M8P

### Results - Standard Deviation (Post-Processing)

<table>
<thead>
<tr>
<th>Date</th>
<th>Session</th>
<th>Reference Station</th>
<th>Rover Station</th>
<th>Standard Deviation [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>E [mm]</td>
</tr>
<tr>
<td>09 March, 2018</td>
<td>1 (9:20-11:20)</td>
<td>Leica (R)</td>
<td>Ublox(M1)</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leica (R)</td>
<td>Leica (M2)</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>2 (14:00-16:00)</td>
<td>Leica (R)</td>
<td>Leica (M1)</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leica (R)</td>
<td>Ublox(M2)</td>
<td>3.9</td>
</tr>
<tr>
<td>10 March, 2018</td>
<td>3 (10:15-12:15)</td>
<td>Ublox (R)</td>
<td>Ublox(M1)</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ublox (R)</td>
<td>Leica (M2)</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>4 (14:14-16:14)</td>
<td>Ublox (R)</td>
<td>Leica (M1)</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ublox (R)</td>
<td>Ublox(M2)</td>
<td>2.8</td>
</tr>
</tbody>
</table>

- Baseline R-M1 (Leica-Leica vs. Ublox-Ublox: 13.5 mm vs. 10.8 mm) for whole position
- Baseline R-M2 (Leica-Leica vs. Ublox-Ublox: 13.1 mm vs. 8.1 mm) for whole position
- Advantage of GPS + Beidou Combination
- Short baseline (700 m)
Postprocessing vs. RTK results (u-center)

3. Session on 10. March 17:00-17:30 for testing RTK Performance

c.a. 15% outliers

<table>
<thead>
<tr>
<th></th>
<th>X [mm]</th>
<th>Y [mm]</th>
<th>Z [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>97.8</td>
<td>61.9</td>
<td>65.3</td>
</tr>
<tr>
<td>Without outlier</td>
<td>7.2</td>
<td>7.3</td>
<td>6.9</td>
</tr>
</tbody>
</table>
Geodetic Application: Monitoring
Automatic Low-Cost GPS Monitoring System at IIGS (2012)
Outlook

Low-Cost multi-frequency GNSS Receiver?

Piksi Multi GNSS Module
https://www.swiftnav.com

GPS L1+L2
(Hardware-ready for GLONASS G1+G2, BeiDou B1+B2, Galileo E1+E5b, QZSS L1+L2 and SBAS)
Outlook

Low-Cost multi-frequency GNSS Receiver?

High precision positioning

Achieving centimeter-level accuracy by combining RTK technology and u-blox GNSS expertise.

GPS L1+L2
Galileo: E1+E5
Outlook

GNSS Raw measurements of smartphone are accessible!

„Google announced that raw GNSS measurements will be available to apps in the Android N operating system” (May/June 2016)

http://gpsworld.com/google-opens-up-gnss-pseudoranges/
### Outlook

**GNSS Raw measurements of smartphone are accessible!**

<table>
<thead>
<tr>
<th>Model</th>
<th>Pseudorange data</th>
<th>Accumulated delta range</th>
<th>Global systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huawei Mate 10</td>
<td>yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huawei P10</td>
<td>yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huawei Honor 9</td>
<td>yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Samsung S8 (Exynos)</td>
<td>yes</td>
<td></td>
<td>GPS, GLONASS, GALILEO, BDS</td>
</tr>
<tr>
<td>Nexus 9 (non cellular version)</td>
<td>yes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Selectived from https://developer.android.com

Better oder external antenna?
Outlook

Precise Positioning with Low-Cost GNSS for automated vehicles?

A dense reference network (20 km) facilitates low-cost carrier-phase differential GNSS positioning with rapid integer-ambiguity resolution (PPP-RTK), centimeter-accuracy can be achieved.

Murrian et al. (2016)
Bosch, Geo++, Mitsubishi Electric and u-blox to establish joint venture Sapcorda Services to bring high precision GNSS positioning services to Mass Markets

Bosch, Geo++, Mitsubishi Electric and u-blox today announced the creation of Sapcorda Services GmbH, a joint venture that will bring high precision GNSS positioning services to mass market applications.
Summary

• Low Cost GNSS receivers are suitable for the monitoring application (accessible carrier-phase raw measurement, reliable antenna or use shielding)

• Low Cost GNSS receivers are more and more cheaper, they are not limited to single-frequency, single-system

• Carrier-phase raw measurement are accessible from some smartphones, precise positioning could be possible with smartphones (sensor integration, reliable antenna)

• Precise Positioning with Low-Cost GNSS for automated driving should be possible (PPP-RTK, reliable facilities, low-cost and reliable GNSS antenna)
Acknowledgement

The investigations showed are granted by the DAAD (German Academic Exchange Service) project Nr. 5731774 and CSC (China Scholarship Council) within PPP (Project Based Personnel Exchange Program). Therefore the authors cordially thank the funding agencies.
Thank you!

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