REAL-TIME PPP WITH GALILEO, PAVING THE WAY TO EUROPEAN HIGH ACCURACY POSITIONING

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SESSION E2: NEXT GENERATION GNSS POSITIONING

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OUTLINE

- Introduction
  - Precise Point Positioning (PPP)
  - Motivation

- magicGNSS PPP Infrastructure
  - Server
  - Client

- IGS’ MGEX Project

- Galileo contribution to High Accuracy

- Conclusions and future work
PPP: PRECISE POINT POSITIONING

- Absolute positioning technique
- Precise orbits & clocks + observations + detailed models
- Sparse network of reference stations
MOTIVATION

- Background: GNSS POD
  - PPP is a natural evolution
  - Algorithm development, product generation

- Evaluate real-time PPP performances in the field
  - Realistic scenarios
  - Static and kinematic

- Learn and overcome the challenges associated to the end-to-end process
  - Communications
  - Robustness and Reliability

- Learn and overcome the challenges associated to implementing the PPP algorithm in portable devices
  - CPU and memory load
  - Power consumption
PPP DEMONSTRATOR SERVER

- Infrastructure for generation of:
  - Precise multi-GNSS orbits and clocks for real time and post-processing applications
  - RTCM ephemeris corrections for HA positioning in Real-Time

- Modular architecture for distributed processing

- Data retrieval, from a worldwide RTCM station network via NTRIP

- Configurable in Real-Time by means of a database

- Accepts connections from multiple PPP clients
Quality of the Real-Time GPS and GLONASS orbits and clocks has been assessed during the past years versus IGS in the frame of IGS’ Real Time Service (rt.igs.org)

Typical GPS orbit accuracy is about 6 cm, RMS, and clock accuracy is about 0.25 ns, RMS versus IGS rapid products

Typical GLONASS orbit accuracy is about 10 cm, RMS, and clock accuracy is about 0.4 ns, RMS versus ESOC (European Space Operations Centre) products.
RT PPP DEMONSTRATOR CLIENT

- PPP module able to compute HA user position in Real-Time based on:
  - RTCM observations and ephemeris coming from a GNSS receiver via serial port
  - RTCM ephemeris corrections coming from an external service provider

- User logs and runs the PPP client by means of an MMI

- Position generated in NMEA format

- Allows running RTK by means of rtklib
RT PPP DEMONSTRATOR CLIENT PERFORMANCES

- Base station coordinates continuously monitored

- Real-Time PPP performances assessed versus RTK in open field kinematic environments

- Centimetric consistency between RTK and PPP under nominal circumstances
The latest RTCM 3.2 standard developed by the SC.104 intends to support highly accurate differential and kinematic positioning as well as a wide range of navigation applications as PPP.

For POD and PPP 3 types of RTCM messages are crucial:
- Observations
- Ephemeris
- Ephemeris correction messages

Multi-GNSS coverage has been improved, but certain gaps persist:

<table>
<thead>
<tr>
<th></th>
<th>GPS</th>
<th>GLONASS</th>
<th>Galileo</th>
<th>BeiDou</th>
<th>QZSS</th>
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<tr>
<td>Ephemeris</td>
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<td>Ephemeris corrections</td>
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<td>YES</td>
<td>NO</td>
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</table>
IGS’ MULTI-GNSS EXPERIMENT PROJECT

- Established to explore and promote the usage of new navigation signals and constellations within the IGS (http://www.igs.org/mgex)

- Multi-GNSS sensor station network
  - Around 110 stations located in 90 sites
  - RTCM3-MSM real-time data streams (5 streams per registered user)
  - RINEX 3.02 data archive

- Multi-GNSS products from 5 AC`s
  - European Space Operations Centre (ESOC)
  - Center for Orbit Determination in Europe (CODE)
  - GeoForschungsZentrum Potsdam (GFZ)
  - Technische Universität München (TUM)
  - Wuhan University
MAGICGNSS’ GALILEO PRODUCTS

- Experimental *magicGNSS’* web server with MGEX stations for reference product generation

- MGEX’ products used as reference for Galileo product quality assessment

- Centimetric consistency between all the solutions
GALILEO-ONLY PPP

- Data recorded on May 31st 2013 during a 150 minute window with 4 IOV satellites over Tres Cantos.

- Reference products obtained by means of magicGNSS’ web server and MGEX data.

- Addition of GALILEO reduces the convergence time w.r.t. a GPS+GLONASS PPP.

- GALILEO-only PPP of the recorded RINEX 3.02 data
  - Batch PPP provides centimetric accuracy
  - Sequential PPP converges to decimetric accuracy after 45 minutes.
SEQUE NTIAL KINEMATIC MULTI-GNSS PPP

- Multi-GNSS data recording around Tres Cantos (close to GMV’s premises in Madrid) on August 21\textsuperscript{st} for around 25 minutes by means of a Trimble R10 receiver

- Recorded RINEX post-process by a sequential PPP using as reference products the ones obtained by \textit{magicGNSS’} web server and MGEX’ station network
SEQUENTIAL KINEMATIC MULTI-GNSS PPP (2)

- L2 tracking frequently lost around wooded areas
- The number of usable satellites when driving under wooded areas drops to 5 -> GPS+GLONASS real-time PPP greatly affected
E5 tracking under wooded areas more robust than for L2

Does the addition of Galileo (even with just 3 satellites) ease the impact of the L2 tracking losses in the end PPP performances?
Notable PPP improvement by the addition of Galileo

Overall robustness increased by the addition of just 3 satellites

Promising results once the full constellation is deployed
CONCLUSIONS AND FUTURE WORK

- Even with only 3 operating satellites, Galileo has proven to provide a remarkable contribution to the PPP performances increasing the PPP robustness under challenging environments.

- MSM data availability and multi-GNSS ephemeris correction message definition issues need to be solved for multi-GNSS infrastructure testing in real-time.

- Future work focused on testing our magicGNSS’ real-time infrastructure to try to increase the robustness and analyse the benefits of using additional GNSS constellations.
Thank you

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