Improving Accuracy and Redundancy with GPS and GLONASS PPP

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Presentation Overview

Precise Point Positioning
GLONASS
Orbit & Clock Determination
User Algorithms
Performance of GPS & GLONASS
Benefits for the DP User
Integration into DP Systems
Precise Point Positioning

• Absolute positioning technique
  – Used as a real-time system delivering decimetre results
  – Used in offshore positioning for over 10 years

• Correct or model all GNSS error sources

• Single set of orbit and clock corrections for the satellite constellation
  – Valid globally, so position accuracy is maintained regardless of user location
  – Recently seen the addition of GLONASS due to rejuvenation of constellation
Typical PPP Accuracy

• Typical accuracy of PPP using GPS
GLONASS – Why?

• GLONASS is a viable constellation (again!)
  – Significant investment in system
  – Operational system (unlike Galileo & COMPASS)
  – Current constellation is 24 satellites (last launch 09/02/10)
  – Receiver technology much improved
  – Modernization plan (signals, geodesy etc.)
  – Independent positioning system to GPS
What is Needed to Deliver a PPP Solution

• Global Network of Stations
  – Raw GNSS data required for OCDS to calculate orbit and clock corrections to the satellites
  – Upgrade network to track GLONASS

• Orbit and Clock Determination System (OCDS)
  – Processing to calculate orbit and clock corrections

• Formatting and Scheduling of Augmentation Data
  – More data means addition messages

• Data Delivery to User
  – Same techniques but more data being transmitted
  – RTCM NTRIP delivery via Internet

• User/Mobile
  – Upgrade algorithms to handle GLONASS
• APEX Tracking Network
• GPS + GLONASS
JPL Reference Station Network

From JPL website (http://www.gdgps.net/system-desc/images/world.png)
Orbit and Clock Determination

- This is the core requirement for providing a PPP solution

- System takes in the raw GNSS measurement data from all VERIPOS reference stations
  - From primary and secondary receivers at the site

- Data is managed & fed into process which calculates orbit and clock corrections
  - Additional data needed includes satellite info (health etc.) and station info (coordinates, ocean loading etc.)

- Data input and output is monitored to check performance and ensure that enough redundancy is in the system

- Why develop your own OCDS??
  - Independence and flexibility (e.g. addition of other satellite systems)
  - Ability to control development - improvements to orbit and clock determination to derive higher accuracy orbits and clocks
  - Derive additional monitoring capability particularly of the GNSS networks
OCDS System Architecture

- OCDS has 3 components
  - System Control & Monitoring
  - Orbit and Clock generation
  - Ref station raw data management

- Message formatter required to process the multiple formats and streams

- HUBS sequence the data and send to satellite uplink sites
Issues with GLONASS

• Navigation messages
  – Satellites missing and/or excluded
  – Bad/wrong messages
  – Channel changes without prior warning!

• Time systems
  – GLONASS and GPS used different time systems

• Data cleaning issues
  – More problematic for GLONASS than GPS

• GLONASS orbit model
  – Important for the orbits predictions
  – Area for improvement

• GLONASS phase centre variations
  – Area for improvement
System Monitoring Plots

Satellite Clock Estimation

Number of Stations used in Clock Estimation

MJD 55440.994097, Number of satellites: 50

Dynamic Positioning Conference 2010
12-13 October 2010
Orbit and Clock Accuracy

Formal Errors of Satellite Clock, mm

MJD 55440.994097, Number of satellites: 50
Network Control Centre

• Control & monitoring of OCDS
• Monitoring integrity of data network
• GNSS integrity monitoring

• Redundant Systems
• Real-Time Monitoring of orbit and clock corrections
Additional Benefits
Delivery of Data to Users

• Typical delivery is via redundant geostationary satellites
  – Provide global coverage

• How do you deliver the data
  – Orbit corrections change slowly over time compared to satellite clocks

• To increase accuracy and minimise impact on bandwidth
  – Transmit orbits and clocks separately
  – Clocks transmitted at a higher rate than orbits
  – Also aids convergence of position solution
NTRIP Delivery of Data to Users

• More clients requesting delivery of corrections via the internet
  – Particularly new builds where no Inmarsat terminals installed

• NTRIP - Network Transport of RTCM via Internet Protocol
  – RTCM Standard

• RTCM data supplied by this service is identical to that broadcast via geostationary satellites

• Supports mass usage as hundreds of data streams can be transmitted to thousand’s users

• Main issue is control of delivery as service providers have no control of data once it leaves their network
  – Delivery to vessel depends on vessel’s internet delivery system (e.g. KU band)
  – Implementation of monitoring software to confirm that the data has left network
User/Mobile

- Algorithms need to handle both GPS & GLONASS
- Ensure models to correct GNSS errors are the same as those used in the OCDS
- Existing industry standards and guidelines need to be updated to reflect multiple constellations
  - RTCM standard and UKOOA guidelines being updated
- No specific provisions for multi-constellation and high accuracy GNSS systems
  - Independence
  - Quality
  - Consistency
Positioning Performance @ Catu, Brazil

GPS

GPS + GLONASS

Dynamic Positioning Conference 2010
12-13 October 2010
Positioning Performance @ Kristiansund, Norway

![Graphs showing positioning performance for GPS and GPS + GLONASS.]
Benefits to DP Operators

• Why use multiple Global Navigation Satellite Systems?
  – More satellites providing better availability
  – Remove single points of failure
  – Improved error detection & rejection
  – More signals at different frequencies aids resilience to potential interference
  – Better accuracy when new or modernised signals become available
  – Potential to use each system independently or in a combined solution

• Implications of additional GNSS
  – Increased complexity of different modes of GNSS system operation
  – How to achieve visibility on performance and independence of different GNSS systems?
  – New data interfaces into DP systems
Improved Integration into DP Systems

• Additional information would benefit DP systems
  – Solution independence – *GNSS solution type information*
  – GNSS satellite counter - *number of satellites for each GNSS constellation*
  – Ability to weight independent solutions appropriately – *quality information*

• Such information requires a new data interface with DP systems
  – Upgrade of existing standards?
  – Or, proprietary interfaces?

• Opportunity to visualise additional information in DP systems
  – Calculation type (GPS-only, GLONASS-only, GPS+GLONASS etc)
  – Number of GPS / GLONASS / GALILEO satellites
  – GNSS PosRef quality