RTGx/GipsyX: A New Generation of GNSS Navigation Software

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RTGx/GipsyX: JPL’s 3rd Generation GNSS Software

Real Time GIPSY (RTG)

Proto GIPSY | GIPSY-OASIS


Distinguished heritage of quality and achievements
- **GIPSY** pioneered many GPS geodesic techniques and models; holds POD records for GPS and LEOs; hundreds of licenses to academia and industry
- **RTG** is core software for WAAS (U.S), MSAS (Japan), GAGAN (India); core for GDGPS 2000-2014; embedded in JPL’s Blackjack GPS receivers

**RTGx/GipsyX aim for even higher quality and utility standards**
- **RTGx** is the navigation software for the Next Generation GPS Control Segment (OCX), developed for the U.S. Air Force under exacting software quality and security standards
- Applies lessons learned from previous software development cycles

**GipsyX** is the post-processing subset of **RTGx** + Terrestrial Reference Frame (TRF) capabilities

RTGx

RT Post Processing TRF GipsyX
Key Features of RTGx/GipsyX

• C++ and Python code, complying with OCX secure coding standards
• Inherited the proven high fidelity physical models from GIPSY, including JPL’s unique in-house models for the GPS satellites (attitude, radiation pressure, and antenna)
• Supports models and data types for GPS, GLONASS, BeiDou, and Galileo
• Real-time and post-processing (backward smoothing) capabilities
• Robust integer ambiguity resolution
• Efficient SRIF filter formulation supporting multi-threading and parallelization with MPI for efficient processing of massive network-based, multi-constellation orbit determination problems
• Earth orientation estimation
• Stochastic process attributes available for any estimated parameter
• Receiver and transmitter can be on the ground or in space
• Extensive hyperlinked documentation using Doxygen technology
• Redesigned user interfaces
• Models for non-GNSS measurements, such as crosslink ranging and DORIS; SLR next
• Native measurement simulation capabilities for highest fidelity simulations of highly complex configurations
• Models for GNSS-based orbit determination of satellites at all altitudes
• Many GDGPS- and OCX-required operational features, including hot start, on-the-fly insertion and deletion of spacecraft/sites, on-the-fly fiducial clock switching,...
Status of RTGx/GipsyX

RTGx for OCX is functionally complete, and has been fully operational in GDGPS since 2014
- RTG is no longer supported by JPL
- Complete real-time product lines for GPS, GLONASS, BeiDou, and Galileo
  - dozens of concurrent filters; thousands of operational hours
  - 1Hz measurements * 100 sites * 70 satellites in a single filter
- Used operationally for real-time GPS performance monitoring for the Air Force

GipsyX is now used for JPL’s post-processed production of science-grade GPS orbit and clock solutions, and the Terrestrial Reference Frame
- GIPSY support by JPL will be phased out
- GipsyX licenses now available from Caltech

RTGx is now used for JPL’s orbit determination of LEOs:
- GRACE
- Jason-3

In development:
- An embedded version of RTGx for JPL’s Trig receivers
The Global Differential GPS (GDGPS) System

Providing mission-critical, real-time services, 24/7, since 2000
Full GNSS capabilities: GPS, GLONASS, BeiDou, Galileo

Driven by RTGx, the navigation software of the Next Generation GPS Control Segment (OCX)

Multiple services to NASA and Society

- Repeat path interferometry with UAV-SAR
- Earthquake monitoring and tsunami prediction
- Media Calibration for Deep Space Navigation
- Space weather monitoring

Real-Time Tracking Network
(200+ sites)

Triple Hot Redundant Operation Centers

Measurements

Products, Services

National Security

Precision Industrial Positioning

Personal Geolocation

Personal Geolocation

YEB - Feb 2017
The GDGPS Real-Time Tracking Network

250+ sites as of Dec 2016

Real-time monitoring of GPS, GLONASS, BeiDou, Galileo; soon QZSS
Natural hazard context implies:
• Geodetic quality instrumentation, high quality monumentation, good field of view
• Data center positioning with access to ample computational resources and full accuracy real-time GNSS orbit and clock states

Realistic tracking scenarios (per GIPSY user survey):
• GPS only
• GPS + GLONASS
• GPS + GLONASS + Galileo
• GPS + Galileo
• GPS + GLONASS + BeiDou + Galileo + QZSS

It is not yet possible to test the ultimate benefits from BeiDou and Galileo because the constellations are not complete

GLONASS will switch to CDMA in the more distant future, but its marginal benefit may be reduced in the presence of three other complete constellations
Real-Time PPP with GPS-Only vs GPS+GLONASS: Sample Time Series (SIRI, Korea)

(April & May 2016, 5 minute POD / 5 minute PPP)

- Vertical PPP error (meters)
- Time (days since April 1, 2016)

- **GPS-only (5.2 cm RMS)**
- **GPS+GLO (4.3 cm RMS)**

M. Miller, JPL, Dec 2016
Real-Time PPP with GPS-Only vs GPS+GLONASS: A Histogram

(4896 station days, April & May 2016, 5 minute POD / 5 minute PPP)

- GPS-only, horizontal (1D) error: 2.1 cm ± 1.5 cm
- GPS-only, vertical error: 2.6 cm ± 2.1 cm
- GPS+GLO, horizontal (1D) error: 4.7 cm ± 2.3 cm
- GPS+GLO, vertical error: 5.6 cm ± 3.1 cm

M. Miller, JPL, Dec 2016