

PPP versus DGNSS

By Chris Rizos, Volker Janssen, Craig Roberts and Thomas Grinter

Is precise point positioning (PPP) a viable alternative to differential GNSS (DGNSS) techniques? In this article we look at the current status of PPP and its potential.

PPP is a GNSS survey method that employs readily available satellite orbit and clock correction data to perform absolute positioning using measurements from a single GNSS receiver. This is an advantage over differential GNSS positioning methods, which require simultaneously observed pseudo-range and carrier-phase data from one or more reference stations with known coordinates. But PPP also comes with a number of severe disadvantages, the most significant being the long time necessary for the ambiguity float solution to converge in order to ensure centimetre-level positioning accuracy. This has limited its use for real-time applications.

receivers for the densification of the ITRF datum, or of static receivers in the context of earthquake studies (for determining pre-, co- and post-seismic motion), and estimation of tropospheric delay – its use as an alternative positioning technique to DGNSS for surveying and mapping applications has been limited. This can be attributed to several reasons.

Firstly, with the advent of cost-effective, centimetre-level accuracy, GNSS-RTK (“real-time kinematic”) positioning provided by an increasing number of continuously operating reference station (CORS) networks around the world, there has been little need for PPP – a technique that does not (directly) use CORS services. Secondly, the availability of satellite orbit and clock error information could, until recently, only support decimetre-level accuracy PPP via post-processed coordinate solutions. Thirdly, the RTCM message and data product standards to support PPP positioning are comparatively immature. Fourthly, no commercial off-the-shelf GNSS receivers have been marketed that have the capability to generate positioning solutions using the PPP method in real-time.

Nevertheless, the post-processed PPP technique can be considered a useful “fill-in” service for existing regional CORS networks in areas where dense CORS coverage is not justified due to low population density, or for economic reasons (such as in developing countries), or operational constraints (such as offshore positioning). In these situations, free PPP post-processing services such as Auto-GIPSY (<http://apps.gdgps.net/>) and CSRS-PPP (http://www.geod.nrcan.gc.ca/products-produits/ppp_e.php) provide converged float solutions at the centimetre-level, making PPP a viable alternative to post-processed DGNSS solutions. Note, however, that long observation session times (up to several hours) are required. There are a number of downloadable PPP software packages that are capable of post-processing GPS (and in some cases GLONASS) data files. One of these is RTKLIB, a well known open source package (<http://gpspp.sakura.ne.jp/rtklib/rtklib.htm>).

Real-time issues

Operating in real-time is far more challenging than in post-processed mode. The critical issues are timely availability of measurement (and other) data over a wireless communications link, in an industry standard format that would allow GNSS receivers to operate reliably with minimum constraints and with comparative ease.

In conventional PPP (real-time or post-processed modes) the only raw pseudo-range

Correction Type	PPP	Differential GNSS
Satellite Specific errors		
Precise satellite clock corrections	✓	✗
Satellite antenna phase centre offset	✓	✓
Satellite antenna phase centre variations	✓	✓
Precise satellite orbits	✓	✓/✗
Group delay differential	✓ (L1 only)	✗
Relativity term	✓	✗
Satellite antenna phase wind-up error	✓	✗
Receiver Specific Errors		
Receiver antenna phase centre offset	✓	✓
Receiver antenna phase centre variations	✓	✓
Receiver antenna phase wind-up	✓	✗
Geophysical Models		
Solid earth tide displacements	✓	✗
Ocean loading	✓	✗
Polar tides	✓	✗
Plate tectonic motion	✓	✗
Atmospheric Modelling		
Troposphere delay	✓	✓
Ionosphere delay	✓ (L1 only)	✗

Table 1: A comparison between the measurement biases and errors that need to be applied or accounted for in typical PPP and DGNSS positioning techniques.

A global reference frame

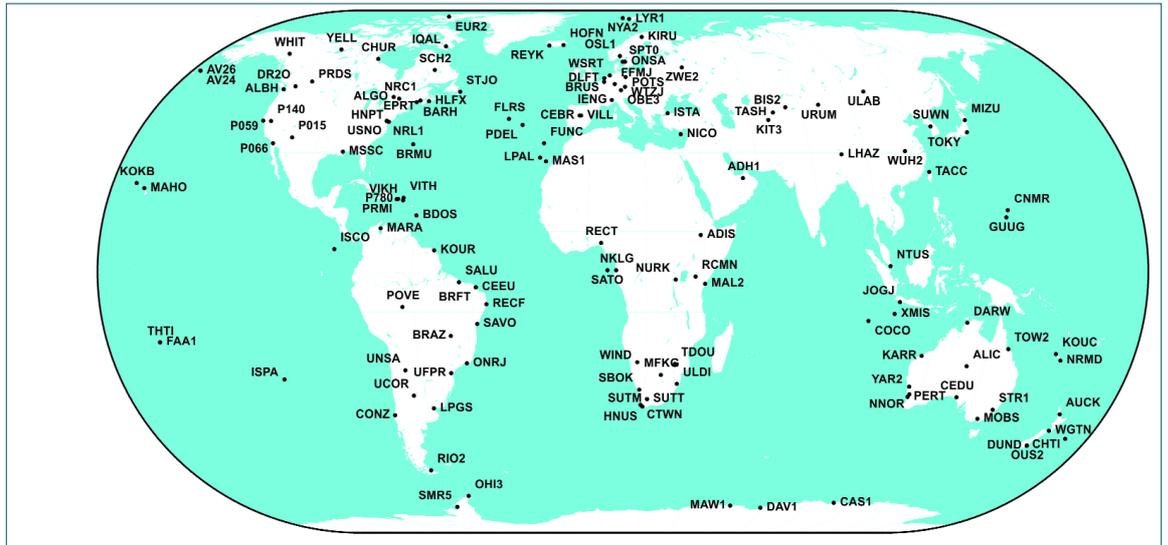
PPP provides a positioning solution in a global reference frame such as the International Terrestrial Reference Frame (ITRF), free of datum inconsistencies associated with differential positioning techniques based on nearby reference stations with coordinates expressed in a national datum (e.g. GDA94 or ETRF2000). However, PPP comes with its own set of issues. Factors like tectonic plate motion and solid earth tides have to be considered (see Table 1), as well as several other special corrections to observations, and it is important to fully understand the implications of transforming between a global and a national or local datum.

PPP in mainstream surveying

While post-processed PPP has many applications in geodesy – such as determination of the coordinates of

The real time IGS network.
Image:

 2011 Oct 14 17:42:15



and carrier-phase measurement data required is that of the user's own receiver. However, for real-time results, sub-decimetre satellite orbit information and sub-nanosecond accuracy satellite clock correction information must be available in real time (or with very low latency, perhaps no more than several seconds delay) at the user receiver. This is a significant impost, both in terms of the provision of real-time satellite system data, and the wireless communications to access such data products. On the other hand, calculation of the orbit and clock data products requires a relatively sparse ground reference station infrastructure and the data analysis capability can be centralised at a few computational facilities with the relevant expertise, and then broadcast to users.

The International GNSS Service (IGS) Real Time Working Group has been investigating the issues associated with real-time CORS infrastructure and data products, and has been running a Pilot Project for the past two years (<http://www.rtigs.net>). The IGS will launch a Real-Time Service (IGS-RTS) in the latter half of 2012. However, there are a number of issues that must be addressed for real-time PPP were it to be based on the IGS-RTS, not the least of which are: (a) the mode of distribution or broadcast of the real-time orbit and clock data products, and (b) the format for such data messages. To encourage user uptake of real-time PPP the provision of IGS-RTS products on its own is not a sufficient condition. An important condition is that instrument manufacturers must implement real-time PPP algorithms inside GNSS receivers. This is generally presaged by the development of appropriate RTCM standards for the broadcast of precise satellite orbit and clock error information.

Note that although the IGS predicted orbits are accurate enough for decimetre-level PPP (by assuming that the "ultra-rapid (predicted)" products have been downloaded hours in advance and are available for use by the receiver/computer as the instant measurements

are made, i.e. in "real-time"), the predictability of the satellite clock corrections is relatively poor (see Table 2). A real-time PPP service would require an order of magnitude improvement in the quality of satellite clock estimates by effectively shortening the time between measurements being made by the PPP service provider's CORSs, transfer of data to an analysis centre where the clock correction parameters are estimated, and then dissemination to real-time PPP users.

Trimble RTX

In an interesting recent development a new commercial real-time positioning product known as "Trimble RTX" has been released in the US, claiming to bridge the "gap" between real-time PPP and Network RTK (NRTK) GNSS. A global CORS network (similar to the IGS's) allows for the computation of precise satellite orbits and clock corrections, while a regional CORS network is used to determine local atmospheric measurement delay corrections. It is claimed that this technique is capable of providing real-time positioning at the 4-centimetre level horizontally (95%), with initialisation times of less than one minute. The necessary satellite orbit and clock correction information are broadcast by an L-band satellite downlink from a geostationary satellite, similar to the use of SBAS satellites for wide-area

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Product	Parameter	Accuracy	Latency
Ultra Rapid (predicted)	Orbit	10 cm	Real Time
	Clock	~ 5 ns	
Ultra Rapid (estimated)	Orbit	< 5 cm	3 hrs
	Clock	~0.2 ns	
Rapid (estimated)	Orbit	< 5 cm	17 hrs
	Clock	0.1 ns	
Final (estimated)	Orbit	< 5 cm	~ 14 days

Table 2: Precise GPS satellite orbits and clock corrections provided by the IGS (<http://igs.org/components/prods.html>.)

GNSS. This has the distinct advantage of complete coverage, as opposed to real-time DGNSS which can be hampered by radio or mobile telephony communications of variable signal quality and patchy reception. No doubt similar commercial products will be shortly available from other GNSS user equipment manufacturers and/or service providers.

More satellites

The ability to utilise extra satellites available in the GLONASS constellation enhances the capabilities of PPP and its possible applications. Currently four IGS analysis centres routinely provide GLONASS precise orbit products. The independent GLONASS orbits are of 10-15 cm level accuracy, and orbits from the four organisations are combined to generate the IGS final GLONASS orbit data products. Only two data analysis centres provide GLONASS clock data, accurate at the 1.5 ns accuracy level, at 5-minute intervals. Since this temporal density is not sufficient for most kinematic PPP applications, interpolation of the satellite clock corrections is necessary.

M-GEX

The Galileo and Beidou constellations are currently being deployed. The IGS has launched a new initiative, the "Multi-GNSS Experiment" or M-GEX (see Call for Participation at: ftp://igs.org/pub/resource/pubs/IGS_M-GEX_VF.pdf), that will, in the first instance, establish a global tracking network of multi-GNSS capable tracking receivers. M-GEX also seeks to encourage the analysis of the M-GEX data in order for IGS analysis centres to gain valuable experience in computing satellite orbits and clock correction information for all GNSS constellations. However, it is still too early to confidently predict the full benefits of multiple GNSS constellations – where over 100 satellites broadcast up to four times that number of signals on which pseudo-range and carrier-phase measurements can be made – for precise positioning users.

More frequencies

The Galileo constellation, once fully operational, will broadcast signals in three frequency bands. China's Beidou will also transmit on a minimum of three frequencies. More satellites and more frequencies means more pseudo-range and carrier-phase measurements can be made by a suitably configured user receiver. This is expected to enhance integer ambiguity resolution for PPP, i.e. increase reliability and decrease the required time length of observations. However, there is no 100% interoperability between the four GNSS constellations on three frequencies (i.e. it is not possible to mix pseudo-range or carrier-phase measurements from GPS, GLONASS, Galileo and Beidou in triple-frequency combinations). Nevertheless one would expect

that the widespread availability of triple-frequency GNSS signals by the end of the decade will significantly speed up ambiguity resolution for both PPP and DGNSS techniques.

Fixing integer ambiguities

The fixing of integer ambiguities is usually only applied to double-difference processing algorithms, as all unknown non-integer biases are eliminated or significantly mitigated in such a measurement differencing process. Although the fixing of integer ambiguities is a particularly difficult challenge for the undifferenced measurement processing used by PPP, several methods have been developed to improve the reliability of ambiguity resolution.

However, challenges still remain, primarily reducing initialisation times and correctly accounting for the ionospheric delay in the GNSS measurements. It is unlikely that a PPP solution, using a global or wide-area CORS network, will ever become as effective as short-/medium-baseline GNSS-RTK or GNSS-NRTK due to the difficulty in providing sufficiently accurate ionospheric corrections. A regional CORS network with inter-receiver spacing of the order of a "few" hundred kilometres (and preferably much less), however, has the potential to significantly improve the modelling of the spatial variability of the ionospheric delay bias in GNSS measurements.

PPP for the toolbox

"High performance" (i.e. high accuracy, and high productivity – short periods of observations) real-time PPP has been demonstrated, both in a commercial sense (Trimble's RTX) and by academic researchers. However, the current dependence of real-time PPP techniques on the same CORS networks that are used to deliver DGNSS, including NRTK, means that implementation of real-time PPP depends upon a technology solution that already delivers the same positioning capability as real-time PPP would provide (confusingly such CORS-augmented PPP techniques are referred to as "PPP-RTK"). Because the need for CORS networks will not disappear, it seems that, while PPP will be a useful addition to the GNSS "toolbox", DGNSS-based techniques and services will still be a popular user option for many years to come. The justification for the establishment of CORS by government agencies and the private sector has certainly not been weakened by recent developments in PPP-RTK.

Acknowledgements

Richard Groom is gratefully acknowledged for his editing of a paper delivered by the authors at the FIG Working Week in Rome on May 9, 2012 entitled "Precise Point Positioning: Is the era of differential GNSS positioning drawing to an end?". To see the original paper and full references, visit: <http://www.fig.net/pub/fig2012/techprog.htm>.

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About the authors

Chris Rizos is the Head of the School of Surveying and Geospatial Engineering at the University of New South Wales (UNSW) in Sydney, Australia and is the current President of the International Association of Geodesy.

Volker Janssen is a GNSS Surveyor (CORS Network) in the Survey Infrastructure and Geodesy branch at NSW Land and Property Information in Bathurst, Australia.

Craig Roberts is a Senior Lecturer in Surveying/GPS/Geodesy at UNSW, Sydney, Australia.

Thomas Grinter is a Technical Surveyor in the Survey Infrastructure and Geodesy branch at NSW Land and Property Information in Bathurst, Australia.