Precise Point Positioning (PPP): Method and its Geodetic Usage

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Extended Kalman Filter (EKF), International GNSS Service (IGS), Multi-GNSS Experiment (MGEX), International Terrestrial Reference Frame (ITRF)

ABSTRACT

Combining the precise satellite positions and clocks correction with dual-frequency GNSS receiver, PPP is able to provide position solutions at centimeter- decimeter level. PPP can be regarded as a global positioning approach because its position solutions referred to a global reference frame. As a result, PPP provides much greater positioning consistency than the differential approach in which position solutions are relative to the local base station or stations. Due to this, today PPP has been the demand of large number of market.

1. INTRODUCTION TO PPP

1.1 Background

Point positioning methods has been used for quite long period now. From the use of analogue methods to digital and in the increasing order of the accuracy, positioning methods are being used for various purposes. Earlier it was mainly focused on surveying, mapping and navigation only. But today precise positioning technique has been the demand of every market. From the application of precise positioning in agriculture, timing, infrastructure development, disaster control, aviation to recreation, its demand and importance has been increasing.

Before taking the deeper insight on PPP, it is essential to have an overview on other GNSS techniques. The figure 1 shows the graph of accuracy for different GNSS techniques that we use today in their relation with the baseline. In the graph we can see that positioning by RTK seems to have higher accuracy among other GNSS techniques. But, with increase in length of baseline, its accuracy decreases sharply. Similar is the case with DGNSS. Being a regional Augmented System, SBAS technique have uniform accuracy for upto the baseline length of 1000km only. But the accuracy of PPP technique here seems is independent with the increase in the baseline.

1.2 Introduction

Precise Point Positioning (PPP) from its name one can say it's a point positioning technique that renders precise location. PPP technique uses single dual frequency receiver for positioning. Unlike differential positioning techniques it does not require access to observations and correction data from one or more close reference stations that are accurately-surveyed. PPP just requires precise orbit and clock data, computed by a processing center with measurements from reference stations.

PPP is a global precise positioning service which requires the availability of precise reference satellite orbit and clock products in real-time using a network of GNSS reference stations distributed worldwide. PPP technique can be carried out in any parts of the world with access to satellite and internet.

Combining the precise satellite positions and clocks with a dual-frequency GNSS receiver, PPP is able to provide position solutions at centimeter- decimeter level. Therefore we can take PPP as a complete package of Precise Orbit and Clock information + User Satellite Tracking information + Error Modelling.

1.3 Working Principle of PPP

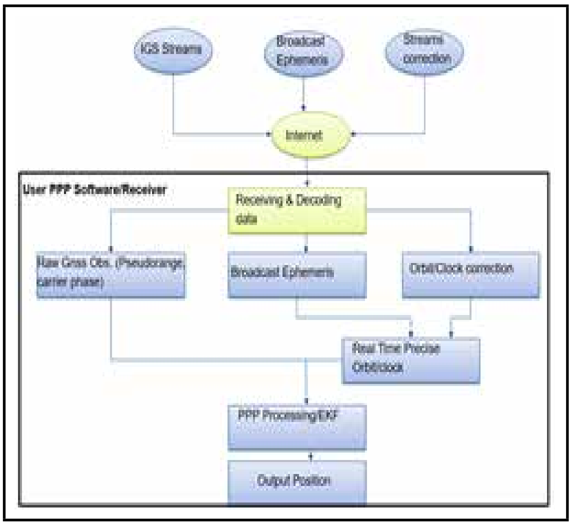

Figure 1: Working architecture of Real Time PPP

This diagram is an example of how Real Time PPP works. The input for PPP are both the undifferenced first-order ionosphere-free linear combination of multi-GNSS code and the carrier-phase measurements. The raw form of streams of IGS, Broadcasted ephemeris and correction data are available via internet to the receiver with PPP software. The receiver then receives these information and decode it to Broadcast ephemeris and clock/ orbit correction. Now with the combiniation of these along with the Raw GNSS Observation (Pseudorange, carrier phase) received on a GNSS receiver we get Real Time Precise Orbit/clock. This is then subjected to further processing and filtering. The filtering technique used for PPP is EKF (Extended Kalman Filter) for noise removal. Finally with the removal of outliers and noise with these processing we get out position data along with correction data in the real time.

1.4 Correction model and strategies

PPP being a GNSS technique uses GPS/ GLONASS/BDS/GALILEO constellation. Therefore, the availability of satellite must be ample for its observation.

Extended Kalman filter (EKF) is an extended version of Kalman filter which is employed to process GNSS measurements i.e raw pseudorange and phase observations are processed to produce the estimates of position. The Extended Kalman Filter is the optimal way to fuse observations of different random variables that are Gaussian distributed.

MGEX-IGS precise orbital and clock products (Derived from real-time streams+ broadcast ephemeris) are used to eliminate satellite orbit and clock errors.

For Receiver antennae phase center, PPP uses absolute antennae phase center model for correction of offset between receiver antennae reference mark and antennae phase center.

GNSS technology is based on very stable and accurate clocks on board the satellites and in the ground receivers. Their synchronization is of the utmost importance for a proper operation of the system. However, the time transfer between satellite and ground receiver is affected by relativistic effects. In order to address this issue "factory offset", is applied to satellite clocks prior to the satellite vehicle (SV) launch. The proper time, i.e. the time maintained by the atomic clocks on-board the SVs, used for the signal generation, has to be aligned to GPS Time (in case of GPS).

The total delay in the line of sight in troposphere is derived as the sum of the hydrostatic and wet delay in zenith direction multiplied by respective mapping functions, and a gradient correction. The tropospheric model consisting of the Saastamoinen vertical propagation delay model and the Niell mapping function is commonly used to account for the tropospheric wet and dry components.

IERS Convention is used mainly for correction for other effects due to solid earth tides and ocean tides.

1.5 Advantages of using PPP

Unlike differential methods PPP do not need any reference station. Use of single receiver is sufficient. Therefore the use of sophisticated instrument at the base is reduced in this technique. With this the number of manpower is also reduced which will definitely lead to the decrease in the cost of project. Thus with PPP we get quality data with reduced cost. And with the reduced cost and increased quality, PPP provides a cost effective solution.

PPP can be regarded as a global position approach because its position solutions referred to a global reference frame. As a result, PPP provides much greater positioning consistency than the differential approach in which position solutions are relative to the local base station or stations. Due to this, PPP has been the demand of large number of markets including agriculture, timing, infrastructure development, disaster control, aviation etc.

1.6 Special Issues related to PPP

It is necessary to address special issues that are related to PPP. When operating in differential mode, it is in many cases possible to fix the carrier phase ambiguities to their correct integer values. This is possible due to sufficient cancellation of satellite and receiver hardware biases through the differencing process. However, working with undifferenced observations, as in PPP, it is not possible to resolve the carrier phase ambiguities. The carrier phase ambiguities always has to be estimated in the adjustment in a so-called float solution. Due to burden of carrier phase ambiguities, PPP being a float solution, needs a certain time span of continuous observations to meet high accuracy requirements

Coordinates estimated with PPP will be in the same global reference frame as the satellite orbits. It is referred to the IGS realization of recent International Terrestrial Reference Frame (ITRF) at the time of observation. However, in most mapping applications especially for engineering surveying tasks the user would like to transform the ITRF coordinates into local or regional frames. Therefore there arises the questions while working in national or regional level.

PPP is totally based on the IGS products, satellite clock corrections and earth orientation parameters, a number of different products for its processing. These all are combined in different aspects to give out the position of a place but these products differ in different characteristics regarding latency, update rate, sample interval and accuracy.

2. PPP-GEODETIC USAGE

We have seen that many static reference station of precise point has been destroyed by natural and artificial causes. They require a lot of cost and effort to rehabilitate and reform. This would not be a problem if we have a single homogenous global framework but there exists numbers of local system in the world and they are not homogenous to give one global homogenous system.

We have always faced the limitations in the number of baseline points in the area with high economical potential. Many infrastructural projects has to undergo additional cost for point positioning at the beginning of the project. Due to these implications, the use of PPP in geodesy as in measurement or earth and earth objects seems vital.

2.1 Online Services - PPP

Today we have number of online services that provides the post processing facilities to process the observation of PPP. Many online services provide the possibility to upload RINEX (Receiver Independent Exchange Format) observation files to let them process fully automated on a server. The results are returned via email or ftp just within a short while. Here are the list of few such services which provides post processing services for both kinematic and static modes of PPP technique.

- CSRS-PPP by Natural Resources Canada (NRCan)
- GPS Analysis and Positioning Software (GAPS) by University of New Brunswick (UNB)
- Automatic Precise Positioning Service (APPS) by Jet Propulsion Laboratory (JPL)

2.2 PPP for Nepal

PPP has proven to provide sufficient accuracy for establishment of controls in real time and non-real time mode. Its application can be useful to Nepal. In a scenario where Nepal is still facing problems with the unknown changes in its control point network distributed nation-wide, using the application of PPP can not only help in rehabilitation of disturbed points with desired accuracy but also can be very useful in understanding the actual shift of the country in larger scale. The advantages of using PPP is the use of accurate satellite and clock correction and its reference with IGS stations. These correction today are readily available for PPP receivers via internet And there are many free online services as mentioned above which can be used for processing of observation file for higher accuracy.

PPP can be beneficial not only in establishing controls but also for monitoring small changes in land masses. Integration of PPP with network RTK technique can lead to improved positional accuracy and performance especially for engineering jobs, particularly reducing the convergence time.

REFERENCES

Collier, P. (2017). Demonstrating the benefits of QZSS in Australian Agriculture. *Spatially Enabling Australia and New Zealand.*

Gottfried Thaler, A. K. (2011). Precise Point Positioning – Towards Real-Time Applications. *Vermessung & Geoinformation*, 171-179.

KARABATIĆ, A. (2011). *Precise Point Positioning (PPP).An alternative technique for ground based GNSS troposphere monitoring.*

Katrin HUBER, F. H. (2010). Precise Point Positioning - Constraints and Opportunities. *FIG Congress 2010.*

Liang Wang 1, 2. Z. (2018). *Validation and Assessment of Multi-GNSS Real-Time Precise Point Positioning in Simulated Kinematic Mode Using IGS Real-Time Service.*

Marcin Malinwoski, J. k. (2016). *A comparative study of Precise Point Positioning, Accuracy Using Online Services.*

Novatel. (n.d.). Retrieved November 2018

Sunil Bisnath, J. A. (2018). *Innovation Examining the Precise Point Positioning near Future.*

Sunil Bisnath, Y. G. (2009). Precise Point Positioning: A powerful technique with Promising Future. *Algorithms and Methods INNOVATION*, 48-49.

Wang, G. Q. (2012). Millimeter-accuracy GPS landslide monitoring using Precise Point Positioning with Single Receiver Phase Ambiguity (PPP-SRPA) resolution: a case study in Puerto Rico. *Geodetic Science*.

Witchayangkoon, B. (2000). *Elements of GPS Precise Point Positining.*

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