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Developement Of Open Source Software For Global Positioning System Data Processing

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***Abstract* - GPS is a high-precision three-dimensional real-time global satellite navigation system, is a more advanced navigation and positioning system. According to the received navigational satellite signal, GPS receiver can calculate the body's position and velocity, and it is small and light; positioning accuracy and velocity accuracy are high, not accumulating with time; regardless of time, geographical constraints, and work around the clock , with good long-term stability. Precise relative positioning based on a short observation time span yields ambiguities that are heavily correlated together with position estimates with poor precision. For good estimation of the integer values, the LAMBDA method has been applied using open source software PROCTORGPS. For developing the PROCTORGPS software the GPS Tool Kit Core libraries are utilized. QT Frame work is used to develop the user interface. Post-processed positioning in open source software with double difference method indicates that RMS accuracy from 1-10 cm can be attained in station coordinates.**

Keywords – GPS, PROCTORGPS, QT, LAMDA Method, Precise Point Positioning.

I INTRODUCTION

GPS is a high-precision three-dimensional real-time global satellite navigation system, is a more advanced navigation and positioning system. According to the received navigational satellite signal, GPS receiver can calculate the body's position and velocity, positioning accuracy and velocity accuracy with good long-term stability.

In GPS observation three major components as follows,

- GPS date and time with satellite status and health
- Orbital information (Ephemeris data) for satellite position
- Almanac which contains information and status concerning all the satellite,

Every satellite receives from the ground antennas, a message containing information about its orbital parameters, clock status, and other temporary data. This information is sent back to the user through the navigation message. Navigation message has 1500 bits frame with 5 sub frames. First sub frame states the GPS data. Second and third sub frames will hold the Ephemeris data. Fourth and fifth sub frames holds the Almanac information. This observed information is processed for locating user's coordinates with WGS 84 datum. Error correction can be done in the post processing using GPS software.

The raw GPS data having error which cannot be used directly as surveyed one. Hence the data have to be processed with some algorithm. For GPS data processing, GPS Processing software used which are all design and developed by the GPS receiver manufacturer as proprietary one. Proprietary software is also known as closed structure in which all computation mathematics cannot be understood by the user. The user can only use interface module to get final output for processed location information.

The Open source software is more useful for understanding the processing concepts with detailed mathematical modules. User can choose own processing method with various conditions. For developing the open source software, full description about the GPS processing concepts should be known.

II FUNDAMENTAL GPS MEASUREMENTS

There are two types of fundamental measurements used in position determination, namely pseudorange measurements and carrier phase measurements.

A. Pseudorange Measurement

A pseudorange is the measurement of the time shift between the code generated by a receiver and the code transmitted from a GPS satellite. If the receiver and satellite clocks are synchronised with the GPS time, the travel time of the satellite signal will be equal to the difference between the transmission time and the reception time. The range between the satellite and the receiver can be calculated by multiplying the travel time with the speed of light. In practice, the satellite and receiver clocks are not synchronised with the GPS Time. Moreover, there are some errors or biases when the satellite signal propagates from the satellite to the receiver.

The pseudorange measurement can be expressed as

$$R = \rho + \Delta r + di + dtr + c \bullet (\Delta\delta i - \Delta\delta j) + dmR + Er \quad (1)$$

Where

R is the measured pseudorange

ρ is true range or geometric range

Δr is the orbit bias

di is the ionospheric bias

dtr is the tropospheric bias

$\Delta\delta i$ is the receiver clock error

$\Delta\delta j$ is the satellite clock error

dmR is the multipath error on the pseudorange

εR is the pseudorange measurement noise

c is the speed of light

The true range or geometric range can be represented by:

$$\rho=\sqrt{((X j - x i)2 + (Y j - y i)2 + (Z j - z i)2)} \quad (2)$$

Where

X_j, Y_j and Z_j are the satellite coordinates

x_i, y_i and z_i are the receiver coordinates

The pseudo range measurement is generally used in applications where the accuracy is not high (few meter level), as is typical for single-epoch navigation applications.

B. Carrier Phase Measurement

Carrier phase is the measurement of the phase *difference* between the carrier signal generated by a receiver's internal oscillator and the carrier signal transmitted from a satellite. In order to convert the carrier phase to a range between the satellite and the receiver, the number of full cycles and the fractional cycle must be known. However, at the first time that the satellite signal is locked on to by the receiver, only the fractional phase can be measured. If the satellite signal is assumed to be continuously locked, the receiver will keep track of *changes* to the phase. Therefore, the initial phase cycle is still *ambiguous* by a number of full cycles. To use the carrier phase as a measurement for positioning, this initially unknown number of cycles (or the phase ambiguity) must be resolved or accounted for in some way.

The basic equation for the carrier phase measurement is:

$$\varphi = \rho + \Delta r - di + dtr + c\bullet(\Delta\delta i - \Delta\delta j) + dm\varphi + \varepsilon\varphi + \lambda \bullet N \quad (3)$$

Where

φ is the carrier phase measurement in unit of metres

$dm\varphi$ is the multipath error on the carrier phase

$\varepsilon\varphi$ is the carrier phase measurement noise

λ is the wavelength of the carrier phase

N is the integer carrier phase ambiguity

The definition of the remaining terms (ρ, Δr, di, dtr, c, $\Delta\delta I$ and $\Delta\delta j$) is the same as in Equation (1). It can be seen that there are similarities between Equations (1) and (3). However, the major differences are the presence of the integer carrier phase ambiguity term ($\lambda \bullet N$), and the reversal of sign for the ionospheric bias term (di). In addition, the level of the carrier phase measurement noise (at the mm level) is much smaller than the level of the pseudorange measurement noise (typically at the metre level). Therefore, the carrier phase is extensively used as the primary measurement in precise (cm level) GPS positioning applications.

With regard to Equations (1) and (3), both the pseudorange and carrier phase measurements are contaminated by many errors or biases that affect the positioning accuracy.

III GPS PROCESSING

Processing differentially correctable GPS rover files requires a computer, a data transfer cable, GPS software, and internet access. GPS receivers typically come with manufacturer-specific software and data transfer cables. Each software package operates differently, but the basic process is the same. It is extremely important that whenever field crews return from the field, GPS files are transferred from GPS receivers to computers or network folders that are routinely backed-up. Files should be transferred to an appropriately-named folder (such as "Raw" or "Backup"). Files can be selected one by one or in batches for differential correction with base station files. Base stations and associated files necessary to correct rover GPS files can be selected via the GPS software interface with the internet or through ftp sites, if provided by the base station of interest. The GPS software uses the base station files to calculate rover file corrections. In order for corrections to be calculated, the base station needs to have collected data from the same satellites and times that the roving GPS receiver collected data.

IV INTEGER AMBIGUITY RESOLUTION

The satellite broadcasts a sine wave carrier signal with a certain phase. The signal is received by the GPS antenna with another phase at the time of reception. The receiver generates an identical copy of the signal as the one generated by the satellite and compares the generated phase with the observed one to derive the phase observation. However the integer number of wavelength between the satellite and receiver during the travel time of the signal is not known. This number is called integer ambiguity and is denoted by the letter N. It is essential that the integer ambiguity is known in order to achieve centimeter level positioning and the integer ambiguity resolution is a process central to network Real Time Kinematic concept.

As the real valued ambiguity is mixture of the integer ambiguity and the uncalibrated phase delay originating in the satellite and the receiver only the double differenced ambiguity between two receivers and two satellites has an integer feature and can consequently be fixed to an integer value. This is because in double differencing the receiver and satellite hardware delays are eliminated. The LAMBDA Method is a technique commonly employed for ambiguity resolution. The LAMBDA Method is an implementation of the least squares principle in the sense that it maximizes the probability of correct ambiguity resolution. It is an efficient realization to solve integer least squares problem. The generalized least squares model follows [5].

$$L= Ax+By \qquad (4)$$

The variance covariance matrix of the observation vector I is Q_1. The parameter vector x and y represent the unknown parameter such as the baseline coordinates respectively. A and B are the design matrices relating the observations to the unknowns.

$$\min_{\hat{x}} (\hat{x}-x)^T Q_{\hat{x}}^{-1} (\hat{x}-x) \qquad (5)$$

The minimization is solved by a search over grid points. Each grid point represents an ambiguity vector with all integer values in the ambiguity parameter space. The resulting vector is the least squares estimate of the 'fixed' ambiguity [5].

V PRECISE POINT POSITIONING

PPP processing of undifferenced smoothed pseudoranges with fixed precise satellite orbits and clocks has been done by combining precise IGS satellite clocks at 15 min intervals with 30-second tracking data from selected IGS stations with stable atomic clocks, 30-second precise satellite clocks. These products satisfy GPS users observing at high data rates in either static or kinematic modes for applications requiring meter precision. For fixed ambiguity resolution LAMBDA (Least-squares AMBiguity Decorrelation Adjustment) method [6] is used.

A. IGS Data Products

The IGS Precise Orbit products come in three flavors; the Final, Rapid and Ultra-Rapid that differ mainly by their varying accuracy and latency resulting from the extent of the tracking network used for their computation. The IGS Final orbits are combined from 7 contributing IGS Analysis Centers (ACs) and are usually available on the eleventh day after the last observation. The Rapid orbit product is combined 17 hours after the end of the day of interest. The latency is due to orbit computation time and delays in the delivery of 24-hour tracking data files from stations of the global IGS tracking network. Recently, Data Centers have been asked to forward hourly tracking data to accelerate product delivery. This new submission scheme was required for the creation of an Ultra-Rapid product, with a latency of only a few hours, to satisfy the more demanding needs of the meteorological community and future LEO (Low Earth Orbiter) missions.

VI SYSTEM FLOWCHART

To compute a receiver's position and velocity from its corresponding RINEX observation (o) and navigation (n) files applying pseudorange and Doppler observations. Figure 1 shows the flow diagram of the position and velocity computation. First the RINEX n-file is read and the ephemeris is stored in a matrix. Then one epoch of the pseudorange and Doppler observations are read from the RINEX o-file. If for some reason the ephemeris for a certain satellite is not available, the pseudorange is excluded from the computation. Ionospheric effect is corrected using both the pseudorange observations of L1 and L2.

Satellites position, velocity and clock error are computed from the ephemeris at this epoch and then following receiver position, satellites elevation angle, azimuth angle and DOP. And they are calculated once again after the satellite selection procedure is carried out on the basis of the former elevation angle and thus more accurate results can be obtained therefore. Troposphere correction and Earth rotation correction are considered. All subsequent computations of position and velocity will exclude pseudoranges from satellites with elevation angle lower than the settled mask value. Line-of-sight vector can then be calculated after receiver position is known. Until now, we know satellite positions and velocities, receiver position; line-of-sight vectors from satellites to receiver, and Doppler frequency observations, so receiver velocity can be calculated using least-square method to get an optimum result. Save all the results to a file using append mode. Check if the current epoch is the last one or if it reaching the end of the RINEX files, if no, read the next epoch of the RINEX o-file and repeat the procedure above; if yes, end the program and plot the results.

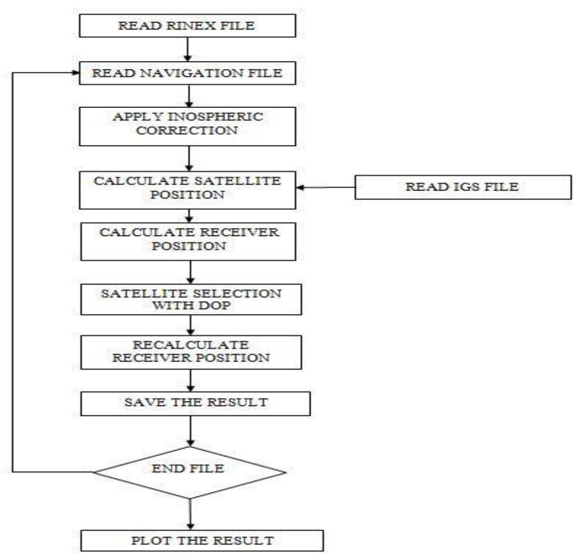

Figure 1: Flow diagram for the position and velocity Computation

VII SOFTWARE METHODOLOGY

PROCTORGPS software is developed with C++ language in QT framework. GPSTk has been chosen for background library support.

A. GPSTk Core Library

The GPSTk core library provides the most robust, broadly useful, and platform independent code in the GPSTk [1], it provides a number of models and algorithms found in GPS textbook and classic papers, such as solving for the user position or estimating atmospheric refraction. Common formats are supported as well, such as RINEX or SP3. There are several categories of function that provide the base functionality for the GPSTk applications and for a number of other independent projects

- GPS time: Conversion among time representations such as MJD, GPS week and seconds of week, and many others.

- Ephemeris calculations: Position and clock interpolation for both broadcast and precise ephemerides.

- Atmospheric delay models: Includes ionosphere and troposphere models.

- Position solution: Includes an implementation of a Receiver Autonomous Integrity Monitoring algorithm.

- Mathematics: Includes Matrix and Vector implementations, as well as interpolation and numerical integration.

- GNSS data structure: Data structures that contain observations mapped to satellites.

- Application framework: Includes processing command lines options, providing interactive help and working with file systems.

B. PROCTORGPS SOFTWARE

The PROCTORGPS is open source software which is developed in QT framework in which the software can be designed and created as executable file. Initially PROCTORGPS is planned to create a post processing module only. Most of the GPS Post processing software will not provide the intermediate results in processing. But this PROCTORGPS is structured to provide the intermediate results which can be useful for more GPS processing concepts. In PROCTORGPS software modules are developed for precise point location from GPS observation with the help of advanced processing algorithm and IGS data inclusion in post processing. For development the GPSTk core library functions are used as reference library. In navigation panel the list of imported files are grouped like navigation files, observation files, satellite ephemeris data, Ionospheric data etc. The viewer can check the RINEX data with view and plot option as user's option. In post processing various processing options like positioning mode, Frequencies mode, Solution type, Elevation mask, Ionospheric correction, Ambiguity resolution, IGIS data etc., are provided in User interface.

VIII FIELD WORK

The field work was done in ANNA UNIVERSITY play ground on 5-10-2012. The survey was done as single base and single rover instrument. The observation was done with LEICA instrument. Finally the raw observation files were converted into RINEX 3.0 format. That tracked files were fed in open source software as inputs in command window.

Positioning mode	: Static
Frequencies	: L1+L2
Solution type	: Forward
Elevation mask (^{O})	: 15
Ionosphere correction	: Dual- Frequency
IGIS data	: week 1708 IGR
Integer ambiguity resolution	: LAMBDA METHOD

IX RESULT

The processed output files were kept in RINEX file format. The loop closure was verified.

TABLE I

POSTPROCESSED RINEX DATA

Point id	Epoch	Easting	Northing	ellip.height	posit+height
1	10/5/2012 11:30	417315.1189	1438448.659	-54.9261	0
2	10/5/2012 11:38	417368.7183	1438509.178	-55.0053	0.0011
3	10/5/2012 12:08	417357.882	1438501.062	-54.9723	0.0017
4	10/5/2012 12:28	417338.1923	1438504.087	-54.7482	0.0016
5	10/5/2012 12:48	417344.2567	1438543.291	-54.4797	0.0016
6	10/5/2012 13:02	417364.1208	1438540.572	-54.7296	0.0023

I CONCLUSION AND FUTURE WORK

The observation equations, estimation technique and correction models used for GPS PPP using IGS orbit/clock products were obtained using PROCTORGPS. In future PROCTORGPS will be designed have more models for precise point positioning. Complete SDK will be designed to introduce new functions in user interface with developed algorithm for post processing. Aiding Real time data access from IGIS source for rapid post processing will help to get faster post processed survey data in real time kinematic application.

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