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Analysis of GPS Single Point Positioning and Software Development

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Abstract
When it comes to GPS positioning we all have an overview of how it works. Various soft wares commercial or free are also provided to perform positioning with accurate results, for example RTKLIB. Have we ever wondered how the parameters like elevation mask angle and ionospheric error on and off conditions are affecting the GPS positioning. Text books generally emphasize to the basic theory of understanding the process but not how these parameters are affecting the positioning results. This paper aims to make the first attempt to show the clear picture of the performance enhance of GPS Positioning on proper knowledge of input parameters. A case of static positioning of a receiver has been shown in this paper. A simple effort has been done to make users aware of RINEX observation and Navigation file structure. The algorithm and code was developed and tested under MATLAB environment. The statistical results are quite interesting and plotted effectively to show the dramatic influence of parameters affecting positioning result. This paper aims to make users understand the behavior of Positioning in best simple way and to bring out the ideal condition to achieve the effective results for GPS Positioning.

Keywords
GPS Point Positioning, Ionospheric Error, Elevation Mask, MATLAB, RINEX, Tropospheric Error

I. Introduction

GPS is a Global Positioning System based on satellite technology. The basic principle of GPS is to calculate the range between the receiver and a few simultaneously supervise satellites. The positions of the satellites are predicted and transmitted along with the GPS signal to the user. The known position of the satellites and the measured distances between the receiver and satellite gives the receiver location. The whereabouts change of receiver, is then the velocity of the receiver. The main use of the GPS are positioning and navigating [1]. As we look back we see the background of GPS that says it was first designed and contrived by the U.S. Department of Defense [2, 10]. In 1978 the first GPS was launched, but it was fully operational in the mid-1990s.Twenty Four satellites together makes a GPS constellation. There are 6 orbital planes with 4 satellites in each plane. The orbital planes escalating nodes are bent on at 55 degrees. Each GPS satellite is in a nearly circular orbit with a semi major axis of 26578 km and a period of about twelve hours. Each satellite carries 4 atomic clocks.

A. GPS Positioning (C/A Code)

GPS point positioning uses only one GPS receiver .This receiver determines the user's position instantly by determining the pseudo code ranges, while four or more satellites are visible. From the civilian C/A-code receivers it was observed that the expected horizontal GPS positioning that can be performed with relatively low accuracy [2]. In this study we are going to learn more precisely about single or point position.

1. Point Positioning System

The point positioning is a way to determine the user's position with the help of a single frequency receiver. In this method the user's receiver simply measures the distance between the receiver and the satellites and then with the help of a triangulation method to find out the user's co-ordinate. These 3-D co-ordinates require at least 3 satellites to measure its distance but in most cases 4 satellites are taken to reduce the timing error. This receiver is either operated in a static or dynamic mode [4-5]. The accuracies obtained here completely depend on the user's quality of GPS receiver selected, area, period of the observation time and many other factors. When we use static and long term absolute GPS measurements with enhanced equipment and post processing techniques, we can achieve a high level accuracy of 1 meter.
Hence after finding out the co-ordinates of the satellites we can put them in further pseudorange equation for unknown receiver position [3]. If we take into consideration more pseudo ranges it will only increase the redundancy of the solution. Suppose if we have seven satellites, we shall get 7 pseudo ranges equation yet only 4 unknown results.

2. GPS Point Positioning Accuracies:

The accuracy determination is very complicated and unstable due to various factors that contribute towards error in the GPS observation. But we can still observe horizontal positional accuracies in a Single Point Positioning in range of 10m to 30m [10]. Some of the more significant components of the error budget include: receiver and antenna quality, reference frames, satellite geometry, receiver platform, atmospheric condition, receiver noise, receiver mask angle, location computation and multipath errors.
In general, there are two main components that determine the accuracy of a GPS position solution:

- Geometric Dilution of Precision (GDOP)
- User Range Error (URE)

In surveying terms while computing trilateration position GDOP is referred to as "strength of figure". It varies rapidly with time since the satellites are moving. The accuracy of the individual range measurement to each satellite is known to be URE. It also varies between different satellites, atmospheric conditions, and receivers. Absolute GPS are largely dependent on which code (C/A or P-Code) is used to determine positions which gives absolute range accuracies. These range accuracies (URE), when coupled with the geometrical relationships of the satellites during the position determination (GDOP), result in a 3-D confidence ellipsoid that depicts uncertainties in all three coordinates. Given the continuously changing satellite geometry, and other factors, GPS accuracy is time/location dependent. Error propagation techniques are used to define nominal accuracy statistics for a GPS user.

3. GPS Range Error Factors

There are various errors that affect the GPS performances. Especially the pseudorange that we are taking into consideration is a sum of all systematic and range biases. There are also other factors that affect to the final range error which affect overall GPS error are ephemeris error , receiver noise , multipath effect, tropospheric and ionospheric refraction , atmospheric absorption and satellite clock and electronics inaccuracies. Moreover the random observation errors and the unexplainable and unpredictable time variation in GPS can neither be eliminated nor modeled to correct. These above errors are discussed below which are more or less eliminated in GPS [6, 8].

(i). Ephemeris Errors and Orbit Perturbations

The error in prediction of satellite position is called satellite ephemeris error. When transferred to user in the satellite data, these are almost less than 8m i.e. 95% [7].Due to many factors affecting directly to the satellite orbits these errors are really hard to measure directly. Even when modelling the orbit of the satellite it becomes nearly impossible to accurately measure or compensate these errors. These produce equal error shifts and in calculated point positions and it is not practical for real time point positioning applications.

(ii). Clock Stability

The time measurements are really important for GPS readings that contain rubidium and cesium time standards that are usually accurate to 1 part in 10 12 [s/s] and 1 part in 10 13[s/s] respectively, while most receiver clocks are activated by a quartz standard accurate to 1 part in 10 8. A time offset is the difference between time recorded by satellite clock to that recorded by the receiver clock.

The time co-ordination between the GPS satellite clocks is kept to within 20 nanoseconds (ns) through the broadcast clock corrections as determined by the ground control stations and the synchronization of GPS standard time to the Universal Time Coordinated (UTC) to within 100 ns. Random time drifts are unpredictable, thereby making modelling difficult.

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(iii). Ionospheric Delays

Ionospheric delay of a microwave signal depends on its frequency. These signals get dispersed or scattered when they pass through a highly charged environment like the ionosphere therefore creating an error in GPS range value.

It is difficult to apply Ionospheric correction in C/A phase positioning. Single-frequency receivers used in a point and differential positioning mode typically rely on ionospheric models that model the effects of the ionosphere. But here for C/A method of positioning we have used the Klobuchar Model according to IS-GPS-200 method to calculate ionospheric delay [7].

(iv). Tropospheric Delays

The troposphere does not disperse the L1 band signals but it gets refracted due to the moisture content in lower atmosphere.

To calculate the troposphere delay we can use a modified model Saastamoinen Model.

(v). Multipath

This occurs when the signal arrives to the receiver at more than one path. This occur generally at large reflective surfaces like metal surfaces or buildings. This creates inaccurate GPS positions when processed. The high quality receiver like Choke Link Antenna can help in minimizing the multipath effect. Whereas taking the mean of GPS signals over a course of time (i.e. different satellite configurations) also helps in reducing the effects of multipath [11].

VI. Receiver Noise

The ability of the GPS receiver to measure a finite time difference greatly affected by the receiver noise that creates a variety of errors. The noise can be considered predominantly arising from signal processing, clock/signal integration and correlation methods, receiver resolution, signal noise and others [11].

II. Location and Receiver Description

For static point positioning we considered the Chulalogkorn University GPS station, Pathumwan, Bangkok, Thailand. The station id is given as CUSV. It was installed in 2008-05-12. The approximate position of station is
X coordinate (m) : -1132913.7678
Y coordinate (m) : 6092530.5657
Z coordinate (m) : 1504633.5192
Latitude (N is +) : +134409.29
Longitude (E is +) : +1003202.07
Elevation (m,ellips.) : 76.06

Fig. 1: Chulalogkorn Station

The receiver used in Chulalogkorn station is Trimble Netrs, this monitors and surveys continuously providing good accuracy for GPS. The receiver strong point can be research of atmosphere, data generation of surveys and the infrastructure related to geodetic. When it comes to tuff environments and applications related to science, Trimble can be ideal, since it has GPS stations spread widely.

If we talk about the features of the receiver it helps for technology tracking for GPS, more easy to set up even if at far-flung areas with the use of internet. The consumption power is very less.

The receiver uses Linux framework that is much more easier to make some customization which we cannot find in other systems. It is so designed to configure all receivers in network even as because the files can be stored and used quickly. It is possible to be operated according to the requirements.

It also gives security and safe access to the configuration of receiver with a low maintenance cost. The most important feature is we don't need a local computer for it , it can be accessed from any convenient location . If there occurs some sudden shutdown it can load from the last known good configuration.

Coming to performance specification it has a high match for L1 and L2 signals , it has a very low noise tracking to L1 and L2 signals and a very high dynamic response. It is useful for low elevation tracking.

Talking about antenna options it has a Zephyr Geodetic and rover, and EDO Dornne and Margolin Choke Ring Antenna. The receiver was set up by Delft University of Technology, Netherlands.

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III. Methodology

The basic Methodology involves calculation of receiver position first and then apply corrections.

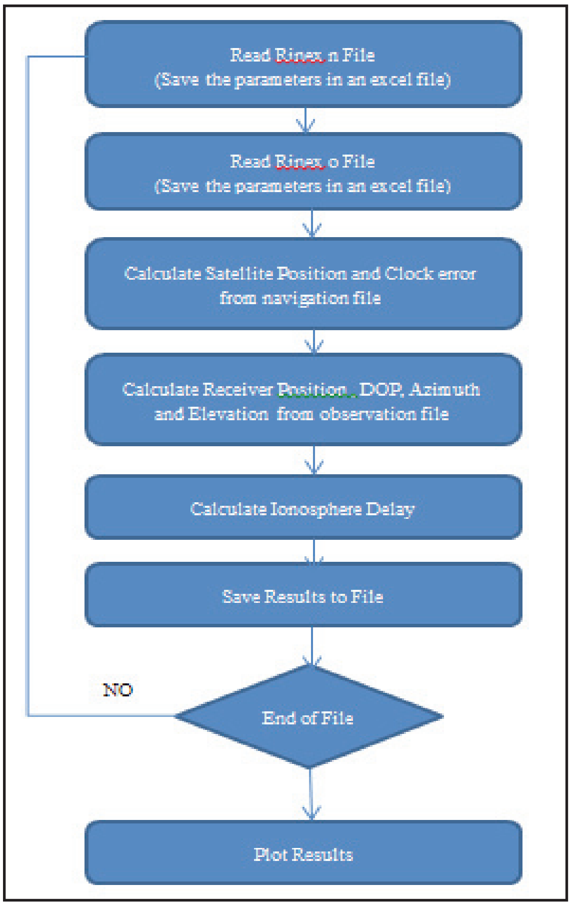

Fig. 2: Workflow for Point Positioning

A. Rinex n File Structure

```
     2.10           N: GPS NAV DATA                         RINEX VERSION / TYPE
teqc  2013Mar15     gpsops              20150216 00:02:33UTCPGM / RUN BY / DATE
Linux 2.4.21-27.ELsmp|Opteron|gcc -static|Linux x86_64|=+   COMMENT
CUSV                                    MARKER NAME         COMMENT
21904S001                               MARKER NUMBER       COMMENT
-1132913.7678 6092530.5657 1504633.5192                     COMMENT
                                                            COMMENT
This data is provided as a public service by NASA/JPL.      COMMENT
No warranty is expressed or implied regarding suitability   COMMENT
for use.  For further information, contact:                 COMMENT
Dave Stowers, NASA/JPL m/s 238-600                          COMMENT
4800 Oak Grove Drive, Pasadena CA 91109 USA                 COMMENT
                                                            END OF HEADER
 2 15  2 15  1 59 44.0 5.480237305164D-04 2.273736754432D-12 0.000000000000D+00
    5.000000000000D+00-7.187500000000D+00 5.069139721445D-09-5.006788952400D-01
   -2.793967723846D-07 1.437649840955D-02 9.935349225998D-06 5.153765422821D+03
    7.184000000000D+03 5.587935447693D-08-2.062240155209D-01 2.682209014893D-07
    9.408638267321D-01 1.805937500000D+02-2.321076091324D+00-8.461066723105D-09
    3.903734034763D-10 1.000000000000D+00 1.832000000000D+03 0.000000000000D+00
    2.000000000000D+00 0.000000000000D+00-2.048909664154D-08 5.000000000000D+00
    1.800000000000D+01 4.000000000000D+00
```

Fig. 3: Structure of Navigation File

1st Line of Data Part

PRN 2, Year 2015, Feb, 15,1 hour 59minutes and 49 seconds then express the observer clock toc that are the clock correction coefficients

af0 = 5.480237305164D-04[s/s2],

af1= 2.273736754432D-12[s/s],

af2=0[s]

We can use clock correction coefficients to fix clock error as below

$t^t = t^{T-b}$

$b = af0 + af1\ (t^T - t_{oc}) + af2\ (t^T - t_{oc})^2 - TGD$

where,

t^T = Satellite Clock , t^t = true GPS time

TGD=Group Delay parameter

2nd Line of Data Part

IODE(Issue of data , ephemeris): 5.000

Crs(correction of orbit1): -7.18750[m]

Δn(correction for mean motion): 5.069721445D-09[rad/s]

M0(Men anomaly): -5.006788952400D-01[rad]

3rd Line of the Data Part

Cuc(Correction for orbit2): -2.793967723846D-07[rad]

e(Eccentricity): 1.437649840955D-02

Cus(Correction for orbit 3) : 9.935349225998D-06[rad]

√a(semi major axis): 5.153765422821D+03[m1/2]

4th Line of the Data

toe(Time of ephemeris): 7.184000000000D+03[s] of GPS week

Cic(Correction for orbit 4): 5.587935447693D-08[rad]

Ω0(Ascending Node): -2.062240155209D-01[rad]

Cis(Correction for orbit 5): 2.682209014893D-07[rad]

5th Line of Data Part

i0(inclination): 9.408638267321D-01[rad]

Crc(Correction of orbit6): 1.805937500000D+02[m]

ω(Argument of perigee): -2.321076091324D+00[rad]

Ω(Change rate of ascending node): -8.461066723105D-09[rad/s]

6th line of data

i(change of rate of inclination): 3.903734034763D-10[rad/s]

Code on L2 channel : 1

W/N(GPS week Number): 1.832000000000D+03[rad]

L2 P data flag:0

7th Line of Data Part

URA(Ranging Accuracy): 2.000000000000D+00[m]

SVhealth(health of GPS): 0.000000000000D+00

TGD(Group delay): -2.048909664154D-08[s]

IODC(Number of Issue of data, clock): 5.000000000000D+00

8th Line of Data Part

t_{ot}(Transmission time of message): 1.800000000000D+01[s] of GPS week

FIT(Fitting interval): 4.000000000000D+00[h]

There are total number of 21 parameters given for each satellite at one epoch. Count the total number of epoch and read the navigation file to save the parameters to an excel file.

B. Rinex o File structure

```
     2.11           OBSERVATION DATA    G (GPS)             RINEX VERSION / TYPE
teqc  2013Mar15     gpsops              20150216 00:02:33UTCPGM / RUN BY / DATE
Linux 2.4.21-27.ELsmp|Opteron|gcc -static|Linux x86_64|=+   COMMENT
BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION       COMMENT
CUSV                                                        MARKER NAME
21904S001                                                   MARKER NUMBER
GGN                 JPL                                     OBSERVER / AGENCY
4549261303          TRIMBLE NETRS       1.1-5               REC # / TYPE / VERS
60078678            TRM41249.00     NONE                    ANT # / TYPE
 -1132913.7678  6092530.5657  1504633.5192                  APPROX POSITION XYZ
        0.0000        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     6    L1    L2    P2    C1    S1    S2                  # / TYPES OF OBSERV
    30.0000                                                 INTERVAL
                                                            COMMENT
This data is provided as a public service by NASA/JPL.      COMMENT
No warranty is expressed or implied regarding suitability   COMMENT
for use.  For further information, contact:                 COMMENT
Dave Stowers, NASA/JPL m/s 238-600                          COMMENT
4800 Oak Grove Drive, Pasadena CA 91109 USA                 COMMENT
                                                            COMMENT
```

Fig. 4: Structure of Rinex Observation File

The header contains the information of GPS station and summary of the observation data type.

```
15  2 15  0  0  0.0000000  0 10G13G24G18G15G06G25G05G29G02G12
-25197308.04148 -20448740.09246  20791606.8114   20791615.6824          48.5004
         36.0004
 -4063493.82345 -25014424.37242  25279184.8214   25279191.3484          31.2504
         15.5004
 -1379996.41055                                  25345347.8084          31.5004

-22514952.24047 -17388020.44045  21408998.4414   21409006.9034          47.2504
         33.5004
 -4338475.52145  -3370731.82042  24593202.7604   24593205.2434          34.5004
         16.2504
-13282161.34046 -10990357.71143  23393712.0084   23393719.1224          40.5004
         22.5004
-21804930.56247 -16972619.97345  21783273.4594   21783282.4484          44.2504
         33.2504
-20449834.94347 -15911689.77644  22314405.5494   22314414.3044          42.5004
         29.0004
-15479856.98347 -12041018.35245  21916191.5084   21916202.1384          45.5004
         30.7504
```

Fig. 5: Body of Rinex Observation File

From the first line of the observation file the 31st character tells us the number of satellites followed by the satellite number shown at that epoch.

From the second line the type of data related to each satellite is given. So for second line it shows us the L1 L2 P1 C1 S1 S2 observation for PRN 13. Similarly the third line for PRN 24 till PRN 12. This is for one epoch. We need to read the whole observation file and calculate the total number of epoch present and save the structure to an excel file. Generally the difference between each epoch is 30seconds.

C. Satellite Position Calculation

The satellite position is calculatd from the parameters in navigation file. The clock error is already corrected according to equation(1). The position of GPS satellite in ECEF co-ordinate is calculated as,

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} cos\Omega & -sin\Omega cosi \\ sin\Omega & cos\Omega cosi \\ 0 & sini \end{pmatrix} \begin{pmatrix} rcosu \\ rsinu \end{pmatrix} \quad (1)$$

1. Receiver Position and DOP calculation

The receiver position was derived using Least Mean Square Method. In Least Mean Square Method the iteration continues till the error is reduced to zero. Four pseudorange observations are needed to resolve a GPS 3-D position. Traditionally, there are often more than four satellites in a story. We require a minimum of four satellite ranges to resolve the clock biases contained in both the satellite and the ground-based receiver. Thus, in solving for the X-Y-Z co-ordinates of a point, a fourth unknown (i.e. clock bias--Dt) must also be included in the solution. The solution of the 3-D position of a point is simply the solution of four pseudorange observation equations containing four unknowns, i.e. X, Y, Z, and Δt.

A pseudorange observation is the combination of true range and the satellite/receiver clock biases and other effects given as

$$R = p^t + c\,(\Delta t) + d \quad (2)$$

Where,

R = observed pseudorange
Pt = true range to satellite (unknown)
c = velocity of propagation
Δt = clock biases (receiver and satellite)
d = propagation delays due to atmospheric conditions

2. Error Correction

The ionospheric error correction is applied to the receiver position. Since we used single carrier frequency C/A code for positioning, the Kobluchar model of ionosphere delay was used to correct the position. The results were saved to file.

IV. Results and Discussion

The positioning results were calculated according to the steps described above. This was affected by various parameters and these parameters were studied carefully to check the positioning accuracy. Positioning on 15/feb/2015 at Chulalongkorn University was done. Rinex observation file cusv0460.o and Rinex navigation file cusv0460.n was downloaded from igscb.jpl.nasa.gov website. The number of epoch calculated were 2879.

We assume origin of graph, Lat=13.7359[deg], Lon=100.5339[deg], h=76.06[m] which were given by RINEX.o header. The troposphere correction was already applied which varies between 0-20 meter for 5 degrees elevation mask and from 0 – 50 meters without elevation mask. In order to properly understand the effect of elevation mask parameter first non weighted analysis was done and later on checked with weighted analysis.

A. Non Weighted Analysis

In non-weighted analysis we reduce the number of satellite selection with the help of elevation mask. If we consider an elevation mask angle of 5 degrees then the satellites having elevation less than 5 degrees at that point of epoch will be eliminated and rest satellite will be used for the receiver position calculation.

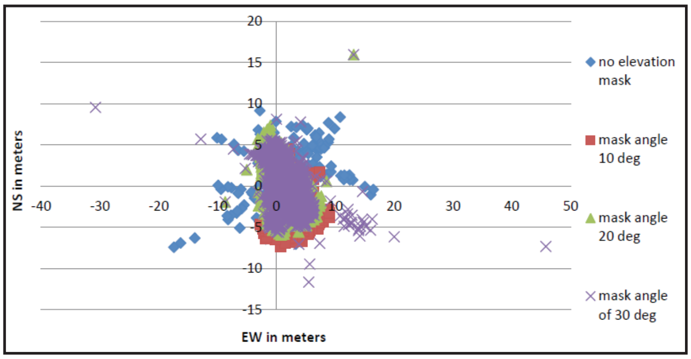

Fig. 6: Non Weighted Analysis With Different Elevation Mask

Table 1: Statistical Error of Elevation Mask 0 , 10, 20 and 30 Degrees

NUM of Data		2879				
					Unit=m	
MASK 0	EW`	NS	UD	2D	H	3D
AVG	2.287	-0.538	3.1856	3.838	5.1493	6.824
STD	2.172	2.181	6.0197	1.856	4.4596	4.241
RMS	3.155	2.867	6.8107	4.263	6.8107	8.035
MAX	16.47	9.171	16.271	18.92	55.181	58.33
MIN	-17.4	-7.41	-55.18	0.089	0.0011	0.975
MASK 10	EW	NS	UD	2D	H	3D
AVG	2.212	-0.586	3.7929	3.521	4.3643	5.940
STD	1.475	2.679	4.1928	1.480	3.5942	3.356
RMS	2.659	2.742	5.6538	3.820	5.6538	6.823

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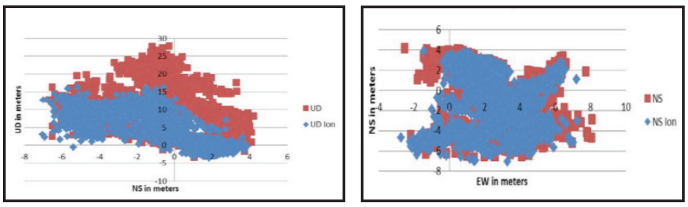
MAX	8.981	4.533	20.844	9.708	20.844	21.20
MIN	-2.73	-7.328	-4.862	0.111	0.0001	1.186
MASK 20	EW	NS	UD	2D	H	3D
AVG	1.630	-0.111	3.1599	3.209	4.4619	6.021
STD	1.756	2.615	25.747	1.515	25.553	25.48
RMS	2.396	2.618	25.94	3.549	25.944	26.18
MAX	13.15	15.95	1331.0	20.68	1331.0	1331.
MIN	-8.70	-5.927	-198.8	0.081	0.0019	0.345
MASK 30	EW	NS	UD	2D	H	3D
AVG	1.640	0.204	2.8732	3.288	5.8973	7.417
STD	2.482	2.560	30.032	2.153	29.587	29.50
RMS	2.975	2.569	30.169	3.931	30.169	30.42
MAX	45.82	15.956	1331.0	46.40	1331.0	1331.1
MIN	-30.7	-11.63	-440.1	0.081	0.0001	0.4105

According to DOT we should keep an elevation mask angle of 10 – 20 degrees. Now why is it advised so. This can be studied from the above statistics results how with the increase in elevation mask the standard deviation reduced but again at 30 degrees mask the trend reversed and standard deviation increased. Same with RMS error and other parameters. So from the above statistics we can say it is advisable to keep an elevation mask angle between 5 degrees to 20 degrees for better positioning result.

For our study we considered the elevation mask angle of 5 degrees in-order to reduce the processing time and quick results. Then after the 5 degree mask angle an ionospheric on/off condition as checked with the positioning result. The ionosphere delay is a major factor playing in the GPS positioning. We know that ionosphere spreads from 500 to 1000 km so the speed of signal is mostly affected during travelling. The carrier phase is not so long but the pseudo range is , so the correction is done to pseudorange. We add the delay to pseudorange.



(a) (b)

Fig. 7: (a) Positioning with and without ionosphere correction along EW-NS non-weighted method. (b) Positioning with and without ionosphere correction along NS-UD non-weighted method

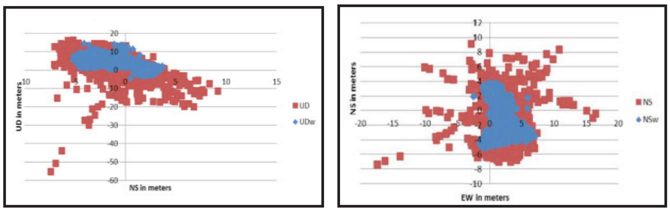
So from above figure it states that ionosphere correction helps in positioning accuracy. But with an elevation angle mask greater than 10 degrees the positioning results may increase more. But the number of satellites will decrease so in an alternate way we can use an weighted method. The statistics are shown below how the results vary with ion correction. The RMS error reduced from 3.11 to 2.86 after ionospheric correction.

Table 2: Statistics Result of Elevation Mask 5 Degrees With and Without ION Correction

ION CORR OFF	EW	NS	UD	2D	H	3D
AVG	2.4116	-0.341	9.2391	3.8067	9.3758	10.530
STD	1.971	2.7023	6.9528	1.6217	6.7673	6.3199
RMS	3.1146	2.7239	11.563	4.1377	11.563	12.281
MAX	8.0974	4.2086	27.777	9.3178	27.777	27.860
MIN	-2.535	-6.713	-3.255	0.335	0.001	1.714
OFFSET	2.411	-0.341	9.239	2.435	9.239	9.554
ION CORR ON	EW	NS	UD	2D	H	3D
AVG	2.4022	-0.619	4.474	3.663	4.867	6.496
STD	1.5587	2.66	4.5827	1.496	4.162	3.804
RMS	2.863	2.731	6.404	3.957	6.404	7.528
MAX	7.256	3.879	16.281	8.724	16.281	18.471
MIN	-2.730	-7.038	-3.536	0.591	0.001	1.193
OFFSET	2.402	-0.619	4.474	2.480	4.474	5.1158

B. Weighted Analysis

In a weighted method the number of satellites remain the same but we give less weight to the low elevation satellites and try positioning. At first with ionospheric correction on , the weight was put on and off to check accuracy.



(a) (b)

Fig. 8: (a). Positioning with and without ionosphere correction along EW-NS weighted method, (b). Positioning with and without ionosphere correction along NS-UD weighted method

From the above results we can analyze that weighted method with ionosphere correction gives us the best appropriate results. The statistics drawn from the above analysis shows that the maximum and minimum deviation as compared from the non-weighted analysis, weighted analysis showed more better results.

Table 3: Statistic Results of Applying No Weight and Weight to Positioning

NUM OF Data		2879				
				Unit=m		
No Weight	EW	NS	UD	2D	H	3D
AVG	2.287	-0.53	3.195	3.838	5.152	6.827
STD	2.172	2.816	6.019	1.856	4.460	4.243
RMS	3.155	2.867	6.815	4.263	6.815	8.039
MAX	16.478	9.171	16.281	18.924	55.171	58.327
MIN	-17.41	-7.41	-55.17	0.0896	0.0017	0.9841
OFFSET	2.287	-0.53	3.195	2.350	3.195	3.966
Weighted	EW	NS	UD	2D	H	3D
AVG	1.9354	-0.26	3.371	3.076	3.737	5.155

STD	1.393	2.293	3.243	1.246	2.814	2.515
RMS	2.384	2.308	4.678	3.319	4.678	5.736
MAX	7.148	3.733	14.362	7.976	14.362	15.600
MIN	-2.430	-5.16	-4.665	0.241	0.001	1.129
OFFSET	1.935	-0.26	3.371	1.953	3.371	3.896

So from above table we conclude that weighted positioning gives us better result but when we consider weighted analysis with the ionospheric error it gives the best accuracy of near error of 3.3 meters.
Finally, the positioning results for Chulalogkorn University Receiver Station was,

Table 4: Positioning Result of Chulalogkorn University

Chulalogkorn University	X	Y	Z
AVG	-1132915	6092534	1504633
STD	1.7087	3.4029	1.7944
MAX	-1132911	6092545	1504636
MIN	-1132922	6092526	1504628

When we calculated the Latitude Longitude and Height we got results as below,
Lat = 13.7359 deg +/-0.000 deg
Long = 100.5343 deg +/- 0.000 deg
Height = 73.9034 m +/- 3.6760 [m]
DOP is considered important when it comes to positioning. A good DOP provides more precision. Generally it is considered to be a distinct property to evaluate the geometric arrangement from receiver to satellite. We can say DOP is recorded to be less if the number of satellites are more. The wider the angle of satellites available at that moment gives better DOP.The DOP of Chulalogkorn station along time series of XYZ was normalized by average. Where a GDOP is considered to be ideal if below 1 meters. In this case we had varying GDOP in between 0.5 to 2 considering it to be excellent.

C. Comparison With Commercial Software RTKLIB

To check the accuracy of our MATLAB code we compared the results with commercial software RTKLIB. This is an open source software for GNSS precise positioning. It consists of program libraries that are portable and can be used easily. The results achieved were quite good .

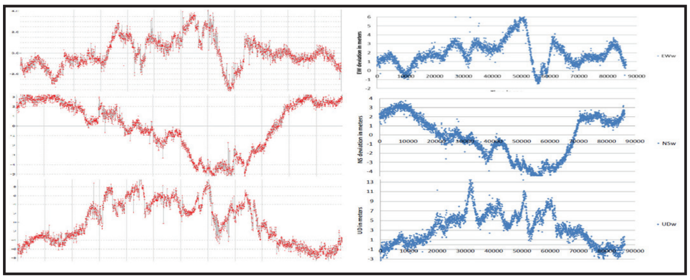


Fig. 9: (a) EW, NS and UD Results of RTKLIB Indicated in Red and Our Script in Blue Respectively

V. Conclusion

The main aim of the study was to learn the basics of GPS positioning and to develop positioning script using MATLAB environment. This was achieved. The positioning involved C/A method of positioning. The algorithm was at first written down and understood for better understanding and then later on analyzed. Since, many students only consider analyzing results using commercial software hence it lacks depth of understanding of individual parameter related to the process and analyze blindly. Experimenting can become easy if we understand the process by our self and then analyze things. It became easy to gain an idea of writing codes and changing values. All the important aspects related to positioning was tried to cover including the GDOP, Troposphere and Ionosphere effects and angle of elevation , the weighted and non-weighted method.
The algorithm evaluated the positioning with respect to elevation mask angle with non-weighted analysis and weighted analysis. The angle of elevation when masked to 5 degrees yielded better results. But better results appeared with weighted analysis. The procedure followed for point positioning was least mean square technique , at first when all satellites were taken into consideration the GDOP value was high near to 3meters later on when masked to 5 degrees of elevation the GDOP value came down to 2 meters. The single point positioning can give much better results on further modification to the pseudo range algorithm. At first the positioning was done without considering troposphere and ionosphere delay and no mask so the positioning range was quite dispersed about +/- 100m. With the application of all possible correction the results drastically changed to about +/- 10m accuracy.
The conclusion hence drawn from the above statistics and result is that if we go for an weighted analysis with troposphere and ionosphere correction that yields a much accurate results that a non-weighted one. The software can be developed accordingly for positioning which can have such features to analyze how parameters and process differing can affected the positioning results, this can give us a better insight and knowledge to understand GPS positioning.
We tried comparing our software results with the commercial software available in the market like TRIMBLE and RTKLIB, the variation with the commercial software were minimal. These difference in results arise due to the troposphere and ionosphere model used in the software. But a good accuracy similar to the commercial software was achieved.
To achieve accuracy up to decimeter level we can try experimenting with the data further like checking the number of cycle slips per hour. Once we can determine the number of cycle slips it may become easier for us to predict the number of slips to a satellite. Whereas , the other parameters were not studied in this experiment like effect of Selective Availability and Data acquisition length. With this investigation considering the above conditions are the highest possible methods to get the best accuracy.

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