Accuracy comparison between cheap multiband GPS chip and single band enterprise GPS receiver for static position observation in geodetic purposes.

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Abstract

Global Positioning System (GPS) is widely used to designate position. Many brands of GPS instruments, GPS Kits and GPS evaluation Kits are available in the global market. Expensive GPS device are considered to be more accurate, thus expensive instruments are used for higher accuracy mapping and control point establishment for geodetic purpose. Some GPS vender produce highly accurate GPS instruments with many options for GPS data corrections, such as real time correction system with user friendly software for visualization of GPS data and processing facilities.This paper intends to compare the accuracy between cheap multiband GPS chip and single band enterprise GPS receiver, which are used to determine static position for geodetic purpose.In this study 'Ublox Neo 7M GPS kit with raspberry PI 3B' (which is a cheap multiband GPS) accuracy is compared to Magellan Promark 3 instruments. The 'ublox center' software is used for data logging to the Neo 7M as .ubx file and raw data file for Magellan (Single Band GPS) logging in the receiver itself. Nine control points are observed with 3 hours continuously observation in each stationwith both devices simultaneously, to meet the second order control point establishment standard of Department of Survey, Nepal.

Positions are determined for Neo 7M chip by using logged ubx file to calculate mean of latitude, longitude and elevation, whereas for Magellan GPS, Raw files are imported in GNSS solution software without any corrections. Both outputs are considered as relative position of the observations without any corrections. Absolute Positions were calculated by using raw data file of Magellan GPS receiver as rover station, and two base stations were setup for the post processing purpose. Differences are calculated from absolute and both relative positions. The residuals are minimum for Neo 7M than Magellan with respect to the absolute position for horizontal position. With this detailed study and observation, Neo 7M is seen better for horizontal positioningand Magellan is better for height determination.

Key words: Cheap GPS chip, Enterprise GPS, Accuracy Assessment, Geodetic positioning

Introduction

GPS is a readily developed technology for the determination of any position on the earth's surface(Prasad and Ruggieri 2005). GPS technology is based on space segment, control segment and user segment. Interaction with these segment enables possibilities to accumulate more error from various sources of medium such as atmospheric error, ionosphere error, clock error, multipath error etc(Wells, Beck et al. 1987).Varioustechniques such as post processing; real time kinematics are used to eliminate the errors(Ebner and Featherstone 2008). In Nepal, post processing is the most popular technique used to minimize the error. In order to locate geodetic positioning, a first order control point is used as a base station, and rover station is setup to new station to link national control network for national mapping agency. Disturbances in control points, especially due to construction works and frequent earthquakes in Nepal, it is impossible to get control points from national mapping agency(Bai, Liu et al. 2016). For the small mapping project there are no CORS (Continuously Operating Reference Stations) and VRS (virtual reference station) stations to use GPS data for differential corrections. Thus, it is necessary to explore the types of GPS chips, GPS evaluation kits and GPS receivers which are cheap in price(Noureldin, Karamat et al. 2008, Montini, Prost et al.

2015)(Wallner, Avila-Rodriguez et al. 2007, Scheck 2010). Which also provides the framework to explore processing and transformation technique and tools for determination of geodetic control points. This study explores the accuracy achievement by using two GPS set. First one is Ublox Neo 7M which cost about 37USD (GPS kit, Antenna with Raspberry PI 3B Device for data logging) and the other Magellan, which costs about 1000 USD (Receiver, Antenna, tripod and other accessories)(Mirabelli, Napolitano et al. 2003, Thiel and Ammann 2009).

To minimize the error, this study was carried out in clear weather. DOP (Dilution of Precision) values less than 3 was acceptance to maintain quality in the observation. Open area and distance from tall buildings were selected to eliminate the multipath error. From the dataset, accuracy of Ublox Neo 7M chip is 2.5 metre in autonomous and 2m in SBAS (Satellite-based augmentation systems), in ideal case. Accuracy of Magellan GPS is 2m in autonomous and 0.005 m + 1 ppm for horizontal, 0.01 m + 2 ppm for   Vertical and Azimuth is< 1 arc second for static positioning for geodetic purpose.The observations from both of the mentioned GPS were taken together in the same time, with the data interval of 5 seconds to achieve consistency in result, which allowed to compare the data in same condition. Three hours long observation was taken and processed, which allowed to meet the requirement of third order control point as per guidelines of Department of Survey, Nepal.

Methodology

In this study, Case study was adopted with national standard for observation time duration and process from Department of Survey, Nepal

Specification adopted

Observation Duration   : Minimum 3 hours for each static station

Data logging interval   : 5 seconds

Order of geodetic works: Second order geodetic Network

DOP accepted   : Less than 3

Height considered   : WGS ellipsoid

Receiver antenna   : Centric in station with geodetic tripod and perfectly level in base plate

Instrument Used

Ublox 7M GPS chip with Raspberry PI 3B module, which is considered as cheap GPS and Magellan Promark 3 GPS receiver with accessories, considered as expensive GPS were used for the study.

Data Used

The base RINEX data of two stations (NAST Station and JIRI station) was provided by UNAVCO (Formally called University NAVSTAR Consortium).At same observation time, Ublox Neo7M chip and Magellan GPS receiver were used to determine corrected decimal degree position and thatwas considered as absolute position for the study.

Study area

Nine stations within Banepa, Dhulikhel and Panauti municipalities were monumented for the study. To minimize the error, all of the stations were setup in open area, far from tall buildings, trees and hills. Further, a good sunny day was chosen for the observation. Figure 1 represents the nine stations and their locations.
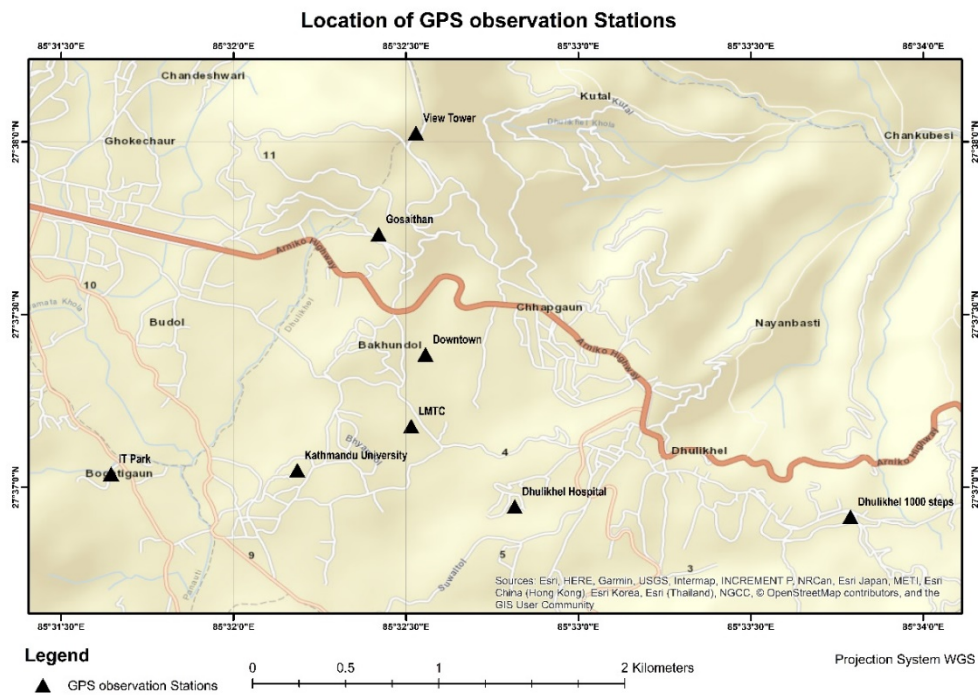
Figure 1: Observation stations showing their name and location

Method adopted

With reference to Google Map, 9 control points were set out. Wooden pegs were used for the purpose of monumentation. On each control point, GPS observation was taken from both devices for continuous 3 hours. Then after, the data was processed considering thedata from two base station (NAST station and JIRI Station). Thus, obtained geographical co-ordinates of each station were compared, and accuracy was determined by taking the absolute co-ordinate as the reference. TransLT software was usedtoconvert geographic coordinate to projected WGS UTM data and to compare data of each station.The workflow figure 2 represents the detailed procedure of the methodology.
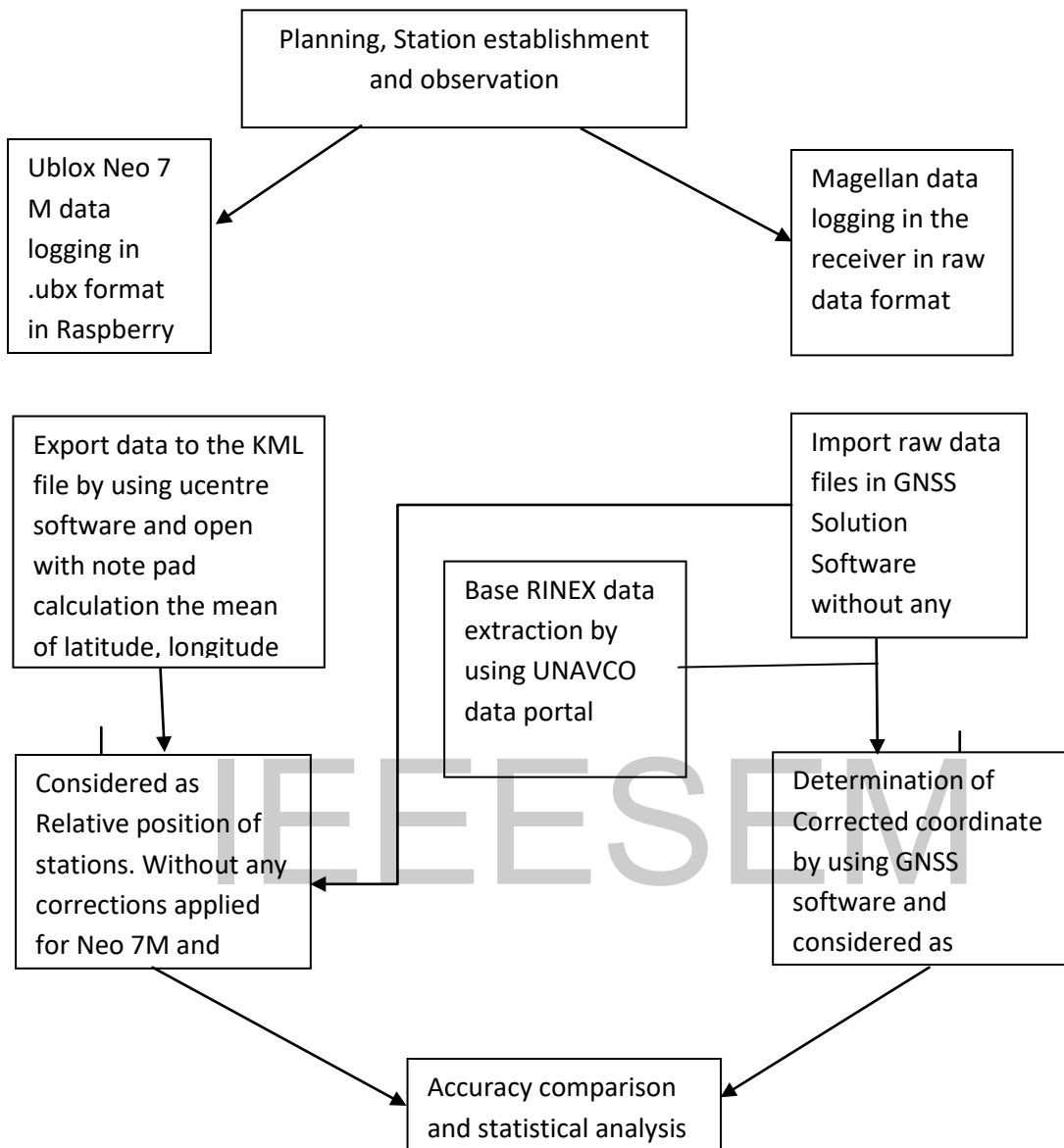
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┌─────────────────────────────┐
│ Planning, Station establishment │
│       and observation        │
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Ublox Neo 7 M data logging in .ubx format in Raspberry

Magellan data logging in the receiver in raw data format

Export data to the KML file by using ucentre software and open with note pad calculation the mean of latitude, longitude

Import raw data files in GNSS Solution Software without any

Base RINEX data extraction by using UNAVCO data portal

Considered as Relative position of stations. Without any corrections applied for Neo 7M and

Determination of Corrected coordinate by using GNSS software and considered as

Accuracy comparison and statistical analysis

Figure 2: Workflow diagram of accuracy comparison

Acquisition of relative position by using Ublox 7M GPS chip

The relative coordinate was extracted by using. ubx log file from ucentre software which was installed in Raspberry PI 3 and connected to the Ublox 7M GPS receiver chip. The ubx file was exported to .KML file format and opened with notepad. Average latitude, longitude and elevation was computed from the .TXT file and resulted elevation was calculated by subtracting height of GPS

antenna from the average elevation of the stations. Table 1 shows the relative position obtained by using ublox 7M GPS chip.

Table 1 Observed Coordinates in Latitude, Longitude and Elevation by using Ublox 7M GPS

Station Number	Station Name	By using Ublox Neo 7M GPS kit		
		Longitude	Latitude	Height(m)
2001	Dhulikhel Hospital	85.54690222	27.61574117	1481.200
2002	Kathmandu University	85.53639118	27.61750554	1491.2044
2003	Dhulikhel 1000 steps	85.56313919	27.61526335	1555.1566
2004	LMTC	85.54189105	27.61963613	1482.5744
2005	Gosaithan	85.54036211	27.62888000	1552.1925
2006	View Tower	85.54209526	27.63375787	1682.9567
2007	HRDC	85.51219943	27.62899280	1514.2558
2008	IT Park	85.52743990	27.61734100	1453.8430
2009	Downtown	85.54261689	27.62310717	1473.3743
	Mean	85.53922636	27.62224722	1520.7508

The box plot diagram figure 3, 4 and 5 represents the distribution of Latitude, Longitude and Elevation, which was prepared using R software.
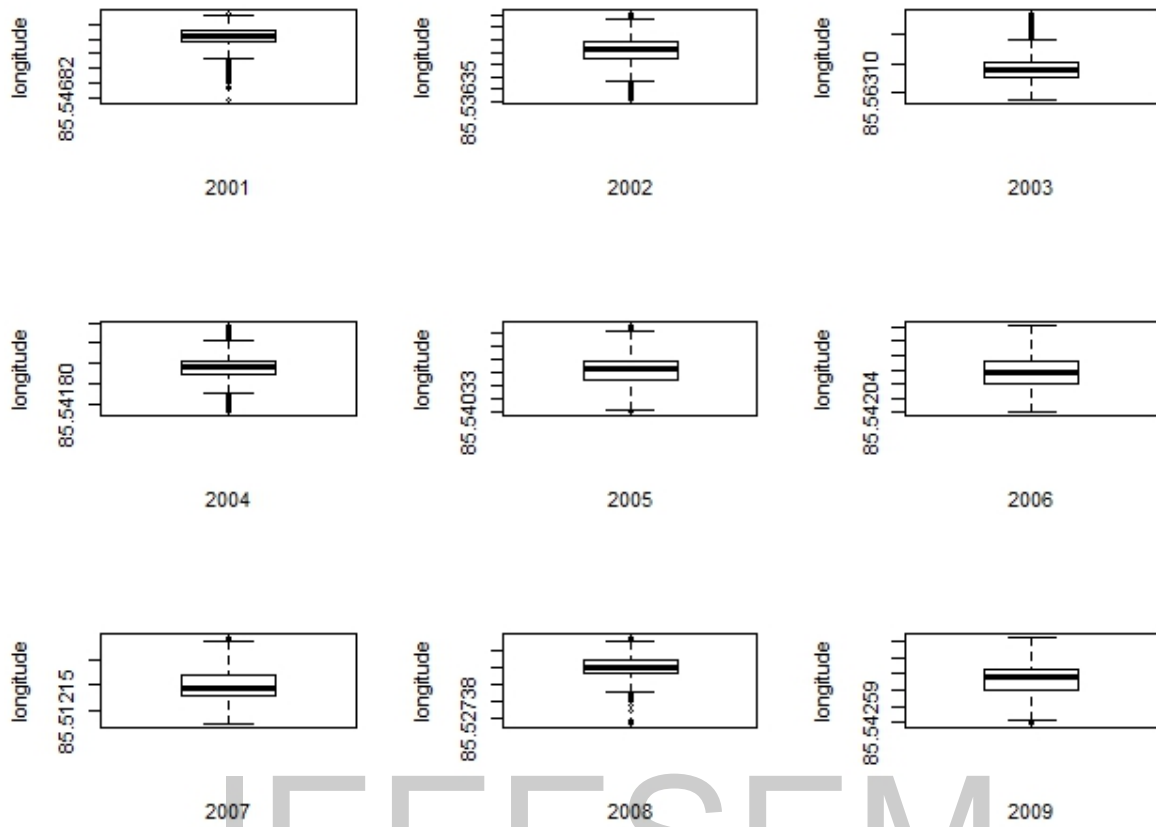
Figure 3: Distribution of longitude for every data login time interval for each station
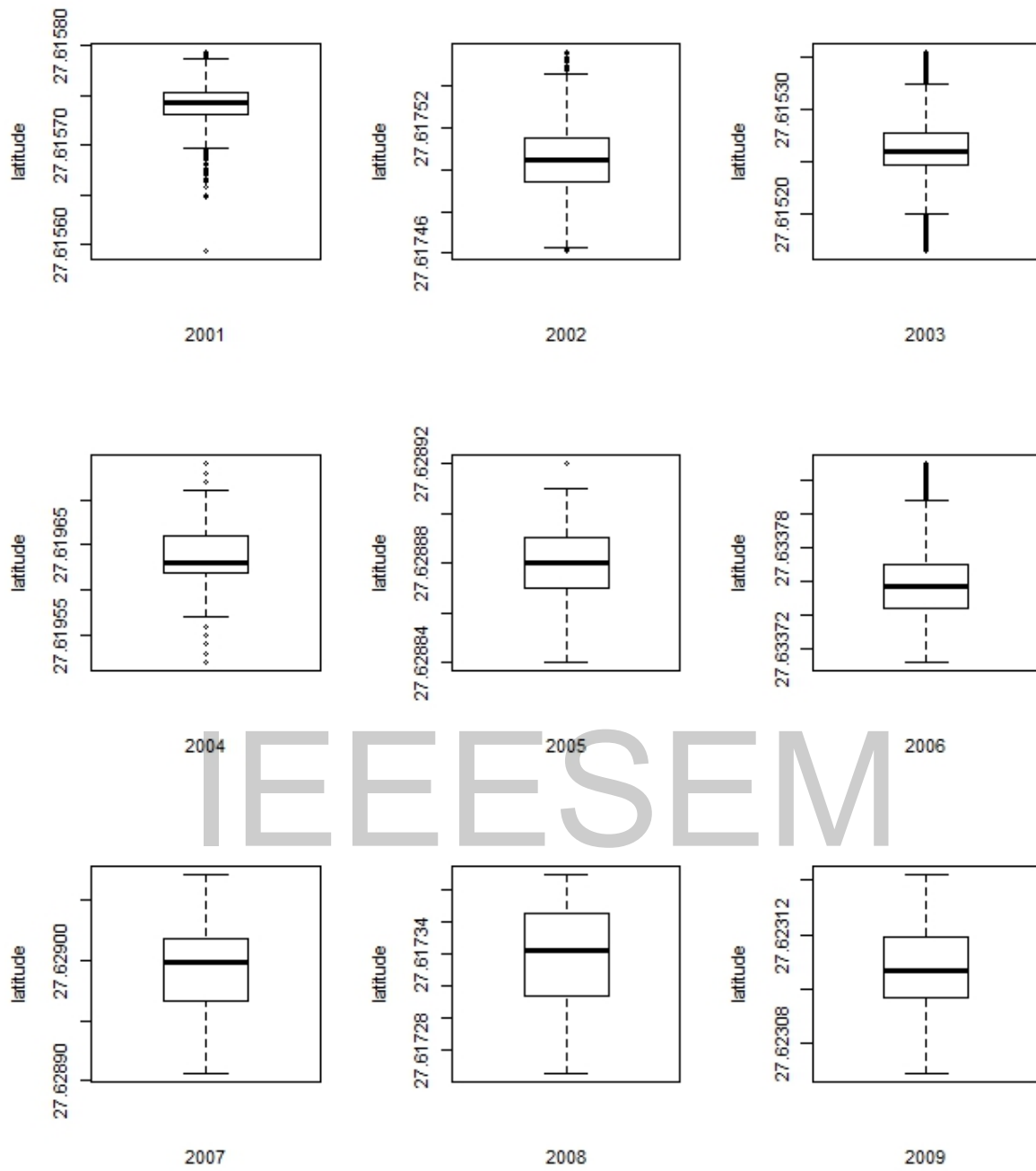
Figure 4: Distribution of latitude for every data login time interval for each station
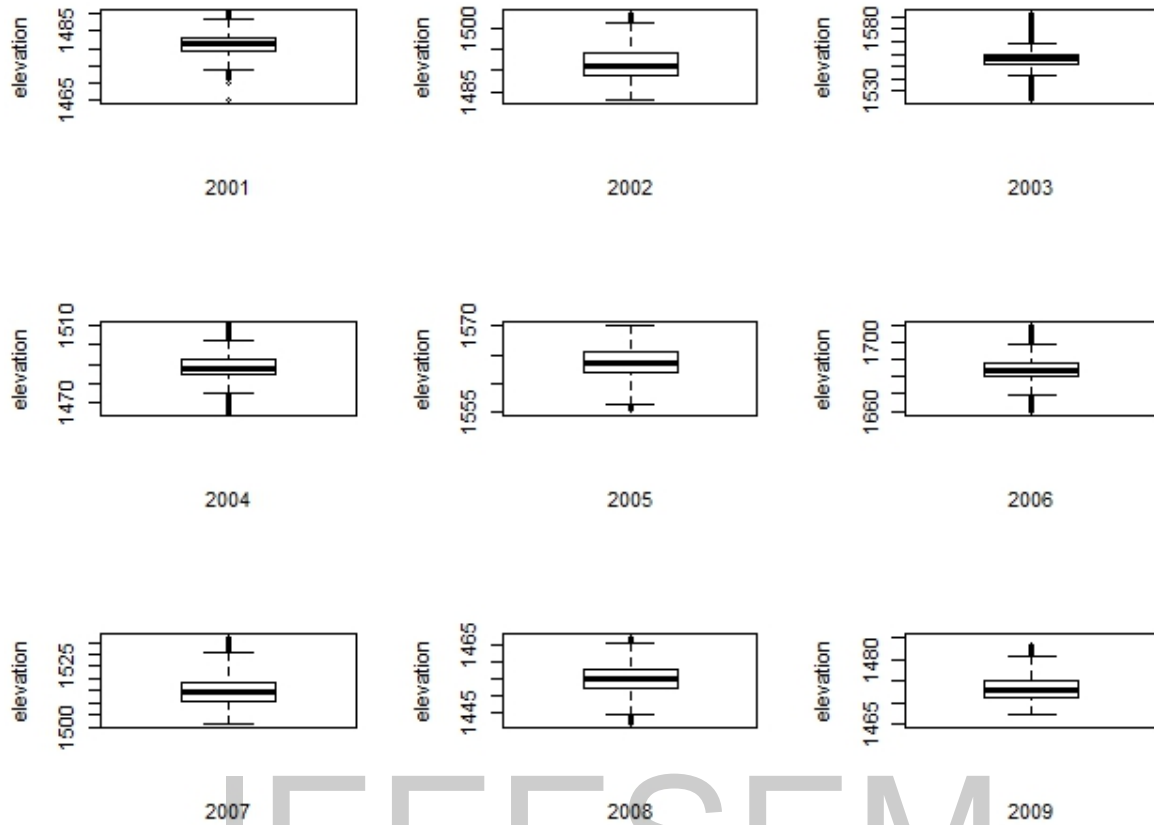
Figure 5: Distribution of elevation for every data login time interval for each station

Acquisition of relative position using Magellan

The raw file formats were imported in the GNSS Solution software from Magellan GPS receiver, other than exporting the data no other processing were conducted. The table 2 represents the relative position of the station using Magellan GPS.

Table 2: Observed Coordinates in Latitude Longitude and elevation by using Magellan GPS

Station Number	Station Name	By using Single band Magellan GPS		
		Longitude	Latitude	Height(m)
2001	Dhulikhel Hospital	85.54688346	27.61577482	1438.282

2002	Kathmandu University	85.53637918	27.61751339	1450.1300
2003	Dhulikhel 1000 steps	85.56313330	27.61525825	1511.3975
2004	LMTC	85.54189499	27.61962476	1444.1682
2005	Gosaithan	85.54034380	27.62889121	1528.2908
2006	View Tower	85.54209910	27.63377372	1640.4129
2007	HRDC	85.51222132	27.62902941	1477.2141
2008	IT Park	85.52745519	27.61735292	1415.5105
2009	Downtown	85.54265120	27.62312777	1440.6679
Mean		85.53922906	27.62226069	1482.8971

Table 2 represents the coordinates of all the stations along with station number and name. The coordinates from the Chip GPS was obtained by averaging the data obtained in each second from the receiver manually, whereas the coordinate of the single station was obtained directly from the Magellan. Then after, the coordinates of each station observed from the Ublox 7M GPS Chip is listed in Latitude, Longitude and Height along with the coordinates observed from the Magellan GPS. The mean of the coordinates observed from each GPS is now calculated. Here, we can notice that both the coordinates and the mean data is found to be different from two different GPS devices.

Determination of absolute position by using Magellan and RINEX data from CORS Station

The table shows the absolute coordinates of each station in latitude and longitude after processing. The data from Magellan is now processed using the base data from the JIRI Station and NAST Station, using differential correction.

Table 3: Processed Coordinates in latitude and longitude

Station Number	Station Name	By using Single band Magellan GPS Post processed (Absolute)		
		Longitude	Latitude	Height(m)
2001	Dhulikhel Hospital	85.54691466	27.61574344	1447.8061
2002	Kathmandu University	85.53640693	27.61749725	1458.2004
2003	Dhulikhel 1000 steps	85.56314643	27.61525149	1523.5605
2004	LMTC	85.54191111	27.61962602	1455.6520
2005	Gosaithan	85.54033872	27.62888715	1531.5670
2006	View Tower	85.54213919	27.63377002	1646.4976
2007	HRDC	85.51216311	27.62899758	1479.7386
2008	IT Park	85.52741464	27.61732086	1421.7899
2009	Downtown	85.54260293	27.62308888	1439.9182
Mean		85.53922641	27.62224252	1489.4144

Table 3 represents the absolute coordinates of each station in latitude and longitude after processing. We are considering the post processed coordinates are absolute coordinate for this study.

Comparison of absolute position by using Magellan and RINEX data from CORS Station

The composition table was performed by using absolute position and relative positions from two receivers are given below:

Table 4: Coordinate comparison in latitude and longitude

Station	Station Name	Difference between Absolute and Ublox Neo	Difference between Absolute and

Number		7M GPS kit			Magellan		
		Longitude in Second	Latitude in Second	Height(m)	Longitude in Second	Latitude in Second	Height(m)
2001	Dhulikhel Hospital	0.044794671	0.008155911	33.39345894	0.1123340	0.1129720	9.5241
2002	Kathmandu University	0.056713352	0.029848439	33.00404486	0.0998876	0.0581112	8.0704
2003	Dhulikhel 1000 steps	0.026044283	0.042724108	31.59613658	0.0472564	0.0243500	12.163
2004	LMTC	0.072205494	0.036379951	26.92245586	0.0580216	0.0045548	11.484
2005	Gosaithan	0.084217121	0.025864893	20.62550115	0.0182972	0.0145916	3.2762
2006	View Tower	0.158116507	0.043748855	36.45911470	0.1442992	0.0133076	6.0847
2007	HRDC	0.130765189	0.017192703	34.51720213	0.2095864	0.1145652	2.5245
2008	IT Park	0.090915357	0.072567225	32.05305857	0.1459884	0.1154048	6.2794
2009	Downtown	0.050267316	0.065829587	33.45618301	0.1737592	0.1399876	0.7497
Mean		0.079337699	0.038034630	31.33635064	0.1121589	0.0664272	6.6839778

Table 4 represents the comparison between the observed coordinates in table 3 with accurate coordinates in table 4. The compared values are in secondsfor latitude and longitude, and in meters for height. We can see that the difference in latitude and longitude in absolute and cheap GPS is less than that of absolute and Magellan. However, the error in height is more in Cheap GPS than in Magellan. The maximum error in height if foundto be 36.45 meters and minimum is 20.62 meters.

Comparison of position in the projected coordinate form

The relative coordinates from Table 1,2 and 3 are used as input to projected positions. The following Parameters are used in the WGS ellipsoidal parameter:

Projected Parameter: UTM parameter

False easting: 500000m

False northing:0-meter

Origin of longitude: Greenwich meridian

Central meridian: 87-degree east

Scale factor: 0.9999

To perform the projection TransLT software is used, as result table 5 and 6 are extracted.

Table 5 Coordinate after Conversion in ENZ

Station Number	Station Name	By using Ublox Neo 7M GPS kit			By using Single band Magellan GPS		
		Easting (m)	Northing(m)	Height(m)	Easting (m)	Northing(m)	Height(m)
2001	Dhulikhel Hospital	356615.3320	3055480.1690	1481.2000	356613.5250	3055483.9190	1438.2820
2002	Kathmandu University	355580.3400	3055687.8850	1491.2040	355579.1660	3055688.7680	1450.1300
2003	Dhulikhel 1000 steps	358217.0970	3055408.4960	1555.1570	358216.5090	3055407.9370	1511.3980
2004	LMTC	356125.8850	3055917.5150	1482.5740	356126.2590	3055916.2510	1444.1680
2005	Gosaithan	355987.1030	3056943.4230	1552.1930	355985.3110	3056944.6860	1528.2910
2006	View Tower	356164.5020	3057481.8210	1682.9570	356164.9010	3057483.5730	1640.4130
2007	HRDC	353208.2710	3056989.0750	1514.2560	353210.4800	3056993.1050	1477.2140
2008	IT Park	354696.7550	3055680.1500	1453.8430	354698.2800	3055681.4530	1415.5110
2009	Downtown	356202.0500	3056301.2260	1473.3740	356205.4620	3056303.4680	1440.6680
Mean		355866.3706	3056209.9733	1520.7509	355866.6548	3056211.4622	1482.8972

Table 5 represents the observed coordinates in Easting (E), Northing (N), Height (Z) of each station obtained from Chip and Magellan. The Geographical coordinates were converted to Easting (E), Northing(N) and Height(Z) using the application named as Trans LT. Mean Value of the coordinate is also represented. No Datum Transformation is done, so the above data are still in WGS1984.

Table 6: Absolute Coordinates after conversion

Station Number	Station Name	By using Single band Magellan GPS Post processed (Absolute)		
		Easting (m)	Northing(m)	Height(m)
2001	Dhulikhel Hospital	356616.5630	3055480.4060	1447.8060
2002	Kathmandu University	355581.8830	3055686.9480	1458.2000
2003	Dhulikhel 1000 steps	358217.7960	3055407.1730	1523.5610
2004	LMTC	356127.8510	3055916.3720	1455.6520
2005	Gosaithan	355984.8040	3056944.2420	1531.5670
2006	View Tower	356168.8520	3057483.1160	1646.4980
2007	HRDC	353204.6940	3056989.6480	1479.7390
2008	IT Park	354694.2360	3055677.9490	1421.7900
2009	Downtown	356200.6480	3056299.2150	1439.9180
Mean		355866.3697	3056209.4521	1489.4146

Comparison of absolute and relative projected position

The comparison table 7 was performed by using table 5 and Table 6 with absolute position and relative positions from two receiver, as heighted below:

Table 7: Comparisonbetween the observed converted coordinates with the absolute coordinates

Station Number	Station Name	Difference between Absolute and Ublox Neo 7M GPS kit			Difference between Absolute and Magellan		
		Easting (m)	Northing(m)	Height(m)	Easting (m)	Northing(m)	Height(m)
2001	Dhulikhel Hospital	1.2310	0.2370	33.3940	3.0380	3.5130	9.5240
2002	Kathmandu University	1.5430	0.9370	33.0040	2.7170	1.8200	8.0700
2003	Dhulikhel 1000 steps	0.6990	1.3230	31.5960	1.2870	0.7640	12.1630
2004	LMTC	1.9660	1.1430	26.9220	1.5920	0.1210	11.4840
2005	Gosaithan	2.2990	0.8190	20.6260	0.5070	0.4440	3.2760
2006	View Tower	4.3500	1.2950	36.4590	3.9510	0.4570	6.0850
2007	HRDC	3.5770	0.5730	34.5170	5.7860	3.4570	2.5250
2008	IT Park	2.5190	2.2010	32.0530	4.0440	3.5040	6.2790
2009	Downtown	1.4020	2.0110	33.4560	4.8140	4.2530	0.7500
Mean		2.1762222	1.1709999	31.336333	3.081777	2.037000	6.684

Table 7 represents the comparison between the observed converted coordinates with the absolute coordinates in Easting (E), Northing(N) and Height(H). The maximum error in position is found 4.35m and 1.29m at View Tower station and minimum error is found 1.23m and 0.23m in Dhulikhel hospital station. The mean value of the coordinate is also represented in the table.

Result and Discussion

The table 8 shows the distribution of data in statistical form.

Table 8: Data Analysis

GPS	Ublox Neo 7M GPS kit		Magellan	
	Easting (m)	Northing(m)	Easting (m)	Northing(m)
Standard Error	2.439575601	1.314684288	3.490879291	2.559834305
Error in distance	2.77126756		4.328855495	
Standard Deviation	1.102536145	0.597623441	3.479216848	1.584993687
Standard Error (50%)	3.2787583670	1.7686234414	3.1941057370	-0.4251174243
	1.0736860774	0.5733765585	-3.7643279593	-3.5951047982
Standard Error (90%)	4.3812945119	2.3662468829	6.6733225852	1.1598762627
	-0.0288500674	-0.0242468830	-7.2435448074	-5.1800984851
Standard Error (95%)	5.483830657	2.963870324	10.15253943	2.74486995
	-1.131386212	-0.621870324	-10.72276166	-6.765092172

Table 8 represents the analysis of the entire data. This table shows that the Root Mean Square error (RMSE) of chip GPS is less than that of Magellan. Error in distance is found to be 2.7712m in chip GPS whereas it is 4.328m in Magellan. Standard deviation is also less in Chip than that of Magellan, which shows that the data are deviated from the most probable value more in Magellan than Chip. Other standard errors are also shown in the table.

The figure 6 alongside is the deviation map of the Downtown station. This map shows the deviation of the observed data within 5 meters of most probable value. Data was measured each 5 second so in the figure, only line is visible as the point data that are very close to each other. Closeness of the data indicates the precision of the observed data.
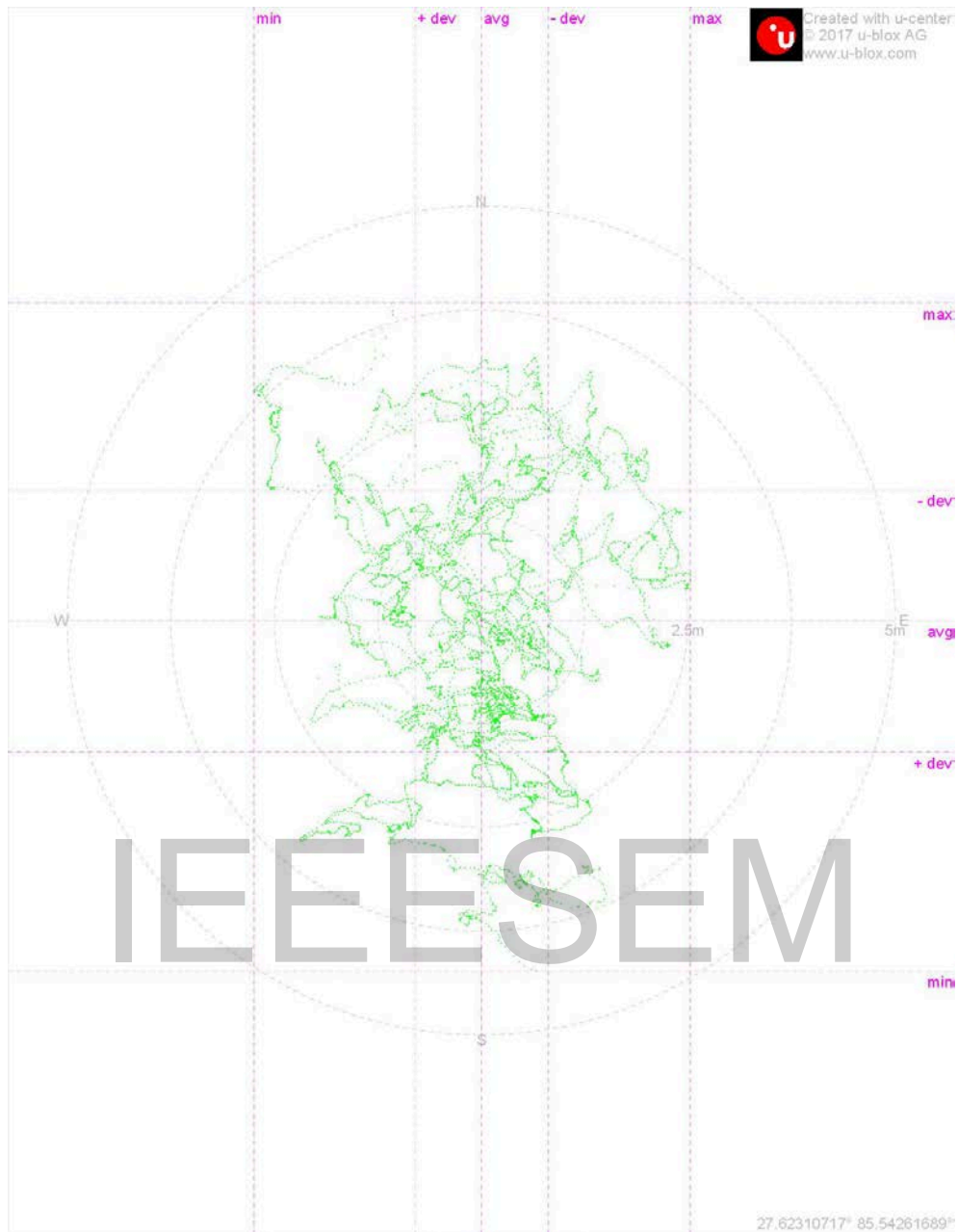
Figure 6 : Distribution of 2D location for every data login time interval via Ublox Chip in a Station

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