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Estimation and Visualization of 2D Orbits of GPS Satellites Using GPS Navigation Data File from Mangalore GNSS Receiver

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ABSTRACT

This paper is to estimate and visualize the 2D orbits of the GPS satellites based on GPS navigation data file generated from Mangalore GNSS receiver. The Global Navigation Satellite System (GNSS) determines position, velocity and time with high accuracy by the process of Trilateration. It is a satellite navigation system. The Receiver Independent Exchange Format (RINEX) File is used to extract the parameters from GPS navigation data file. These parameters are implemented in the formulas by using MATLAB software and the XYZ coordinates of GPS satellite are obtained and they are plotted individually in 2 Dimension.
Keywords: GPS, GNSS receiver, Trilateration, RINEX File, MATLAB software.

I. INTRODUCTION

A global coverage satellite navigation system is termed as GNSS. The geographic location of user can be found using the GNSS system. This GNSS system include the Global Positioning System (GPS) of United States, Global Orbiting Navigation Satellite System (GLONASS) of Russian Federation, Galileo of Europe and many more [5]. The space based radio positioning system called Global Positioning System (GPS) provides the user's 3 dimensional position, time and velocity information in any type of weather and anywhere on Earth. The GPS satellite provides services to community. In the modernization of the air traffic system of the globe, GPS acts as backbone. Even though the GPS satellite orbit's height is high it can provide user location 24 hours a day with the accuracy ranging from 50 to 100 meters [2].

The GPS satellite is operated by U.S. Department of Defense which consists of 32 satellites out of which 24 are visible at a time and aims at determining the user position, time and velocity accurately. The 3 segments of GPS are Space, Control and User segments.

The users are transmitted with radio signals by a constellation of satellites. The GPS satellites rotate an altitude of 12,550 miles in medium Earth orbit (MEO). The satellite revolves around the Earth twice a day with a period of 11 hours 58 minutes. The satellites in GPS constellation are arranged into six equally spaced orbital planes placed at an angle of 60 degrees and 55 degrees to equator. Each plane contain four satellites.

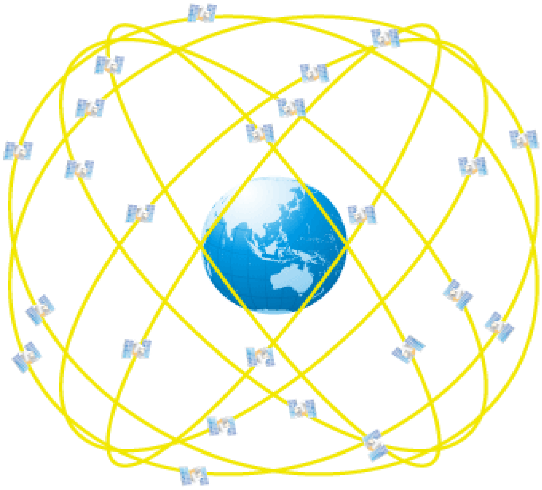

Figure 1. Orbits of GPS satellites.

The Control segment monitors the path of satellite and rectify the satellites clocks. The User segment contains GPS receiver which receives the signals from GPS satellites and calculates position and time [3]

II. DETERMINATION OF USER POSITION

The Trilateration process is used to determine locations of user by locating points and by measuring the distance using circles. A GPS device accurate position is determined provided it transmits GPS satellite signals high above the Earth. A GPS satellite requires minimum three satellites to locate the user position anywhere on the globe which means that a GPS can locate longitude, latitude and altitude. But we prefer four satellites to locate the position of user as when we use three satellites we get high positional error and clock error in order to rectify that we use four satellites to locate position of user anywhere on the globe by the process of Trilateration. This process have some practical applications in surveying and navigation, including GPS. In contrast to triangulation, it does not measure angles.

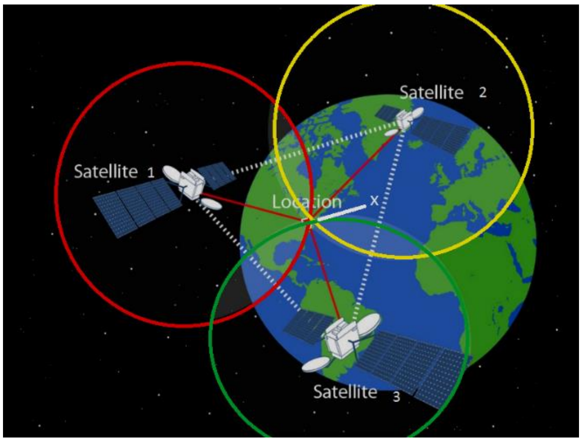

Figure 2. Process of Trilateration.

III. DETERMINATION OF PATH OF SATELLITE ORBIT

There are some parameters which are useful for evaluation or estimation of GPS satellite position around the globe. These parameters are extracted from GPS navigation data file by comparing it with RINEX File [1]. Some of the parameters are shown in the below table.

Table 1. Structure Of Parameters

A	The long axle of elliptical orbit.
IODE	Extrapolation time interval of satellite parameter.
IODC	Clock correction parameter
IDOT	Rate of inclination angle
Crs	Radius of the sine harmonic term
Δn	Difference in mean from computed value
Mo	Mean anomaly at reference time value
Cuc	Argument of latitude of the cosine harmonic term
E	Value of Eccentricity
Cus	Argument of latitude amplitude of the sinusoid harmonic term
Toe	Reference time
Cic	angle of inclination of the cosinusoid harmonic term
Ωo	Longitude of node
Cis	Angle of inclination of the sine harmonic term

Io	inclination angle
Crc	Radius of the cosine harmonic term
Ω	Rate of change of right ascension
omega	Argument of perigee
T	Epoch time

These set of parameters extracted from GPS navigation data file are then applied to the formulas and used to obtain XYZ coordinates by using MATLAB software. The set of mathematical equations or formulas used in determining satellite position [7] are shown below.

The radius of elliptical orbit:

$$A = (\sqrt{a})^2 \quad (1)$$

Computed mean value in rad/s:

$$no = \frac{\mu}{A^3} \quad (2)$$

Time ephemeris epoch in seconds (t is GPS system time):

$$tk = t - toe \quad (3)$$

Corrected mean value:

$$n = n0 + \Delta n \quad (4)$$

Mean anomaly evaluation:

$$Mk = M0 + (n * tk) \quad (5)$$

Kepler´s equation for eccentricity:

$$Mk = Ek - esinEk \quad (6)$$

The equation (6) is solved by iteration method by using Newton-Raphson method of iteration assuming Ek = Mk as the initial condition.

$$\dot{Ek} = \frac{\dot{Mk}}{(1-ecos\ Ek)} \quad (7)$$

Value of true anomaly from tan:

$$\upsilon k = tan\text{-}1 \left\{ \frac{\sin Ek\sqrt{1-e2}}{\cos Ek - e} \right\} \quad (8)$$

$$\dot{\upsilon k} = \frac{\sin Ek\dot{Ek}(1+\dot{e}\cos \upsilon k)}{(1-\cos Eke)\sin \upsilon k} \quad (9)$$

Argument of latitude:

$$\Phi k = \dot{\upsilon k} + \omega \quad (10)$$

$$\dot{\varphi k} = \dot{\upsilon k} \quad (11)$$

Argument of latitude evaluation of the second harmonic:

$$\partial uk = Cus * \sin(2\varphi k) + Cuc * \cos(2\varphi k) \quad (12)$$

$$\partial \dot{u}k = 2[Cus * \cos(2\varphi k) - Cuc * \sin(2\varphi k)]\dot{\varphi}k \quad (13)$$

Argument of radius evaluation of the second harmonic:

$$\partial rk = Crs * \sin(2\varphi k) + Crc * \cos(2\varphi k) \quad (14)$$

$$\partial \dot{r}k = 2[Crs * \cos(2\varphi k) - Crc * \sin(2\varphi k)]\ \dot{\varphi}k \quad (15)$$

Argument of inclination evaluation of the second harmonic:

$$\partial ik = Cis * \sin(2\varphi k) + Cic * \cos(2\varphi k) \quad (16)$$

$$\partial \dot{\imath}k = 2[Cis * \cos(2\varphi k) - Cic * \sin(2\varphi k)]\ \dot{\varphi}k \quad (17)$$

Corrected argument of latitude:

$$uk = \varphi k + \partial uk \quad (18)$$

$$\dot{u}k = \dot{\varphi}k + \partial \dot{u}k \quad (19)$$

Corrected argument of radius:

$$rk = A(1\text{-}ecosEk) + \partial rk \quad (20)$$

$$\dot{r}k = Ae\sin Ek\ \dot{Ek} + \partial \dot{r}k \quad (21)$$

Corrected argument of inclination:

$$ik = i0 + ((IDOT) * tk) + \partial ik \quad (22)$$

$$\dot{\imath}k = IDOT + \partial \dot{\imath}k \quad (23)$$

X satellite coordinate of satellite orbital plane:

$$\acute{x}k = rk\cos uk \quad (24)$$

$$\dot{x}k = (\dot{r}k\cos uk - rk\sin uk)\ \dot{u}k \quad (25)$$

Y satellite coordinate of satellite orbital plane:

$$\acute{y}k = rk\sin uk \quad (26)$$

$$\dot{y}k = (\dot{r}k\sin uk + rk\cos uk)\ \dot{u}k \quad (27)$$

Corrected longitude of ascending node:

$$\Omega k = \Omega 0 + (\dot{\Omega} - \dot{\Omega}e)\ tk - \dot{\Omega}e\ toe \quad (28)$$

$$\dot{\Omega}k = \dot{\Omega} - \dot{\Omega}e \quad (29)$$

X coordinate in ECEF Frame:

$$xk = \acute{x}k * \cos\Omega k - \acute{y}k * \cos ik * \sin\Omega k \quad (30)$$

X coordinate in ECEF Frame:

$$yk = \acute{x}k * \sin\Omega k + \acute{y}k * \cos ik * \cos\Omega k \quad (31)$$

X coordinate in ECEF Frame:

$$zk = \acute{x}k * \sin ik \quad (32)$$

From the above set of equations, we get XYZ coordinates of GPS satellite which depends on universal gravitational parameter of earth's rotation rate. According to WGS-84 model the values are:

$$\mu = 3.986005 \times 10^{14}\ m^3/s^2 \quad (33)$$

$$\dot{\Omega}e = 7.292115167 \times 10^{-5}\ rad/s \quad (34)$$

The XYZ coordinates obtained with respect to ECEF (Earth Centered and Earth Fixed) coordinate system are then plotted in two dimensions by using MATLAB tool.

IV. VISUALIZATION OF SATELLITE ORBIT PATH

The XYZ coordinates obtained in ECEF system by implementing the formulas in MATLAB and plotting the two dimensional plot with the help of MATLAB where y-axis represents data or value of GPS satellite and x-axis represents time at which GPS satellite was present or visible.

The below figure shows the two-dimensional plot of XYZ coordinates of GPS satellites.

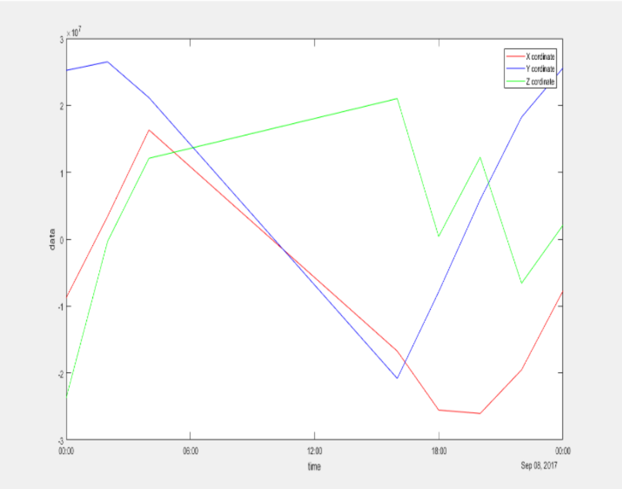

Figure 3. Visualization of path of GPS satellite.

IV. CONCLUSION

The present work focuses on finding the position, velocity and time of the GPS receiver with user by the process of Trilateration, where we use three satellites to identify user location anywhere on globe. To find the orbital path of GPS satellite we extracted some parameters from GPS navigation data file and compared with RINEX File. These parameters are then implemented in formulas by using MATLAB and XYZ coordinates in ECEF system are obtained and a 2-dimensional plot. In future it can be interpolated to make it smooth curve by increasing the number of samples and to convert the 2-dimensional plot into 3-dimensional plot.

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