Design of Combination Model Based on Pseudo-Range

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Abstract: The GPS/GLONASS dual navigation system increases the number of visible satellites(there are at least 9 satellites visible, or an average of 14, up more than 20 anywhere in the world), and make the geometry graphics of the satellite better, then improve the positioning accuracy and satellite navigation capabilities. Therefore, The GPS/GLONASS integrated positioning will have a broad application prospects.

Keyword: Integrated-Positioning; Satellite Selection Algorithm; Least Squares Algorithm.

1. Introduction

The so-called GPS/GLONASS Integrated technologies, that is to use a receiver to receive and measure both GPS and GLONASS of two satellite signals, providing users the performance that only GPS receiver or GLONASS receiver can not get, in order to accurately measure the three-dimensional position, three-dimensional velocity, time and attitude parameters anywhere and any time in the world.

This paper describes the principle and mathematical model of the GPS and GLONASS single positioning system, on this basis proposes positioning mathematical models of Galileo/GPS integrating systems based on pseudo-range, and the calculation methods of the two coordinates based on this model, and compare the advantages and disadvantages of the two methods by simulation.

2. The Integrated Positioning Model of Dual System

GPS uses the location principle of time of arrival (TOA) to determine the position of users. This principle need to measure the time of signals that from satellites of known position to the receiver underground, then the propagation time of the signal multiplied by the signal speed (the speed of light), that will be the distance from the satellite to the receiver(As it contains such a distance produced by the amount of the corresponding deviations of the time difference between the local clock and system clock, which is called the "pseudo", and expressed by ρ).The receiver measure the propagation time of several signals that broadcast by satellites whose location is known, and then determine their position.

According to the conditions above, we can establish the basic mathematical equations that determining the position of satellite as follows:

$$\rho_j = \sqrt{(x_j - x_u)^2 + (y_j - y_u)^2 + (z_j - z_u)^2} + c \cdot t_u$$

And:

(xj ,yj , zj) is the coordinates of satellite whose position is known.

(xu ,yu , zu) is the coordinates of receiver that is unknown.

tu is the system-deviation of the clock in the receiver that is unknown.

ρj is the distance between satellite and receiver.

The geometric significance of pseudo-range equation is: As a visible satellite to be the globe, and the geometric distance from satellite to receiver to the radius for spherical. The local receiver must be in the sphere, As shown by figure 1. Similarly, the receiver will also be in the sphere of another 3 satellites. The intersection of spherical of four satellites is the position of the receiver on the ground.

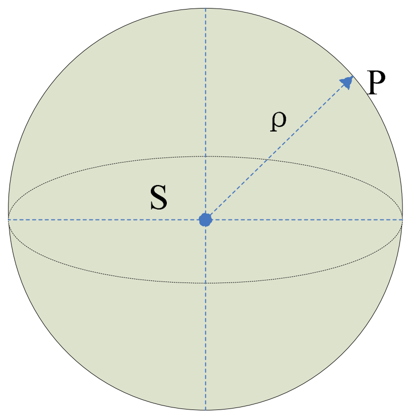

Figure 1. The Geometric Model of Single Satellite

In the equation above, there are four unknowns all needing to be solved. Therefore, in a GPS or GLONASS single system-receiver, it requires a minimum of signals of four satellites to measure the information of the location of the user. However, in the GNSS integrated receiver, as there is the difference which is unknown between the two systems, so it also needs one more satellite to participate in positioning, then solving for the unknowns. Therefore, we at least need five satellites to fitting 5 simultaneous equations in the GNSS integrated receiver, the user's location can be measured.

3. Position Calculation Methods

Usually, the dual integrated system makes the number of visible s positioning satellites double, and the number of satellites can be used will be more than five generally, so there will be more than 5 pseudo-range equation available, but solving the navigation solution requires only five pseudo-range equations. Here, this paper proposes two kinds of processing algorithms:

3.1. Satellite Selection Algorithm

When the ranging error is certain, the geometry graphics between five satellites involving in positioning and user will directly affect the location error. Using satellite selection algorithm can help to select five satellites which are in good positioning condition from the visible satellites. In positioning, the accuracy of single-point positioning is related to the size of the GDOP.

Therefore, when the accuracy of pseudo-range observation is certain, the reduction of number of the accuracy factor is an important way to improve the positioning accuracy.

Under normal circumstances, when the angle from receiver to every satellite observed is large, the GDOP value is small, or when the volume of the polyhedron constituted by receiver and satellites is the largest, the GDOP value is minimum. When the volume of the polyhedron constituted by the selected five satellites reaches maximum, we can get the minimal geometric dilution of precision (GDOP). But this method needs to know the approximate location of the site.

The specific steps of Satellite selection algorithm is following:

1). First select the largest satellite elevation as the first satellite.

2). Select the second satellite, the vector angle between which and the first satellite is close to 109 degrees.

3). Use the volume of polyhedral maximizing to be the vector-side constraints to choose the third satellite.

4). Select another two satellites from the rest satellites, calculate the volume of polyhedron, and select the largest volume of that group to establish satellite to solve equations.

3.2. Least Squares Algorithm

When the multi-channel receiver can track to more than five or more satellites, and the number of equation observed is more than the number of unknown parameters to be solved, we can use mathematical methods to fit the more than five pseudo-range equations as five to solve.

The linear matrix pseudo-range equation is:

$$G\Delta x = \Delta\rho$$

Δx is the linear vector offset of the value of the user location and the time-deviation, $\Delta\rho$ is the vector difference between the pseudo-range value associated with location of the user and the pseudo-range value associated with the linear points. The value of $\Delta\rho$ has component the number of N . N is the number of the satellites visible (N>5). G is a matrix of N×5.

When the N is bigger than 5, that means the number of the equation is greater than the number of unknowns. Generally speaking, this kind of equations is invalid, because the error of the value of $\Delta\rho$ will make any value of the Δx be not the exact solutions to the equations. At this time, we can use least squares algorithm to obtain position of the user and the valuation of time offset. Therefore, The essence of this method is to make the square of the residual value of the Δx smallest. Denote the square of the residual as RSE, so:

$$R_{SE}(\Delta x) = (G\Delta x - \Delta\rho)^2$$

After expanding, at last we get:

$$\Delta x = (G^{T}G)^{-1}G^{T}\Delta\rho$$

When is Nonsingular, it has a unique solution.

The specific steps and process are shown as follows:

1). First fit an initial positioning coordinates according to all the satellite coordinates information.

2). Fill the classic undifferentiated position matrix with it.

3). Calculate the pseudo-range residuals, and determine whether it diverges.

4). Do least-squares estimated computation to the matrix of the equations and iterate for 5 times.

3.3. Comparison of Experimental Simulation

In order to compare the merits of the two methods to position resolution, we conducted following experiment:

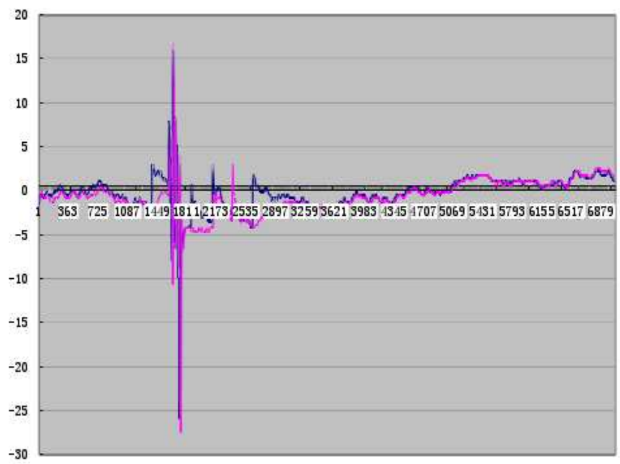

Figure 2. The Comparison of the two methods

At the same time, in the location of known geodetic coordinates, we used the two methods above to solve the position in two GNSS receivers, and set the positioning frequency as 1 HZ. After 10 hours of continuous point pagers, analyzing the position error of the two ways by the positioning data recorded, and we got the position error shown in Figure 2.

4. Summary

Through the data errors above, we can see that when using the satellite selection algorithm and the least squares algorithm to locate, the difference of the last positioning error of the two methods is not so large. But, when the positioning frequency of the receiver increased (the positioning frequency is increased to 51 HZ in the test), the receiver using satellite selection algorithm can not run normally, as its large computation make it can not calculate regularly. But the receiver using the least squares algorithm still works normally. When in the vector of the high-speed operation, also means under the conditions of high dynamic, it often requires the navigation equipment to work in the location frequency of 50HZ or higher, otherwise the carrier is not likely to fly on the intended flight path. Therefore, in engineering applications, we recommend to use the least squares algorithm with smaller computation and high solving high-frequency.

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