

The Research of Dynamic Tracking Algorithm Based on Hybrid Positioning System

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Abstract In signal-degraded environments such as dense urban area and indoor environment, GPS (Global Positioning System) signals are either blocked or strongly degraded by natural and artificial obstacles, which cannot meet the surging demands for position information, the combination of different GNSS (Global Navigation Satellite System) could be a suitable approach to fill this gap. This paper presents a hybrid positioning method combining GPS and GLONASS, simulation results show that Extended Kalman Filter Algorithm is an effective method to deal with data fusion in hybrid positioning system, so this system can improve the positioning accuracy in the environment without enough GPS satellites.

Keywords GPS • GLONASS • Integrated navigation • Extended Kalman filter

1 Introduction

GPS is used for wide variety of scientific applications, but it cannot locate successfully in dense urban areas and mountainous areas [1], therefore, the standalone GPS isn't able to provide an accurate and continuous absolute positioning, a possible approach to solving this problem is to consider the combining positioning system.

GNSS are worldwide, all-weather navigation systems, which are able to provide three-dimensional positioning [2], velocity and time synchronization. Currently, with the development of GNSS, the number of global navigation satellites in view can be greatly increased in the same epoch moment, multi-constellation navigation system will improve navigation accuracy, integrity and reliability. The present GNSS are GPS, GLONASS, Galileo and Compass [3], but the latter two are still

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in the development phase. As of 24 January 2012, a total of 31 GLONASS satellites [4] are in orbit.

Now that GLONASS has reached its full constellation [5], and it's the positioning standard of Russian. This paper presents hybrid location method combining GLONASS and GPS to achieve accurate positioning, making up for the defects of GPS signals substantially lose accuracy and availability in dense urban areas and indoors. This method improves positioning precision and availability.

2 Hybrid Positioning System Model

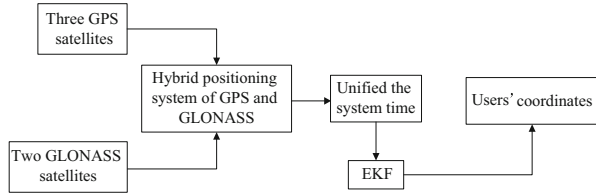
An integrated GNSS system based on GPS and GLONASS, provides a significantly increased satellite availability [5], the model of GPS/ GLONASS hybrid positioning system can be expressed in Fig. 1.

The GNSS are considered quite similar to each other, but they also present several significant differences [6], the main difference is time scale adopted by system, therefore, when GPS and GLONASS are used together, an additional unknown must be estimated, there will be 5 unknown parameters at each epoch, then by analyzing the pseudo-range observation equations, the true distances between a receiver and a satellite can be expressed as:

$$\begin{cases} \rho_{GPS1} = \sqrt{(x_1 - x_u)^2 + (y_1 - y_u)^2 + (z_1 - z_u)^2} + c \cdot t_{GPS} \\ \rho_{GPS2} = \sqrt{(x_2 - x_u)^2 + (y_2 - y_u)^2 + (z_2 - z_u)^2} + c \cdot t_{GPS} \\ \rho_{GPS3} = \sqrt{(x_3 - x_u)^2 + (y_3 - y_u)^2 + (z_3 - z_u)^2} + c \cdot t_{GPS} \\ \rho_{GLOASS1} = \sqrt{(x_{a1} - x_u)^2 + (y_{a1} - y_u)^2 + (z_{a1} - z_u)^2} + c \cdot (t_{GLONASS} - t_{GPS}) \\ \rho_{GLONASS1} = \sqrt{(x_{a2} - x_u)^2 + (y_{a2} - y_u)^2 + (z_{a2} - z_u)^2} + c \cdot (t_{GLONASS} - t_{GPS}) \end{cases} \quad (1)$$

Where ρ_{GPSi} is the pseudo-range of GPS satellite, $\rho_{GLONASSi}$ is the pseudo-range of GLONASS satellite, (x_i, y_i, z_i) is the coordinate parameters of GPS satellite, (x_{ai}, y_{ai}, z_{ai}) is the coordinate parameters of GLONASS satellite, $t_{GLONASS}$ is the GLONASS time, (x_u, y_u, z_u) is the position of object, t_{GPS} is the GPS time, C is the speed of light.

Fig. 1 The location schematic of double constellation



3 Integration Positioning Algorithm

Because of the nonlinear equation with GPS and GLONASS pseudo-range observation model, we need to use Extended Kalman Filter (EKF) algorithm to estimate location information.

3.1 Establishment State Equation

This paper considers two dimensional case, uses Uniform motion model in the x direction, and Singer model in the y direction, the process of discretization of the state vector [7] can be described as the following:

$$X_k = [x(k), x_o(k), y(k), y_o(k), y_{oo}(k)]^T \tag{2}$$

Where $x(k), x_o(k)$ denotes the position and the speed of the goal in x direction separately, $y(k), y_o(k), y_{oo}(k)$ denotes the position, the speed and the acceleration of the goal in y direction separately.

The process of target state equation can be defined as:

$$X_k = AX_{k-1} + W_{k-1} \tag{3}$$

The transition matrix is given as:

$$A = \begin{bmatrix} 1 & T & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & T & (\alpha T - 1 + e^{-\alpha T})/\alpha^2 \\ 0 & 0 & 0 & 1 & (1 - e^{-\alpha T})/\alpha \\ 0 & 0 & 0 & 0 & e^{-\alpha T} \end{bmatrix} \tag{4}$$

The covariance matrix of the state noise is represented as:

$$\mathbf{Q} = E[W_k W_k^T] = 2\alpha\sigma_m^2 \begin{bmatrix} T^3/3 & T^2/2 & 0 & 0 & 0 \\ T^2/2 & T & 0 & 0 & 0 \\ 0 & 0 & q_{11} & q_{12} & q_{13} \\ 0 & 0 & q_{21} & q_{22} & q_{23} \\ 0 & 0 & q_{31} & q_{32} & q_{33} \end{bmatrix} \quad (5)$$

Where

$$\begin{aligned} q_{11} &= \frac{1}{2\alpha^5} \left(1 - e^{-2\alpha T} + 2\alpha T + \frac{2\alpha^3 T^3}{3} - 2\alpha^2 T^2 - 4\alpha T e^{-\alpha T} \right) \\ q_{12} = q_{21} &= \frac{1}{2\alpha^4} \left(e^{-2\alpha T} + 1 - 2e^{-\alpha T} + 2\alpha T e^{-\alpha T} - 2\alpha T + \alpha^2 T^2 \right) \\ q_{13} = q_{31} &= \frac{1}{2\alpha^3} \left(1 - e^{-2\alpha T} - 2\alpha T e^{-\alpha T} \right) \\ q_{22} &= \frac{1}{2\alpha^3} \left(4e^{-\alpha T} - 3 - e^{-2\alpha T} + 2\alpha T \right) \\ q_{23} = q_{32} &= \frac{1}{2\alpha^2} \left(e^{-2\alpha T} + 1 - 2e^{-\alpha T} \right) \\ q_{33} &= \frac{1}{2\alpha} \left(1 - e^{-2\alpha T} \right) \end{aligned}$$

Where α denotes motor frequency, T denotes Sampling time interval, σ_m^2 denotes acceleration variance of the goal.

3.2 Establishment Observation Equation

The observation equation with GPS and GLONASS can be defined [8] as:

$$\mathbf{Y}_k = h(\mathbf{X}_k, k) + \mathbf{V}_k \quad (6)$$

Where \mathbf{Y}_k denotes the pseudo-orange measurements value of satellites, \mathbf{V}_k denotes the observation noise, $h(\mathbf{X}_k, k)$ denotes the observation matrix.

$h(\mathbf{X}_k, k)$ is nonlinear function, the EKF algorithm is represented as follows:

$$\hat{\mathbf{X}}_{k/k-1} = \mathbf{A}\hat{\mathbf{X}}_{k-1} \quad (7)$$

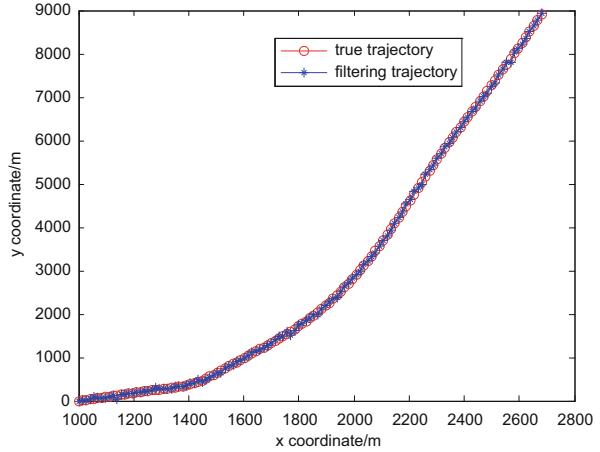
$$\mathbf{P}_{k/k-1} = \mathbf{A}\mathbf{P}_{k-1}\mathbf{A}^T + \mathbf{Q} \quad (8)$$

$$\mathbf{K}_k = \mathbf{P}_{k/k-1}\mathbf{H}_k^T (\mathbf{H}_k\mathbf{P}_{k/k-1}\mathbf{H}_k^T + \mathbf{R}_k)^{-1} \quad (9)$$

$$\hat{\mathbf{X}}_k = \hat{\mathbf{X}}_{k/k-1} + \mathbf{K}_k [\mathbf{Y}_k - h(\hat{\mathbf{X}}_{k/k-1}, k)] \quad (10)$$

$$\mathbf{P}_k = (\mathbf{I} - \mathbf{K}_k\mathbf{H}_k)\mathbf{P}_{k/k-1} \quad (11)$$

Fig. 2 Tracking trajectory



4 Simulation

In order to compare the precision of combined GPS/GLONASS positioning system, the estimator is implemented by Extended Kalman Filter, which is extensively used to integrated system. We choose a test area covered by 3 GPS satellites and 2 GLONASS satellites.

In the test process, assuming the initial clock deviation of GPS and GLONASS is known, the initial position is (1,000, 0), the initial velocity of x direction is 13 m/s, the initial velocity of y direction is 12 m/s, the initial acceleration velocity of y direction is 0, the acceleration variance in movement is 3.8, the motor frequency is 0.1, observations time interval is 1 s, a total of 120 s.

We adopt EKF algorithm to track the target trajectory, assuming the observation error of GPS obey Gaussian distribution by mean to 0, standard deviation to 5 m. Also, assuming the observation error of GLONASS obey Gaussian distribution by mean to 0, standard deviation to 25 m. Simulation results are shown in Figs. 2, 3, 4, 5, and 6.

Figure 3 shows the positioning tracking trajectory result in x direction. Figure 4 shows the positioning tracking trajectory result in y direction. We can found that simulation trajectory is consistent with true trajectory.

Figures 5 and 6 shows that the pseudo-range measurement error result. We can found that pseudo-range positioning has the precision of 20 m, which can meet the demands for position information.

Fig. 3 Tracking trajectory of x direction

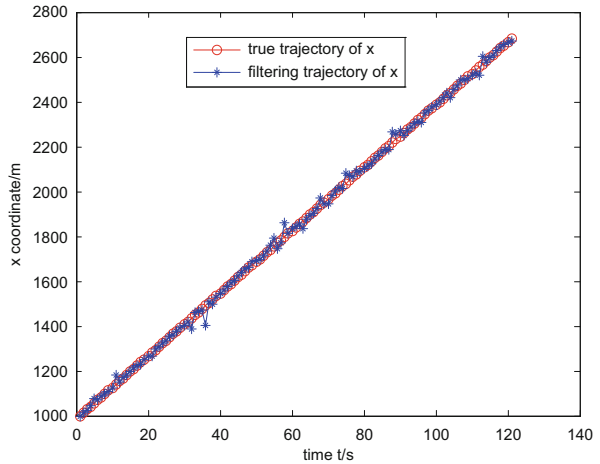
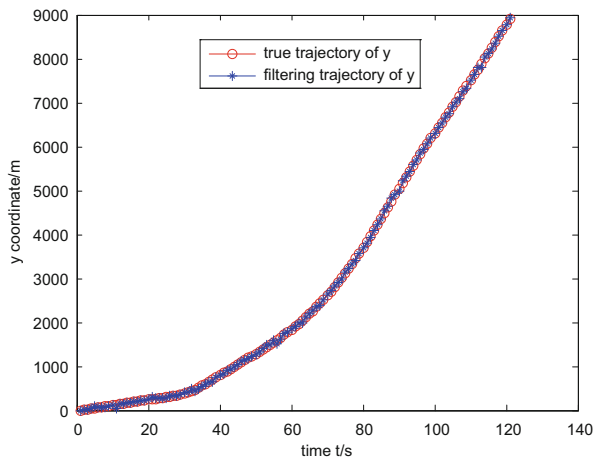


Fig. 4 Tracking trajectory of y direction



5 Conclusion

Based on the research results presented in this paper, the hybrid positioning technology based on GPS/GLONASS is effective, the integrated system not only to improve accuracy of positioning, but also to make up for the defects when the number of GPS satellites are not enough in dense urban areas and indoors. A data fusion algorithm based on EKF is designed for GPS/GLONASS hybrid positioning. Through our theoretical analysis and simulation verification, this EKF algorithm can improve the performance of hybrid navigation system, simulation filtering trajectory is consistent with true trajectory basically. The experimental results verify that the combined GPS/GLONASS navigation positioning have great applications for navigation users, especially in limited satellite conditions.

Fig. 5 Positioning error in x direction

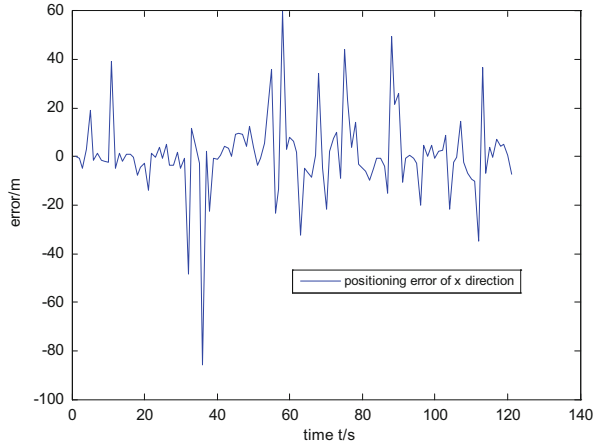
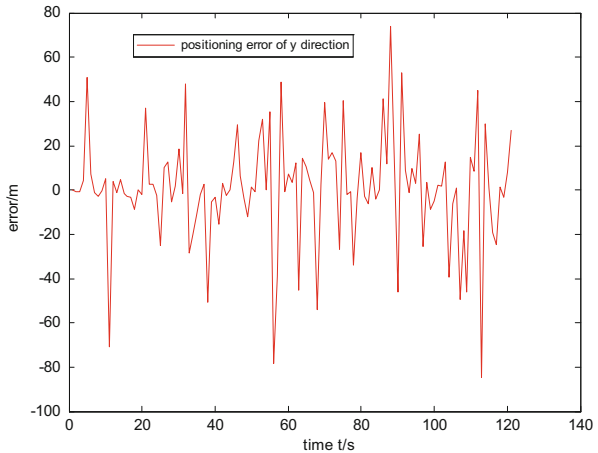


Fig. 6 Positioning error in y direction



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