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Application of Combined Positioning Algorithm of Volume Image Sequence on Mapping of Large Scale Topographical Map

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Abstract

In order to give full play to ability of existing devices, the combined positioning algorithm of volume image sequence is proposed, which is applied in large scale topographical map. Firstly, the observation equations of observable image sequence are analyzed, and the five different coordinates relating with space 3D coordinate of object can be calculated. Secondly, the combining positioning algorithm based the characteristics of hyperbolic curve and Kalman filter is put forward and the corresponding mathematical model is constructed. Finally, the dynamic measured data of a highway is used as basis, the corresponding simulation analysis is carried out, and results show that the new combined positioning algorithm can improve the precision of mobile measurement system effectively.

Keywords*: combined positioning algorithm; large scale topographical map; volume image sequence*

1. Introduction

Over almost three decades, the mobile measurement technology with multi sensor integration taking dynamic, close range photogrammetry without control. This kind of measurement technology integrates charge coupled device camera, inertial measurement unit sensor, and global position system positioning device, which can measure the 3D coordinate of object quickly, the core of mobile measurement is to apply charge coupled device camera to obtain close range stereo measurable image, however when the coordinate of object is calculated under no underground control point, the higher position of camera and attitude data are needed, therefore, the current position and attitude can be measured based on the inertial measurement unit sensor and global position system fixed on the carrier. The elements of exterior orientation for every charge coupled device camera can be calculated according to the relative position relationship between the camera and carrier, then the 3D coordinate of object can be calculated based on forward intersection of photo topography, from here we see that quick measurement precision of 3D coordinate for object can be achieved based on mobile measurement system without control can be decided by position and attitude precision. The combination between inertial measurement unit sensor and global position system can offer the necessary position and attitude for close range photogrammetry [1].

In practical application the integrated navigation of mobile measurement system exists the following problems: single use of global positioning system can not ensure the continuity o position because the occlusion and interference of signal. When the inertial measurement unit sensor positions independently, the positioning accuracy can not be ensured because of drift and error accumulation. All information in mobile measurement system can be applied sufficiently in positioning measurement. In order to give full play to ability of existing devices, and the combined positioning algorithm based on charge coupled device camera, inertial measurement unit sensor, and global position system [2].

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2. Observation Equations of Observable Image Sequence

In mobile measurement system, the inertial measurement unit sensor and global position system can obtain position and attitude measurement parameters in form of geodetic coordinates. The projection of ground target point on observable image can be denoted by the left and right coordinate system. In order to be benefit for description and understanding, and simply computing complexity, when the space coordinate of object points is calculated based on object point image coordinate, the station coordinate system should be used as the transition, therefore the five different coordinates relating with space 3D coordinate of object can be calculated according to picture pointed coordinate of ground target on measurable image tablets, which are the right angle coordinate system, the left side coordinate system, the right side coordinate system, the left image coordinate system and the right coordinate system.

When the focal length, image center coordinate, camera coordinate, attitude angle and scale factor of charge coupled device camera are known, the 3D coordinate of object target A can be calculated based on stereoscopic image by the following expressions [3]:

$$X_T = \lambda R_M X_M + X_0 \tag{1}$$

$$X_T = \lambda' R'_M X'_M + X'_0 \tag{2}$$

$$X_M = R_p X_p \tag{3}$$

$$X'_M = R'_p X'_p \tag{4}$$

where, $X_T = (x_T, y_T, z_T)^T$, $X_0 = (x_0, y_0, z_0)^T$, $X'_0 = (x'_0, y'_0, z'_0)^T$ are the coordinate column vectors of ground point A, left and right charge coupled device camera in rectangular coordinate system. $X_M = (x_m, y_m, z_m)^T$, $X'_M = (x'_m, y'_m, z'_m)^T$ are relative coordinate column vector of point A in station coordinate. $X_p = (x_p, y_p, -f)^T$, $X'_p = (x'_p, y'_p, -f')^T$ are the coordinate column vector of imaging point A left and right coordinate. R_p and R'_p are transition matrixes between left, right photogrammetric coordinates and station coordinate, the parameters of matrix are given based on previous standard check, which have higher precision. R_M and R'_M are the rotating matrixes between left, right photogrammetric coordinates and geodetic coordinate, which can be decided by path angle α, pitch angle ω and roll angle κ. λ and λ' are length proportion factors of image and station coordinates.

$$\lambda = \frac{B_x z'_m - B_y x'_m}{x_m z'_m - x'_m z_m} \tag{5}$$

$$\lambda' = \frac{B_x z_m - B_z x_m}{x_m z'_m - x'_m z_m} \tag{6}$$

where, B_x, B_y, and B_z are the projection in X, Y, and Z directional projection of base lines of two cameras on the left station coordinate.

If X axis and base line of left and right station coordinate system has the mutual coincidence, then $B_x = B$, $B_x = B_y = 0$, then the following expressions can be obtained:

$$\lambda = \frac{Bz_m^{'}}{x_m z_m^{'} - x_m^{'} z_m} \quad (5)$$

$$\lambda^{'} = \frac{B_x z_m}{x_m z_m^{'} - x_m^{'} z_m} \quad (6)$$

3. Combined Positioning Algorithm

The positioning algorithm applies the characteristics of hyperbolic curve, and the corresponding positioning model is shown in Figure 1.

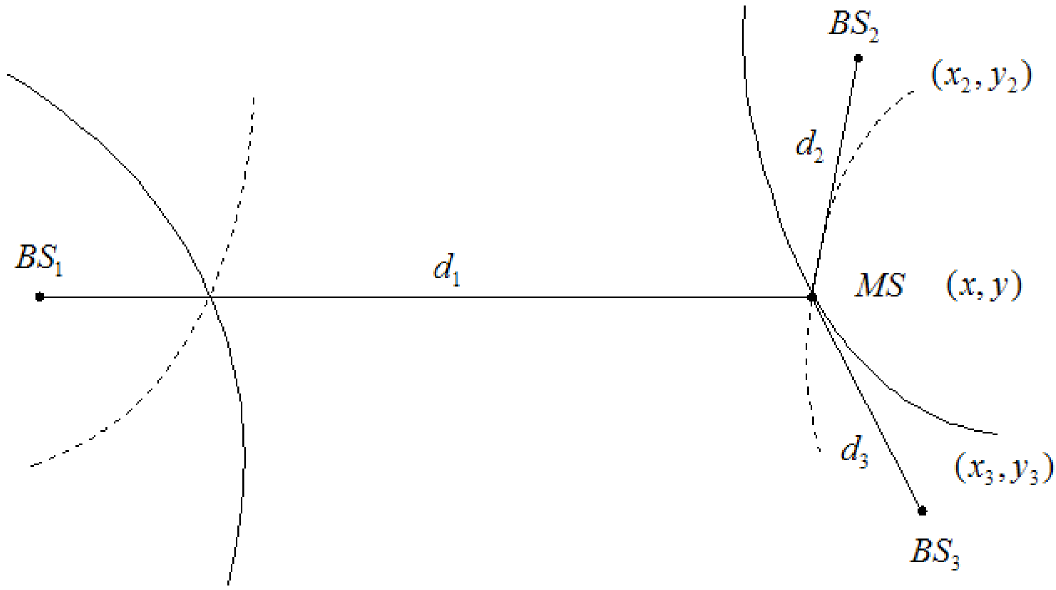

Figure 1 .Combined Positioning Model of Volume Image Sequence

The measurement equation of combined positioning model is expressed as follows [4]:

$$d_i = \sqrt{(x_i - x)^2 + (y_i - y)^2} \quad (7)$$

$$d_{i,1} = d_i - d_1 \quad (8)$$

$$d_i - d_1 = \sqrt{(x_i - x)^2 - (y_i - y)^2} - \sqrt{(x_1 - x)^2 - (y_1 - y)^2} \quad (9)$$

where $K_i = x_i^2 - y_i^2$, $d_{i,1}$ denotes the distance difference between MS and BS_i, BS_1, then the following expression can be obtained:

$$d_{i,1} = c\tau_{i,1} = d_i - d_1 \quad (10)$$

where c denotes light propagation velocity, $\tau_{i,1}$ denotes the measurement value.

In order to solve the nonlinear equation group, the linearization processing is carried out firstly, and the corresponding expression is listed as follows [5]:

$$d_i^2 = (d_{i,1} + d_1)^2 \quad (11)$$

After consolidation and simplification, the following expression can be obtained:

$$x_{i,1}x+y_{i,1}y+d_{i,1}d_1=\frac{1}{2}(K_i-K_1-d_{i,1}^2) \quad (12)$$

x, y and d_1 can be considered as the unknown number, the expression (12) can be transferred to the linear equation group, then the position coordinate of MS can be obtained through solving the equation group.

The Kalman filter is applied in processing distance value between base stations BS_i and MS, the corresponding status and observation equations are defined by [6]:

$$X(k+1)=\Phi X(k)+\Gamma u(k) \quad (13)$$

$$Z(k)=HX(k)+v(k) \quad (14)$$

where $\Phi=\begin{bmatrix}1 & T & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & T\\ 0 & 0 & 0 & 1\end{bmatrix}$, $\Gamma=\begin{bmatrix}0.5T^2 & 0\\ T & 0\\ 0 & 0.5T^2\\ 0 & T\end{bmatrix}$, $H=\begin{bmatrix}1 & 0\\ T & 0\\ 0 & 1\\ 0 & 0\end{bmatrix}^T$, $X=\begin{bmatrix}x\\ \dot{x}\\ y\\ \dot{y}\end{bmatrix}^T$, $Z=\begin{bmatrix}x\\ y\end{bmatrix}$.

u and v are processing noise and observing noise of zero mean value, T denotes the sampling period.

The one step prediction equation of Kalman filter algorithm of status evaluation is expressed as follows:

$$\tilde{X}(k+1|k)\cong X(k+1)-\hat{X}(k+1|k)=\Phi(k)\tilde{X}(k|k)+G(k)W(k) \quad (15)$$

The co variation equation of one step prediction can be expressed as follows:

$$P(k+1|k)\cong E[\hat{X}(k+1|k)|Z^k]=\Phi(k)P(k|k)\Phi^T(k)+G(k)Q(k)G^T(k) \quad (16)$$

The observation vector of prediction can also be obtained as follows:

$$\tilde{Z}(k+1|k)=H(k+1|k)\tilde{X}(k+1|k) \quad (17)$$

The prediction error of observation vector can be expressed as follows [7]:

$$\varepsilon(k+1)=Z(k+1)-\hat{Z}(k+1|k)=Z(k+1)-H(k+1)\hat{X}(k+1|k) \quad (18)$$

The co variation between the prediction and observation error can be expressed as follows:

$$S(k+1)=E[\hat{Z}(k+1|k)\hat{Z}^T(k+1|k)|Z^k]=H(k+1)P(k+1|k)H^T(k+1)+R(k+1) \quad (19)$$

The gain of Kalman filter can be obtained as follows [8]:

$$K(k+1)=P(k+1|k)H^T(k+1)S^{-1}(k+1)=P(k+1|k)\frac{H^T(k+1)}{H(k+1)P(k+1|k)H^T(k+1)+R(k+1)} \quad (20)$$

The status updating equation of Kalman filter algorithm can be expressed as follows:

$$\widehat{X}(k+1|k+1) = \widehat{X}(k+1|k) + K(k+1)\varepsilon(k+1) \quad (21)$$

4. Case Study

In order to verify the correctness of combined positioning algorithm, the dynamic measured data of a highway is used as basis, the procession of obtaining data is listed as follows:

(1) The data collection vehicle fixes two charge coupled device cameras at same time, and a measurement global position system receiver, a set of inertial measurement unit sensor and a set of time synchronization device, a same type global position system receiver is fixed on the base station with known coordinate, which is used to difference computing.
(2) The inertial measurement unit sensor can offer the attitude parameter, and the precision is 0.5°.
(3) The charge coupled device camera is used to obtain the stereoscopic pair.
(4) The pre calibration is carried out for obtaining the coordinate projection function between global position system antenna and charge coupled device camera.
(5) The professional software is used in carrier phase difference positioning, and then the coordinate of station is calculated, which is considered as reference value.
(6) The C/A code information is used for single point filtering solution, and then the coordinate of station is calculated.
(7) The direct media interface image information is added, and then effectiveness of combined positioning algorithm can be verified.

The traditional surveying and mapping and the new method based on combined positioning algorithm are used respectively, and the corresponding results are obtained. The x axis error based on two methods is shown in Figure 2 and Figure 3 respectively.

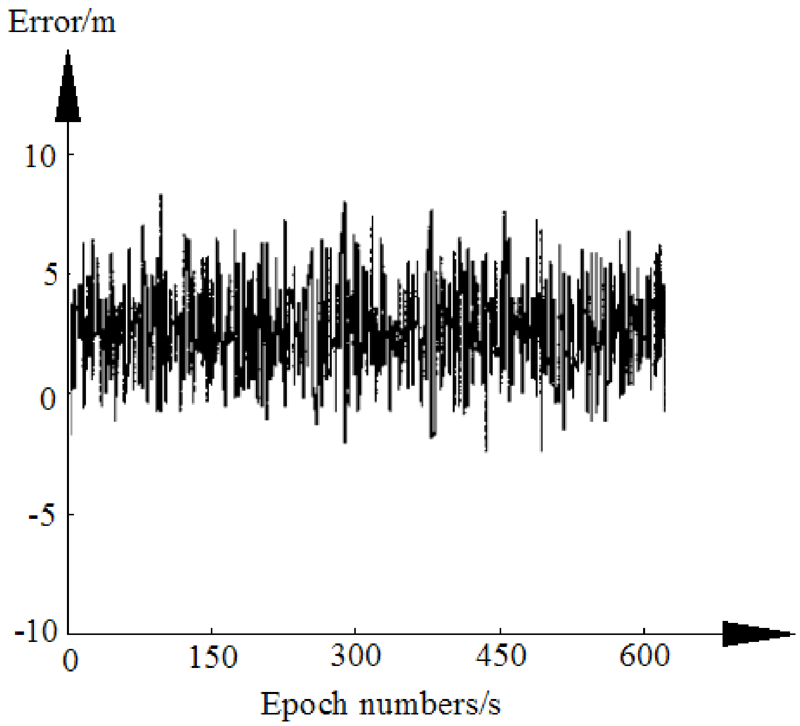

Figure 2. X axis Error based on Traditional Method

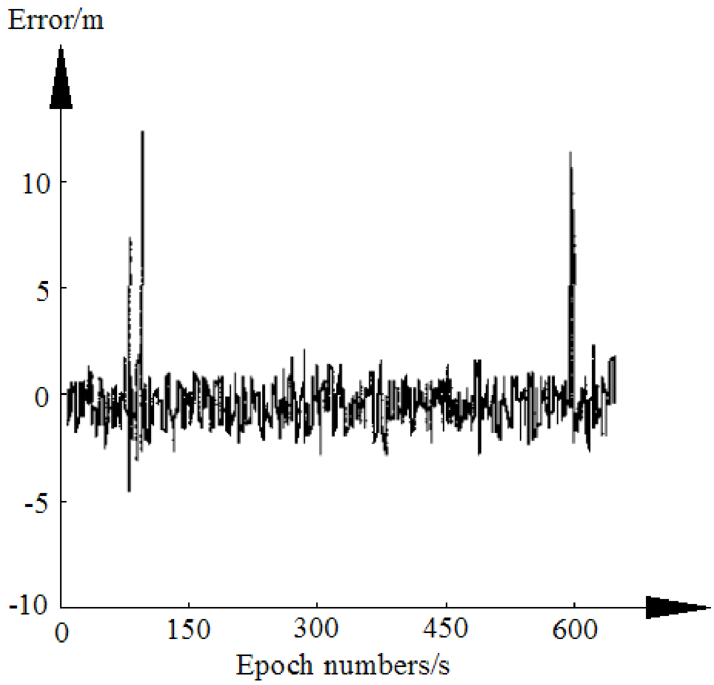

Figure 3. X Axis Error based on New Method

As seen from analysis results, the positioning error obtained from the new method based on combined positioning algorithm has higher positioning precision than that obtained from traditional method, the positioning reliability of large scale topographical map can be improved, which has stronger practice meaning, in addition, all kinds of data can be applied effectively. This method is better than traditional means based on the computing reuslts, which higher positioning precision.

5. Conclusions

The image based on volume image sequence can provide the positioning parameters of carrier, which can add a set of inertia positioning measurement device for mobile measurement system, then the positioning precision can be improved accordingly. And simulation results show the combined positioning algorithm is proposed for improving the precision of mobile measurement system, and the cost of system can not be improved. Therefore this method has wide application view.

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