International Journal of Multimedia and Ubiquitous Engineering
Vol.11, No.4 (2016), pp. 391-396
http://dx.doi.org/10.14257/ijmue.2016.11.4.39

The Study of Visual Measurement Based on GPS Navigation

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Abstract

GPS has its weaknesses in reality. This paper introduces vision measurement for the GPS system. Through feature detection, stereo matching, feature tracking and motion estimation to 3D drawings, GPS is able to get an accurate location and an estimation of direction with less error. Experiment has proved that vision measurement can be applied into navigation in the steep and rugged terrain. The improved GPS system is more accurate and can be put into practice in vaster areas.

Keywords*: GPS Navigation System, Binocular Stereo Vision, feature matching, feature tracking, motion estimation*

1. Introduction

Modern people rely more and more on GPS navigation. However, it has loop-holes, such as positioning error caused by signal attenuation due to building block and signal instability indoors and in some areas. Kalman filter algorithm, centralized Kalman filter algorithm or dispersed Kalman filter algorithm are some of the solutions to enhance the fault tolerance [1-4]. Deri L. and his team carried out an in-depth study of GPS navigation technology [5-7]. Triangulation could serve to high-precision positioning within a mobile communication network, but as base stations are required, the cost turns high and the coverage is limited [1]. Vision measurement which adopts cameras to get visible image information, is capable of high-precision positioning and covering a wide range of areas. And as camera is an alienable part of phone and digital camera, it is easier to be popularized. Therefore, there is a chance to apply vision measurement to GPS navigation system to provide better life for people and meet the demand of production [1].

This paper incorporates binocular stereo vision into the navigation system. Through feature detection, stereo matching, feature tracking and motion estimation to 3D drawings, GPS is able to get an accurate location and an estimation of direction with less error. Experiment has proved that vision measurement can be applied to navigation into navigation in the steep and rugged terrain. The improved GPS system is more accurate and can be put into practice in vaster areas.

2. Vision Measurement Method

Vision measurement is usually realized through feature tracking in image sequences with the help of single camera, stereo camera or omnidirectional camera. Stereo camera is the best choice because it provides 3D information of the vision. Thus, this paper bases itself on Binocular Stereo Vision.

Binocular Stereo Vision uses a pair of cameras to get the images and process image sequences so as to detect the accurate position and posture of the camera and the carrier. The technical process is described below:

At time t1, detect feature points of one 3D drawing. Implement the stereo matching and the 3D rebuilding to get a new group of feature points and three-

ISSN: 1975-0080 IJMUE

dimensional coordinates. At t2, repeat these steps to the photographed 3D drawing to get another feature points and three-dimensional coordinates. Through feature tracking algorithm, we can get the relationship between two groups of feature points and between feature points at t2 and three-dimensional coordinates at t1. Based on that, it is able to get accurate position and posture of the left (or the right) camera at t1 and t2 through RANSAC [9].

Feature points matching, including stereo matching and feature tracking in image sequences is the core of the technique, the accuracy of which has a say of latter estimation of positions and postures. Many efforts have been put to go deeper.

3. GPS Navigation Based on Vision Measurement

In the GPS system, the key of vision measurement is to follow the characteristics of the first pair of 3D drawings in the next pair. Through feature matching, how three-dimensional coordinates change is clear. Thus, we can know for sure the position and the posture of the object at t1 and t2. GPS vision measurement navigation includes feature detection, stereo matching, feature tracking, and motion estimation.

3.1 Feature Detection

Feature points detection complies with two principles: (a) obvious and clear, which contributes to stereo matching and feature tracking (b) evenly distributed and widely covered, which helps to reflect the overall condition of the object.

The first principle is easy to be achieved through Harris corner detection operator [10]. Add grids to the left image. Those points with outstanding characteristics in each grid can be selected as candidates. Then compare the candidates. If a feature point shows the most obvious characteristic among 9 grids (3 lines and 3 rows) where this point locates at the center, such point is the winner and the rest 8 are overlooked. Apply this process to all candidates. Thus, we can make sure that the selected feature point is at least from grid away from each other. Next, set up a threshold and delete those that fail to meet the threshold.

3.2 Stereo Matching

3.1 Manage to filter feature points at 2 dimensions. But the estimation requires us to find out 3D feature points. Therefore, stereo matching is needed to get the three-dimensional coordinates of corresponding scene points.

As feature points have obvious characteristics, stereo matching can cover a wide range of area to avoid any overlook. The search range can be expanded from one line to three lines. Calculate the best match point by multi-feature matching methods.

Cars are objects that don’t require much on the accuracy of the three-dimensional reconstruction. It is tolerable that the stereo matching cannot achieve sub-pixel accuracy. Two-dimensional coordinates of feature points and three-dimensional coordinates of corresponding scene points are used to estimate the motion of the car. Then we can use a three rows-three lines neighborhood in which the parabolic fits the maximum correlation value to get the parallax of sub-pixel.

3.3 Feature Tracking

When the car moved for a while, shot another pair of 3D drawings and find out the corresponding feature points in the new image. It takes several steps: (a) use the vehicle odometer and the posture measuring instrument to estimate the position and posture of the vehicle at the time before and after, so that we can know how the absolute coordinates change (fixedly connected with the vehicle); (b) based on that, calculate new coordinates of scene spots in the left image and estimate the corresponding coordinates in the next image. (c) according to the feature points after stereo matching in the left image, find out the exact corresponding points in the estimated coordinate region in the latter left image. And subject the left and the right image to stereo matching to get the three-dimensional coordinates of scene spots.

Figure 1. Part of the Samples

Given that we have had the three-dimensional coordinates of scene spots in the latter pair of drawings, we can deduce the coordinates in the right image. In the process of feature points tracking, three-dimensional coordinates of scene spots can describe the range of the points, which benefits feature tracking. Noticeably, there is only partial overlap of two left images, so feature point detected in the previous left image will not appear in the second one.

3.4 Motion Estimation

Theoretically speaking, if the three-dimensional coordinates of scene spots in the coordinate system are known, then we can use the least squares method to figure out the relative transformation of the two systems.

$$\begin{bmatrix} x_{2i} \\ y_{2i} \\ z_{2i} \end{bmatrix} = R \begin{bmatrix} x_{1i} \\ y_{1i} \\ z_{1i} \end{bmatrix} + T$$

This way is easy to achieve. But the accuracy is influenced by tracking error or matching error. Therefore, it is suggested to optimize the feature point set:

First, take the advantage of distribution of deviation before and after the transformation. Calculate the transformation matrix according to initial motion estimation or the feature point set. We can tie the feature points in the previous image to the next image and find out the deviation. Correct feature points with deviation are concentrated in a relatively small area (known as the central area), and error feature points deviate from the correct ones. The statistics provide the information of distribution of feature points deviation. Remove the error feature points that lie far from the center area so that the quality of feature point set is improved.

Next, continue the optimization by selecting feature point set randomly:

(i) Select a small feature point set. Use the least squares method to estimate the motion between two locations;

(ii) With the estimated motion of all feature points, project them from the previous left image to the next left image. If the deviation of the projection position from the real position is less than a certain value, then the feature point set is trusted and added with credit;

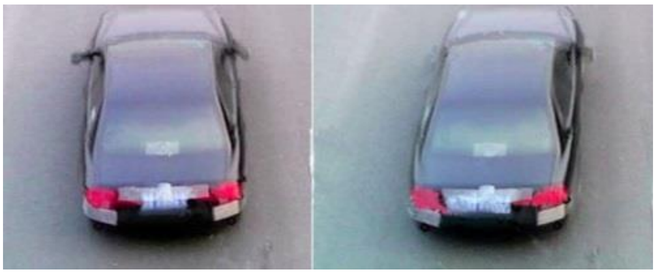
(iii) Repeat step (i) and (ii) until the motion with the highest credit is selected out.

This method relies on the corresponding scene spots in two images to learn about the change of position and posture. Therefore, an overlap is needed before the algorithm is valid. The overlapped part should be clear enough to provide feature points for motion estimation.

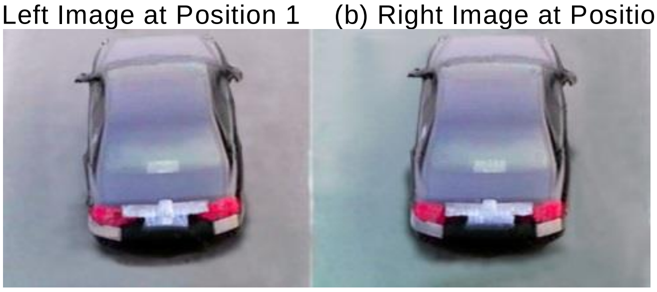
4. Experiment Result

Select 500 cars for vision measurement navigation experiment. Figure1 presents the details.

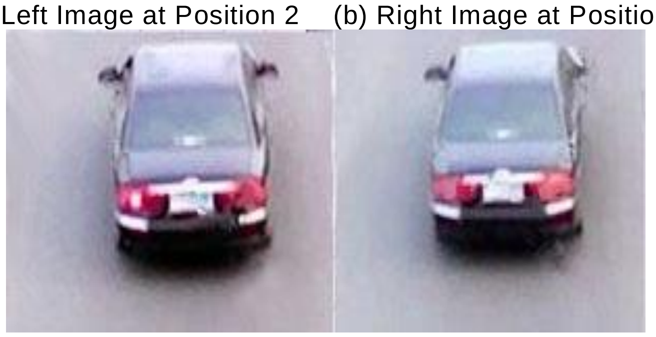
Shot a pair of pictures at t_1. Shot a pair 100m away at $t_2$and 200m away at t_3, as is shown in Figure2.



(a) Left Image at Position 1 (b) Right Image at Position 1



(a) Left Image at Position 2 (b) Right Image at Position 2



(a) Left Image at Position 3 (b) Right Image at Position 3

Figure 2. Three Stereo Pairs in Different Positions

(i)the 1st and 2nd frame

The experiment starts with two different initial conditions, as Table 1.

Table 1. Experiment Results 1 with the Visual Odometry Algorithm

parameter		θ(°)	φ(°)	ψ(°)	Tx(mm)	Ty(mm)	Tz(mm)
Accurate value		0	0	0	0	100	0
condition1	initial value	0	0	0	0	100	0
	computed value	0.03	0.13	-0.47	11.15	85.36	-2.19
condition2	initial value	2	0	-1	7	80	9
	computed value	0.03	-0.13	-0.47	11.15	85.36	-2.19

(ii) the 2nd and 3rd frame

The experiment starts with three different initial conditions, as Table 2.

Table 2. Experiment Results 2 with the Visual Odometry Algorithm

parameter		θ(°)	φ(°)	ψ(°)	Tx(mm)	Ty(mm)	Tz(mm)
accurate value		0	0	0	0	100	0
condition 1	initial value	0	0	0	0	100	0
	computed value	0.43	0.80	-0.80	-4.55	87.16	-15.49
condition 2	initial value	1	1	-2	8	120	12
	computed value	0.81	1.33	-0.43	-22.08	97.22	-15.22

(iii) the 1st and 3rd frame

Table 3. The Experiment Starts with Two Different Initial Conditions

parameter		θ(°)	φ(°)	ψ(°)	Tx(mm)	Ty(mm)	Tz(mm)
accurate value		0	0	0	0	200	0
condition 1	initial value	0	0	0	0	200	0
	computed value	0.65	0.73	-1.05	4.41	180.48	-12.94
condition 2	initial value	1	-2	-1	10	180	3
	computed value	0.65	0.73	-1.05	4.41	180.48	-12.94

From the above three positions, it is clear that vision measurement makes it possible to find out accurate position and posture even though the distance has changed. Vision measurement can tolerate large initial estimation and be applied to navigation for steep and rugged terrain. Besides accurate 3D rebuilding, accurate matching and tracking of feature points of motion estimation are important factors of vision measurement and holds key to accurate navigation.

5. Conclusion

This paper studies the high-precision navigation algorithm of cameras to address the low accuracy of GPS navigation and high cost of mobile communication navigation. This algorithm can be transplanted into stereo vision and feature tracking system to rebuild 3D scenarios of work and life. It better equips the society with information technology and serves as guidance to computer vision related problems.

Besides high-precision navigation and positioning, vision measurement and its core technology can also be applied to 3D rebuilding of sequence images and the feature tracking system, contributing to information society, smart city, security and national defense.

References

[1] Z. B. Ping and H. Jian, "The Study of GPS Vision Navigation System of Multi-stage Real-time Matching Algorithm", Science Technology and Engineering, vol. 14, no. 13, **(2014)**, pp. 208-212.
[2] X. D. Gao, D. Y. You and S. Katayama, "Seam tracking monitoring based on adaptive Kalman filter embedded ehnan neural network during high-power fiber laser welding", IEEE Transactions on Industrial Electronics, vol. 59, no. 11, **(2012)**, pp. 4315-4325.
[3] H. Z. Qiu, H. Y. Zhang and H. F. Jin, "Fusion algorithm of correlated 10-cal estimates", Aerospace Science and Technology, vol. 8, no. 7, **(2004)**, pp. 619-626.
[4] V. Venkataraman, G. Fan and J. P. Havlicek, "Adaptive Kalman filtering for histogram-based appearance learning in infrared imagery", IEEE Transactions Oil Image Processing, vol. 21, no. 11, **(2012)**, pp. 4622-4635.
[5] L. Deri, "Effective Traffic Measurement Using Ntop", Network Traffic Measurements and Experiments, vol. 6, no. 8, **(2000)**, pp. 138-143.
[6] L. Deri, "Improving Passive Packet Capture: Beyond Device Polling", Proceeding of the 4th International Conference on System Administration and Network Engineering. Amsterdam, Holland: IEEE Press, **(2004)**, pp. 814-826.
[7] F. Fusco, L. Deri and J. Gasparakis, "Towards Monitoring Programmability in Future Internet: Challenges and Solutions", Proceeding of the 21st Tyrrhenian Workshop on Digital Communications. Ponza, Italy: IEEE Press, **(2006)**, pp. 514-528.
[8] M. Songde and Z. Zhengyou, "Computer Vision - Computer Theory and Algorithms", Beijing: Science press, **(1998)**.
[9] M. A. Fischler and R. C. Bolles, "Random sample consensus: a paradigm for model fitting with applications to image analysis and automated cartography", Communications of the ACM, vol. 24, no. 6, **(1981)**, pp. 381-395.
[10] H. Jian and Q, Na-iming, "Journal of Nanjing University of Science and Technology (Natural Science)", vol. 32, no. 2, **(2008)**, pp. 176-181.

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Boping Zhang, Associate professor/ Master Degree Candidate, the main research fields: image processing. The paper is subsidized by science and technology key project of Henan Province (132102210491).

