The 12th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI 2015)
October 28~30, 2015 / KINTEX, Goyang city, Korea

Position Estimation Using Multiple Low-Cost GPS Receivers For Outdoor Mobile Robots

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Abstract – Recently, the application of navigation system to electric devices such as cars, airplanes, and cellphones has become common. This common usage increases the demand for GPS, and therefore, GPS accuracy has become important. However, applying an external correction device or using a high-accuracy GPS receiver is very expensive; thus, practical applications of robotic systems using this technology are limited. Therefore, in this paper, we propose a method of using multiple low-cost GPS receivers in position estimation to enhance accuracy and decrease system buildup cost. The position estimation is based on the following steps: 1) sensor modeling of each GPS receiver, and 2) position estimation using extended Kalman filter based on the model of each sensor.
The result of this study showed enhanced accuracy of the position estimation and the correlation between the number of GPS receivers used and accuracy of the position estimation. The position-estimation accuracy can be enhanced with low system buildup cost, and therefore, the proposed method can contribute to the field of robot control in outdoor environment.

Keywords - Multiple GPS receiver, EKF, Outdoor positioning system

1. Introduction

Position estimation has become very important as the number of robots with navigation system increases. GPS was generally used for localization in outdoor environment, and the usage has increased since SA was discontinued in 2000[1]. The increase in GPS usage promoted research on enhancing its performance. Several successful methods investigated to increase the GPS accuracy are GPS/INS[2], DGPS[3], and Network RTK[4]. However, the construction cost of these systems is many times more expensive than that of a general GPS receiver.

In this paper, we propose a multiple GPS receiver system using low-cost GPS receivers, namely, LS20031. The system is based on the following two steps: first, the performance of each sensor is measured by error modeling, and second, position estimation with enhanced accuracy is obtained by extended Kalman filter (EKF) using the error-model result in the first step. In the verification of the effectiveness of the proposed method, the accuracy enhancement result relative to the number of GPS receivers used is also presented. The major part of this paper focuses on the experimental evaluation of the accuracy enhancement of our method based on experimental data.

2. System Configuration and Design

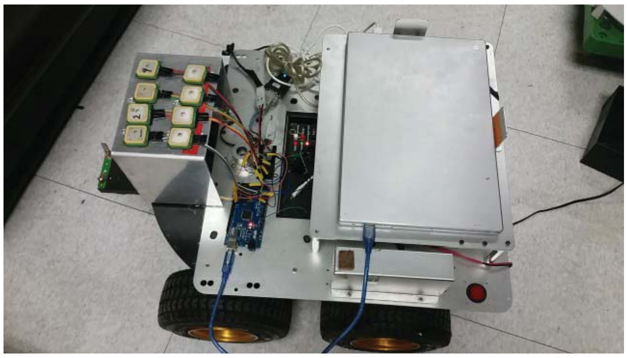

Fig. 1. Sensor system attached to a mobile robot

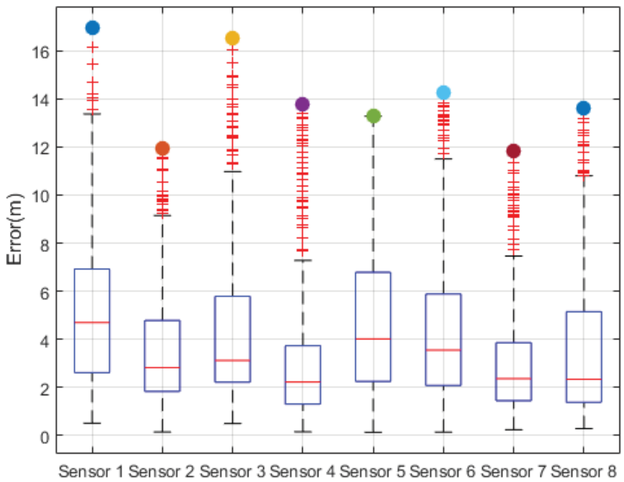

Fig. 2. Box plot chart of the error models of each GPS receiver

The system design is shown in Fig. 1, and the error model of the GPS receiver is shown in Fig. 2.

The position estimation of a robot is determined by the covariance matrix[5] of the EKF, and the covariance matrix is determined by the error model of the GPS receivers. Therefore, the algorithm of the suggested method is based on the following steps: first, using the

978-1-4673-7971-7/15/$31.00 ©2015 IEEE

system design shown in Fig. 1, we measure the 1σ value of the accuracy of each GPS receiver. Second, the measured accuracies are used to determine the covariance of the EKF. Third, the position estimation is calculated using the determined covariance matrix.

3. Experimental Result

3.1 Case using four GPS receivers

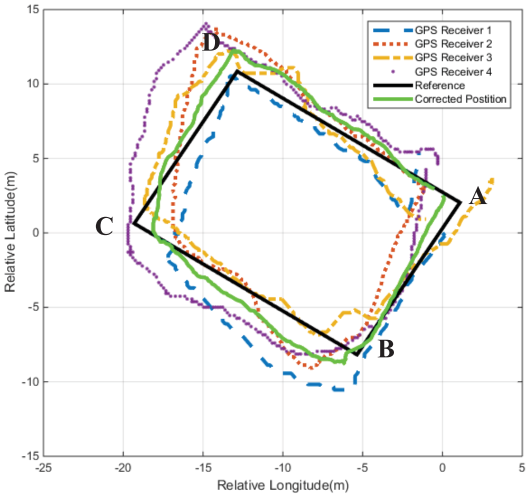

Fig. 3. Position estimation of single and multiple GPS receivers

The robot moved along the black line in a clockwise direction, starting from point A. The number of GPS receivers used in the position estimation is four, and the result is shown in Fig. 3. The blue, red, yellow, and purple lines represent the estimated positions of GPS receivers 1, 2, 3, and 4, respectively. The green line in Fig. 3 represents the result of the position estimation of the multiple GPS receivers using covariance matrix in the correction process. The position estimation of the multiple GPS receivers emerged to be more accurate than that of the single GPS receiver in terms of both maximum and root-mean-square errors.

3.2 Valid number of used GPS receivers

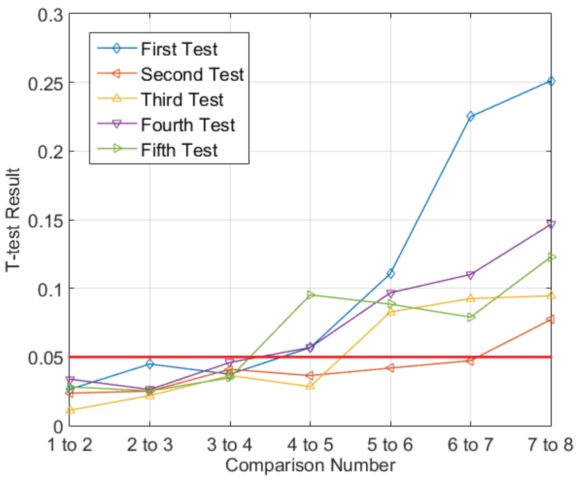

Fig. 4. Correlation between the comparison number and the T-test result.

The correlation between the number of GPS receivers used in the position estimation and the accuracy enhancement is analyzed by a t-test. Figure 4 shows the result of the five experiments. The t-test results show that reasonable accuracy enhancement can be obtained using up to four GPS receivers in the position estimation. However, the use of more than four GPS receivers cannot guarantee reasonable accuracy enhancement.

3. Conclusion

In this paper, we propose a method of using multiple low-cost GPS receivers to enhance the position-estimation accuracy, and we evaluated the accuracy enhancement through experiments. In addition, the correlation between the number of GPS receivers used in the position estimation and the validity of the accuracy enhancement is reported using the obtained data. The advantage of our method lies in its ability to realize high-accuracy position estimation with a low-cost buildup system. Because only GPS receivers are used in this method, applying other sensors or correction devices can possibly further enhance the position-estimation accuracy. Therefore, the proposed method can contribute to the field of robot control in outdoor environment.

Acknowledgement

This research was supported in part by the R&D Convergence Center Support Program (714002-7, Education and Research on Agricultural Automation), Ministry of Agriculture, Food and Rural Affairs and in part by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (NRF-2014R1A2A1A10049634).

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