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Processing of GPS Data using Accuracy Enhancement Techniques for Sag Monitoring Device

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Abstract**—**The paper describes an experimental set up used to collect GPS data in real time. The effect of weather of particular location is also considered in the paper. The major problems in GPS measurements may be due to tall buildings, high mountains, overhead foliage etc. The positioning data provided directly by the satellites are subject to variety of error sources such as thermal noise, tropospheric delays, multipath error, ephemeris errors, satellite clock errors and ionospheric delays before they are processed into position and time solution in the GPS receiver. The paper discusses DSP techniques such as Bad Data identification and modification and Kalman filter used to enhance the accuracy of GPS altitude measurements. Results obtained demonstrate that Kalman filter after Bad Data identification and modification technique significantly reduced the errors in GPS altitude measurements.

Keywords*-GPS, Bad data Identification/Modification, Kalman Filter, Signal Processing*

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I. Introduction

From several years, global positioning satellites are revolving in the orbit of earth to provide navigation facilities on sea, in the air and on land. Millions of Global Positioning System (GPS) devices are in use all over the world, in various applications such as agriculture, navigation, mapping, surveying and military [1]. Irrespective of the application, the fundamental function of the GPS device remains same i.e. to obtain the accurate position and timing information anywhere in the world. The major problems to GPS navigation is blockage of satellite reception by tall buildings, high mountains, and foliage overhead, which creates difficulties in its method of working [2]. GPS system is based on the computing of latitude from the GPS receiver to the multiple satellites by multiplying the time delay that a GPS signal needs to travel from the satellites to the receiver with velocity of light. The position of the receiver is computed on the basis of the distance from at least four or five satellites [2]. Various error sources such as tropospheric delays, multipath error, Ephemeris errors, Satellite clock errors and Ionospheric delays, GPS signal noise and receiver noise are the factors that affect the GPS accuracy.

In the paper, two cases are considered for collection of GPS data in real time. The effect of weather of the particular place is also considered. A combination of DSP techniques such as Kalman filter and Bad Data identification and modification (BDIM) have been used for error reduction in observed (raw) GPS height difference. In the paper output obtained after using DSP techniques have been compared with the physically measured height difference to select best technique for processing of raw GPS height difference. Estimated GPS altitude measurements can be used to evaluate overhead conductor sag in power transmission lines.

II. Experimental Set up

The following figure1 shows basic experimental set up used for GPS data collection in real time [3]. In the basic configuration, two handheld GPS receivers.BT359 are connected to the laptop via Bluetooth link. The two GPS receivers are placed at different heights one at the higher with respect to other placed at the ground plane having some static difference.

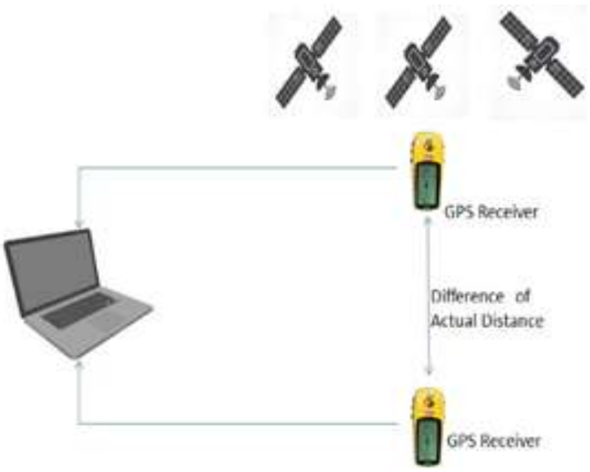

Figure 1. Basic Experimental set up

The real time data (information) is in the NMEA format. This data includes position, velocity, time calculated from GPS receiver. GPS receivers provide data at rate of one reading per second. The GPS height difference was calculated by taking difference of data taken from GPS receivers placed at different altitude. The error may be calculated by comparing physically measured height with measured height using GPS. Also the physically measured height are used for estimation of error. The GPS data has been collected for approximately 250 sec. The two cases has been considered for errorestimation of measured GPS height in real time as shown in table 1[3].

Table 1. Case Studies

Sr. No.	Location	Actual Height Difference (m)
1.	Girls Hostel-I, Thapar University, Patiala	11
2.	Girls Hostel-E, Thapar University, Patiala	8

III. Digital Processing Techniqe

In the paper, combination of DSP techniques has been used as given in figure 2. The programming for both Kalman filter and BDIM has been done in MATLAB for processing of observed GPS height difference so that estimated GPS height difference may be used for measurement of sag in power lines.

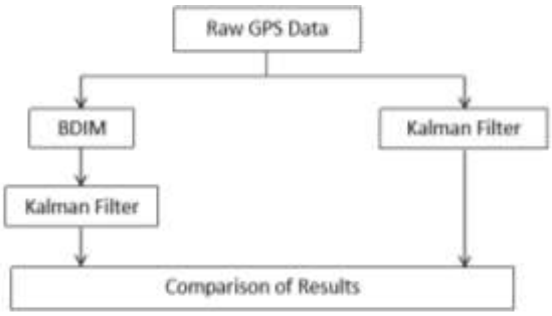

Figure 2.DSP techniques for Processing of Observed GPS Height Difference

1. BDIM

The presence of bad data may be due to momentary loss of satellites, signal reflections and ambient noise. Bad data is recognized through the use of identification of a measurement which differs from the mean value of GPS height difference in excess of preset tolerance limit of kσ. And σ is the standard deviation values of z as it is measured in the moving window of width T seconds. In order to choose 'T', several trials with different 'T' values were made to obtain best results. The bad data has been replaced by the window mean. The value of k is chosen to obtain proper rejection rate.

2. Kalman Filter

The Kalman filter is based on the linear model stochastic estimation. It is a mathematical toolbox and recursive algorithm. The term recursive means, there is no need of all previous data for the estimation of state [4]. It is one of the most important algorithms for state estimation. It is a mathematical toolbox and thus solves the problem using mathematical equations. Its main aim is to produce results that tend to be closer to the actual values taken from observed measurement that contains noise. It receives one input measurement and returns only one output estimate. It works in a cycle of two distinct phases such as the Predication and the Correction.

Time update based on the just last position also known as prediction step or prior estimated state is responsible for projecting forward the previous prior estimation value to obtain estimation of prior current state and measurement update also known as correction step is responsible to obtain posterior estimate. In measurement update phase, the current prior prediction is combined with current observation information to refine the state estimate. This improved estimate is termed as a posterior state estimate. This phase works in three steps first task is to compute kalman gain, secondly update the state estimated value and then compute the posterior estimated value of state. At completion of each cycle, the new posterior value is taken as the previous estimated prior value for estimation of current prior value in next cycle [4-6]. The procedure is repeated again and again with the state estimated at the previous time instant. It provides estimation of state error covariance recursively.

Kalman filter solve the problem using stochastic difference equation:

x_k = Ax_{k-1} +Bu_k +w_k (1)

z_k = Cx_k + v_k (2)

wherew_k and v_k are the random variables which represents the process noise and measurement noise respectively. In this case, they are assumed to be mutually independent and zero mean white noise. Covariance of $w_k$and $v_k$is given as:

E[$w_k w_k$'] = Q (3)

E[$v_k v_k$'] = R (4)

Kalman filter is a minimum mean square error evaluator. It is the state estimator and produces an excellent estimate. It means that the mean value of summed value of all linear combinations of the estimation errors is minimum value. So the minimal value of sum of squared errors is given by :

E[e_x^T(k)e_x(k)]= E[e_{x1}^2 +e_{x2}^2z+ ....e_{xn}^2] (5)

e_x(k) = x_{est}(k) - x(k) (6)

The kalman filter is also known as "least mean-square estimate". It is assumed that the model is linear, so it is not applicable for nonlinear models. It is assumed that the system is affect with noise so the state of estimation is affected with random noise called process noise and the measurements of Kalman filter contains random white noise called measurement noise. The Kalman Filter algorithm is really fruit-full for the systems model of linear state space. The steps used in this filter are given in figure3 [3] .

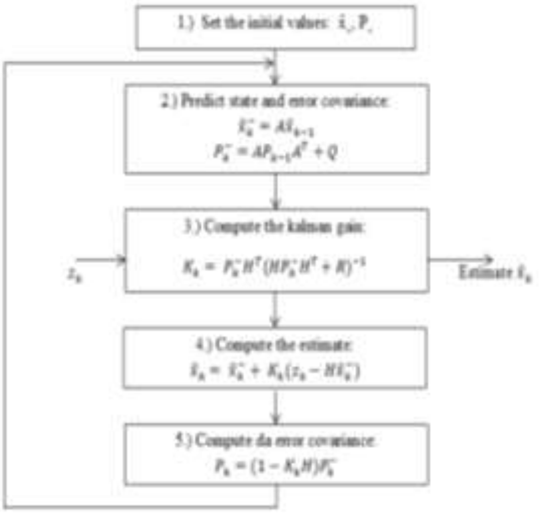

Figure 3 Steps of Kalman filter Algorithm

2.1 Estimation of Parameters

A, B and C are matrices of an appropriate dimensions. Both the Kalman gain and estimation error covariance will stabilize quickly exponentially and then become constant. In present work, the value of Z is taken to be equal to the actual height difference between two GPS receivers. We then simulated distinct measurements. R is the square of the standard deviation of raw GPS measurement data. The state of GPS is static in all the steps so A=1, U is taken as 0 as there is no control input and Q is taken as 0.00005[3]. By selecting these values, wide area may be available to tune the filter. The value of P is chosen such that error covariance converges. The Kalman gain will be smaller, if a posterior error covariance is low.

IV. RESULTS AND DISCUSSION

1. Observed GPS Height Difference

The observed GPS height difference and actual height are depicted in figure 4 and figure5 for case 1 and case2 respectively. It has been observed that the GPS height difference is not closer to actual height due to some inherent errors.

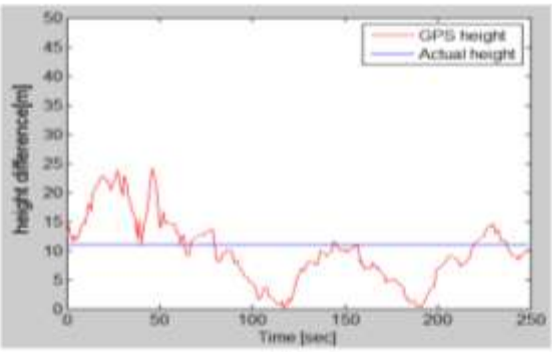

Figure 4 Observed GPS height difference for case 1

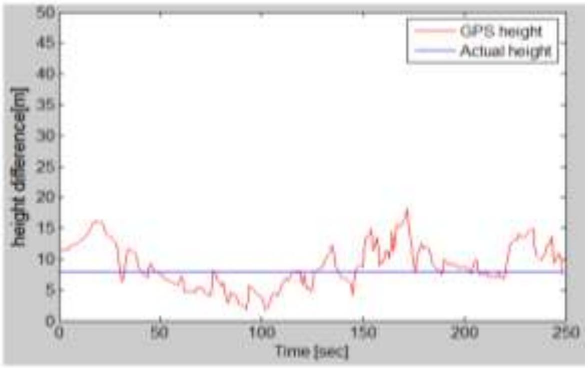

Figure 5 Observed GPS height difference for case 2

2. Processing of GPS Height Difference

(i) Using Kalman Filter

The Figure 6 shows effect of Kalman filter on raw GPS height difference. The processed GPS height difference resulting from Kalman filter is seen to be more close to the actual height difference.

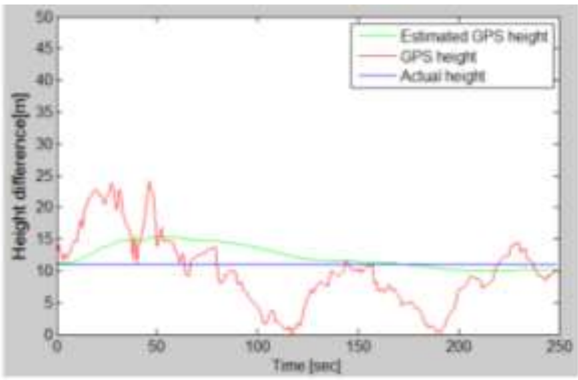

Figure 6. Estimated GPS measurement using Kalman Filter for case 1

In the following figure 7, GPS height has been compared with the estimated GPS measurements obtained using Kalman filter for case 2. It is found that error in estimated GPS height difference has been reduced as estimated GPS height difference is more close to actual height than that of measured GPS height.

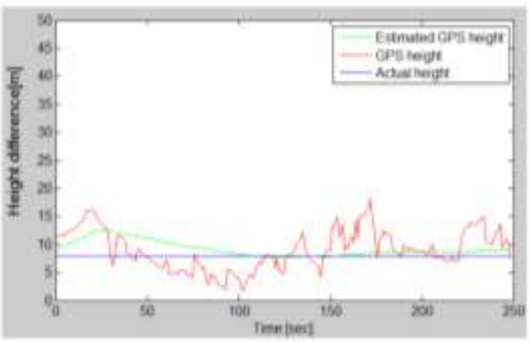

Figure 7. Estimated GPS measurement using Kalman Filter for case 2

(ii) Using Kalman Filter after BDIM Technique

The Figure 8 and 9 depicts raw GPS measured height difference and processed GPS height difference using Kalman filter after BDIM technique. It is observed that error in estimated GPS height difference measurements has been further more reduced, as output of BDIM technique has been processed by Kalman filter.

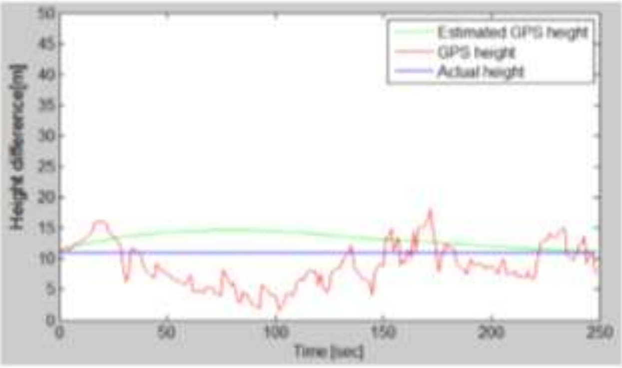

Figure 8. Estimated GPS measurement using Kalman Filter after BDIM for case 1

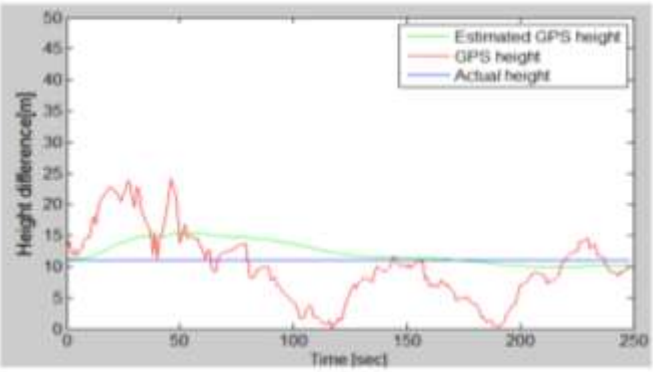

Figure 9. Estimated GPS measurement using Kalman Filter after BDIM for case 2

3. *Error Analysis*

The table2 gives maximum absolute error achieved using Kalman filter and Kalman filter after BDIM technique, for cases under studies.

Table 2Absolute error analysis

Cases	Actual height difference(m)	Maximum absolute error in measuring GPS height difference (m)	Maximum absolute error in measuring GPS height difference using Kalman filter (m)	Maximum absolute error in measuring GPS height difference using Kalman filter after BDIM (m)
1	11	13.1000	4.3316	3.6848
2	8	9.3	3.2493	2.4231

Therefore, Kalman filter after BDIM reduce more errors in GPS measurements as compared to that GPS measurements resulting from Kalman filter and thus gives better accuracy of observed GPS measurements.

V. CONCLUSION

It can be concluded that GPS data has been taken successfully using two handheld GPS receivers BT359 in real time at given locations. The physically (Actual) measured height difference has been used for estimation of errors in observed GPS data. The accuracy of observed GPS height difference has been improved using combination of DSP techniques such as Kalman filter and Kalman filter after BDIM. It can also be concluded that Kalman filter after BDIM combination of DSP techniques is best combination for error reduction in observed GPS height difference. The estimated GPS height difference may be used for monitoring of overhead conductor sag in power lines.

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