Real Time Processing of GPS data using DSP Techniques

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Abstract: The Global positioning system (GPS) accuracy may be affected by various inherent error sources such as satellite errors, receiver clock errors and orbital errors etc. In this paper digital signal processing techniques such as bad data identification and modification (BDIM) technique and Kalman filter has been used to enhance the accuracy of GPS altitude. In this paper the Kalman filter after BDIM significantly reduced the errors in GPS measurements.
Keywords: Global positioning system (GPS), Kalman filter, Recursive filter, bad data identification and modification technique (BDIM).

1. Introduction:

The NAVSTAR Global positioning system (GPS) used in worldwide provides position information at any point at anytime, anywhere on earth in the form of longitude, latitude and altitude. It was first designed and operated by theU.S. Department of Defense [1]. Twenty nine satellites revolve around the earth every 12 hours at 12 miles awayfrom the earth, thus covering the greater area of earth. To evaluate the user's position by using the distance, receiver needed at least four satellites. It requires very clear environment for good accuracy. Each satellite revolves around earth by one time in 12 hours. The GPS system accurately measures the unknown location of a user on earth using the fundamental principle of trilateration [2]. The GPS satellites are positioned in such a way that at least five to eight satellites are accessible at any point on earth at any time. Basically GPS works in three segments- space segment, control segment and user segment. Space segment consists of satellites which broadcast signals, user segment include different GPS receivers and control segments consists of master control station, base control station and ground antennas. While five base station in control segment sends information to the master control station, where master control station corrects the information and send it back to satellites through ground antennas [3]. The accuracy of GPS receiver is affected due to various inherent error sources. These error sources are multipathinterference, user mistakes, satellite and receiver clock errors, orbit errors, satellite geometry, atmospheric interference [4]. Sometimes atmospheric phenomena, clouds and other obstacles like mountains or buildings also produce errors. These errors can be reduced to arrive at a more accurate estimate of coordinates of user [5]. In thepaper, BDIM and Kalman filter DSP techniques has been used to process GPS altitude, the handheld GPS receiver has been used at ground level gives altitude above sea level.

2. DSP Techniques:

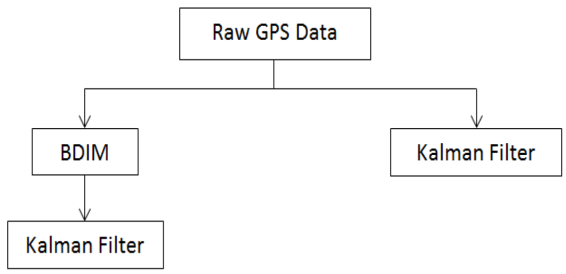

Figure 1: DSP Techniques used to Process GPS Raw Data

The various techniques that has been used are BDIM and Kalman Filter. Figure 1 shows DSP techniques used to process GPS data in real time.

2.1 BDIM:

The presence of bad data might be due to momentary loss of satellites, signal reflections ambient noise may degrade GPS accuracy. Thus in order to improve the accuracy it is important to remove the bad data. Bad data is recognized by identify data which differ mean value of altitude by preset tolerance value (k*σ) [5][12]. Where σ: standard deviation values of *z* as measured in a moving window of width *T*. The bad data has been either replaced by the window mean. In present application value of k is taken as 1 to obtain proper rejection rate. The value of T has been chosen using several trials to obtain best results.

2. Kalman filter:
Kalman filter is a mathematical toolbox which solves the problem by 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 is an optimal recursive filter, optimal in a sense it minimizes the estimated error covariance and is recursive as it does not require to save all the previous values to estimate the next stage, but it needs just previous value at (k-1) time instant to estimate the current value at k time instant in contrast to other estimation techniques [5-6]. Kalman filter is a learning tool. [7]. Kalman filter can be taught using a simple derivation involving scalar mathematics,basic algebraic manipulations and easy to follow to thought experiment [8].
Kalman filter solve the problem by using stochastic difference equation:

$$x_k = Ax_{k-1} + Bu_k + w_{k-1} \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

Kalman filter works in a cycle of two distinct phases: also known as prediction step 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 posteriori estimate. In measurement update phase, the current priorprediction 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, secondlyupdate 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 [9-11]. 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 is a minimum mean square error evaluator. The posterior state estimator error value is evaluated by:

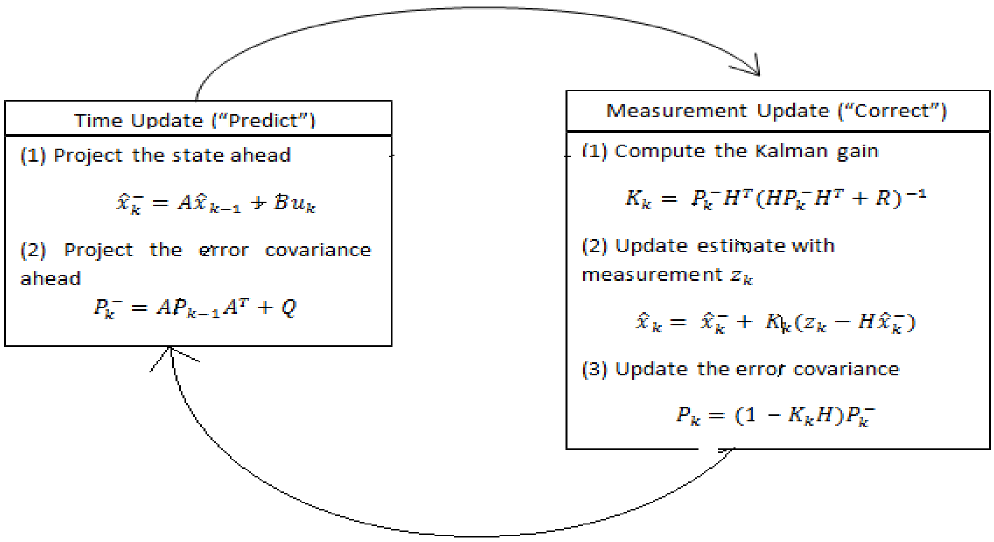

Figure 2: Time and Measurement Update Equations

Where $\hat{x}_k^-$,prior estimated state at k time instant;
A = Matrix that relates the state at the previous time step to the state at the current step in the absence of processnoise;
B = Optional control input 'u' to the state x;
U = Control input;
P = Error covariance;
Q = Process noise covariance;
K = Kalman filter;
R = Measurement noise covariance;
H = Matrix that relates state to the measurement;
Both the estimation error covariance and the Kalman gain will stabilize quickly and then remain constant. In thepresent application the following parameters are considered to obtain better results:

As state does not change from step to step so A is taken as 1. U is taken as 0 as there is no control input [6]; Q has been assumed as 0.00001 as assuming a small but non-zero value gives us more flexibility in "tuning" the filter as we will [10]. In this work, the value of P is chosen such that error covariance converges. Thus P =1 is considered.

3. Data collection:

GPS data has been collected at ground level of Girl Hostel-I, Thapar University, Patiala (India) for 250 seconds. Also the actual altitude of given location has been taken according to survey of India [13] which is used as standard reference for the estimation of error in raw GPS altitude, measurements.

GPS receiver BT359 relays information to laptop via Bluetooth link using NMEA 0183 protocol [14]. GPS data logger software process output of GPS receiver to give 3-D position in form of longitude, latitude and altitude as shown in Figure 3.

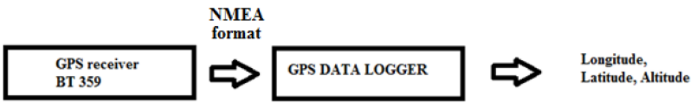

Figure 3: Logging of GPS Data

4. Results and Discussion:

4.1 Observed GPS measurement:

The figure 4 shows the actual altitude and observed GPS altitude measurement:

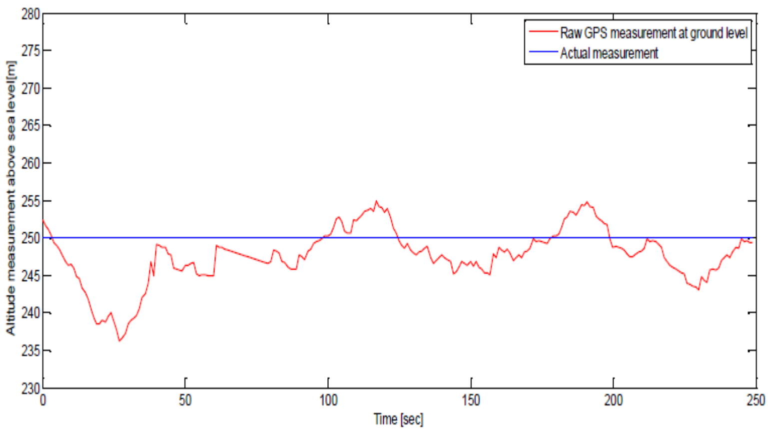

Figure 4: Comparison of raw and actual GPS height

It has been found that the GPS altitude measurement shows an error of 13.8m, which is not closer to the actual altitude. It is because of some inherent sources of error in GPS measurements. These error sources are likely to be affected by various factors such as satellite geometry during time of test, changing ambientweather conditions etc. Inaccuracies in GPS altitude measurements during field test may be due to raw GPS altitude measurement has been processed using combination of Kalman filter and Kalman filter after BDIM.

4.2 Processing of GPS measurement:

Use of Kalman filter significantly reduces the GPS receiver error from 13.8 m to 5.2788 m. Thus improve the GPS accuracy by 8.5212 m.

Using Kalman filter

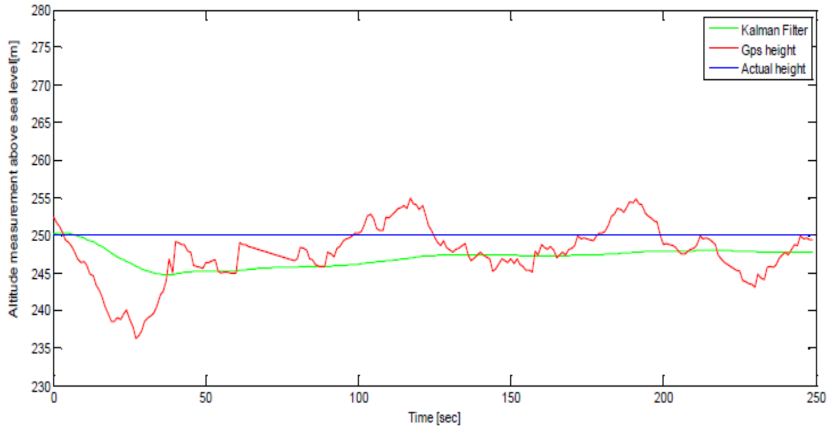

Figure 5: Estimate of GPS measurements by Kalman Filter

Using Kalman filter after BDIM

Kalman filter after BDIM has been proven to remove the GPS error up to large extent.

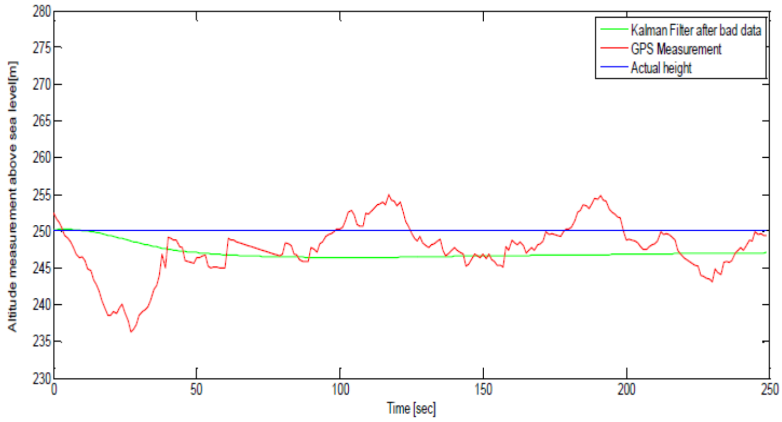

Figure 6: Estimate of GPS measurements by Kalman filter after BDIM

5. Conclusion:

GPS receiver BT359 has been used for data collection at ground level of Girls hostel-I, Thapar university, Patiala (India). It has been concluded that Kalman filter after BDIM gives better results as compared to Kalman filter. Thus Kalman after BDIM significantly reduces error from 13.8m to 3.6420m. The GPS receiver may be cost effective system for overhead conductor sag measurement in power transmission lines.

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