The Measurement Preciseness of the GPS Built in Smartphones and Tablets

[1]Zoltan Horvath, [2]Hanna Horvath
[1]University of Pecs, Faculty of Sciences
[2]Leowey Klara Secondary School

Abstract
Nowadays the use of different navigation systems becomes more important due to the fact that a large amount of money and time can be saved by the optional path. Moreover, indoor navigation is getting toned more and more. In our research, we would like to develop a useful solution in that sphere, but at first, we are about to get acquainted with the reliability of the GPS procurers built in smartphones and tablets.

Keywords
GPS, L1 Regression Analysis, Kalman Filter, GLONASS

I. Introduction

70% of Hungary's population possess a smartphone and 49% of these users employ navigation software and/or service in their gadgets [5]. The minor part of these software and service are free, but the more useful ones need to be bought. As we know, President Bill Clinton's decision made the breakthrough in GPS navigation in 2nd of May 2000. By the official advertisement, because of this act, the "real time geo localization" preciseness increased 10 times, i.e. the "horizontal positioning" is fault decreased 10 times. Due to technical experience, in many cases, we can achieve a preciseness of a couple of meters [3].

II. Material and Methods

In our research we used five smart phones and a tablet. These were the following: HTC HD, HTC 8x, Sonny Xperia J, iPhone 4, iPad2.By choosing these devices, we can try out most of the used operation systems of our times'. In addition, the HTC 8X device applies GLONASS support in order to allocate our location. This support is available up from the series of iPhone 4S.

We used free software in our research. Sports Tracker was a good choice since it is available in Windows Phone, Android and Mac Osoperation systems as well. Another advantage of the software is that it visualizes the number of the satellites and by doing this, it locates our position.Before the research, we required the HTC 8X to be the most precise since this device has GLONASS support besides GPS [7]. This means that the traditional GPS system is expanded with the data of the satellites developed by Russians, therefore it makes it more precise to the users. Presently there are 51 reference stations in Hungary. Pecs is a good location in this network because there are three stations near at hand. These are Siklos (20km from Pecs), Barcs (50km from Pecs) and Kaposvar (50km from Pecs).

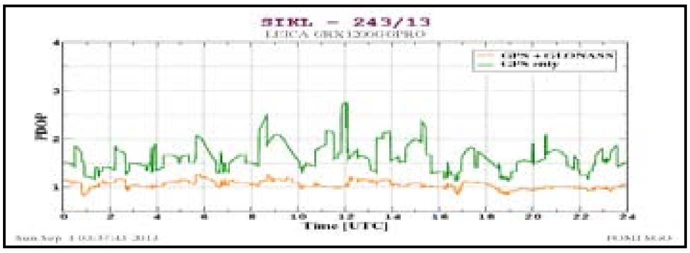

Fig. 1: PDOP From the Satellite Geometry Versus Time(source: http://www.gnssnet.hu)

In the fig. 3 of the reference station of Siklos, we can see that by using GPS+GLONASS in the same time, we get such more precise data compared with the ones with only GPS. As we can see on fig. 1 we get much precise data with the support of GLONASS system. While the data collected by plain GPS are hectic, the hybrid system shows a much more square result.

A. Structure of GPS Signal

All signal components are derived from the output of a highly stable atomic clock. In the operational (Block II/IIA) GPS system each satellite is equipped with two caesiumand two rubidium atomic clocks. The clocks generate a pure sine wave at a frequency f0 = 10.23MHz, with a stability of the order of 1 part in 1013 over one day. This is referred to as the fundamental frequency. Multiplying the fundamental frequency f0 by integer factors yields the two microwave L-band carrier waves L1 and L2 respectively (above two figures). The frequency of the two waves is obtained as follows:

$fL_1 = f_0 x154 = 1575.42MHz$ (1)
equivalent wavelength: λ L1 = c / fL1≈19cm
$fL_2 = f_0 \text{ x } 120 = 1227.60MHz$ (2)
equivalent wavelength: λ L2 = c / fL2 24cm

These are right-hand circularly polarised radio frequency waves capable of transmission through the atmosphere over great distances, but they contain no information. All satellites broadcast the same frequencies (though the received frequencies are slightly different because of the Doppler shift).

B. L1 Regression Analysis

We investigate our results first time with L1 regression. Consider the linear regression model (1):

$$Y_i = \beta_0 + \beta_1 x_{1i} + \cdots + \beta_p x_{pi} + \varepsilon_i \quad (3)$$

Where β_0, β_1,…..,β_p are unknown parameters and $\{\varepsilon_i\}$ are unobservable independent, identically distributed random variables each with median 0. For simplicity, we will assume that the x_{ki}' s are non-random although the results will typically hold for random x_{ki}'s. We will consider the asymptotic behavior of L1-estimators of $\beta = (\beta_0,\ldots,\beta_p)$; that is $\widehat{\beta_0}\,\widehat{\beta_1},\ldots,\widehat{\beta_p}$ minimize the objective function (2)

$$g_n(\Phi) = \sum_{i=1}^{n} |Y_i - \phi_0 - \phi_1 x_{1i} - \cdots - \phi_p x_{pi}| \quad (1)$$

over all $\phi=(\phi_0,\ldots,\phi_p)$

In PetrosHadjicostas (2012) optimization program he seek to minimize [8] (over all k ϵ {2,…, n-2}) (3)

$$z_k = \sum_{i=1}^{k} |\theta_i - \gamma_0 - \beta\phi_i| + \sum_{i=k+1}^{n} |\theta_i - \delta_0 - \beta\phi_i| \quad (2)$$

Subject to at least one of the following conditions:
1A: $\beta \geq 0$ and $\beta(\phi_{k+1} - \phi_k) \geq \gamma_0 - \delta_0$
1B: $\beta \geq 0$ and $\beta(\phi_n - \phi_1) \leq \gamma_0 - \delta_0$
2A: $\beta \leq 0$ and $\beta(\phi_{k+1} - \phi_k) \leq \gamma_0 - \delta_0$
2B: $\beta \leq 0$ and $\beta(\phi_n - \phi_1) \geq \gamma_0 - \delta_0$
This minimization problem can be solved using standard Linear

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Programming techniques. L1 Linear regression assumes that an intercept term is to be included and takes two parameters: the independent variables (a matrix whose columns represent the independent variables) and the dependent variable (in a column vector). L-1 regression is less affected by large errors than least squares regression [4]. The following figure depicts this behaviour (fig. 9).

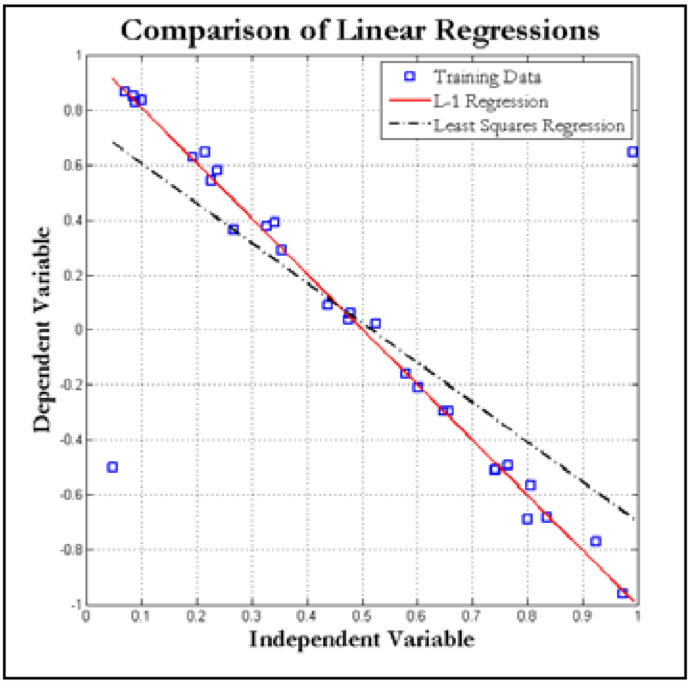

Fig. 1: L1 Regression Analysis

The biggest drawback of L-1 regression is that it takes longer to run. Unless there are many such regressions to perform, execution time is a small matter, which gets smaller every year because computers get faster. L1LinearRegression runs in about 10 seconds for 100,000 observations with 10 predictors on fast PC hardware.

C. Refelctanced GPS Signal Filtering With Kalman Filter

We can filter the reflectanced GPS signal with Kalman filter because we can monitor the GPS. If we know that our smartphone which signal using then we know what this satellite frequency is. After this, we can use the Kalman filter where we give the original frequency (this will the right data) and we say that the other results are the errors [9].

It is instructive first to review the analysis step in the standard Kalman filter where the analyzed estimate is determined by a linear combination of the vector of measurements d and the forecasted model state vector ψ_f [10]. The linear combination is chosen to minimize the variance in the analyzed estimate ψ_a, which is then given by the equation

$$\psi^a = \psi^f + K(d - H\psi^f) \quad (3)$$

The Kalman gain matrix K is given by

$$K = P^f H^T (HP^f H^T + W)^{-1} \quad (4)$$

The error covariance of the analysed model state vector is reduced with respect to the error covariance of the forecasted state as

$$P^a = \overline{(\psi^a - \psi^t)(\psi^a - \psi^t)^T}$$
$$= \overline{[\psi^f - \psi^t + K(d - d^t - H\psi^f + H\psi^f]} \; [\psi^f - \psi^t + K(d - d^t - H\psi^f + H\psi^f)]$$
$$= (I - KH)\overline{(\psi^f - \psi^t)(\psi^f - \psi^t)^T}(I - KH)^T \; K(d - d^t)(d - d^t)^T K^T$$
$$= (I - KH)P^f(I - H^t K^t) + KWK^t$$
$$= P^f - KPH^f - P^f H^T K^T + K(HP^f H^t + W)K^T$$
$$= (I - KH)P^f \quad (5)$$

The analyzed model state is the best linear unbiased estimate [1]. This means that ψ^a is the linear combination of ψ^f and d that minimizes $TrP = (\psi - \psi^t)(\psi - \psi^t)$, if model errors and observations errors are unibased and are not correlated [2].

III. Results

During our research we collected almost 1000 measurement data. From the data, a number of 873 refer to the measurement made around the block [11]. For measuring the fix point, we have 128 results, while this number is 62 for the short interval measurement. Then we observed the results of measuring the fix point, which is seen in the following fig. 2.

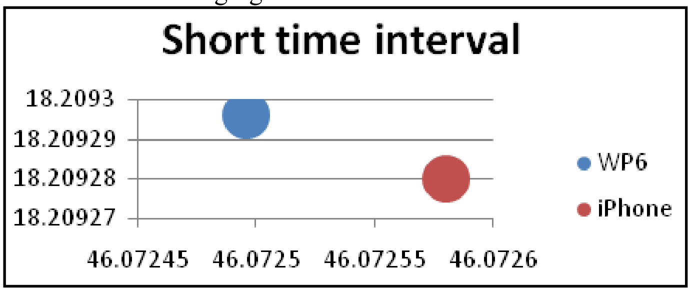

Fig. 2: Results of Measuring the Fix Point

As we can see in the graph, the data collected by these the devices has only a digression of a couple of centimetres. To sum up, we can say that if we measure one point in an open area, where the zenith is 92% visible; there is no significant difference between the two operation systems.

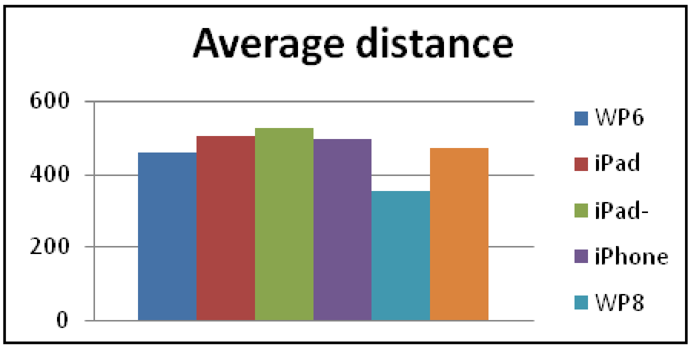

Fig. 3: Average Distance Without Kalman Filter

When we started our research we were in an opinion that the most homogeneous data will be collected by the device which applies GLONASS support as well. As it can be seen in fig. 4, the WP8 device was the one which made this result. From the second place, we did not experience big difference. That is to say, there is no significant difference between the results achieved by the devices which only use GPS. On the other hand, the HTC 8X (WP8) is the absolute number 1 with big difference.

What is then if we can filter the satellite signal at the measurement? Because the smart phones can use small mobile apps where this application can recording all signal. After we can analysed this results and we can separate the signal and the reflectance signal. We can see the results between the original data and the filtered data on the next figures (fig. 4. and fig. 5.).

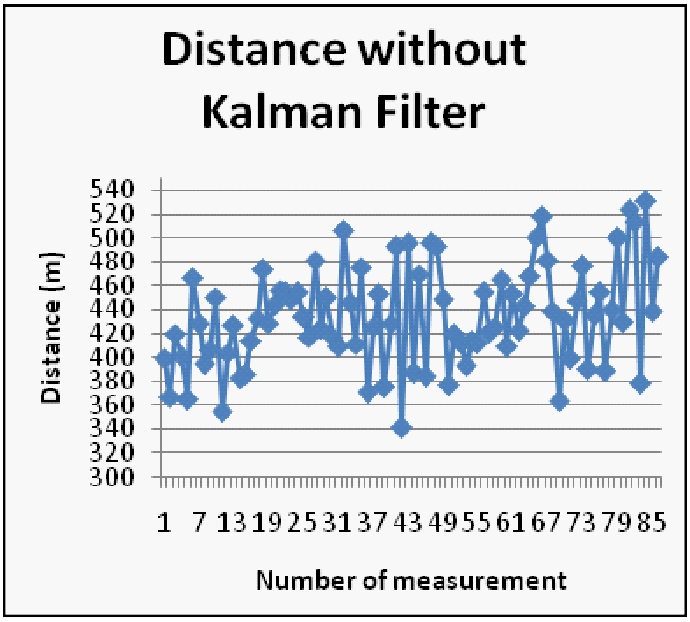

Fig. 4: Original Distance Results Without Kalman Filter

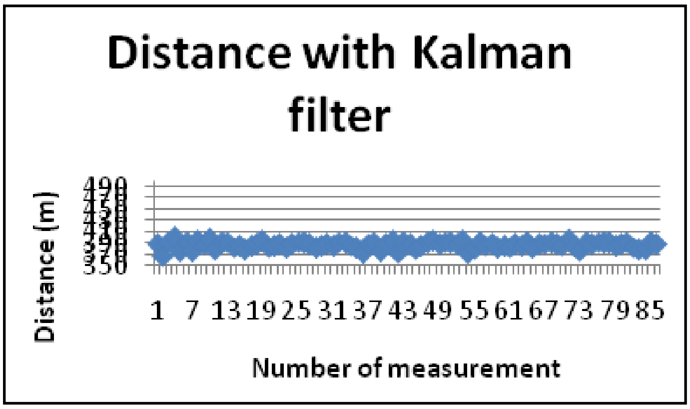

Fig. 5: Modify Distance With Kalman Filter

We can see on these two figures that the different is huge. In the first situation, where we don't used filter than was the deviation 42.2369 and the average distance 434.988m until then when we used the filter the deviation was 6.0826 and the average distance was 386.325 meter.

IV. Conclusion

During our research, we observed how the preciseness and quality supplied by GPS is influenced by certain operation systems. The way we can get accurate data without GPRS and/or Wi-Fi was a point we were curious about, too. Ourresearch clearly points out that the operation system itself does not influence the preciseness of the measured data. On the other hand, if we complete the GPS procurer with GLONASS system, we get a significant difference compared to the conventional procurers. These days, we can get the most precise data with only a released devicewhich has GLONASS support. After this, the standard deviations of the 170 measurements were compared to the plain GPS devices and standard deviation of only 32 meters to 8 meters. It is not difficult to see that if you want to use vehicle navigation, the nearby streets differentiation (turning point), we can find an appreciable difference. But without the GLONASS we can measure strait data by using Kalman filter.

The average measurement distance between GPS+GLONASS and filtering data (with Kalman filter) is 4.271 meter, and the deviation is 0.75. We think that this method probably will good at indoor navigation system development.

V. Acknowledge

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Reference

[1] Burgers, Gerrit, Peter Jan van Leeuwen, GeirEvensen: AnalysisSchemeintheEnsembleKalman Filter.Mon. Wea. Rev.,126, 1719–1724, (1998)
[2] Cheng, D., P. Hadjicostas,"Right-invariant metrics applied to rank correlation coefficients," submitted for publication, 2012
[3] Fisher, N. I.: Statistical analysis of circular data. Cambridge University Press, New York, NY., Vol. 23, 1995
[4] Shu-Chih Yang, Eugenia Kalnay, Brian Hunt: Handling Nonlinearity in an Ensemble Kalman Filter: Experiments with the Three-Variable Lorenz Model. Monthly Weather Review 140:8, pp. 2628-2646, (2012)
[5] FerencBrachmann: About performance requirements set against consumer-grade geolocation technologies, submitted for publication, 2013
[6] PetrosHadjicostas: Using L1-Regression to Estimate a Monotone Two-Piece Linear Relationship Between Two Angular Variables, The operations research society of New Zealand, 46th Annual Conference, pp. 139-147., 10-11., December, (2012)
[7] Youngsun Jung, MingXue, MingjingTong: EnsembleKalman Filter Analyses of the 29–30 May 2004 Oklahoma TornadicThunderstormUsingOne- and Two-Moment Bulk Microphysics Schemes, withVerificationagainstPolarimetric Radar Data. Monthly Weather Review 140:5, 1457-1475, (2012)
[8] ZoltanHorvath, Ferenc Brachmann: Insmartphones and tabletsintegrated GPS accuracy, SZAMOKT-2013, (2013), Submittedpublication
[9] Gartner: [Online] Available: https://www.gartner.com/newsroom/id/2573415
[10] GLONASS: [Online] Available: http://www.novatel.com/assets/Documents/Papers/GLONASSOverview.pdf
[11] GLONASS masked area: [Online] Available: http://www.gnssnet.hu/ASfigures.php?station=SIKL&button=%E1br%E1k.