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Inaccuracy of Smartphone Sensors

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Abstract
Nowadays for almost everybody smartphones are available, which are fitted with more and more sensors. These sensors can assist us in navigation either indoor or outdoor. This is why it is a question of grave importance that how precise, reliable data these sensors provide the users. We shouldn't forget the factors influencing measurement results; even if terminating their influence appears impossible, we can moderate it.

Keywords
Indoor Positioning, Accelerometer, Gyroscope, Smart Phones.

I. Introduction

We began our research by examining GPS and GLONASS sensors used in outdoor navigation [5-6]. Since nearly every fourth person has used navigation software, we found examining how accurate these sensors are and what factors may interfere with them to be interesting. This is also important because indoor positioning is more complex compared to the outdoor. Suffice it to say that outdoor positioning technologies don't work indoor, because the sensors used are shielded. Our research, however, clearly revealed that outdoor positioning is not that simple either, as many might think [2]. Furthermore we didn't get the same result using different softwares, but the same device, operating system and sensors in the same weather conditions [1]. In this case it often occurred that we measured 27-32% discrepancy among our data; this can be seen on fig. 1.

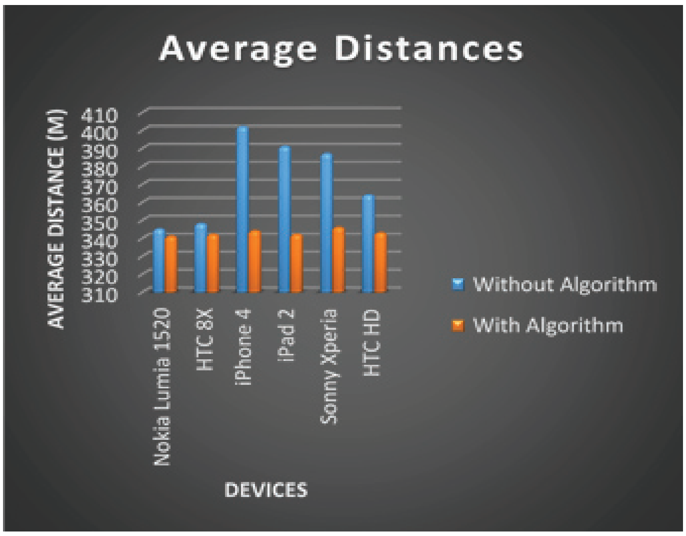

Fig. 1: Average Distance With and Without Algorithm

I don't mention environmental factors, since it's evident that certain weather conditions can greatly distort the accuracy of results. Our experiments were complemented by examining how devices respond if different forces are applied on them. We did this for we would like to make use of the gyroscope and the accelerometer in indoor positioning. Our measurement results showed that G-force can distort the precision of data if it reaches 3G. The other part of our experiment was to examine indoor positioning. For this we used the software developed by Lanoga Kft, which we can see on fig. 2. [8].

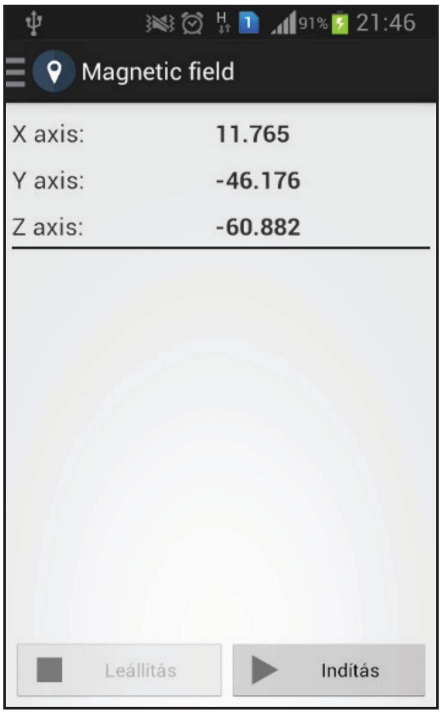

Fig. 2: Monitoring Software

The software can monitor sensors (accelerometer, gyroscope, etc.) in smartphones [11]. From the firs measures it turned out that the sensors are very sensitive during measurements [1]. The data detected during the test are discussed in chapter Results [10]. Many have attempted to use Wi-Fi networks for indoor positioning [7][3]. In this solution we meet with the same error as measuring inaccuracies caused by scattered and reflected signals observed in outdoor navigation.

II. Material and Method

A. Algorithms

Results provided by sensors are not enough to obtain evaluable data for indoor positioning. As we have already proven, it is necessary to use different algorithms to get evaluable and reliable data. First we examined how useful the Kalman filter is, since it is quite effective if we want to process data measured by the original signal from the scattered ones. During our research we recorded nearly 14,000 records, so it seemed obvious to examine the raw data with linear regression [9], since it gives a line; this is called a regression line. Its general formula is the following (1)[10]:

$$Y = \beta_0 + \beta_1 X \qquad (1)$$

However we should not forget that given this many data, measuring errors can occur, so do estimation errors in the regression. This can be described as follows:

$$\varepsilon_i = Y_i\ (\grave{\beta}_0+\grave{\beta}_1 X_i) = Y_i - \grave{Y}_i \qquad (2)$$

Besides, we must mention the error of the regression line, the residual error, or the error variance. This can be expressed as follows:

$$Res = E\left[(Y_i - \hat{Y_i})^2\right] = E[\varepsilon_i^2] = E[(\varepsilon_i - 0)^2] = \sigma_{\varepsilon_i}^2 \quad (3)$$

We encounter it especially when we measure too much reflected signals during recording. Of course, these errors can be filtered further, even with as mentioned above, or with the Bayesian Histogram.

$$f(y) = \sum_{h=1}^{k} 1\,(\xi h - 1 < y \leq \xi h)\frac{\pi_h}{(\xi h - \xi_{h-1})}, y \in R \quad (4)$$

Histogram filters have seen some use in robotics forlocalization due to their computational efficiency.
However, they do not offer an easy way to guarantee convergencedue to information loss in the approximation step.

IV. Results

In this research of ours we examined mainly the magnetometer and the accelerometer. The following measurement results are originated from a measuring at a fixed point, so that we can illustrate the accuracy of sensors better. First we discuss the results measured with the accelerometer. We recorded nearly 14,000 records, thus we had a relatively large set of data to work with. WE measured in two dimensions, so it forms a plane; also the device was fixed to one point. The latter is important because the accelerometer resting on the surface of Earth measures 0 G with a good approximation.

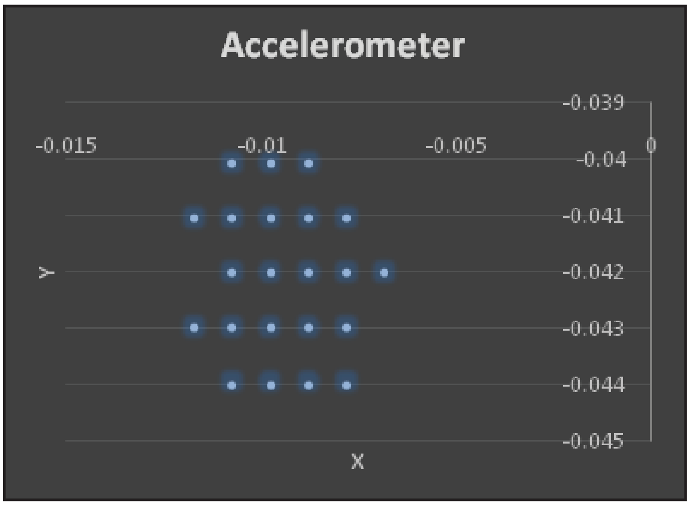

Fig. 3: The Surface of Earth Measures

This result is particularly interesting, since – as we have mentioned earlier – the measured results should be closer to 1, because the device conducting the measuring is fixed at the time of recording data. The results shown on the figure is similar to an event close to free fall, since the values converge to zero. We shouldn't ignore either that the values of the coordinate system are understood in the inertial system based on Newton's first law.
But it is an interesting result that nearly all measurement results show the same dispersion depicted in the inertial system.

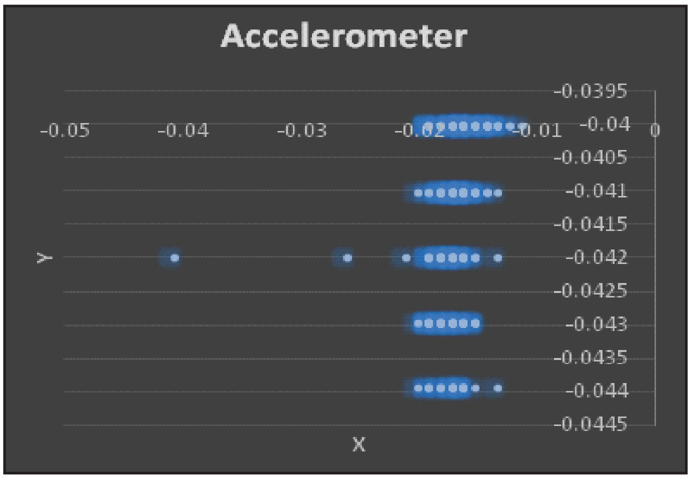

Fig. 4: The Inertial System

Since we gathered more than 10,000 records, we could analyze measurement sequences separately. On the figure above we can see the results of records 3400-7200. Because we can see some value seeming to be errors located far from the central set, we examined their environment. As it is shown on the graph below, if we examine a smaller sequence (3400-4400), the salient results disappear. We observed during our experiments that these errors return periodically (in every 1209 records), and then 15-17 faulty values are stored. But of course, it could be the inaccuracy of the smartphone sensor too.

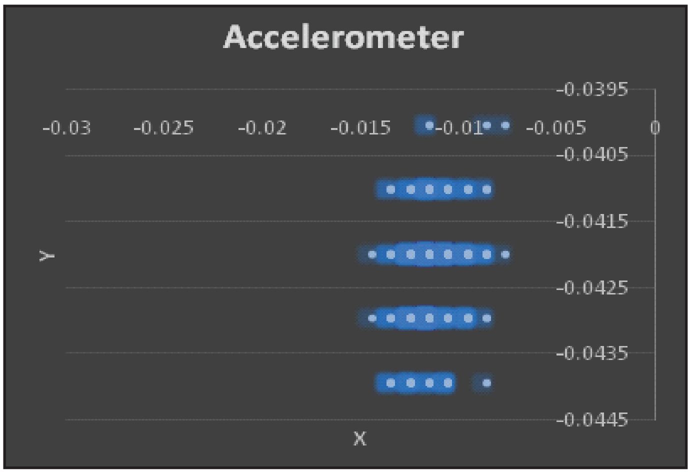

Fig. 5: Periodic Errors

On the next figure we can see the values between 4700 and 6000, where the salient values outline spectacularly.

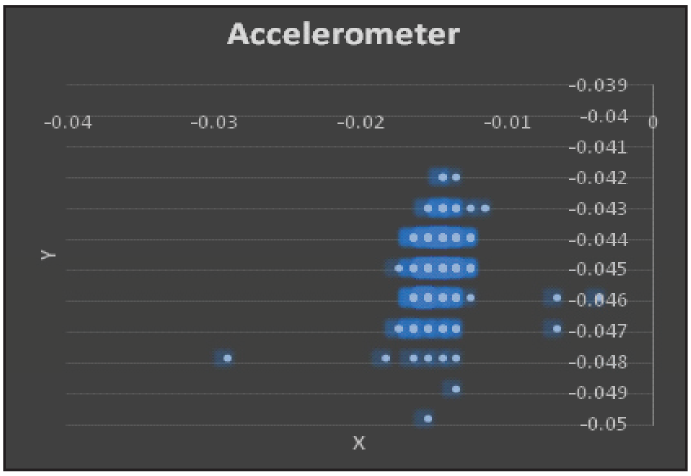

Fig. 6: Values Between 4700 and 6000

Besides errors occurring periodically, using the magnetometer we noticed that other electric instruments (such as computers, refrigerator, etc.) can cause errors. The next graph will show an example to this interference.

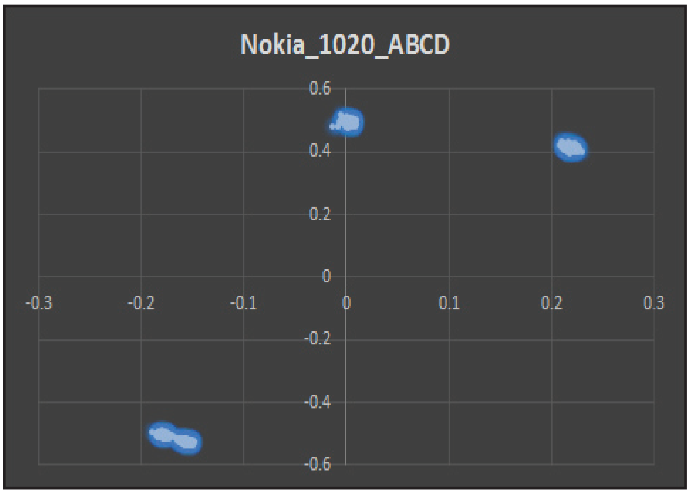

Fig. 7: Error of Interferences

During the experiment we performed measuring in the corners of the premises (950 per corner), then we imaged them in a coordinate system.

As we can see on the fig. 7, corner C and D became too close to each other, although they are further in reality. This error can be remedied in two different ways. Either we switch off the instrument in corner D which causes the interference, or we try to filter the signal. In the present case it can be seen that all measurement results are distorted, hence there will be no original signal to filter, and therefore the second solution is impossible. The next figure shows how measurement results change if the instrument is switched off, and if the results are filtered too.

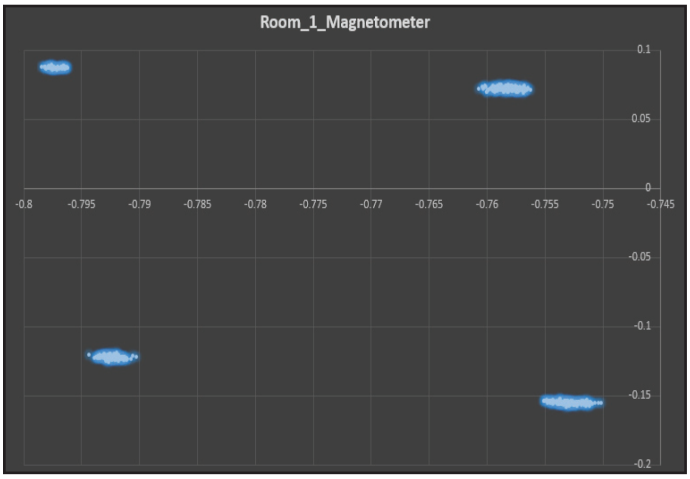

Fig. 8: The Values Without Interferences

As we can see on the graph above, this way the four corners are palpable at the test premises. But we still experience some shift, so in this case we don't perfectly perceive the original testing area. We attempted to estimate the original size of the testing area based on the measurement results. According to theme the longer walls were estimated to be 450 cm, while the shorter ones to be 250 cm long. In reality the longer sides are 432 cm, and the shorter ones are 240 cm long. So we can assert that, even if the used method is not 100% accurate, it is suitable for approximate estimation.

V. Conclusion

At this stage of our research we mainly examined the magnetometer and the accelerometer. In our experiments we gathered and processed nearly 15,000 records. Our studies have shown that there are more interfering factors during indoor measurements than during outdoor measuring. In our opinion the interference causes the greatest problem, since our buildings are full of electric appliances; and the thickness of walls and cable insulation are not effective enough to eliminate it. Another problem is if the interfering appliance is positioned within a 10 cm radius of the device. In this case we cannot find the original signal, so we can't filter the faulty data. The smallest distance, where we could find signal with no disturbance, was 32 cm; but in this case we could use only 24 out of 1000 measurement data to filter.

VI. Acknowledgement

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