RSSI optimization method for indoor positioning systems

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***Abstract*— The aim of this study is to develop a new method for optimizing Received Signal Strength Indicator (RSSI) vaguely used in Indoor Positioning Systems and to compare it to other existing methods. Adaptive filtering, such as Kalman filter, are one of the most used methods for RSSI filtering alongside the median filter. Our approach is to use a new algorithm that restricts the RSSI fluctuation in short periods of time to a changing median range that is calculated based on pervious states. The implementation of the new algorithm is done on Matlab IDE.**

Keywords*— *Received signal strength indication, RSSI, adaptive filtering, Median filter, Kalman filter, Indoor positioning system, Trilateration.

I. Introduction

The fast development of portable technology affects our daily life, we are becoming more and more dependent on smartphones and wearable devices. Now a GPS chip can guide you through the entire terrestrial globe. But it's still inefficient indoors, that's why a new technology emerged that can guide you through indoor places, such as big malls or football stadiums. There are different methods to elaborate Indoor positioning systems (abbreviated to IPS), from fingerprinting, to triangulation and trilateration.

Our approach is to use the trilateration method, where at least three beacons are installed in a closed room, and using scanned RSSI from each bacon, three distances can be calculated, a position is then deducted [4].

The value of the RSSI, depends strongly on the radio Channel problems where different parameters can be identified, like as: multiple reflections due to metal objects in the closed space, the presence of human bodies in the room, the existence of obstacles between emitter and receiver and reception/emission antenna's polarization.

The use of a brut RSSI is not recommended, as it varies vaguely in short periods of time. Thus, we need to filter the RSSI.

Two of the most used filtering methods are median and adaptive filters such as The Kalman filter [3].

Our paper will be divided into two major sections, the first one describes the method that we developed side by side with the Kalman filter. In the second section we will compare results of the two methods cited above.

II. Method

Received Signal Strength Indicator, is very dependent on, the radio Channel fading and shadowing phenomena, the metallic objects and human bodies existence in the closed space [5], disturb strongly the in time measured RSSI value.

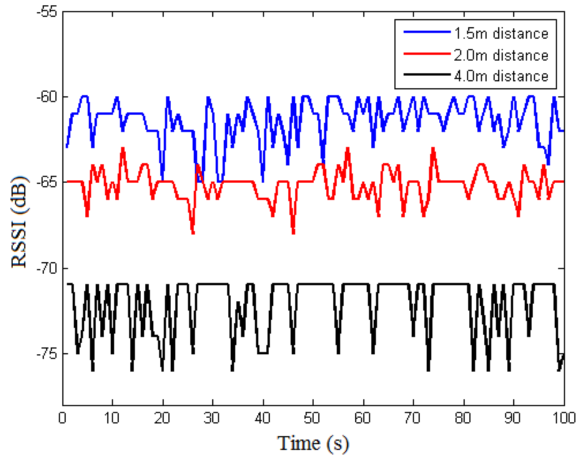

Figure 1. RSSI variance for 3 different distances

In the figure 1, we can observe the variance of the RSSI, it is up to 5dB between two successive values, knowing that the equation for calculating the distance from an RSSI is:

$$d = 10^{\frac{RSSI-A}{-10*n}} \quad (1)$$

Where:

n: signal propagation constant which is 2 in free space but varies with local settings, for our example and after calcul us we set the n to 2.57

A: is the RSSI value of a *1m* distant device which is around -58dB

For the black signal above the calculated distance using equation (1) varies between *3.21m* and *5.01m*. Which translates to more than *2m* error. There for the use of a filtering method is recommended.

a) Kalman filter :

The Kalman filter is an adaptive recursive estimator filter that is capable of estimating data through out a series of incomplete or noisy data [2].

It uses two separate phases, successively, the prediction phase and the update phase. The first one is the estimation of the n-1 state and covariance. The update phase is more of calculating the new state and covariance [6].

The equations for the Kalman filter are [1]:

Prediction phase:

$$\hat{x}_k = A \times \hat{x}_k \tag{2}$$

$$P_k = A \times P_{k-1} \times A_k^T + Q_k \tag{3}$$

Update phase:

$$K_k = P_k \times H_k^T (H \times P_k \times H_k^T + R)^{-1} \tag{4}$$

$$x_k = x_{k-1} + K_k \times (Z_k - H \times x_{k-1}) \tag{5}$$

$$P_k = P_{k-1} - (K_k \times H \times P_k) \tag{6}$$

Where:

$A = \begin{bmatrix} 1 & 0.1 \\ 0 & 1 \end{bmatrix}$

Z = Input Signal

K: The Kalman gain

$\hat{x}$: The estimated state

P: The estimated error covariance

Q and R: noise covariance

b) The RMM algorithm :

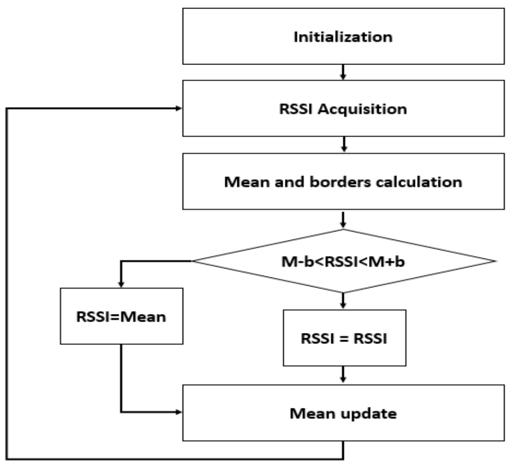

Figure 2. The RMM algorithm

Our approach is based on a basic median filter, at first we set a mean value altogether with its borders. Then we compare every (t) RSSI value to its (t-1) value, if it's over the specified range, the (t) value is then assigned the mean value. Thus, we are preventing peaks over short periods of time. We called our approach the RSSI Moving Median algorithm (RMM).

We predict that the main advantage of the RMM algorithm its simplicity and it's easier implementation in real-time.

III. Results

For our experimentations, we managed to get RSSI from a Bluetooth embedded unit coupled with an Arduino controller using as transmitter, for RSSI's receiver, we have choose smartphone. The RSSI value is then transferred to Matlab using serial communication.

The test that we performed to check the capabilities of the two filters, included two distinct phases, the first one is putting the receiver still at different places and the second one is a moving phase throughout a closed room and with the existence of obstacles and human bodies to emulate a real room activity.

The figure 3 shows the unfiltered RSSI signal compared to the results from the two filtering methods described above.

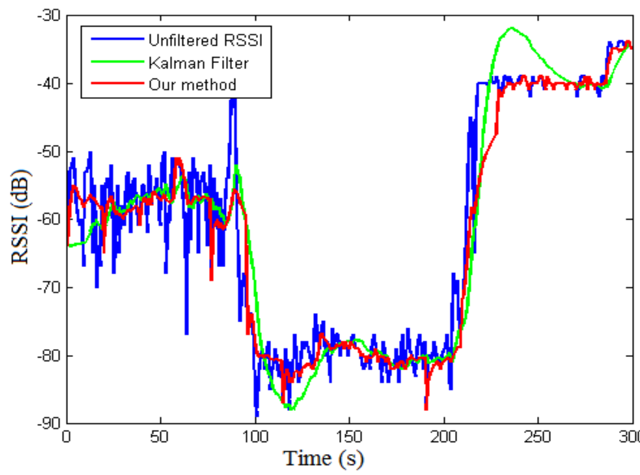

Figure 3. Comparison between unfiltered RSSI and the two filtering methods

After a first examination, we can clearly see that the RSSI signal is very noisy, there for a filtering method is mandatory. In a first hand, we observe that for the stable parts of the signal, the Kalman filter has fewer peaks and is a little more stable than the RMM algorithm. In the other hand, for the movement periods our approach follows in a perfect shape matches to the original signal contrary to the Kalman filter.

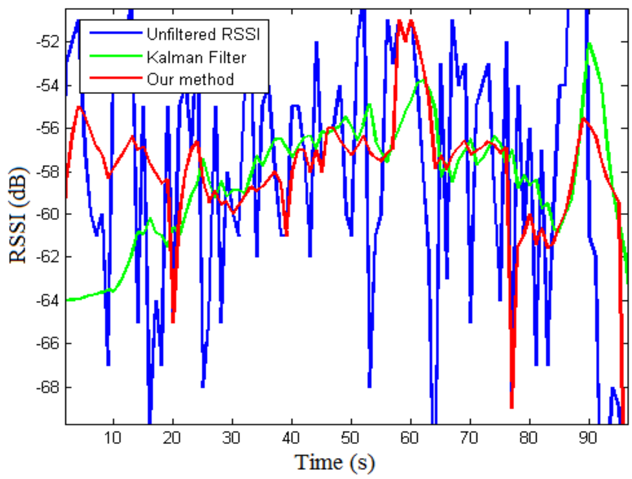

Figure 4. Zoom on the signal *(first stable part)*

The figure 4 shows zooming on the first stable part of the RSSI signal, it is visible that the Kalman filter results are somehow more stable than the RMM algorithm.

The last stable part of the signal indicates that the RMM algorithm has more stability and follows exactly the shape of the unfiltered RSSI signal with elimination of the peak signals as seen in the figure 5.

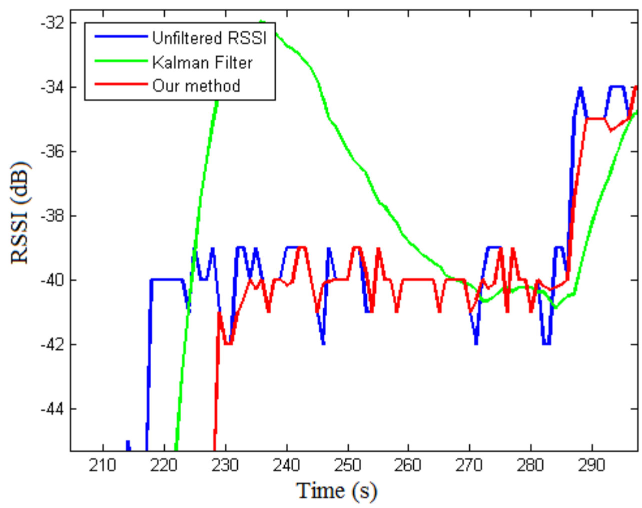

Figure 5. Zoom on the signal *(last stable part)*

For a clearer view on the results we conducted an error comparison, we subtracted the two resulting signals from the original one. As it is shown in the figure 6. This last figure shows that our new optimization gives better results compared to the Kalman filter in a crowded room. The minimal and maximal values of the two signals successively are: *-19.14 dB* and *19 dB* for our method and *–23.59 dB* and *29.01 dB* for the Kalman filter.

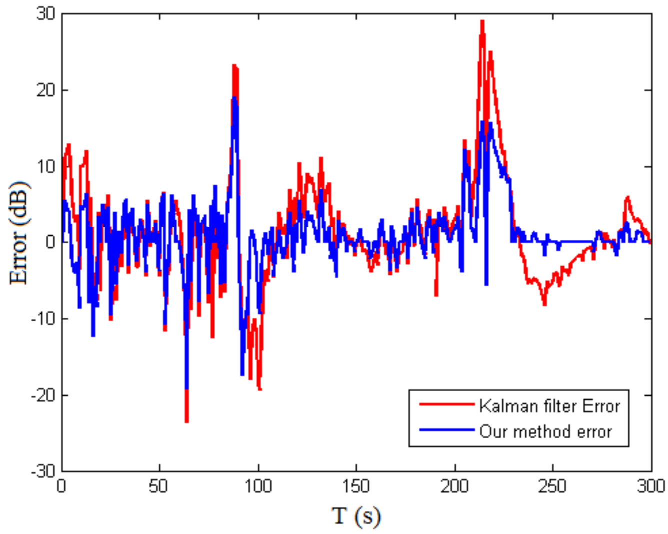

Figure 6. Error comparison

IV. CONCLUSION

RSSI is a very noisy source of data, thus to get the best use of it, a filtering method is mandatory. Our paper describes a newly developed filtering method that uses median filter as a base and then updates the mean value for each sample. We then proceed to compare the results of our method to those of the Kalman filter. The variance of the error signal for the two cited methods are *22.62 dB* for the RMM algorithm and *50.93 dB* for the Kalman filter. The Kalman filter has improved stability in the case of a stable mobile. But unfortunately it's not the case in real world, this is where we observe that the advantage of RMM algorithm is better results in movement. The RMM algorithm is more suitable for a crowded room that includes human presence, and existence of highly moving obstacles and reflectors. The next step is to implement this method into real-time systems.

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