Optimization of a 2D localization system of a moving object based on the propagation time of a signal, with asynchronous distance measurement method.

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Abstract - *This paper presents studies to improve the results obtained by a localization system of a moving object using the asynchronous method as distance measurement method. First, the filtering of the measured values by limiting the values in an interval to eliminate erroneous values, and after, the study of the different calculation methods such as the calculation of the average, the modal calculation and the median to improve the result, and with the shift values selection to stabilize it.*

***Key Words*: Localization system, Plane, Trilateration, Distance, Asynchronous system, Arithmetic average, Mode, Median, Shift values selection**.

1 . INTRODUCTION

There are two methods for a localization system using the propagation time of a signal, synchronous or asynchronous depending on the system used to measure the distance.

Values errors due to trigger signal processing delay are less for synchronous system than for asynchronous system, the source of error in the asynchronous system being the estimation of the source signal departure time.

The synchronous system needs two signals with different speed to make the synchronization and used for the measurement. The measurement signal speed must be slower than the synchronization signal which it must be too high, Indeed, the space of measurement is very limited because of this slow measurement signal speed whose range is weak. [1]

We chose to continue the study on the asynchronous system which is able to do large scale positioning and able to use long range signals.

Thus, in this paper, we will study some methods to improve the values measured by the sensors before applying the trilateration calculation for the asynchronous system.

2 . Improvement of the result by selection and filtering of the measured values

Due to the various disturbances during the measurements and the stability of the system, the measured values are unstable. Table 1 shows the values measured by the system every 500ms with a sensor and whose real distance between sensor and object is 50cm, and it will be kept as a measurement reference in this article.

Peaks in value during the measurements are observed. There are those which are due to non reception of the sensor, (Table 1: Time 9500ms, Time 33000ms.). These peaks can be eliminated by limiting the values in an interval to eliminate erroneous values. The use of maximum and minimum measurement filters is efficient since we know that the values must fall within a predefined field.

There are also peaks of value or measurement errors due to disturbances, (Table 1: Time 21000ms, Time 3800ms). The values are scattered around the 50[cm] line which is the exact position of the object during the measurement.

The following Fig.1 shows the graph of the values measured in relation to the times by a single sensor with a distance of 50cm. The measurement is made every 500 milliseconds.

Tableau-1: Values measured with a real distance between the object and the sensor of 50[cm].

Time [ms]	Distance measured [cm]
0	53.76
500	53.28
1000	48.6
1500	48.6
2000	51.12
2500	49.8
3000	49.92
3500	53.88
4000	49.2
4500	52.2
5000	49.44
5500	50.28
6000	47.28
6500	48.96
7000	51.36
7500	49.44
8000	53.16
8500	51.48
9000	50.28
9500	3319.92
10000	51.6
10500	49.8
11000	49.8
11500	47.28
12000	50.52
12500	50.28
13000	49.32
13500	49.92
14000	51.48

Time [ms]	Distance measured [cm]
14500	48.96
15000	54.84
15500	51.48
16000	48.96
16500	51.12
17000	48.12
17500	54
18000	51.24
18500	51.6
19000	50.28
19500	50.76
20000	48.24
20500	48.96
21000	54.84
21500	53.28
22000	49.56
22500	48.96
23000	48.24
23500	50.64
24000	49.92
24500	49.44
25000	48.96
25500	49.92
26000	48.84
26500	50.28
27000	48.6
27500	51.12
28000	49.08
28500	49.44

Time [ms]	Distance measured [cm]
29000	49.92
29500	47.4
30000	49.92
30500	53.28
31000	52.44
31500	51.96
32000	53.88
32500	54.6
33000	28699.8
33500	48.24
34000	49.44
34500	54.72
35000	48.96
35500	49.44
36000	51.84
36500	48.6
37000	50.28
37500	48.96
38000	58.44
38500	49.32
39000	49.92
39500	46.92
40000	48.12
40500	49.44
41000	46.44
41500	51.12
42000	52.8
42500	49.8
43000	51.96

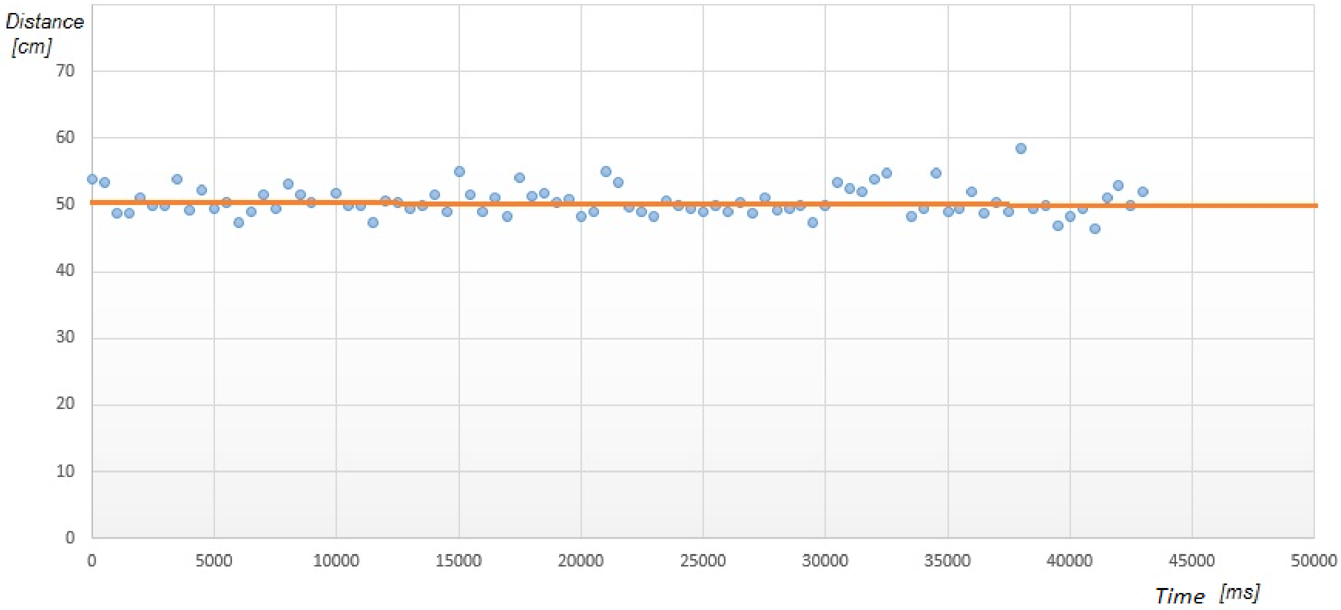


Fig-1 : Graph of the distance measured values.

The quality of the positioning calculation result of the trilateration method depends on the selection or filtering of these measured values.

Indeed, we are going to study and compare methods of filtering and selection of values. The arithmetic average, the mode, the median are calculations to have values closer to the real value. The shift values selection method is also studied for stabilizing and damping of the results.

3 The arithmetic average

The classic method exploiting the calculation of the arithmetic average is a way to have a closer result that does not derive much from the real value. The arithmetic average is defined in Eq.1.

$$average = \frac{sum\ of\ values}{total\ number} \quad (1)$$

Using the series of values $(x_1, .., x_n)$ The average is rewritten in Eq.2.

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad (2)$$

[2] [3]

4 Value processing time and response time

It is necessary to wait for the reception of all the values of a series to be able to calculate the average afterwards, so the processing time depends on the period of the signal (duration between 2 consecutive signals) and the number of values chosen for a series.

Hence the response time which depends on the processing time of each series of values is given by Eq.3.

$$T_r = n.T_s \quad (3)$$

With T_r System response time , n The number of values in a series, T_s The period of the signal.

By applying the arithmetic average to a series of 10 values we have the graph in Fig.2.

It can be seen that the curve of distances obtained by arithmetic average is smoother compared to the curve of the measured values.

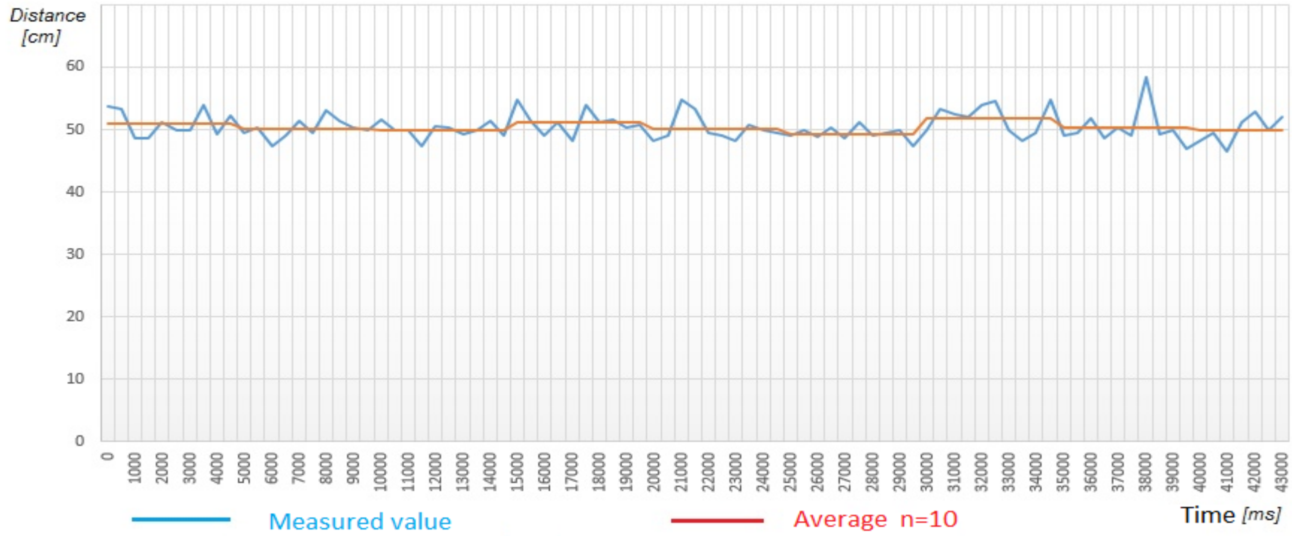


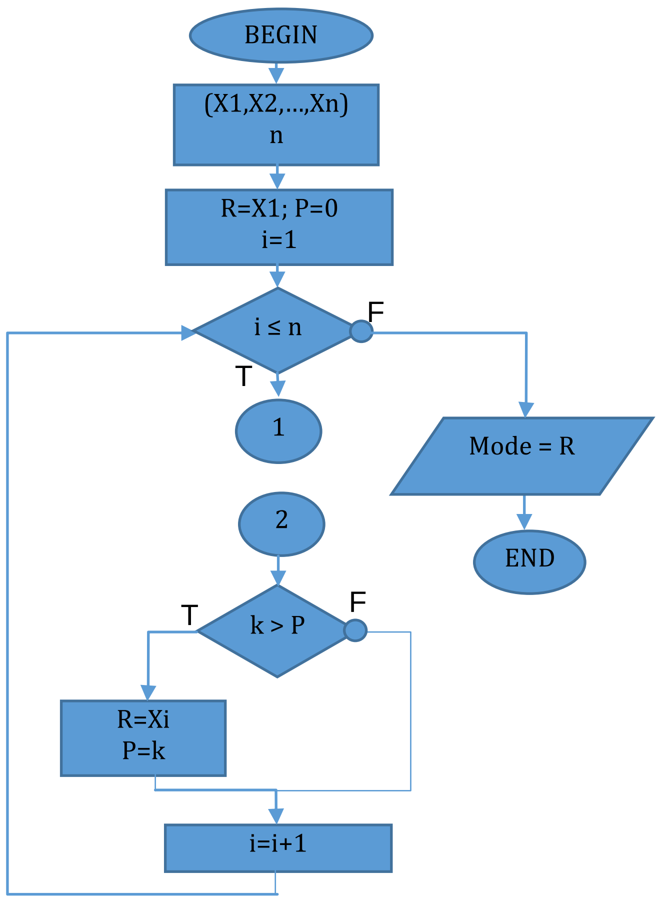
Fig-2 : Graph measured value / arithmetic average (n=10) ,

5 The Mode

Mode is a method for improving the selection of measured values that most closely match the real values. This method consists by selecting the most frequent value in a series of measured values. [2] [3]

Example : the mode of the series {4,2,4,3,2,2}, is 2 because it appears three times. 2 is the value with the highest number of occurrences. [2] [3]

The algorithm in Fig. 3 allows to determine the value of the mode in a series of n values and Fig .4 shows the graph of the values by applying this algorithm by taking n=10.



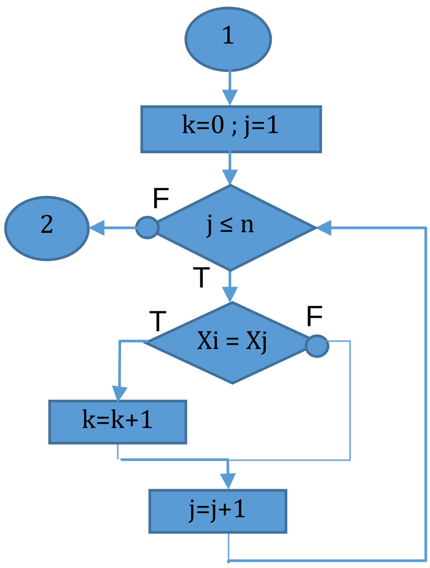


Fig-3 : Mode calculation algorithm.

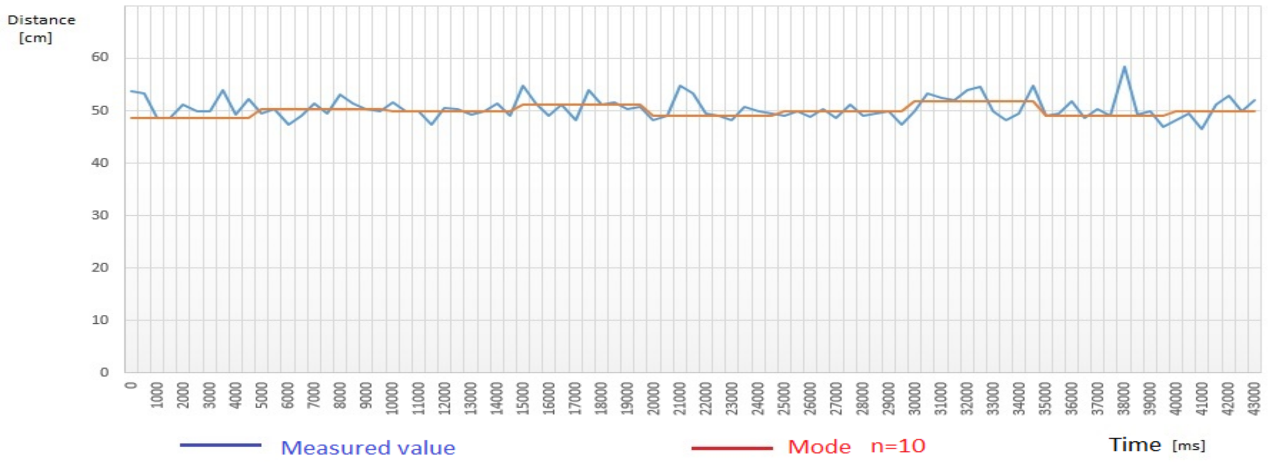


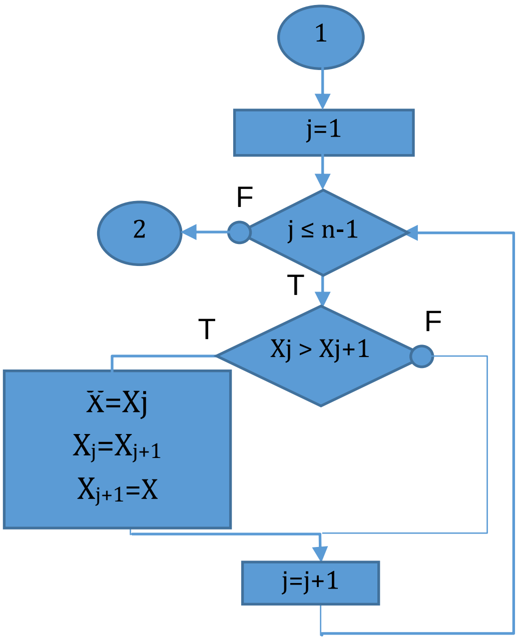
Fig-4 : Graph measured value / mode.

6 The median

It is the central value of a series whose observed values have been arranged in ascending order. It is the value which divides the population studied into two subsets of the same number (if the number of observations n is even, the median is the half-sum of the terms of rank n/2 and (n/2) + 1). [2] [3]

Example : The median of the series : (4, 2, 1, 7, 7) is 4 because, after ordering the values in ascending order (1, 2, 4, 7, 7), 4 is the value that divides the series into two equal halves. [2] [3]

The algorithm in Fig. 5 allows to determine the value of the median of a series of n values and Fig. 6 shows the graph of the corresponding values (with n=11).



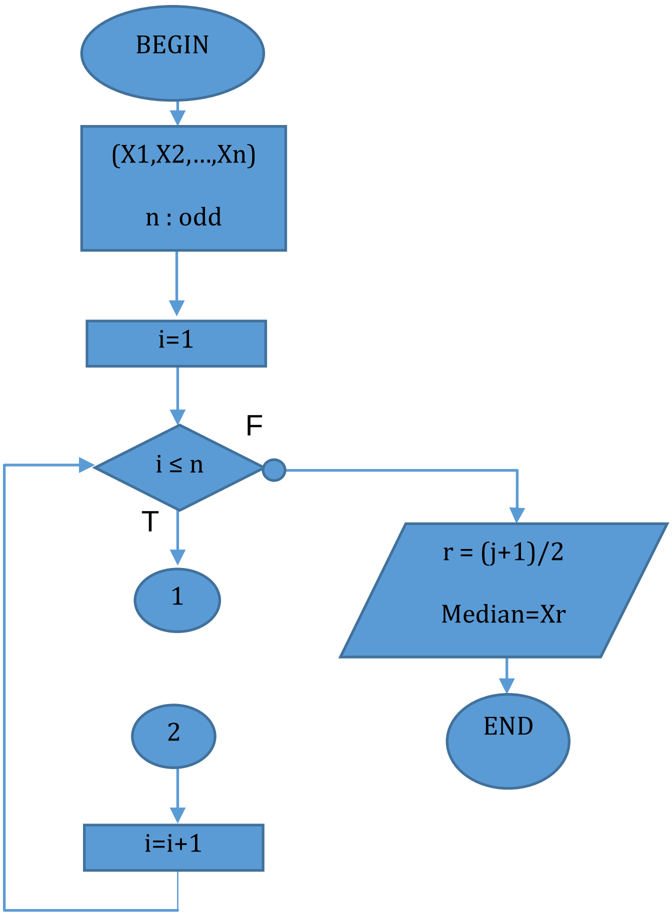


Fig-5: Median calculation algorithm

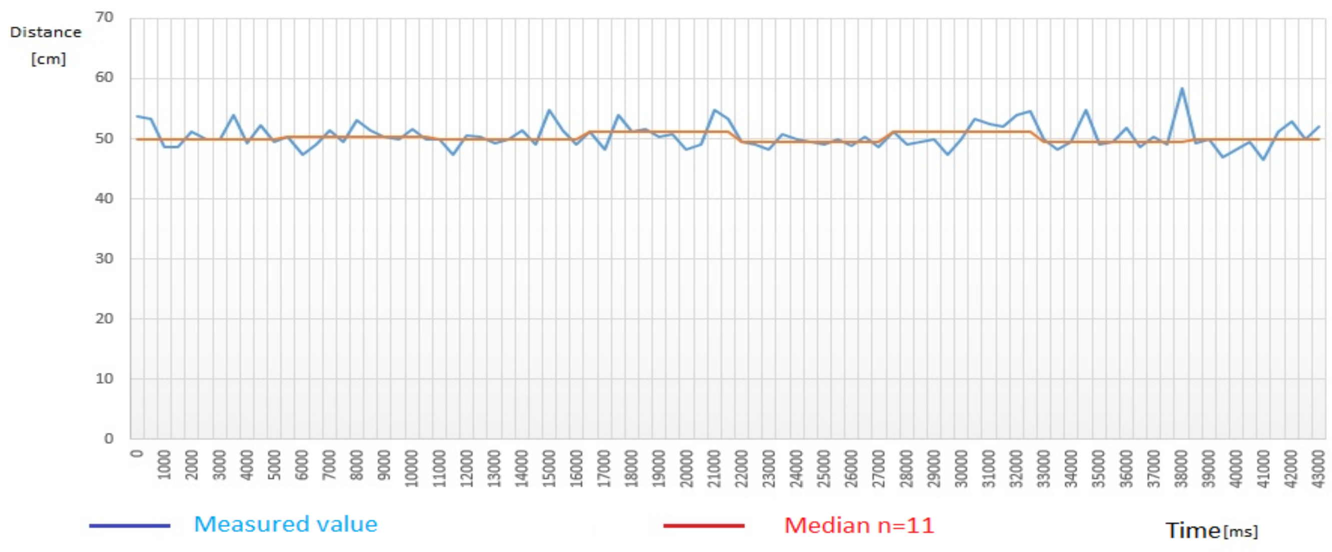


Fig-6 : Graph measured value / Median (n=11).

7 Comparisons and Interpretations

The calculation of the arithmetic average of series of values presents peaks which cause the value of the calculated average to deviate considerably.

The mode calculation cannot succeed on some series of values because of the non-existence of similar values. Indeed, with a precision of 10^{-2} it is rare to find a redundant occurrence.

The median calculation is not affected by the existence of peak values. Moreover, regardless of the measurement series, a result is always obtained by the calculation algorithm.

Figure 7 shows the superimposed graphs obtained by using the average, mode, and median calculation methods. It can be seen that the use of the median gives a result that is closer to reality.

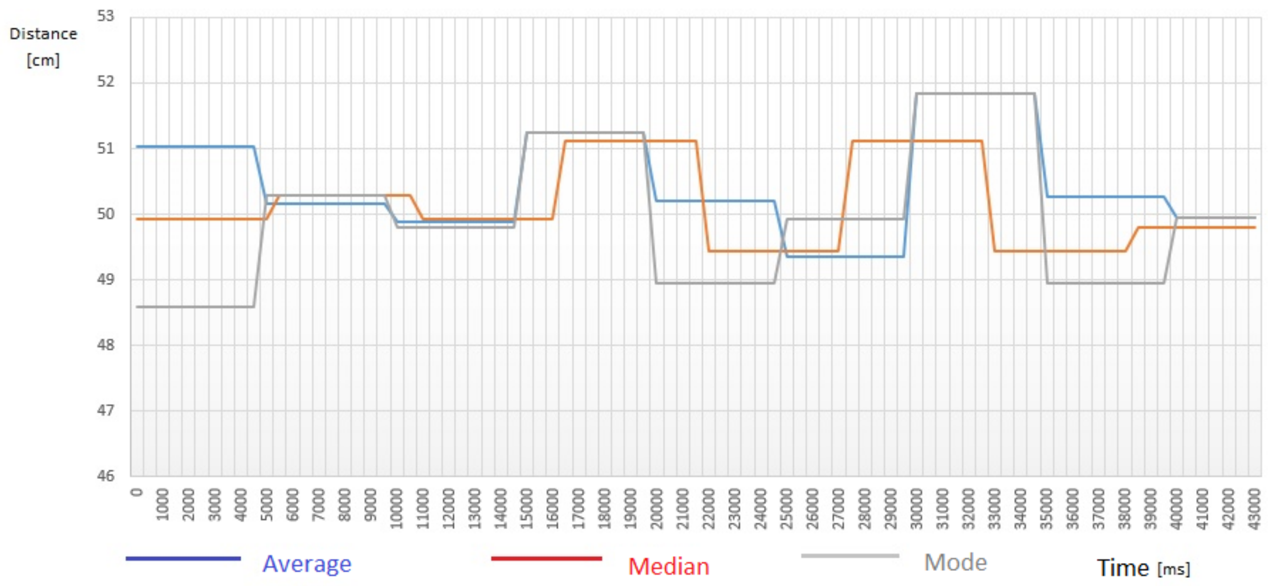


Fig-7 : Graph average(n=10) / mode (n= 10) / median (n=11).

8 Shift values selection

Considering that the object to be located is a mobile object, in order to consider the displacement of the object, the shift values selection is introduced into the system. The shift values selection method provides a more damped result by shifting the selected values one level each time a new value is received. Fig.8 illustrates the values selected at each new series by running the algorithm in Fig.9.

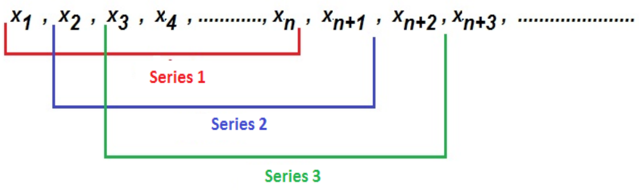


Fig-8 : Illustration of shift values selection.

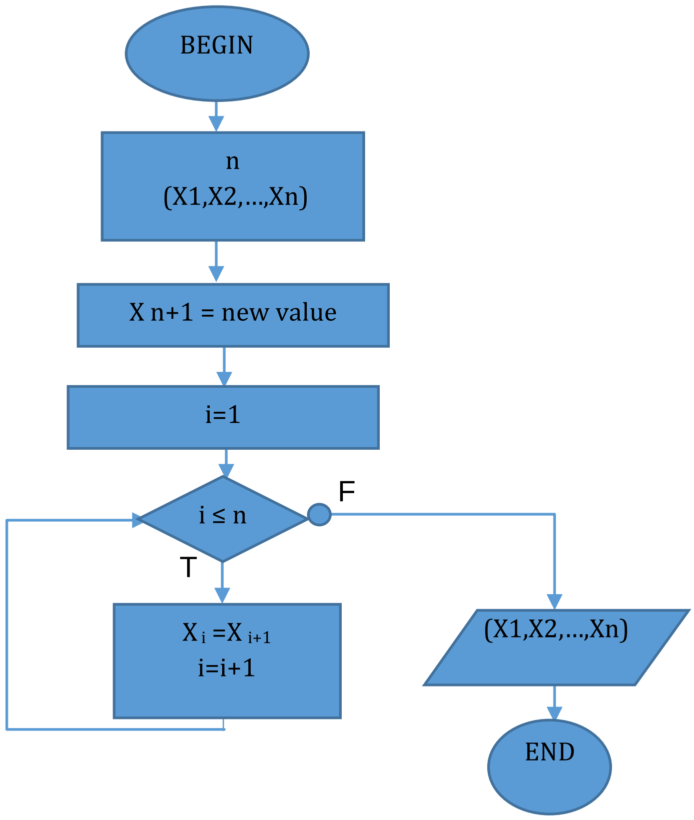


Fig-9 : shift values selection algorithm.

9 Average with Shift values selection

By applying the shift values selection on the calculation of the arithmetic average, Fig.10 is obtained.

Fig-10 : Graph average / average with shift, (n= 10).

10 Median with Shift values selection

Fig.11 presents the measurement results using the median and the median with shift values selection.

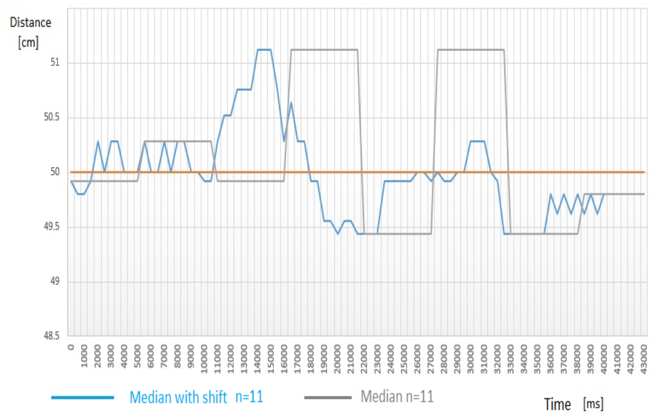


Fig-11: Graph median / median with shift, (n=11).

11 Interpretation

By overlaying the moving average and moving median plots (Fig.12), it can be seen that the moving median curve is closer to the true value curve. This further confirms the effectiveness of the method by median with shift values selection for the asynchronous measurement system.

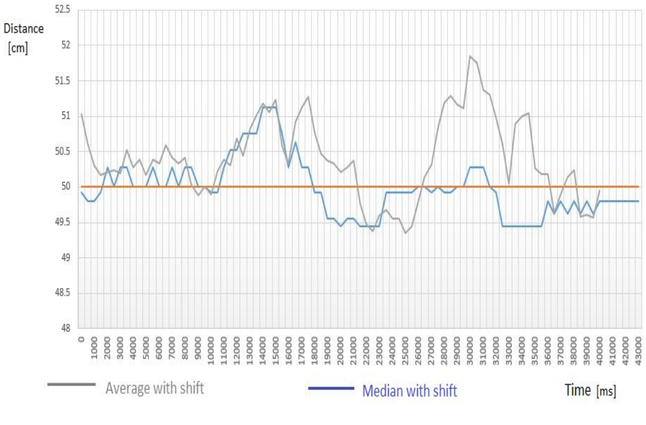


Fig-12: Graph average with shift / median with shift (n=11).

12 Application of the median with shift values selection on the asynchronous measurement system

In static mode (stationary object) the more the number of values selected in a series is increased, the better the result is obtained as shown in Fig.13.

But in dynamic mode (moving object) increasing the number of selected values leads to a delay in response , as shown in Fig.14.

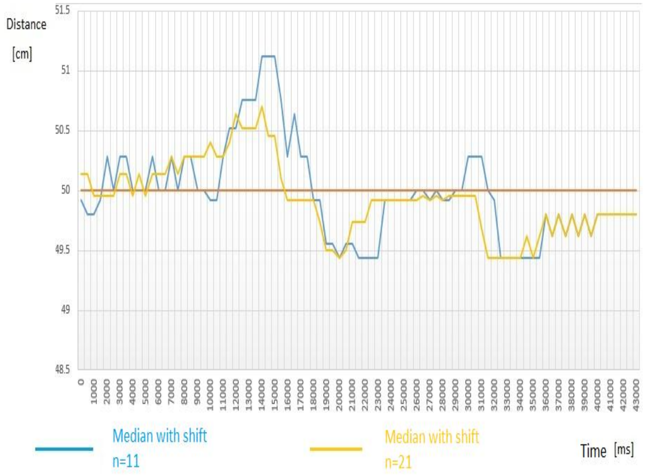


Fig-13: Graph median with shift for stationary object.

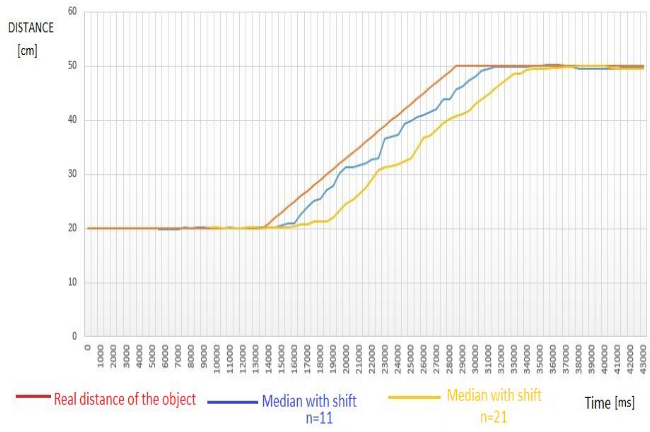


Fig-14 : Graph median with shift (object in movement) with different number of selected value.

13 CONCLUSIONS

After analyzing all the results obtained by some methods applied to improve the accuracy of the distance measurement, the method offering the highest accuracy is the median with shift values selection.

Nevertheless, the precision/response time duality becomes the main constraint for the implementation of the system. Indeed, more measurement precision need more number of measurements, thus generating a delay in the system. In order to further reduce errors on these systems, the review of the TDC (Time to Digital Converter) system could help to refine the calculation of the times.

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