Use of Joint Space Correlation of Satellite Constellation Move in GPS

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Abstract – **The paper sets out an algorithm, which aims at improving the accuracy in fixing the position of an object using the global positioning system GPS.**

Keywords – **GPS; position accuracy; least squares.**

I. Introduction

In the satellite based navigation system GPS, fixing the user's position is accomplished by means of estimating the distances to the four satellites [3]. The user's coordinates are determined from system of equations, connecting these distances with its position.

One way for improving the accuracy of fixing the coordinates is using of additional processing of the initial estimates of these coordinates.

This paper presents an approach for processing the coordinates data according to the results, which were obtained by means of the algorithm suggested in [6]. This algorithm is developed for an immobile or slow-moving object.

A comparison between the results obtained by this approach and true data obtained by GPS receiver has been made.

II. Fixing the Coordinates

Marinov, Stanchev's study [6] gives quadratic model about the distance alteration between the user and the GPS satellites:

$$\left| \begin{array}{l} 0.5[D_1(t)-D_2(t)+R_2(t)-R_1(t)] = \\ =[x_1(t)-x_2(t)]x+[y_1(t)-y_2(t)]y+[z_1(t)-z_2(t)]z \\ \\ 0.5[D_1(t)-D_3(t)+R_3(t)-R_1(t)] = \\ =[x_1(t)-x_3(t)]x+[y_1(t)-y_3(t)]y+[z_1(t)-z_3(t)]z \\ \\ 0.5[D_1(t)-D_4(t)+R_4(t)-R_1(t)] = \\ =[x_1(t)-x_4(t)]x+[y_1(t)-y_4(t)]y+[z_1(t)-z_4(t)]z \end{array} \right. \quad (1)$$

where $D_i(t)$ is the distance between the user and the i th satellite. $R_i(t)$ is the distance from the i th satellite to the origin of the coordinate system.

The satellite's coordinates are x_i, y_i and z_i. The index specifies the satellite's number.

The distance estimation is done using the approach suggested by [6].

After solving the equation system, the result is the object's coordinates x, y, z which have an error. During the processing interval the error is changing with time in a second degree curve, therefore the estimation of the coordinates will have the same character.

Additional processing is needed for improving the accuracy of the estimation of the coordinates. The research shows that the distances to the satellites, whose calculations are based on the estimated coordinates, are different from those on the first processing stage. Setting the estimated coordinates, where the difference is minimum, is used as an algorithm for additional processing. On the other hand, the research work reveals that minimum difference is always on one and the same coordinates regardless of the satellite being used.

III. Research Results

The study is based on different variances of the distances measured by the GPS receiver, striking an average of 1000 realization for each of the different variances.

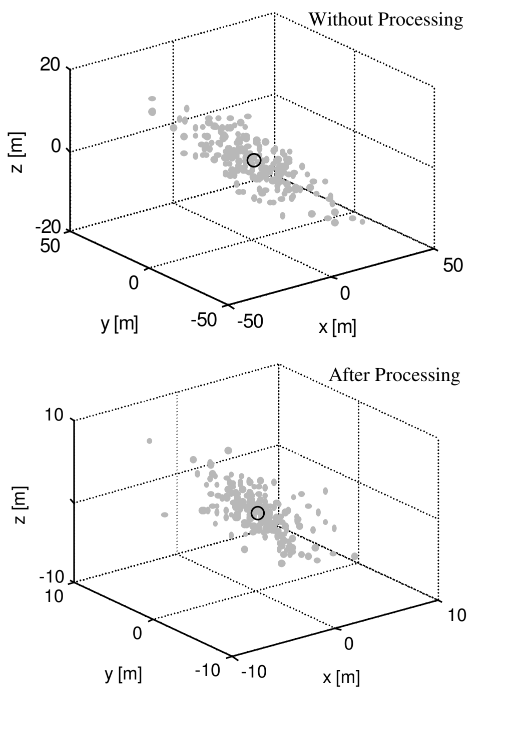

Fig. 1. Coordinate errors for $\sigma^2 = 9\text{m}^2$ and T =200 ms.

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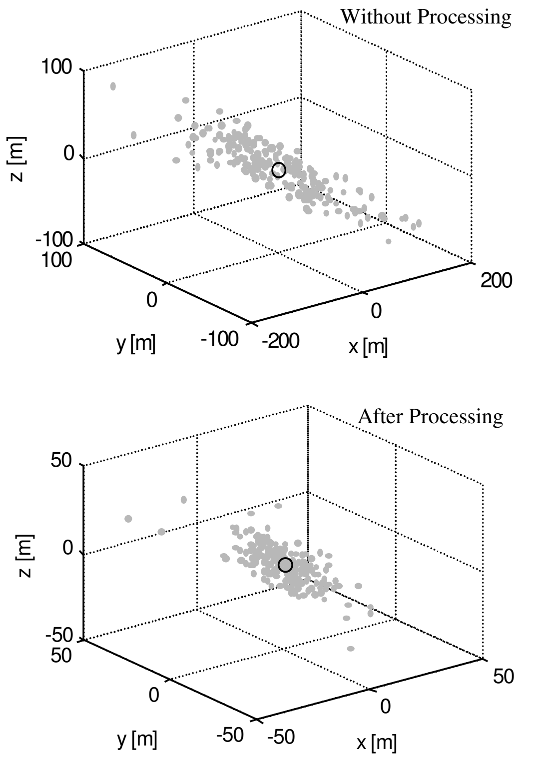

Fig. 2. Coordinate errors for $\sigma^2 = 144\text{m}^2$ and T =200 ms.

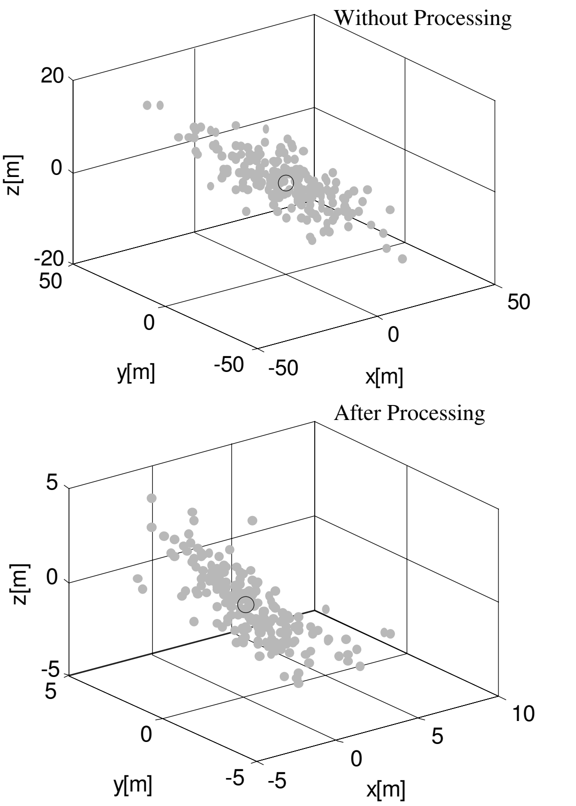

Fig. 3. Coordinate errors for $\sigma^2 = 9\text{m}^2$ and T =500 ms.

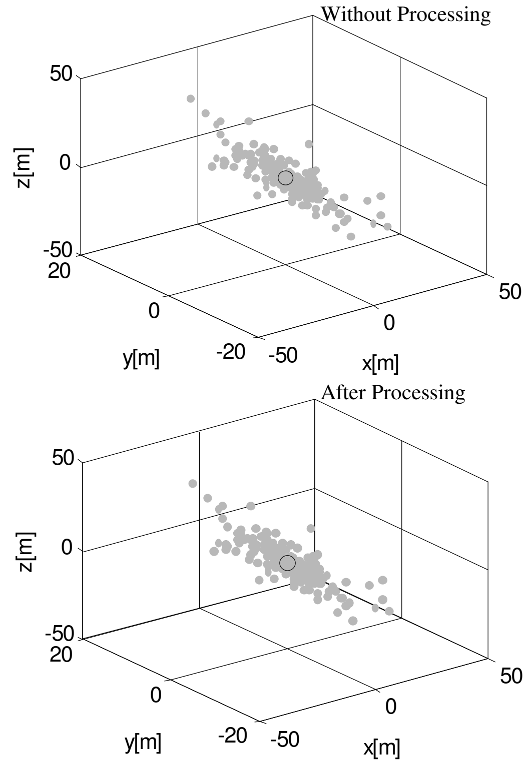

Fig. 4. Coordinate errors for $\sigma^2 = 144\text{m}^2$ and T =500 ms.

Fig. 1 shows the results for the error in fixing the position with variance 9 m^2 and processing interval 200 ms.

It is clear that the coordinate errors are greater in case of no additional processing, rather than the presented algorithm is used. The results prove that the improvement of accuracy is rather than several times when after applying the suggested algorithm. The coordinate errors are no more than 10 meters for all 10000 realizations, when the variance is 9 m^2 and time processing interval is 200 ms.

Fig. 2 shows the results for the error in fixing the position with variance 144 m^2 and processing interval 200 ms.

It is obvious that the coordinate errors are greater in case of no additional processing, rather than the presented algorithm is used. The results prove that the improvement of accuracy is rather than several times when after applying the suggested algorithm. The coordinate errors are no more than 40 meters for all 10000 realizations, when the variance is 144 m^2 and time processing interval is 200 ms.

Fig. 3 shows the results for the error in fixing the position with variance 9 m^2 and processing interval 500 ms.

The results prove that the accuracy is better if time processing interval is 500 ms. The coordinate errors are no more than 8 meters for all 10000 realizations, when the variance is 9 m^2 and time processing interval is 500 ms.

Fig. 4 shows the results for the error in fixing the position with variance 144 m^2 and processing interval 500 ms.

The results prove that the accuracy is better if time processing interval is 500 ms. The coordinate errors are no more than 30 meters for all 10000 realizations, when the variance

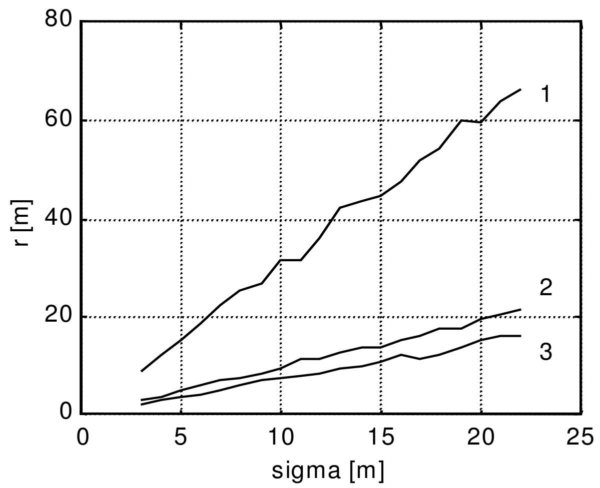

Fig. 5. The averaged error for T=200 ms.

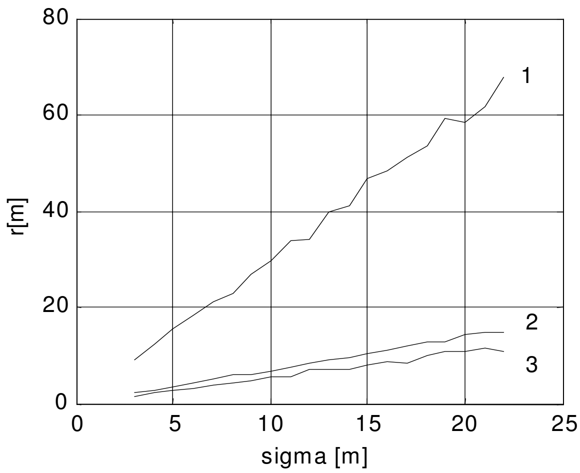

Fig. 7. The averaged error for T=400 ms.

is 144 m^2 and time processing interval is 500 ms.

An averaging of 10000 realizations for each value of the variance is made. The efficiency of the algorithm is valued by the distance between true position and estimated position. The comparison of suggested algorithm with common averaging of coordinates and without any processing of data is done.

Fig. 5 shows the results of the comparison when interval of processing is 200 ms.

The values of errors are the smallest when the proposed algorithm is applied. The distance between true position and estimated position is from 8.77 to 66.38 meters when an additional coordinate processing is not applied (curve 1). The values of the distance are from 2.77 to 20.94 meters in the case of the common averaging (curve 2). In the case of suggested algorithm (curve 3) that distance is from 2.11 to 16.44 meters. The averaged improvement of position accuracy is about 32 % in relation to the common averaging and 321 % in comparison with the case of no data processing.

Fig. 6 shows the results of the comparison when interval of processing is 300 ms.

The values of errors are the smallest when the proposed algorithm is applied. The distance between true position and estimated position is from 9.3 to 71.82 meters when an additional coordinate processing is not applied (curve 1). The values of the distance are from 2.42 to 17.48 meters in the case of the common averaging (curve 2). In the case of suggested algorithm (curve 3) that distance is from 1.93 to 13.06 meters. The averaged improvement of position accuracy is about 32.75 % in relation to the common averaging and 411 % in comparison with the case of no data processing.

Fig. 7 shows the results of the comparison when interval of processing is 400 ms.

The values of errors are the smallest when the proposed algorithm is applied. The distance between true position and estimated position is from 9.13 to 67.86 meters when an additional coordinate processing is not applied (curve 1). The values of the distance are from 2.09 to 14.82 meters in the case of the common averaging (curve 2). In the case of suggested algorithm (curve 3) that distance is from 1.49 to 10.88

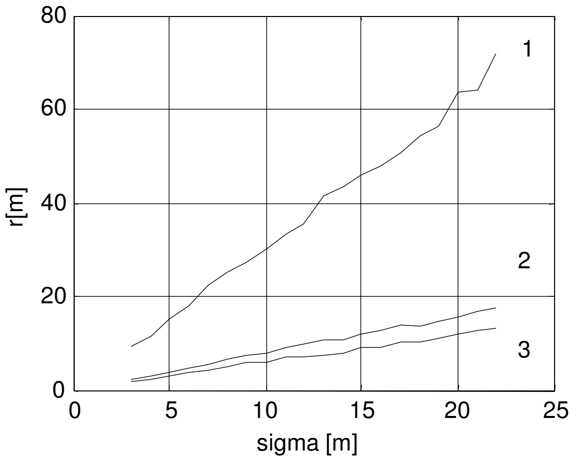

Fig. 6. The averaged error for T=300 ms.

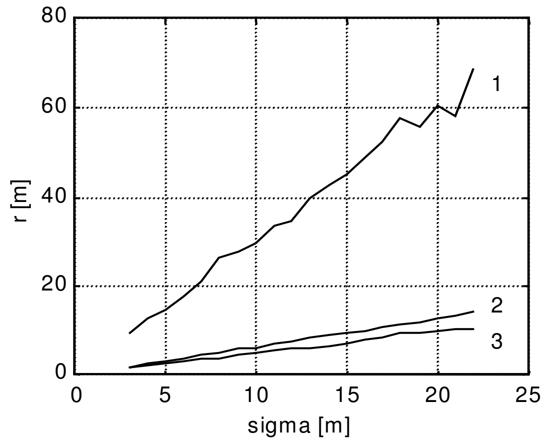

Fig. 8. The averaged error for T=500 ms.

meters. The averaged improvement of position accuracy is about 30.88% in relation to the common averaging and 473% in comparison with the case of no data processing.

Fig. 8 shows the results of the comparison when interval of processing is 500 ms.

The values of errors are the smallest when the proposed algorithm is applied. The distance between true position and estimated position is from 9.32 to 68.5 meters when an additional coordinate processing is not applied (curve 1). The values of the distance are from 1.83 to 14.29 meters in the case of the common averaging (curve 2). In the case of suggested algorithm (curve 3) that distance is from 1.42 to 10.25 meters. The averaged improvement of position accuracy is about 29.33 % in relation to the common averaging and 530 % in comparison with the case of no data processing.

IV. Conclusion

These results reveal that applying the suggested approach there's significant accuracy increase in fixing the user's position. A comparison between the suggested approach and the method about striking average in time shows that there is greater accuracy if the first approach is used. An increase in the processing interval leads to additional accuracy increase. The very nature of this approach implies further optimization of its application.

Acknowledgements

I wish to sincerely thank **associate prof. Ph.D.Veselin Demirev**, from the Faculty of Communications and Communications Technologies, Technical University, Sofia, Bulgaria.

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