# Modeling Mobile Object Location with Satellite Systems

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**Recursive algorithms with Kalman filtering modeling results for mobile object place location with satellite systems are shown in this work. Influence of a situation of an initial estimation on a place location mistake, influence of inconstancy of satellite group on accuracy and increase of reliability at an iterative method of definition of coordinates is presented.**

## 1 Influence of situation of an initial estimation on a place location mistake

Solving a return navigation task in our disposal there are coordinates of n satellites and measured distances up to them. For the decision of this task it is possible to use an iterative method [1]. Essence of an iterative method that to an available estimation of place location the amendments increasing accuracy, with each iteration are added. The calculation will be carried out or determined number of time, or up to achievement of the certain accuracy. As for the decision of a task it is necessary to chose an initial situation of an estimation of coordinates. Usually for such initial situations accept coordinates received in previous measurement.

Having the information on speed of object it is considerably to reduce mathematical expectation of mistake of measurement of coordinates in each of three planes ($\Delta m\{x\}$, $\Delta m\{y\}$, $\Delta m\{z\}$). More favourably for each second measurement, as an initial estimation to take meaning received in the previous measurement and to add to it double move distance. As a result of such correction (with alternation) of an initial estimation the received final estimation will appear on border of the given accuracy, but with opposite the parties concerning an optimum estimation of coordinates.

It is necessary to understand an optimum estimation in this case is estimation maximum precisely appropriate to chosen criterion of optimality. For driven object, on which the estimation of own coordinates will be carried out much more often, than there is a change of external condition, results of modeling are given in the Table 1.

| | Without alternation | With alternation | Improve-ment |
|---|---|---|---|
| $\Delta m\{x\}$, m | 0.00440 | 0.00014 | 31.4 |
| $\Delta m\{y\}$, m | 0.25668 | 0.00978 | 26.2 |
| $\Delta m\{z\}$, m | 0.01675 | 0.00058 | 28.8 |
| $\Delta m\{r\}$, m | 0.2572 | 0.2555 | 1 |

**Table 1.** Mathematical expectation of mistake of measurement of coordinates and distance r.

As it is visible from given the Tables 1, the alternation of an initial situation of an estimation results in repeated reduction of mathematical expectation of mistake in each of plans x, y, z for a series of measurements. It is important to pay attention that the mathematical expectation of size r (distance from an optimum estimation up to final) remained practically constant. The reason in the following, as distance don't be negative, as a result of alternation received, the final estimation will appear only with opposite the parties concerning an optimum estimation of coordinates, but will keep the size and mark. In too time of a mistake for each separate plane alternate on a mark and as a result averaging of the next measurements the increase of accuracy of calculation of coordinates is achieved.

In Fig. 1 the behavior of mistakes in x plane, for a case with alternation and without, for object driven with constant acceleration is shown. It is visible that at alternation in behavior of mistake (delta) there is a high frequency component, which is possible for removing by filtration. And as results in any case are exposed to a filtration, acquisition from application becomes obvious.

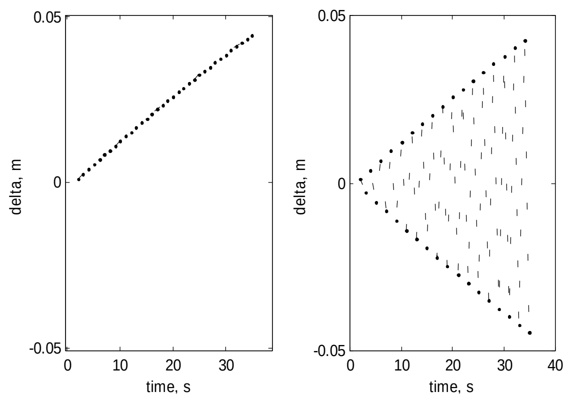


**Figure 1.** Behavior of mistake in x plane during modeling for object driven with constant acceleration (left diagram without alternation, right – with alternation)

The effect of mistakes reduce poorly depends on accuracy of definition of speeds. In the Table 2 the results similar to results from the Table 1 are shown, but the speed V for each measurement got out by a casual image of an interval (1-3) $V_{real}$.

Thus it is possible to find an optimum estimation of coordinates more precisely, keeping algorithm of search and its parameters former.

| | Without alternation | With alternation | Improvement |
|---|---|---|---|
| Δm{x}, m | 0.00440 | 0.00129 | 3.4 |
| Δm{y}, m | 0.25668 | 0.00716 | 36.6 |
| Δm{z}, m | 0.01675 | 0.00171 | 9.4 |
| Δm{r}, m | 0.2572 | 0.2626 | 0.98 |

**Table 2.** Mathematical expectation of mistake of measurement of coordinates and distance r, when speed is definite with low accuracy.

## 2 Influence of inconstancy of group of the satellites on accuracy

In experiment, in the certain order, from a session of definition of coordinates one from the seen satellites was under duress excluded. It was made for check of a hypothesis that the compulsory change of character of behavior of a mistake on one faster can appear favorable and after Kalman filtering we receive increase of accuracy [2].

All seen satellites were conditionally numbered from 1 (highest) up to 10 (closest to horizon). At modeling on turn one satellite with number more or equal k was excluded. Repeating modeling were kept constant conditions and the behavior was observed, depending on k , four parameters: mathematical expectation of a mistake in each of three planes and mathematical expectation distance r from a true situation of object up to measured.

In Fig. 2-5 the behavior of four parameters for 10 recurrences experiment is shown. Them size are given concerning the appropriate parameters for case when all seen satellites are used at definition of coordinates.

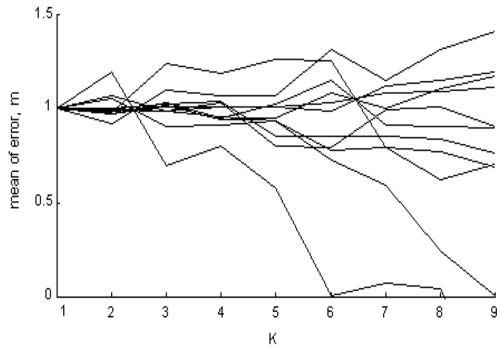


**Figure 2.** Dependence mean of error in x plane of k

As it is visible from the graphics of Fig. 2-5, the alternation of the used satellites don't give an opportunity at once to reduce a mistake of measurement and for nine satellites it will be more then for ten. However, as it is visible from Fig. 2-5, the alternation participating of the satellites near horizon sometimes allows to reduce mathematical expectation of mistakes. Such phenomenon carries causal character.

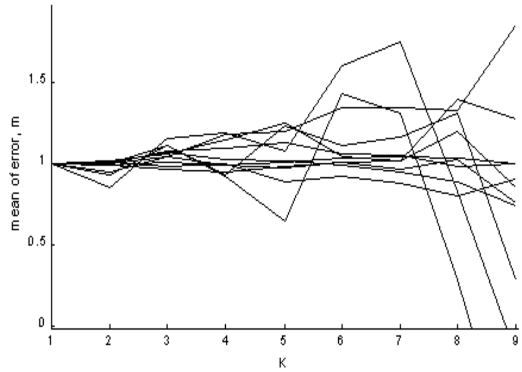


**Figure 3**. Dependence mean of error in y plane of k

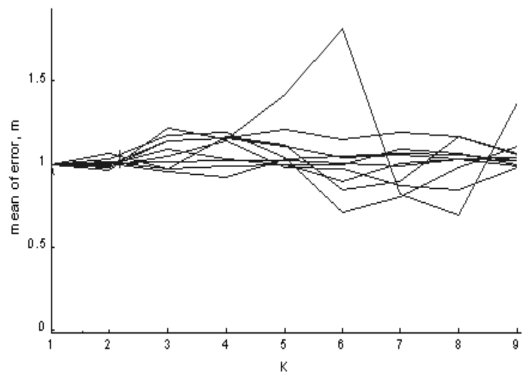


**Figure 4**. Dependence mean of error in z plane of k

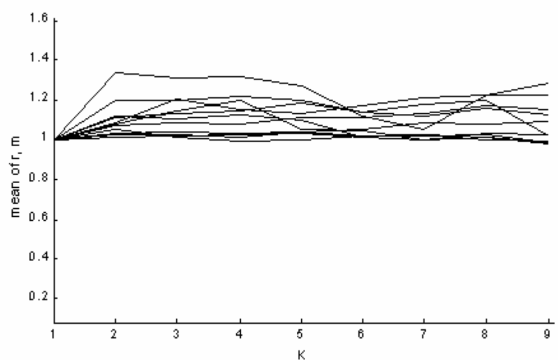


**Figure 5.** Dependence mean of distance r from a true situation of object up to measured of k

## 3 Increase of reliability at an iterative method of definition of coordinates

The application of an iterative method allows to apply a simple way of a finding of the satellite which brings in to result of measurements the maximal error. As on each step of calculations the mean-squared error vector is accessible to us, it is favorable to exclude from accounts the date connected to the satellite, which gives the maximal contribution to this vector.

In Fig. 6 the diagrams of mistakes for each of three planes are shown when measured up to one of satellites the range is overestimated. On the diagram the moments when in a session of definition of coordinates take part this satellite are clearly visible (error increase). After exception error measurements diagrams of mistakes are shown in Fig. 7.

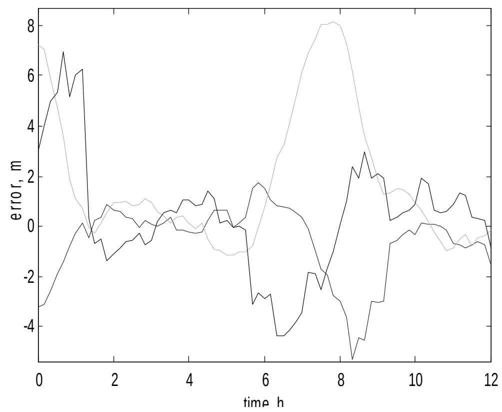


**Figure 6.** Behavior of mistakes for three planes and all satellites

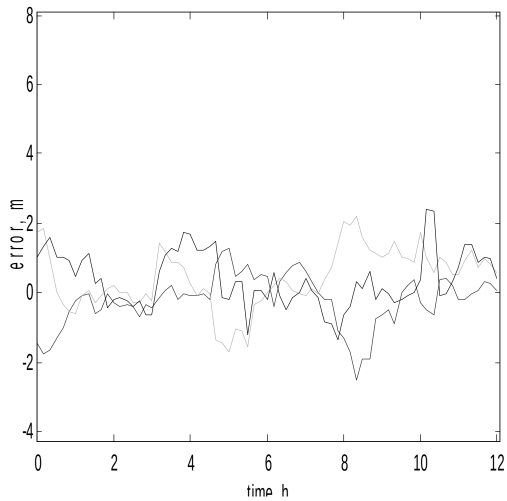


**Figure 7.** Behavior of mistakes for tree planes without satellite which distance measuring error is large

For finding and exception of satellite, which brings in to result of measurement the maximal error, the sample criterion was used:

$$\frac{D_{izm,i} - D_{est,i}}{\sum_{j=1}^{N}\left(D_{izm,j} - D_{est,j}\right)} > x_{alarm}$$

where: $D_{izm,j}$ – measured distance from satellite i,
$D_{est,i}$ – estimated distance from satellite i,
$\xi_{alarm}$ – variable which depends on number of the used satellites N and determines allowable border of mistake.

The meaning of expression $D_{est}$ can be calculate having made preliminary iterations or can be taken from the last session of definition of coordinates, in a case if the conditions of measurement have changed not strongly.

## 4 Conclusion

The considered methods of increase in accuracy of an estimation of position of mobile objects due to an initial estimation and change amount of used satellites can be used at a filtration of results of processing. The offered simple algorithm of increase of reliability of satellite system is checked up by modelling in conditions of use iterative method of definition coordinates of mobile objects.

## References


[1] *Global Position System: Theory and Applications*, Volume I, II. / Edited by Parkinson B.W., Spilker J. J. – Washington, AIAA, 1996.

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