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POSITION PRECISION OF UNDERWATER OBJECTS WITH ADAPTIVE KALMAN FILTER

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Анотація. В статті описано підхід до вирішення проблеми втрати зв'язку з підводними об'єктами внаслідок втрати сигналу GPS. Запропоновано метод вирішення цієї проблеми, а також перевірено його на доцільність використання.

Аннотация. В статье описан подход к решению проблемы потери связи с подводными объектами вследствие потери сигнала GPS. Предложен метод решения этой проблемы, а также проверено его на целесообразность использования.

Abstact. The paper describes an approach to solving the problem of communication loss with underwater objects caused by the loss of GPS signal. The method of solving this problem is proposed, and its feasibility for use was also tested.

INTRODUCTION

The exploration of the world oceans by mankind was started centuries ago. Today a wide variety of underwater vehicles and submarines of different classes and types are utilized. Many underwater vehicles and instruments are used for scientific research purposes. In experiments involving the exploration of Earth's geomagnetic field, the underwater boats are used as a stable platform for the targeted sensor hardware. They are also utilized with military purposes including: reconnaissance, communication, large scale environmental measurements, or general purpose exploration.

Today special attention is focussed on underwater instruments which rely on the use of a GPS navigational system. But a problem that must be solved is when the GPS signal is lost. This paper presents a development approach for solving this problem.

OUR APPROACH

A GPS system is the kernel of complex navigation used for modern submarines and underwater vehicles because of its unmatched accuracy and reliability. However the loss of satellite signals occurs often and they can remain lost for long periods of time. This can lead to potentially dangerous situations. Therefore we are investigating the possibility of providing increased reliability to modern submarine and underwater instruments navigation systems under in condition of intermittent GPS signals. Different filter approaches used to update Inertial Navigational Systems (INS) with intermittent GPS data are compared with our adaptive Kalman Filter approach.

To basic advantages of the Inertial Navigational Systems belong: continuity of object position-finding, absolute stability to noisy signal, independence of object manoeuvring.

The fundamental disadvantage of Inertial Navigational Systems lays in such a thing: because of the instrumental errors on every step, the error of object position-finding is accumulated. It is shown on figure 1.

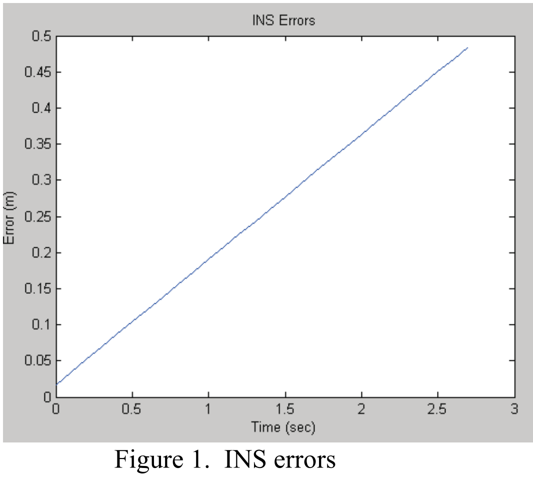

Figure 1. INS errors

Therefore the problem of INS signal correction in condition of GPS signal loss appears. With this purpose Attitude and Heading Reference Systems were proposed.

In Attitude and Heading Reference Systems a great amount of filters can be used. They are filter of Wiener, algorithms RLS, LMS. However the most accurate method of state vector estimation is Kalman filter .

For this filter realization a priori information about the cross-correlation matrixes of input signal and measured noises is needed. The main goal of Kalman filter is minimization of dispersion estimation of vectorial discrete casual process $x(k)$ that changes as follows

$$x(k+1) = \phi(k)x(k) + v(k); \quad (1)$$

where $\phi(k)$ - transition matrix, $v(k)$ - casual vector.

The algorithm of estimation on the basis of Kalman filter realizes the compatible model of INS and GPS errors for determination of current navigation parameters. However the first disadvantage of Kalman filter is that realization of calculable chart on this algorithm is difficult at large dimension of the state vector , and the second defect – is that in the real tasks a priori information about the input and instrumentation noises are set unexactly. It can cause the divergence of algorithm. That’s why its modifications are mostly used. These modifications are named the adaptive Kalman filters [1,2].

The propose approach is based on using adaptive Kalman filter. The structure of proposed AHRS is depicted on figure 2.

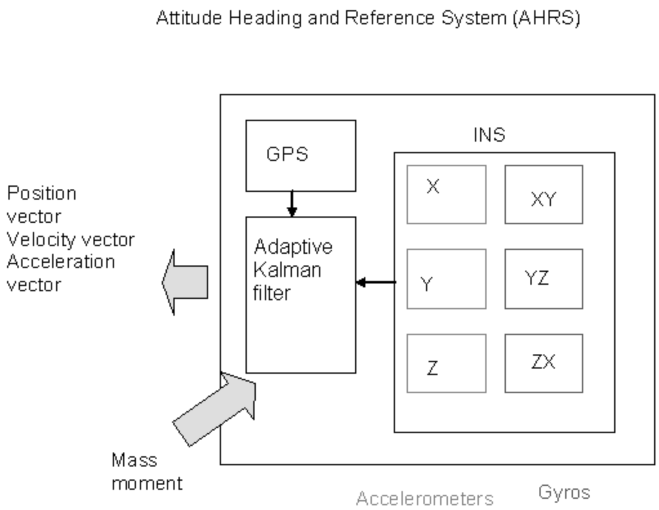

Figure 2. The structure of AHRS

On the figure 3 the summarizing chart of adaptive filtration method is represented. Input discrete signal $x(k)$ is processed by digital filter, in the result of what an output signal $y(k)$ is got. This output signal is compared with the model signal $d(k)$. Difference between them forms error signal $e(k)$. The task of the adaptive filter is to minimize the error of model signal. With this purpose, block of adaptation after processing each sample analyses the error signal and additional data from the filter, using the results of this analysis to adapt the parameters (coefficients) of filter.

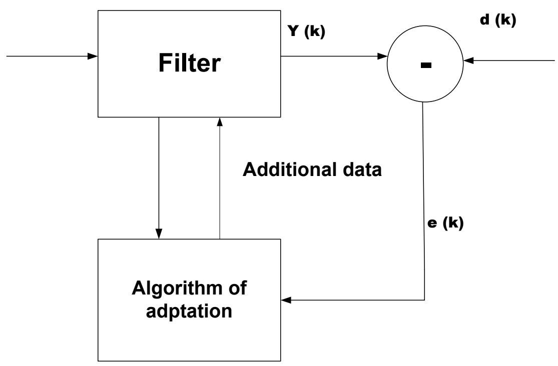

Figure 3 . The chart of adaptive filtration

Offered method can be generalized by means of such executions sequence :

1) The initial parameters of filter are calculated on the basis of GPS and INS information.

2) During GPS signal loss its prognosis for to three coordinates (x, y, z) by means of extrapolation is done.

3) Prognosed signal of GPS is fed on Kalman filter after what on the basis of INS data the calculation of auxiliary array of adaptive filter is made.

4) After filtration the corrected values of coordinates (x, y, z) are got.

The algorithm of proposed method is shown on figure 4.

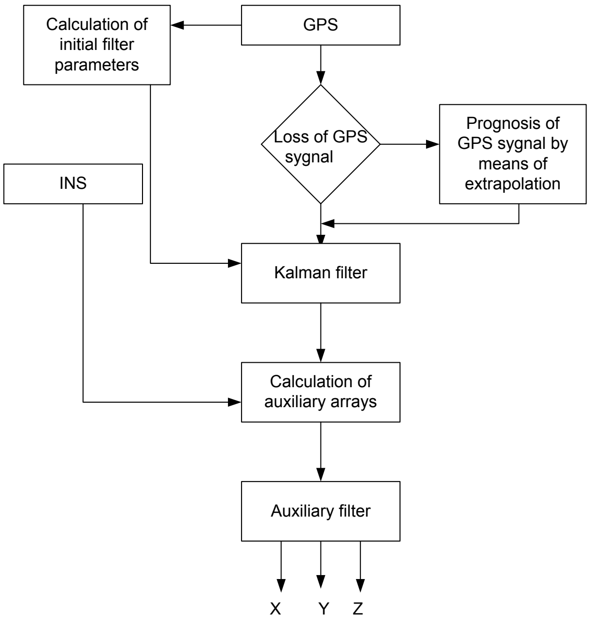

Figure 4. Algorithm of estimation AHRS data on the basis of adaptive Kalman filter

Such method was realized as a program module. The results of program execution is shown on figure 5.

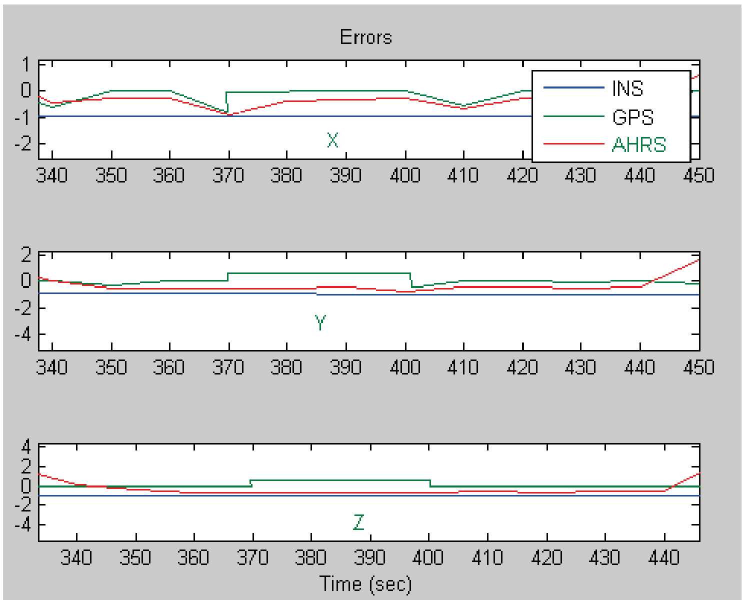

Figure 5. The results of program execution

The figure 5 shows that at time 370-400 seconds GPS signal was lost and based on adaptive Kalman filter AHRS errors are less than errors of INS.

CONCLUSIONS

Analysing the existent problem of underwater instruments development in this article a new approach of INS data correction when the GPS signal is lost on the basis of AHRS that uses adaptive Kalman filter is offered. The algorithm of estimation on the basis of Kalman filter realizes the compatible model of INS and GPS errors for determination of current navigation parameters that allows to increase the accuracy and reliability of navigational systems.

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