AIRCRAFT FAULT DIAGNOSIS SYSTEM DEVELOPMENT

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Abstract: Dichotomizing algorithms of diagnostics and reconfiguration of the navigation system which process indicators of inertial, satellite and optical subsystems in real time for typical types of refusals are considered in the work. The given approach provides majority diagnostics of measuring system with system and hardware redundancy at a minimum necessary set of sensors. The main idea of a method is the comparative analysis of all measuring subsystems behind reference value. The reference value is the parameter which is synthesized from all diagnosable subsystems, in this work – a course corner. When obtaining the only parameter by gages of the different nature it is possible to provide firmness of an algorithm. Also reasonably the possibility of the introduction of optical systems with the use of algorithms of computer sight for ensuring system redundancy of the navigation system is described. The system is intended for identification only of one type of refusal for a unit of time. A positive factor of an invention is the universality that allows using system on any operating small autonomous aircraft. For the introduction of a system, there is no requirement in finishing the hardware. Use of system of failure diagnostics will reduce the risk of loss of the aircraft when performing a task, will increase its efficiency and accuracy of indicators. As a result of researches, the algorithmic dependence of signals of the navigation system was established that allowed to make the analysis and diagnostics with the following renewal of the lost parameter thanks to system and hardware redundancy of devices. Practical use of the system in actual practice with an influence of artificially created obstacles and noise is shown. Developments in area of aircraft safety are necessary due to the need for an increase in level, at the emergence of emergency situations.

Keywords: Functional firmness, diagnostics, compensation, reconfiguration, orientation, fault tolerance, optical navigation system. emergency situations.

1. Introduction

In the conditions of the growing requirements for a functioning of small autonomous aircraft (SMALL) performance of a flight task with the set indicators of quality and increase in the probability of return of an object is necessary.

For avoid or reduce to influence of failures of measuring devices on system productivity in general, it is necessary to establish continuous control of functioning and also to control all system in general [1]. For ensuring functional firmness it is necessary existence of structural redundancy. Characteristic of use of structural redundancy is an opportunity not only implementation of compensation of refusals, but also improvement characteristic. These circumstances define need of the solution of a task of ensuring functional firmness of elements of a control system of small-sized unmanned aerial vehicle (UAV) with the minimal structural redundancy [2, 3].

Development of system is relevant and necessary through a possibility of the increase in the degree of protection of the aircraft and integration into the control systems existing for today. Use of this system will provide maintaining functional abilities of the aircraft during the performance of a task. Introduction of this system does not need hardware transformations.

Considering the current state of a problem which is investigated, the purpose is the development of a method of diagnostics and renewal of the damaged channel of data on the basis of inertial, satellite and optical systems [4]. For achievement of a goal, it is necessary to enter an additional unit of structural redundancy and to develop an algorithm of diagnosing of the system.

2. Methods

The main idea of a method is the use of sensors of the different nature of measurements at a calculation of one parameter. For the realization of an algorithm, it is necessary to determine the reference parameter to which it is possible to lead reference values of all subsystems independently. This parameter is the corner of a course which can be received from inertial system which part are the accelerometer, sensors of angular speeds and the magnetometer, from the satellite navigation system (SNS), in case of the constant movement of the aircraft and also from optical system, with use of algorithms of Loukas to Canada, affine transformations and search of movement of couples of descriptors [5].

First of all, a check is carried out between blocks of the inertial system, satellite and optical. As according to conditions, at the same time there can be only one refusal, to the predicament the equation (1) will allow revealing time and the place of refusal to within a subsystem [6–8].

According to hypotheses, it is possible to assume that in the only point of time there is one mistake, among three units. Therefore data reading is compared to the control size of a corner of a course and when there is a difference of values above of the established norm, it is possible to claim that the mistake takes place there to be [9, 10]. Lower (**Fig. 1**) a fragment of a dichotomizing tree is represented, which describes the process of search of the place of failure where 1 – positive result, and 0 – negative result.

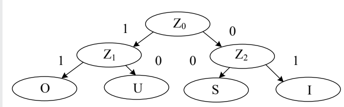

Fig. 1. A dichotomizing fragment of a tree of processes of search of refusals in the magnetometer, the satellite navigation system, and optical devices: O – refusal in optical system, U – uncertain refusal, S – the failure of the satellite navigation system, I – diagnostics of INS

The analysis allows to create the following equations of predicates:

$$Z_0 = \{\psi_{INS}(t) == \psi_{SNS}(t)\} \text{and} \{\Delta\psi(t) \text{»} 0\} = \\ = \begin{cases} 1 - \text{Diagnostics of optical system;} \\ 0 - \text{Diagnostics of SNS;} \end{cases}$$

$$Z_1 = \{\psi_{INS}(t) = !\psi_{OPTIC}(t)\} \text{and} \{\Delta\psi(t) \text{»} 0\} = \\ = \begin{cases} 1 - \text{Refusal in optical system;} \\ 0 - \text{Uncertain refusal;} \end{cases}$$

$$Z_2 = \{\psi_{OPTIC}(t) = !\psi_{SNS}(t)\} \text{and } \{\Delta\psi(t) \text{»} 0\} \\ = \begin{cases} 1 - \text{Refusal in SNS;} \\ 0 - \text{Diagnostics of INS.} \end{cases}$$

The following step is diagnostics of the accelerometer and angular velocity sensors (AVS) (**Fig. 2**).

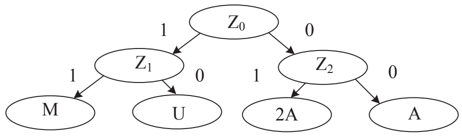

Fig. 2. A dichotomizing fragment of a tree of the process of search of refusals in the magnetometer, the accelerometer and units of AVS: M – refusal in the magnetometer, U – uncertain refusal, 2A – refusal in AVS or the accelerometer (axis x), A – refusal in the accelerometer

At the stage, Z_0 are checked all to a milestone of the accelerometer and a pitch axis of the AVS.

$$Z_0=\left\{\int_t^0 \dot{\theta}_{AVS}dt+\zeta_{noize}(t)==\operatorname{arctg}\left(\frac{\sqrt{g_x^{\ 2}(t)+g_y^{\ 2}(t)}}{g_z^{\ 2}(t)}\right)\right\}$$

and

$$\left\{\Delta\theta(t)+\zeta_{noize}(t)\text{»}0\right\}=$$
$$=\begin{cases}1-\text{Diagnostics of AVS and magnetometer;}\\0-\text{Diagnostics of AVS and accelerometer.}\end{cases}$$

Having established a camera axis perpendicular to the horizontal plane, the image it is possible to use in quality information for diagnostics and renewal of the absent parameter (**Fig. 3**).

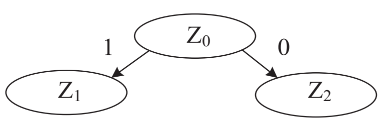

Fig. 3. The chart of a dichotomizing fragment of a tree of process of search of refusal in the accelerometer and uncertainty of AVS

$$Z_0=\left\{\theta_{INS}(t)==\theta_{SNS}(t)\right\}\text{and}\left\{\Delta\theta(t)\text{»}0\right\}=$$
$$=\begin{cases}1-\text{Refusal in AVS;}\\0-\text{Refusal in accelerometer.}\end{cases}$$

Further the value of a corner of a course decides by means of the optical block on use of a method of definition of descriptors in the sequence of shots.

3. Results

Modeling of refusals was carried out in the program way. Such refusals as the change of coefficient of transfer, loss of power, casual peak values, temporary losses and deteriorations in a signal of the navigation satellite system are considered.

During the performance of an experiment, a number of basic schedules are received (**Fig. 4, 5**) behind which it is possible to claim about the practical use of this system when using with the existing control systems.

As the entire period of refusal the system renewed value of the damaged channel with an admissible accuracy (less than 3 %), it is possible to consider that the algorithm is capable to identify existence, time and the place of refusal.

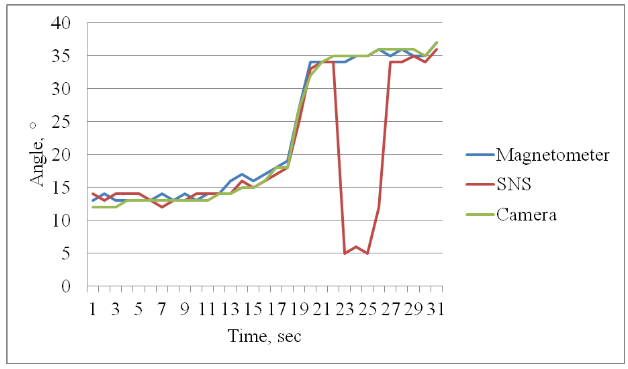

Fig. 4. Image of cancel at the satellite navigation system

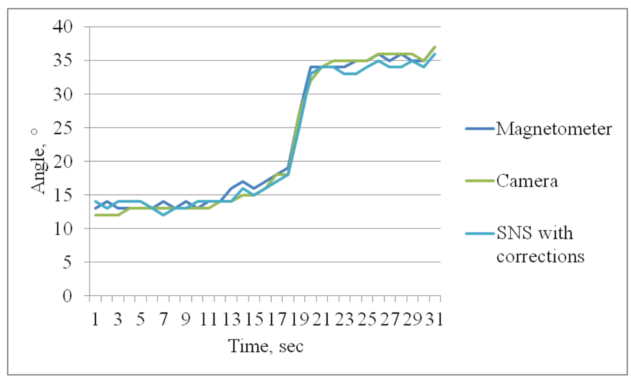

Fig. 5. A satellite navigation system signal after renewal

4. Discussion

Positive qualities of a research are increases in speed of work in diagnostics, lack of long-term process of adaptation for calculation of the correct value of the damaged channel and also the fact that this system is developed for a standard set of measuring devices which can be installed aboard all modern autonomous aircraft.

Shortcomings of the system are its sensitivity to external factors (visibility), ability to work accurately only during one refusal for a unit of time.

Research useful to control systems of small-sized aircraft which own a standard set of measuring systems with an optical system, any aerodynamic configuration.

Further researches will be the diagnosis of other types improved by introduction and a cause of failure.

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