DEFINITION OF CORRELATION AMONG FLIGHT PARAMETERS OF THE PLANE FOR RESTORATION OF FLIGHT INFORMATION

Nail Balayev

Institute of Information Technology of ANAS, Baku, Azerbaijan
nail_turkabadli@yahoo.com

Currently flight safety provision is a problem of exceptional urgency. Processing of flight information (FI) recorded on flight recorders is important for provision of safety. Its quality level, processing method and completeness level of algorithms seriously affects the safety. The errors made during processing are divided in two categories, and these problems are characterized as first and second type errors. First type errors attest to some kind of malfunction of the plane, although it is not so in reality and the processing has made an error itself. In some situations, after processing of FI, airworthiness conclusion is made. But in reality, there are malfunctions in the aviation technology. These types of errors are classified as second type errors. First type errors result in unnecessary additional expenses for repair and technical service, and second type errors results in more serious situations. Thus, in spite of malfunctions present on the plane, airworthiness decisions are made. This decision makes safety of the flight questionable [1, 2]. For this reason, good organization of FI processing, application of new methods and algorithms, and production of new programming must be performed for maximal improvement of errors in FI and minimal loss of information.

Several software products have been created for processing of flight information. Created program complexes differ in their processing quality and functional capabilities. Modern FI Processing programs must firstly provide the user with reliable and distinct information about flight safety level for effective use of the aircraft fleet; and capabilities to make decisions on preparedness level of flight crew and basic staff, technical, marketing and financial decisions.

Overhead FI processing program complexes evaluate the technical condition of the airborne vehicle and errors in actions of the flight crew [4,5]. Program complex provided capabilities such as automated processing and express-analysis. Automated processing mode allows detailed analysis of the flight using parameters recorded in flight recorders. But it takes plenty of time. In express-analysis mode, infringements in air navigation techniques, errors in actions of flight crew are exposed and analyzed in a very short period of time. Thus, using the processing results, performed flight is estimated and necessary measures are taken.

There are a number of program complexes processing FI in western countries and CIS area. One of these program complexes is Gartal Pro system created in Azerbaijan [3]. This software allows automated processing of FI, performance of express-analysis, editing of calibration table and compilation of flight path on map.

In this system, during retrieval of FI, incomplete information frames are left out, and only complete frames are used. While retrieving FI from the flight recorders, compliance of FI frames to given sizes are checked. In conditions aren't met, those frames are left out and we lose those frames. In order to retrieve those frames, completeness of the frames must be restored. FI is recorded in frames as addressed information from different sensors. The value of each parameter is recorded in code.

Increasing complication of aircrafts, complications of their aircraft instrumentation, increasing number of functions of the on-board systems have resulted in increasing the volume of FI. Occurrence of losses and loss of information frames are possible during recording of FI on magnetic tape type flight recorders and transcription of flight data to processing systems from flight recorders.

The reasons for this may be as following: pollution of magnetic head, crumpling of magnetic tape, high stretching speed of magnetic tape, power supply surges, sub-quality nullification, and effect of static electrical loads. In addition to these, first stage of collection and processing of FI which is "decreasing of parameters' recording quality" depends on following reasons [1]:

1. Destruction of magnetic layer on tapes of flight recorders;
2. Unsatisfactory demagnification of magnetic tapes during their placement in flight recorder;
3. Use of polluted magnetic heads;
4. High detonating of on-board tape stretching mechanisms;
5. Malfunctions of sensors.

Different methods are developed for restoration of lost information frames. For restoration of distorted or partially destroyed parameters in flight information taken from board register, we suggest it's restoration by identifying the correlation with other parameters. For this reason, we will calculate the correlation coefficients between flight parameters, and evaluate the degree of dependence between them. It is possible to restore one parameter based on a value of another parameter using this dependence.

Let's look through calculation of correlation coefficients between parameters characterizing the take-off stage of the flight. This algorithm was performed in Gartal Pro system processing FI. The order of correlation coefficient calculation is provided below.

Let's assume that, it's required to analyze the numerical characteristic of accidental ξ, η quantities. ξ quantity receives equally probable x_i values, general number of considered quantities in equal to *n*. Mathematical expectation is determined with following formula [6]:

$$M\xi = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{1}$$

K-degree moment will take the $\nu_k(a) = M(\xi - a)^k$ form. In other words, is as following:

$$\nu_k(a) = \sum_{i=1}^{n}(x_i - a)^k \tag{2}$$

If $a = 0$, then this moment is titled as start moment, if $a = M\xi$, then – it is titled as central moment.

In special cases, if $k = 2$, $\nu_k(M\xi)$ central moment is titled as dispersion:

$$D\xi = \nu_k(M\xi) = M(\xi - M\xi)^2 = M\xi^2 - (M\xi)^2 \tag{3}$$

From mathematical point of view, sometimes it is more expedient to use $\Delta(\xi) = \max_{1\le i\le n}\{x_i\} - \min_{1\le i\le n}\{x_i\}$ relation.

Accordingly, correlation between ξ and η quantities, receiving x_i and y_i values, is calculated as following:

$$r(\xi,\eta) = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{\sqrt{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2}\sqrt{n\sum_{i=1}^{n} y_i^2 - \left(\sum_{i=1}^{n} y_i\right)^2}}. \tag{4}$$

In case of $r(\xi,\eta) = 0$, there is no linear relation. In case of $r(\xi,\eta) > 0$, "direct" dependence, in case of $r(\xi,\eta) < 0$ "inverse" dependence is experienced.

As seen from the formula, when divergences of ξ and η variables from their average value have the same sign, selective correlation coefficient is positive, and if they have different signs is negative. Correlation coefficient is an immeasurable quantity and its quantity is not dependant on measure units of the variables. Correlation coefficient can have values from a negative unity (-1) till positive unity (+1):

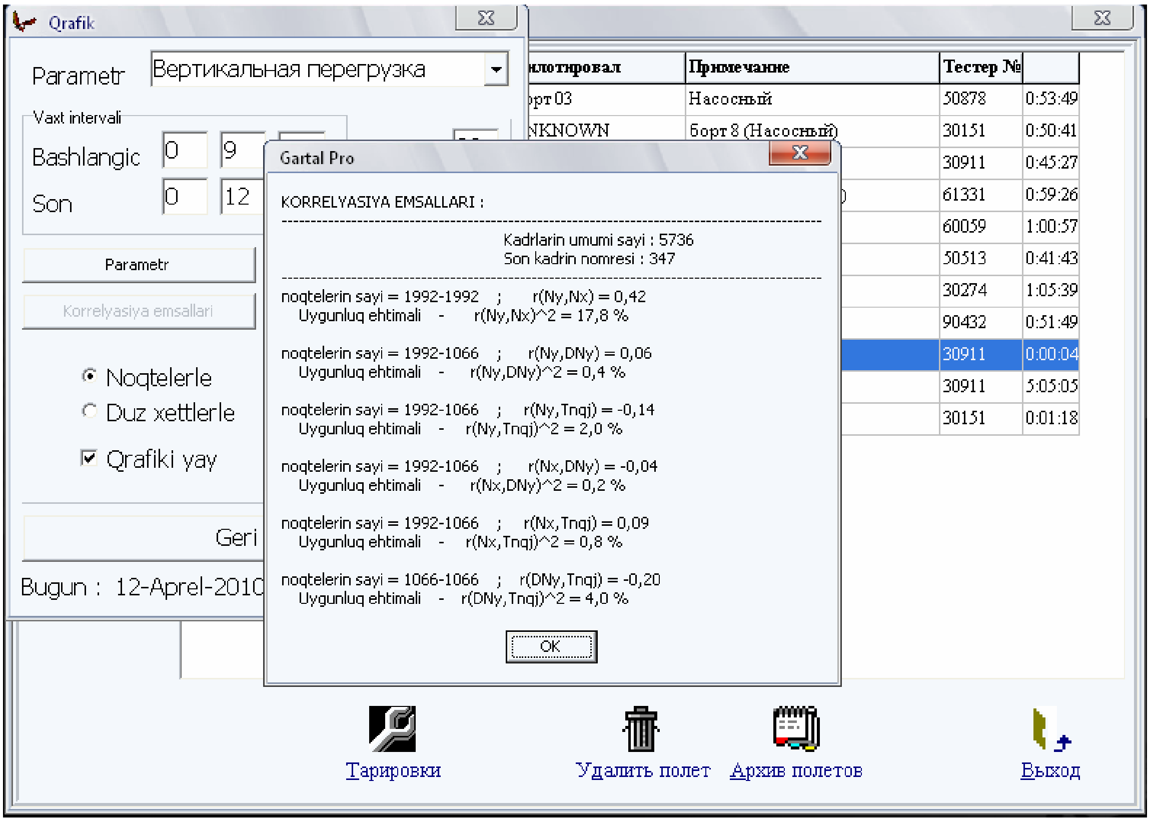
$$-1 \le r(\xi,\eta) \le 1 \tag{5}$$

If the correlation coefficient takes on a value near to negative unity, then there's a dense linear inverse relation between variables. If the correlation coefficient takes on a value near to positive unity, then there is a "direct" dependence, if the correlation coefficient takes on a value near zero, then there is no linear relation between variables.

Using the value (4), we can calculate the correlation coefficient between parameters characterizing the take-off stage of plane. Parameters characterizing the take-off stage are as following: vertical load, lengthwise load, pitching angle, alteration of vertical load. Let's assume that, there has been a loss in information on vertical load taken from board register FI. For this, firstly we have to calculate the correlation coefficients between vertical load and lengthwise load, pitching angle and change of vertical load. Analyzing the gained results, we use the vertical load and the parameter with biggest correlation coefficient. Then we analyze the values of these two parameters, and define the capacity function expressing the dependence between them. Using the received dependence, we define the lost values of vertical load through the parameter with a correlation coefficient closest to it.

In order to perform the abovementioned, let's use the formula (4) and create a program module. This module must define the correlation coefficients between the parameters characterizing the take-off stage of the flight.

Algorithms were prepared using above-mentioned mathematical definitions, and added to Gartal Pro system. Using this algorithm, let's calculate the correlation coefficients between parameters with relatively close alteration characteristics during take-off stage of the flight. Correlation coefficients between vertical load and lengthwise load, alteration speed of vertical load and pitching angle is calculation at the take-off moment. This calculation and its result are performed as below in the software:



Picture 1. Calculation of correlation coefficient among selected parameters.

Using this algorithm, it possible to calculate the correlation coefficient among different parameters and argue about their closeness level. If the correlation coefficient of two parameters is close to unity, then they are correlated. Using these results, it is possible to define the lost values of one parameter using the values of another parameter correlated with it.

Results of the module calculating the correlation coefficient is shown in Picture 1. This module calculates the correlation coefficient in the take-off stage between vertical load and lengthwise load, vertical load and alteration of vertical load, vertical load and pitching angle, lengthwise load and alteration of vertical load, lengthwise load and pitching angle, alteration of vertical load and pitching angle. As seen, the largest correlation coefficient $r(n_y, n_x)=0.42$, is between the vertical load and lengthwise load. Thus, it is possible to define the lost values of vertical load, by defining the dependence between these two parameters and using the values of lengthwise load parameters.

Based of given algorithm, we can calculate the incomplete parameters in flight information, which will result in increasing of reliability of flight information. Creation of new capabilities in Program complexes applied during FI processing, improvement of user interface, new processing methods and preparation of algorithms result in increased flight safety.

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