Automatic piloting assessment

Georgi Yordanov

Bulgarian Air Force Academy „Georgi Benkovski“, Dolna Mitropolia, Bulgaria,
georgi_mitkov_iordanov@abv.bg

Abstract: The article examines the principle of the automatic processing of flight data and the assessment of the piloting techniques. It is very important the assessment to be impartial and objective. The use of known models for automatic processing of flight data records and the development of the method for automatic evaluation of the elements performed in flight tasks would lead to a reduction of the subjective factor and optimization of flight assessment. The main requirements are very accurate recognition of the performed elements and the application of approved valuation standards.

Keywords: *aviation, flight, piloting, flight data, assessment*

1. Introduction

Flight training is a complex and responsible process and requires experienced specialists, a good organization and a very good quality control of the flight activity. Assessment of the trainees is complex and involves an evaluation of their theoretical knowledge, their practical skills, and their physical endurance and discipline.Assessment is an essential component of the teaching process and determines how, what, and how well a student is learning. A well designed assessment provides a trainees with something constructive upon which he or she can work or build. An assessment should provide direction and guidance to raise the level of performance.

The evaluation of practical skills is of paramount importance in forming the final grade of the trainee. It is done after each flight, evaluating all the elements of the exercise. For this purpose, flight instructors complete a grade sheet, which, together with other documentation related to flight task, is stored in student's personal file.

In order to maintain the high quality of the training, the training methodology must be continuously improved and assessment optimized. The main steps to increase the level of the training are:

- up-to-date training programs;
- updating of the manuals regulating flight activity;
- clear standards for the evaluation of piloting techniques;
- the use of modern flight simulators;
- a very good quality control.

The main goal in optimizing the assessment of piloting techniques is to reduce the subjective factor. This could be achieved using a computer application for automatic flight data processing and analysis. The subjective factor can be reduced by automatically and correctly evaluating the performed elements of the flight task in accordance with the approved standards.

2. Flight data recorders

Flight recorders are electronic devices that record and store important information related to the operation of the aircraft, the operation of its systems, the communication of the crew with the air traffic controller (other aircraft) and the sounds in the cockpit. The sensors are installed on or in the aircraft and are used to measure flight parameters such as airspeed, heading, fuel consumption, altitude, engine temperature, engine rpm, etc. The accessed signals are sampled, filtered, decoded, encrypted, and subjected to an adaptive compression process prior to being stored on self-protected memory device. The present recorders make it possible to record a large number of important parameters on a relatively small and secure storage, and the information can be easily downloaded, processed and analyzed after the flight ends. Computer technology and software allow fast and accurate processing of downloaded information with the ability to visualize.

The information related to the piloting of the aircraft is used in the assessment of the trainees. The flight data recorders record a sufficient number of parameters necessary for a qualitative analysis of the performed flight tasks and an objective assessment of the included elements.

3. Automatic flight data processing

The creation of rational means for automatic processing of flight information uses sufficiently simple models for processing flight data. This also could be embedded in computer analysis software.

3.1. Initial processing of the recorded flight data

Initial processing of flight information involves extracting the data from the aircraft's recorder then decompressing and decrypting it using support equipment and software. It is very important the recorded information to be accurately restored. The processed data can be presented in graphical or tabular form(Figure 1.).

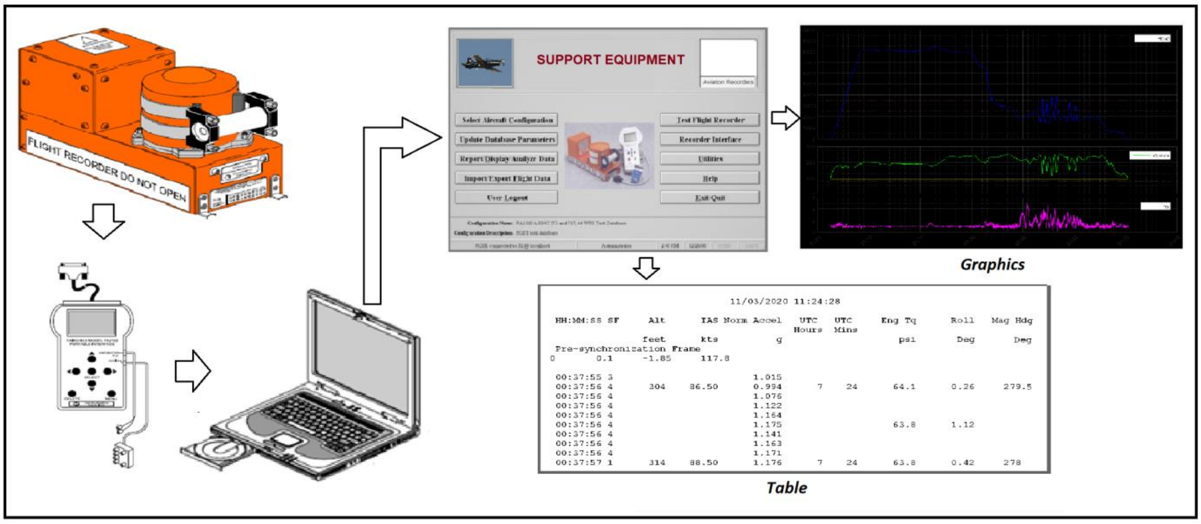

Figure 1.

The data recorded in tabular form is used for in-depth analysis of the completed exercise. In analyzing and evaluating the piloting technique of performed elements in the exercise, several parameters are used. Usually these are – airspeed, altitude, heading, roll, normal acceleration, engine rpm, etc. The data presented in tabular form represent columns of numbers. The length of the columns depends on the duration of the flight and the priority of recorded parameter. Depending on the capability of the flight data recorder, the parameters are recorded every second and the most important of them several times per second. Initially each parameter is processed separately depending on its priority. This includes removing control messages, rounding its values, determining its absolute values, specifying the length of the record, etc. As the lengths of the recorded parameters may be different, they must be equated. For example in 15 seconds can be saved 15 values of the airspeed, 30 values of the roll, and 150 values of the normal acceleration.

3.2. Secondary processing of the recorded flight data

The secondary processing of the flight information involves a qualitative analysis of the recorded flight data. The qualitative analysis is used to determine the elements performed in the flight task and to detect deviations of the parameters from their set values.

The analysis of the flight information is performed in the following areas:

- Analysis of the take-off and landing;
- Analysis of the of simple or complex aerobatics elements;
- Analysis of the en route flight;
- Analysis of combat missions and the obtained results;
- Special analysis.

Of particular importance for the analysis is the correct determination of the beginning and end of the stage or of the element. Also the objects to mandatory determination are its duration, the maximum or minimum values of the considered parameters, etc.

To identify a stage or a element, it is necessary to define several control points, each of which is characterized by the measurement of each of the parameters selected for analysis. The number of control points depends on the studied element. The characteristics of the elements and the stages performed in the flight tasks should be well known, because their characteristics used for identification are set in advance.

First, the flight data is divided into sections(Figure 2.). This requires a pre-set value of some of the studied parameters ($P_{pre\text{-}set}$). Usually the choice of such a parameter depends on the flight task, the type of elements and the plane in which they are performed. For example, for elements of simple aerobatics performed in the horizontal plane, this could be the bank angle(γ), and for elements performed in the vertical plane – airspeed(V) or normal acceleration (ny)(Figure 3.).

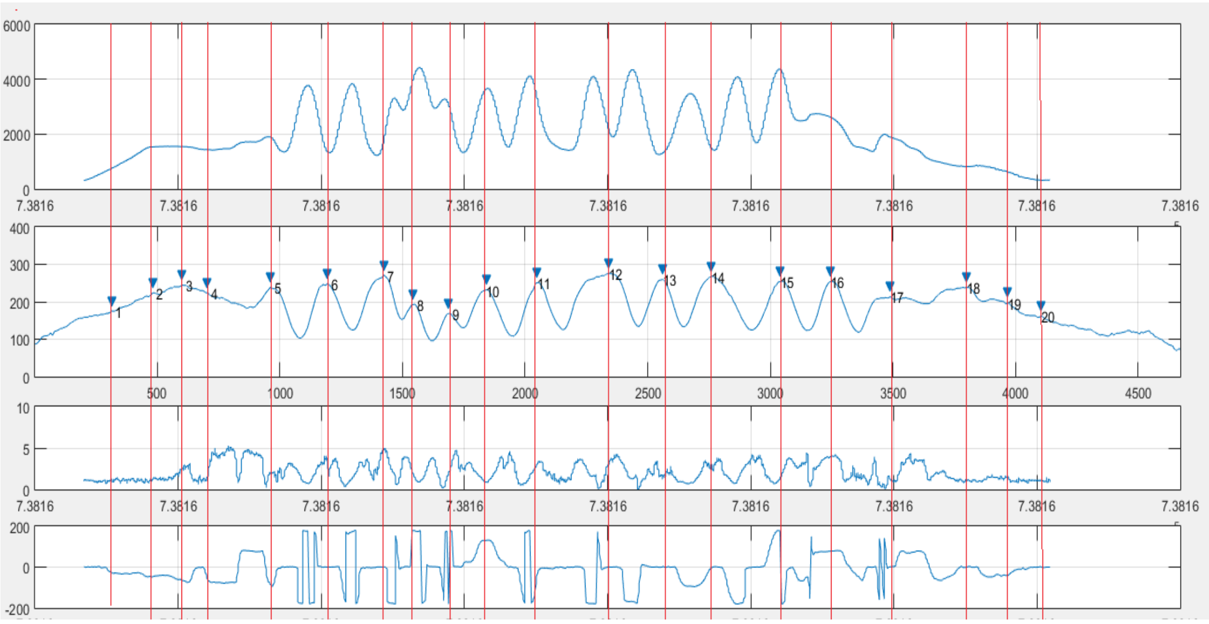

Figure 2.

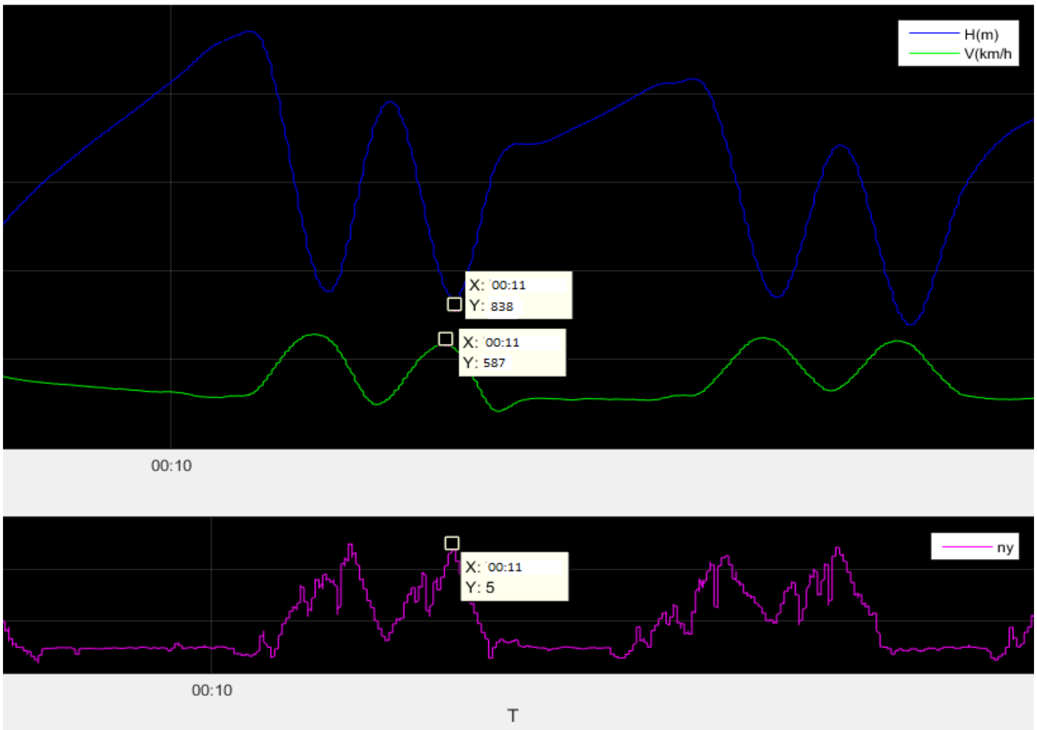

Figure 3.

Next, for each section are determined its duration (Δt), the first and last values of the parameters, the change of parameters and their maximum and minimum values.

$$(1)\quad S(i) = f\begin{pmatrix} Pr_{(1)first};\ Pr_{(1)last};\ Pr_{(1)min};\ Pr_{(1)max};\ \Delta Pr_{(1)};\ Pr_{(1)last} - Pr_{(1)first} \\ Pr_{(2)first};\ Pr_{(2)last};\ Pr_{(2)min};\ Pr_{(2)max};\ \Delta Pr_{(2)};\ Pr_{(2)last} - Pr_{(2)first} \\ \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \\ Pr_{(n)first}; Pr_{(n)last}; Pr_{(n)min}; Pr_{(n)max}; \Delta Pr_{(n)}; Pr_{(n)last} - Pr_{(n)first} \end{pmatrix}$$

- *S(i)* - sections
- *Pr(n)* – a recorded parameter

The obtained data are compared with pre-set values of the parameters characterizing the stages of the flight or the performed elements in the exercise. If the data match, it is assumed that the corresponding stage or element is performed in this section. In order to distinguish similar elements or variants of any of them, additional features or limitations in some of the parameters are used. For example: a heading, a pitch angle or a bank angle.

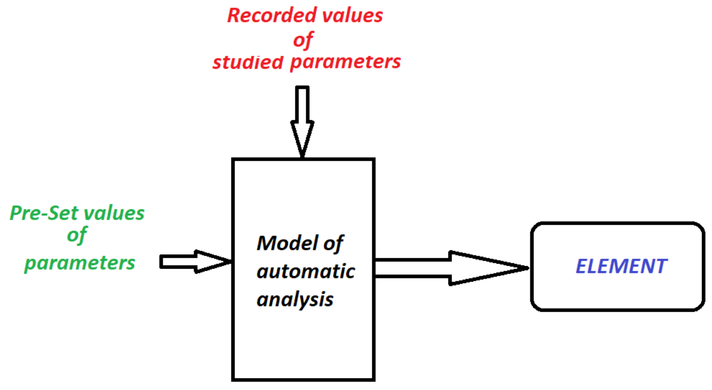

Figure 4.

$$(2)\quad t_{pre-set} - \delta \leq \Delta t \leq t_{pre-set} + \delta$$

$$(3)\quad P_{pre-set} - \delta \leq Pr \leq P_{pre-set} + \delta$$

- $P_{pre-set}$ – a pre-set value of the studied parameter
- δ – a threshold value

The threshold value is a very important for identifying the elements. In the case of a small or a very large tolerance the elements could be missed or confused.

There are several models for automatically identifying the stages of the flight or the elements performed in the exercise. To be more reliable and accurate the identification, several of the models can be combined.

4. Models of flight elements

4. 1. Type model

This model shows the position of the center gravity of the aircraft relative to the ground. The flight trajectory can be divided by changing the altitude into three types [1]:

- T_1 – level flight ($\Delta H = 0$);
- T_2 – climb ($\Delta H > 0$);
- *T3* – descent ($\Delta H < 0$).

The change of heading allows the trajectory to be divided into two more varieties:

- *M1* – without turns ($\Delta\psi = 0$);
- *M2* – with turns ($\Delta\psi \neq 0$).

Depending on the positive or negative value of $\Delta\psi$ the turn can be determined on the left or right.

The following relations are used in the formation of logical variables (Table 1.):

- altitude:

(4) $X_1^H \;=>\; \delta H \le \Delta H \le \delta H$

(5) $X_2^H \;=>\; \Delta H > \delta H$

(6) $X_3^H \;=>\; \Delta H < \delta H$

- heading:

(7) $X_1^\psi \;=>\; -\,\delta\psi \le \Delta\psi \le \delta\psi$

(8) $X_2^\psi \;=>\; \Delta\psi > \delta\psi$

(9) $X_3^\psi \;=>\; \Delta\psi < \delta\psi$

The sequences of logical variables X_3^H and X_1^ψ formed in time make it possible to determine each spatial trajectory, but not the elements of aerobatics. An additional parameter is needed to describe them. This is the normal acceleration. It introduces three new varieties:

(10) $ny = 1$

(11) $ny > 1$

(12) $ny < 1$

They determine the straightness or distortion of the trajectory. Few new elements are defined (Table 2.).

A sequence of three additional ratios is used to identify aerobatic figures related to the transverse rotation of the aircraft:

(13) $\gamma > \Delta\gamma_{\text{pre-set}}$

(14) $\Delta\gamma = const$

(15) $\gamma > \gamma_{\text{pre-set}}$

For more accurate operation of the identification algorithm, additional conditions are introduced for the individual stages: for example, execution time at each stage.

Table 1.

Sign	Trajectory	Variables	Sign	Elements	Discription
T_1	Level flight	**$T_1 = X_1^H$** $-\delta H \le \Delta H \le \delta H$	**M_1**	Straight and level flight	**$M_1 = X_1^H . X_1^\psi$**
			M_2	Level flight with turns	**$M_2 = X_1^H . \overline{X_1^\psi}$**
			M_{2L}	Level flight with left turn	**$M_{2л} = X_1^H . X_2^\psi$**
			M_{2R}	Level flight with right turn	**$M_{2д} = X_1^H . X_3^\psi$**
T_2	Climb	**$T_2 = X_2^H$** $\Delta H \ge \delta H$	**M_3**	Straight climb	**$M_3 = X_2^H . X_1^\psi$**
			M_4	Climb with turns	**$M_4 = X_2^H . \overline{X_1^\psi}$**
			M_{4L}	Climb with left turn	**$M_{4л} = X_2^H . X_2^\psi$**
			M_{4R}	Climb with right turn	**$M_{4д} = X_2^H . X_3^\psi$**
T_3	Descent	**$T_3 = X_3^H$** $\Delta H \le \delta H$	**M_5**	Straight descent	**$M_5 = X_3^H . X_1^\psi$**
			M_6	Descent with turns	**$M_6 = X_3^H . \overline{X_1^\psi}$**
			$M_{6л}$	Descent with left turn	**$M_{6л} = X_3^H . X_2^\psi$**
			$M_{6д}$	Descent with right turn	**$M_{6д} = X_3^H . X_3^\psi$**

Table 2.

Sing	Trajectory	Description
E_1	Straight climb $/ny = 1/$	$M_3(ny = 1)$ or $(\Delta H > 0).(\Delta\psi = 0).(ny = 1)$
E_2	Energetically climb $/ny > 3/$ in the vertical plane along a convex curve	$M_3(ny > 3)$ or $(\Delta H > 0).(\Delta\psi = 0).(ny > 3)$
E_3	Energetically climb with turn $/ny > 3/$ in the vertical plane along a convex curve	$M_4(ny > 3)$ or $(\Delta H > 0).(\Delta\psi \neq 0).(ny > 1)$
E_4	Straight descent $/ny = 1/$	$M_5(ny = 1)$ or $(\Delta H < 0).(\Delta\psi = 0).(ny = 1)$
E_5	Energetically descent $/ny > 3/$ in the vertical plane along a convex curve	$M_5(ny > 3)$ or $(\Delta H < 0).(\Delta\psi = 0).(ny > 3)$
E_6	Energetically descent with turn $/ny > 3/$ in the vertical plane along a convex curve	$M_6(ny > 3)$ or $(\Delta H < 0).(\Delta\psi \neq 0).(ny > 3)$

4.2. Mathematical model.

The mathematical model of description is used to identify the aerobatic maneuvers performed in the exercise. Aerobatic maneuvers are divided into maneuvers from the horizontal, vertical and inclined planes [1]. This model includes the change of the trajectory of the aircraft and some limitations in the parameters characterizing the individual elements (Figure 5.).

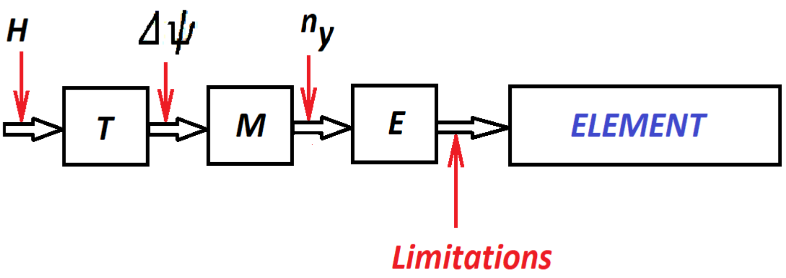

Figure 5.

For example:

360 Turn. Characteristics: the altitude and speed from the beginning to the end of the figure are constant. Limitations: change of course greater than 330°.

(16) $F_T = \{M_2.[|\Delta\psi| \geq 330^o]\}M_2$

- $\{\ldots\ldots\}M_2$ – requirement for continuity of the maneuver.

Loop. Characteristic features: normal acceleration $ny > 3$, change in altitude and speed in both halves of the figure and at control points. Limitations: change of roll – up to 10°, change of heading to be greater than 330°.

(17) $F_L = \{[T_2(ny > 3).(\Delta\vartheta \geq 75^o)][|\gamma| \leq 10^o][T_3(ny > 3)(\Delta\vartheta \leq -75^o)]\Pi[\Delta\psi \geq 330^o]\}_{T2,T3}$

- Π – requirement for correct sequence of performance.

The absence of the necessary characteristics for more than the set time means that the figure is not fulfilled.

5. Automatic piloting assessment

For each type of aircraft there are determined permissible indicators characterizing the performance of the elements. They are determined taking into account the characteristics of the aircraft itself and the level of training of the pilot. In practice, it is considered that the less the maximum deviation from set values, the higher the quality of piloting. The threshold values of the assessed parameters are selected on the basis of static studies and recommendations from experienced pilots. The choice of high thresholds leads to inflated grades, which contradicts the safety rules. Traditional assessment depends on a grading scale of “excellent”, “good”, “fair” and “poor”.

Computer software for automatic processing and analysis of flight information, which automatically indentifies the stages of the flight and the performed elements, can also be used for their automatic assessment. Used evaluation criteria and standards are introduced into the program (Figure 6.).

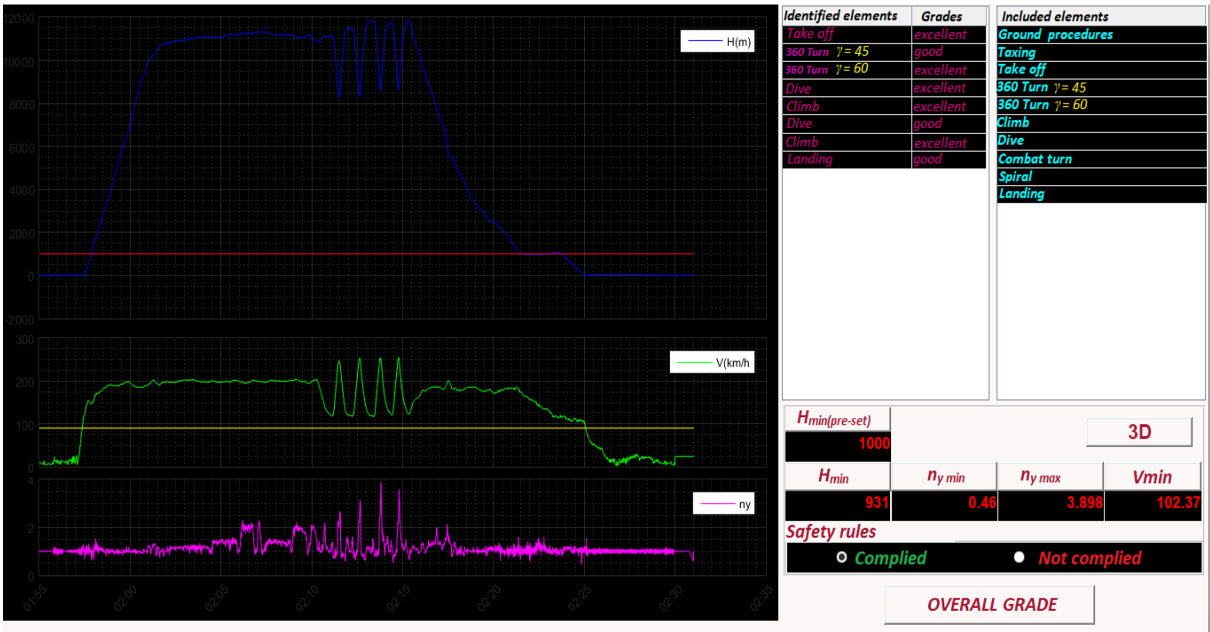

Figure 6.

Firstly all values of the evaluated parameters are determined at each control point of the identified stage or element. The obtained data is compared with the set values for the correct performance. These values are described in the flight manuals for the aircraft.

Next, the deviations are calculated and compared with the pre-set evaluation standards. The evaluation of the each element is the arithmetic mean of the results obtained for each evaluated parameter. For example, an element will be considered "excellent", if the deviations of all evaluated parameters are within "excellent", if a parameter goes beyond these standards, then the assessment of the element will be reduced.

(18) $$O_E = \frac{O_{p(1)}+\ldots+O_{p(n)}}{n}$$

Overall flight assessment includes grades of all assessed stages of the flight and all performed elements and represents their arithmetic mean. This is provided that all assessed elements are equivalent.

(19) $$O_{Ft} = \frac{c.O_{E(1)}+\ldots+c.O_{E(n)}}{n}$$

- c – criterion for the complexity of the elements

A criteria can be introduced for the complexity of the performed element, which changes the assessment in such way that the lower assessment of the easy-to-perform elements has less impact on the overall assessment.

6. Conclusions

- The computer application for automatic analysis and evaluation of flight tasks must include several models for automatic identification of the performed elements.
- The elements included in the flight exercises must be known in detail.
- The initial processing of flight data is essential and plays an important role in the automatic analysis of information.
- The automatic identification of the elements in flight tasks depends on the type of exercise and the spatial plane in which the elements are performed.

- The number of identified elements depends on the number of used parameters, respectively on the capabilities of the flight data recorder – the larger number of recorded parameters allows the detection of more elements.
- Setting too small or too large threshold values of the studied parameters leads to omission of one element or to its confusion with another one.
- The reliability in detecting the elements increases with the addition of more studied parameters and additional limitations.
- The detected elements must correspond to the ones set in the exercise – this can also be used as an indicator of the reliability of the identification.
- In order to perform the automatic assessment of the element, control points must be determined and the values of the parameters recorded in them must be compared with the evaluation criteria and standards set in advance.
- The overall grade of the flight task is determined as the arithmetic mean of the grades of the elements and depends on their number and their complexity.

References

1. Rumen Georgiev, "Technical tools and algorithms for flight information processing", “Vasil Levski” National University, Faculty of Aviation, Dolna Mitropolia, 2004.
2. Flight Crew Standardization and Evaluation Manual.
3. Source [online] Available:https://www.mathworks.com/matlabcentral/answers/.