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[1]Y. V. Hryshchenko,
[2]V. G. Romanenko,
[3]T. O. Pinchuk

IMPROVING THE METHODS OF ASSESSING THE QUALITY OF AIRCREW PILOTING TECHNIQUE

[1,2,3]Avionics Department, Faculty of Air Navigation, Electronics and Telecommunications,
National Aviation University, Kyiv, Ukraine

E-mails: [1]hryshchenko18@nau.edu.ua, ORCID 0000-0002-1318-9354,
[2]rvg11235@ukr.net, ORCID 0000-0003-0048-5549, [3]5725162@stud.nau.edu.ua

Abstract—*The article presents aircraft flight data in the landing approach mode, which was obtained on an integrated flight simulator and in actual flight conditions, processed by various probabilistic-statistical methods. These data were used to assess the quality of flight crew piloting techniques. We have reviewed the methods based on the Neyman–Pearson criterion, and the optimal Bayesian criterion is considered. When using them, we revealed the presence of a deterministic sinusoidal component in the flight parameters. We also used the method of analyzing autocorrelation functions and the method of analyzing the spectra of flight parameters of normalized and unnormalized autocorrelation functions. In a comparative analysis of these methods, we have shown that the most informative approach is the analysis of the spectra of flight parameters of normalized and unnormalized autocorrelation functions. This paper shows that the successful completion of the landing stage largely depends on the accuracy of the aircraft entry to the glidepath intercept point.*

Index Terms—Autocorrelation functions; human factor; parameter amplitude; spectrum analysis; director control mode; flight simulator.

I. INTRODUCTION

An analysis of aviation accidents shows that the greatest number of them occur due to the fault of the human operator. A human error in aviation is an incorrect or untimely action to control an aircraft without deliberately violating the established rules of flight operation. Most pilot errors are of a causal relationship, as they can be due to deficiencies in onboard information systems and equipment, both in general and in a specific flight situation. For example, most modern aircraft do not have standard equipment to detect the presence of volcanic ash, dust accumulation or other fine particles in the air. As you know, they can cause all aircraft engines to stop and other in-flight failures. An example of information limitation in the case of an abnormal situation in flight may be the failure of any functional aircraft system or avionics failures. Also, the limitation of information may be due to adverse weather conditions, difficult flight conditions and other factors. Such and similar situations lead pilots to a state of increased psychophysical pressure or stress. In most cases, this is the cause of an inadequate assessment of the current situation in flight and subsequently leads to incorrect actions when flying the aircraft. Thus, in the presence of the above factors, we can conclude that it is not entirely correct to say that only a person was wrong. Also, the concept of the human factor in piloting implies the presence of another type of error. They are called personal nature errors and depend only on the individual characteristics of the human operator, his psycho-emotional state and state of health.

One of the effective ways to reduce human errors and improve flight safety is the continuous improvement of pilot training. It involves the training effort of airstaff according to some techniques. Among these methods, there are also those devoted to stress-relieving training activity [1]. In the presented work, we aim to improve the methods of assessing the quality of piloting techniques in avionics failures.

II. PROBLEM STATEMENT

Aim. Evaluation of the quality of piloting techniques depending on the impact of negative factors in flight

On modern aircraft, in most cases, landing is carried out in automatic control mode. The transition to the director control mode increases the psycho-physiological pressure of the aircrew. Failures of some avionics systems can cause stress for pilots. The accuracy of the glideslope capture affects the quality of the glide path piloting technique [2]. Complex flight simulators make it possible to simulate such situations. Also, it imparts a stable skill to counteract psychophysiological pressure and to deteriorate the quality of piloting techniques.

For manual piloting, it is necessary to keep the arrows of the flight director display (or its frame in the multi-function display) in the center. When the autopilot is engaged, it maintains such a position automatically. When approaching along with the Instrument Landing System (ILS), the director display shows the necessary position of the aircraft to maintain the heading and glide path [3], [4].

Arrows of flight directors are a very useful tool that displays hints for directing pilot or autopilot control signals along a selected and calculated flight path. These arrows in any type of aircraft are usually located in the main attitude indicator (flight director, multi-function display etc.). The arrows show the required attitude of the aircraft to reach the set parameters and maintenance of these parameters.

Arrows of the flight directors are used to fly on a given heading at a given speed and altitude. An integrated aircraft simulator is used in the training of pilots to simulate the above flight parameters. Use the aircraft Mode Control Panel (MCP) to set the required parameters. We can activate the arrows of the flight indicators through a special toggle switch located on the same panel. The arrows are displayed on the flight director indicator in the form of two intersecting lines that form a cross shape.

For example, the movement of a vertical arrow accompanies a change in heading parameters. With a climb or decrease in altitude, the horizontal arrow changes its position. When the aircraft moves to the left, the vertical bar on the instrument shifts to the left, and when the aircraft moves to the right, the arrow will shift to the right. With varying climb times or heading changes, the flight director will automatically calculate and update the desired position.

If the pilot manages the directors manually this will increase his workload. Because he himself must program the parameters to perform each procedure or maneuver.

III. Problem Solution

Methods and algorithms for assessing characteristics

In flight, inadequate actions of pilots can lead to aviation accidents (Fig. 1). Methods for assessing the characteristics of an ergatic control system and a system for training crews on an integrated flight simulator are necessary to eliminate an inappropriate increase in the amplitude of aircraft flight parameters (IAAFP).

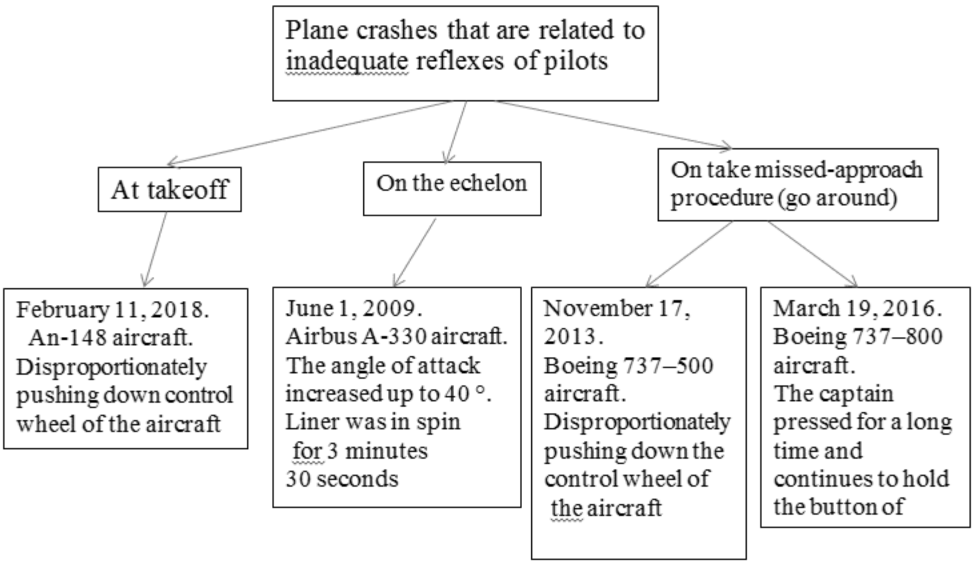

Fig. 1. Air accidents of modern aircraft, which are associated with IAAFP

Methods and algorithms for estimating the characteristics of ergatic aircraft control systems require automated processing. The instructor staff should provide information to the spectra of the autocorrelation functions of the flight parameter in the form of coefficients for IAAFP using polyparametric trend algorithms. In case of failures of the system for transmitting information about the value of the angle of attack or speed over the areas of correlation fields. Let's consider the presence of a deterministic component of the flight parameter in the form of comparative coefficients for flights without failure and with failures according to the Neyman–Pearson and Bayes criteria (Fig. 2).

We can use autocorrelation analysis to evaluate flight quality from the end of the third turn to the fourth and beyond until landing. Let's calculate the coefficients for modulo comparison of its first negative values y_{amp} using normalized autocorrelation functions.

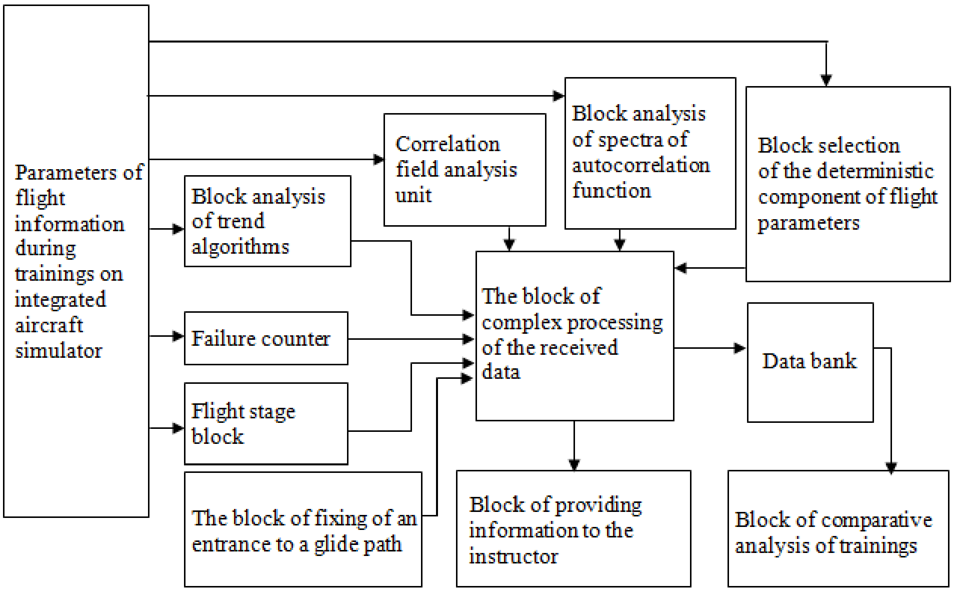

Fig. 2. Scheme of Obtaining Initial Data From Objective Control Systems and Providing them to the Training Specialists

TABLE I. VALUES ON THE MODULUS OF THE FIRST NEGATIVE AMPLITUDE WHEN FLYING AFTER THE 3RD TO 4TH TURN AND WHEN FLYING AFTER THE 4TH TURN TO LANDING

No	Pilot	Flight after the 3rd to 4th turn	Pilot	Flight after the 4th turn before landing
1	4	0.0027797	3	0.0093231
2	1	0.019928	1	0.056971
3	1	0.06815	2	0.091785
4	3	0.17819	3	0.12093
5	3	0.18558	1	0.20234
6	3	0.21424	2	0.24683
7	2	0.22582	4	0.30369
8	3	0.23082	1	0.30708
9	3	0.23975	4	0.30907
10	3	0.27341	3	0.33677
11	3	0.27361	3	0.37931
12	4	0.29059	4	0.38101
13	1	0.31251	3	0.41716
14	4	0.33913	2	0.46557
15	2	0.35425	4	0.47752
16	1	0.40327	2	0.51386
17	2	0.41642	1	0.60838
18	4	0.44514	3	0.60857
19	1	0.46516	3	0.61652
20	2	0.46975	3	0.63843
21	3	0.61236	1	0.66751
22	2	0.67	3	0.85517
23	2	0.76226	2	1.2745
24	3	0.82037	2	1.3527

Next, we group the data according to the value of y_{amp} and compile a table as y_{amp} increases (Table I). In the next step, we calculate the spectrum of the unnormalized autocorrelation function with the smallest exponent y_{amp} and compare it with the large exponents [5].

Using experimental analysis, we found that this method of assessing the quality of piloting techniques and psychophysiological stress of the human operator in flight on the B-737-500 is better from the fourth turn to landing than on the glide path. With the help of an oscillograph chart, we can define the flight information and the accuracy of glideslope capture. Negligence when entering the glidepath intercept point in the director control mode has a negative effect on the quality of flight during the glide path and landing.

However, the method of analyzing the spectra of flight parameters of unnormalized autocorrelation functions seems to be more illustrative for assessing the quality of the crew's piloting technique.

Figure 3 shows an example of calculating the spectrum of autocorrelation functions of the bank angle, and Table II shows the dependence of the values of their spectra.

$$S_t := \sum_{i=0}^{26} \left(K_i \cdot e^{\frac{-i\cdot 2\cdot \pi \cdot i\cdot t}{27}} \right) \qquad S_t := \sum_{i=0}^{26} \left(\Psi_i \cdot e^{\frac{-i\cdot 2\cdot \pi \cdot i\cdot t}{27}} \right)$$

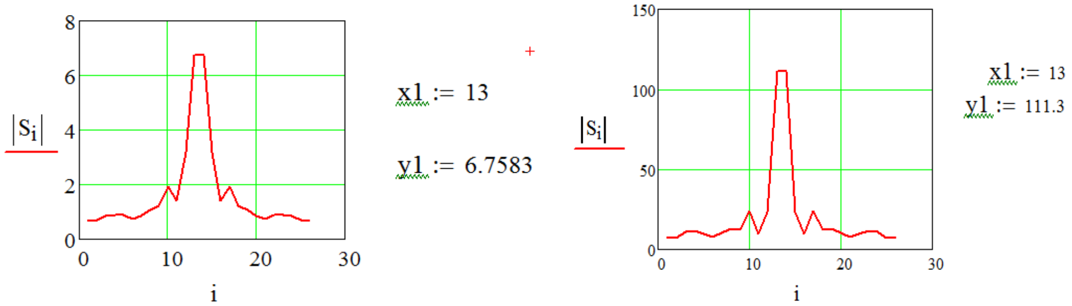

Fig. 3. Listing of the Calculation of the Spectrum of Normalized (y_{norm} = 6.1635) and Unnormalized (y_{unnorm} = 111.3) Autocorrelation Functions

TABLE II. THE UNNORMALIZED SPECTRUMS OF AUTOCORRELATION FUNCTIONS

No	Pilot	Flight after the 3rd to 4th turn	Pilot	Flight after the 4th turn before landing
1	3	2.7489	2	19.36
2	3	4.2039	3	23.556
3	3	13.849	1	87.758
4	2	111.3	2	185.96

We found the psychophysiological pressure of the human operator during flights from the end of the third turn to the fourth turn, by comparing the data obtained on the flight simulator (FS) in the case of complex failures that do not affect aerodynamics and aircraft control systems. Predicted limits of entry into the glide path by correlation functions in the form of an ellipsoid are presented in [6].

On the FS of the An-148 aircraft it is established that without failures and in case of not difficult failures the law of distribution of a bank angle does not contradict the normal law of distribution, and at difficult complex failures does not contradict Weibull's distribution.

In the actual flight on the An-148 aircraft from the end of the second turn (excluding turns) to landing, the calculations showed that the pitch distribution ϑ does not contradict the normal distribution.

Let's consider the flight quality assessments on the An-140 aircraft with the engines turned off to demonstrate the imitation of failures. Table III shows the calculation of the areas of the contours of the correlation fields, which are obtained by comparing the parameters of the bank angle and the angle of attack in case of failure of one of the engines.

The above methods must be applied in a complex manner. Conduct quarterly checks on a complex simulator. Store data in a data bank block for constant comparison of results. These methods by no means exclude existing simulator training programs.

Analysis of ergatic aircraft control systems requires automated processing.

TABLE III. AREAS OF CONTOURS OF CORRELATION FIELDS

Area, cm^2	Flight	Quality indicator
70–80	To failure	The quality is good
30–45	In case of failure	The quality of piloting is poor
50–60	After the failure	The quality is neither bad nor good

IV. CONCLUSIONS

When considering methods based on the Neyman–Pearson criterion and the optimal Bayesian criterion, it is necessary to allow the presence of a deterministic sinusoidal component in the parameters. Using experimental analysis, we found that this method of assessing the quality of piloting techniques and psychophysiological stress of the human operator in flight on the B-737-500 is better from the fourth turn to landing than at the moment of the glide path. According to the conducted research, we can conclude that the quality and success of a good landing depends on the accuracy of the aircraft's entry into the glidepath intercept point. The predicted glide path entry limits by correlation functions represent an area in the form of an ellipsoid. The method of analyzing the spectra of flight parameters of normalized and unnormalized autocorrelation functions seems to be more illustrative for assessing the quality of flight crew piloting techniques. Compared to other methods, with the help of this method, we can obtain spectrograms in the form of graphs, which quite informatively display the patterns of the aircraft piloting process.

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Hryshchenko Yurii. ORCID 0000-0002-1318-9354. Candidate of Science (Engineering). Associate Professor.
Avionics Department, Faculty of Air Navigation, Electronics and Telecommunications, National Aviation University, Kyiv, Ukraine.
Education: Kyiv Civil Aviation Engineers Institute, Kyiv, Ukraine, (1987).
Research interests: flight safety and dependability of technical and ergonomics systems.
Publications: 43.
E-mail: hryshchenko18@nau.edu.ua

Romanenko Viktor. ORCID 0000-0003-0048-5549.
Candidate of Science (Engineering). Associate Professor.
Avionics Department, Faculty of Air Navigation, Electronics and Telecommunications, National Aviation University, Kyiv, Ukraine.
Education: Kyiv Civil Aviation Engineers Institute, Kyiv, Ukraine, (1988).
Research interests: flight safety and dependability of ergonomics systems.
Publications: 43.
E-mail: viktor.romanenko@nau.edu.ua

Pinchuk Tetiana. Student.
Avionics Department, Faculty of Air Navigation, Electronics and Telecommunications, National Aviation University, Kyiv, Ukraine.
E-mail: 5725162@stud.nau.edu.ua

Ю. В. Грищенко, В. Г. Романенко, Т. О. Пінчук. Вдосконалення методів оцінювання якості техніки пілотування льотного складу

Дані з пілотування повітряного судна в режимі заходу на посадку, отримані на комплексному тренажері літака та в умовах реальних польотів, обробляли різними ймовірно-статистичними методами. Їх використовували для оцінювання якості техніки пілотування льотного складу. Розглядалися методи, побудовані на основі критерію Неймана–Пірсона та оптимального Байєсовського критерію. При використанні їх було виявлено наявність детермінованої синусоїдальної складової у параметрах польоту. Також застосовувався метод аналізу автокореляційних функцій та метод аналізу спектрів параметрів польоту нормованих та ненормованих автокореляційних функцій. Порівняльний аналіз цих методів показав найінформативніший метод аналізу спектрів параметрів польоту нормованих та ненормованих автокореляційних функцій. У роботі показано, що успішне завершення етапу посадки багато у чому залежить від точності входу літака до точки глісади.
Ключові слова: автокореляційна функція; амплітуда параметра; людський фактор; спектральний аналіз; директорний режим керування.

Грищенко Юрій Віталійович. ORCID 0000-0002-1318-9354.
Кандидат технічних наук. Доцент.
Кафедра авіоніки, Факультет аеронавігації, електроніки та телекомунікацій, Національний авіаційний університет, Київ, Україна.
Освіта: Київський інститут інженерів цивільної авіації, Київ, Україна, (1987).
Напрям наукової діяльності: безпека польотів і надійність технічних і ергатичних систем.
Кількість публікацій: 43.
E-mail: hryshchenko18@nau.edu.ua

Романенко Віктор Григорович. ORCID 0000-0003-0048-5549.
Кандидат технічних наук. Доцент.
Кафедра авіоніки, Факультет аеронавігації, електроніки та телекомунікацій, Національний авіаційний університет, Київ, Україна.
Освіта: Київський інститут інженерів цивільної авіації, Київ, Україна, (1988).
Напрям наукової діяльності: безпека польотів та надійність ергатичних систем.
Кількість публікацій: 43.
E-mail: viktor.romanenko@nau.edu.ua

Пінчук Тетяна Олександрівна. Студентка.
Кафедра авіоніки, Факультет аеронавігації, електроніки та телекомунікацій, Національний авіаційний університет, Київ, Україна.
E-mail: 5725162@stud.nau.edu.ua

Ю. В. Грищенко, В. Г. Романенко, Т. О. Пинчук. Совершенствование методов оценки качества техники пилотирования летного состава

Данные по пилотированию воздушного судна в режиме захода на посадку, которые получены на комплексном тренажере самолета и в условиях реальных полетов, обрабатывали различными вероятно-статистическими методами. Их использовали для проведения оценки качества техники пилотирования летного состава. Рассматривались методы построенные на основе критерия Неймана–Пирсона и оптимального Байесовского критерия. При использовании их было выявлено наличие детерминированной синусоидальной составляющей в параметрах полета. Также применялся метод анализа автокореляционных функций и метод анализа спектров параметров полета нормированных и ненормированных автокорреляционных функций. Сравнительный анализ этих методов показал, что наиболее информативным является метод анализа спектров параметров полета нормированных и ненормированных автокорреляционных функций. В работе показано, что успешное завершение этапа посадки во многом зависит от точности входа самолета в точку глиссады.
Ключевые слова: автокорреляционная функция; амплитуда параметра; человеческий фактор; спектральный анализ; директорный режим управления.

Грищенко Юрий Витальевич. ORCID 0000-0002-1318-9354.
Кандидат технических наук. Доцент.
Кафедра авионики, Факультет аэронавигации, электроники и телекоммуникаций, Национальный авиационный университет, Киев, Украина.
Образование: Киевский институт инженеров гражданской авиации, Киев, Украина, (1987).
Направление научной деятельности: безопасность полетов и надежность технических и эргатических систем.
Количество публикаций: 43.
E-mail: hryshchenko18@nau.edu.ua

Романенко Виктор Григорьевич. ORCID 0000-0003-0048-5549.
Кандидат технических наук. Доцент.
Кафедра авионики, Факультет аэронавигации, электроники и телекоммуникаций, Национальный авиационный университет, Киев, Украина.
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Количество публикаций: 43.
E-mail: viktor.romanenko@nau.edu.ua

Пинчук Татьяна Александровна. Студентка.
Кафедра авионики, Факультет аэронавигации, электроники и телекоммуникаций, Национальный авиационный университет, Киев, Украина.
E-mail: 5725162@stud.nau.edu.ua