Assessment of Operator-Pilot Training in Conflict Situations

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Abstract. With the progress in manned and unmanned aircraft technology, the preparation of an operator of aerial vehicles becomes an important task, and its main assignments are training for piloting the aircraft to complex fly conditions and readiness to sharp transition from the remote control to handle control. Despite the intensive use of aircraft, in particular, unmanned aerial vehicles, for solving military tasks, the scope of application of these devices is gradually expanding in the interests of solving peacetime tasks. Apart from delivering monitoring of territories and objects, the delivery of goods, money, the creation of temporary radio networks for receiving and transmitting information and others are covering. To solve these problems, a qualified training of specialists serving this equipment is necessary. Based on the theoretical and practical training of the operator, criteria for evaluating the operator's activities are justified and put forward. The evaluation model of the quality training process of specialists in the maintenance and operation of aircraft proposed. Examples of applying this model are given.

Keywords: Socio-technical system, Operator-pilot, Assessment Criteria, Quality, Maintenance, Operation.

1 Introduction

Socio-technical systems are widespread in many areas of modern industry including aviation. Therefore, studying the problem of training the pilot-operator as an element of a socio-technical system is relevant. The development of such systems and the rapid rate of aviation engineering development take the lead over human qualities. This constrains the growth of operator possibilities for interaction with modern aircraft and leads to conflict situations. Nowadays researches in the area of safe operation of aviation engineering require the creation of new approaches, methodologies, and techniques. This is caused by the following reasons [1]:

1) drastic increase of flight speeds and altitudes; extension of meteorological constraints on carrying out flights;
2) increasing the intensity of air traffic;

3) complication of the construction as a result of increasing dimensions and automation level;
4) arising additional factors connected with the operation of aging engineering;
5) features of operating conditions;
6) necessity of training and retraining of operator-pilots;
7) computerization of technological processes related to execution and provision of flights;
8) application of "glass cockpits" or cockpits of the high information technologies; the possibility of different types of terrorism.

The contemporary approach to providing safe flight is as follows. It is necessary to use the functioning of the human-machine system ("aircraft-operator-pilot") as a whole. Such an approach provides research on features and undesirable aspects of interacting human-machine system components.

The control of the unmanned vehicle can be carried out in manual, automatic and semi-automatic modes, with the human operator playing a significant role in the preparation and conduct of the flight. Automation of flight does not at all exclude a person from flight control but changes the direction of his activity.

As stated above, aircraft and flight simulators together with an operator-pilot represent closed-loop systems, which belong to the class of human-machine systems. Such a system represents a set of engineering devices and operators, which provides the functioning of these components. There are two types of human-machine systems. Structure schemes of these systems are represented in Figures 1 [2].

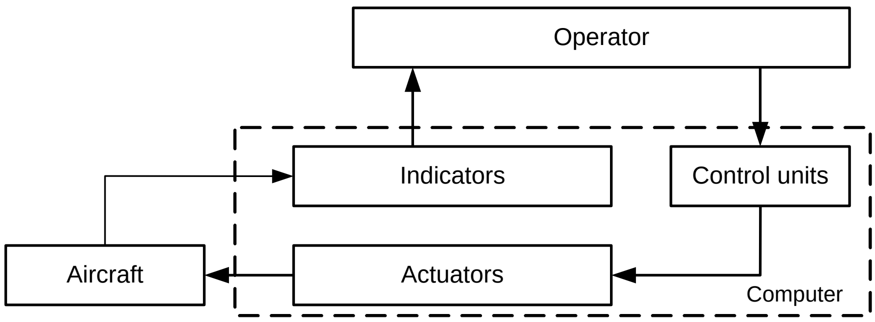

Fig. 1. Structure of the human-machine system of the first type.

In the first case, an operator-pilot closes a channel of forming controls in the system. Otherwise, an operator is a unit of the control system. In the second case, operator functions are checking the operation of the system, and the prevention of accidents.

Modern human-machine systems include computers, which carry out aircraft control by the optimal program, prevent accidents, and detect failures with localization of fault place. In other words, they free an operator from many functions. The operator comes into operations in the case of computer failure. Such systems are called automated control systems.

So, it is possible to make the following conclusions. On the one hand, the computer carries out complex functions instead of an operator that widens the functional possibilities of the system. On the other hand, the increase of computer functional possibilities leads to the necessity of their integration, so the relative role of an operator increases.

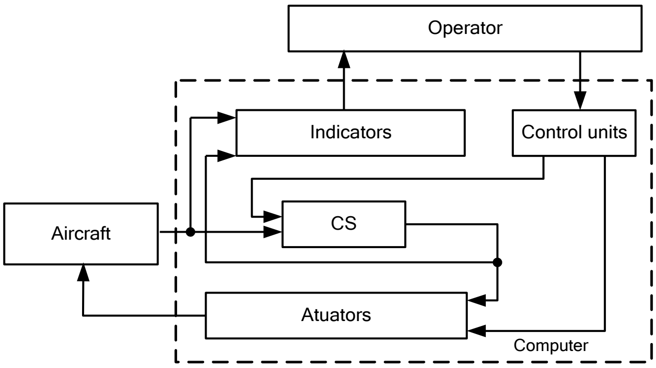

Fig. 2. Structure of the human-machine system of the second type (CS is a control system)

The flight control system consists of a receiving and transmitting station, a software interface located, as a rule, on a tablet computer, an operator and an aircraft itself. The control of the military unmanned apparatus usually involves two operators, one of whom controls the flight of the apparatus (air vehicle operator), and the second one for performing a useful task (mission payload operator). In this regard, the management task is not simple but requires special training of the operator, who must cope with the control tasks in the conditions of natural and deliberate interference, loss of the communication line, loss of direct visibility, delay of transmitted information, managing of several devices and others.

High-quality performance of tasks to a destination requires time to prepare the device for departure in manual or semi-automatic modes, at the same time the preparation of the flight in automatic mode requires much more time-consuming. These circumstances impose some specific requirements for the training of operators who can ensure the performance of the task in adverse flight conditions.

2 Papers Review

The important function of the operator-pilot is decision-making, especially in difficult situations. The mathematical model of the decision-making process for human-operator as an element of the socio-technical system is represented in [3]. Deterministic and stochastic aspects of this problem are discussed in [4].

An overview of human influence in various areas related to the current and future use of unmanned aerial vehicles is presented in [5]. The study notes that the operator must have specific training, which is not necessarily the same as that of the aviators.

However, issues related to the skills, knowledge, and abilities of operators require additional research.

The complexity of ensuring the possibility of interaction between the operators of different stations is noted in [6], which is advisable to have for organizing interaction when managing a group of UAVs. The need for precise operator actions to solve useful problems is emphasized in [7]. For training operators, of course, appropriate simulators should be used. In the development of simulators, an important place is given to an adequate mathematical model of UAVs, one of the versions of which is based on the physical laws of the motion proposed in [8].

Researchers [9] proposed a simulator for training UAV operators of a new type, involving the simulation of the actions of an aircraft. The simulator allows you to simulate the passage of signals, testing on these signals of the airplane in real-time, which allows for the initial assessment of operators.

In [10], the error distribution curve of the UAV operator was obtained in the form of the Chi-square Pearson distribution based on the histogram of the error probability density from measurements of the operator's activity, which can be used for the initial assessment of operators. The authors of [11] note the need to develop standards for the selection and training of UAV operators.

In [12], it is proposed to evaluate the abilities of the UAV operator according to the profile generated by the special software, which is based on the combination of cluster analysis and fuzzy logic. The proposed evaluation metrics make it possible to evaluate the effectiveness of interaction in group management.

Features of aircraft control, which define approaches in training of operators for such moving vehicles are represented in [13, 14]. These features are presence of airborne payload and redundant inertial sensors for UAVs. Training of quadrotor operators also required special approach [15, 16].

A preliminary analysis of the work carried out in the development of effective simulators for the training of operators allows us to draw a preliminary conclusion about the need for research to improve the quality of training of UAV operators.

These studies should focus on the development of metrics that allow both to select personnel and improve its training, as well as to serve as the basis for the standards being developed.

3 Flight Control Problems

The most vulnerable for flight control is the UAV control channel. The problem is the limited bandwidth of the radio channel, since the narrowband path is more susceptible to the effects of noise and interference present in the communication channel; in flight, loss of communication is also possible, in places with significant reflections, false signals and commands may be received or erroneous signals and radio control commands may be received. Also, the low data rate is imposed by the complexity of the radio control commands.

In connection with the wide use of GPS navigation, for the interception of control, false signals are used that mimic the correct signal and cause the target to incorrectly determine its position and thus allow it to intercept control (spoofing).

In addition to radio control problems, it may be difficult to perform a payload. Considering the UAV that monitors (photographs) the ground situation, it should be noted several problems arising from its work, namely: delays and loss of video information; overlay frames and their passes; camera shake; poor spatial resolution; delays in updating information.

4 Operator Actions

Changing of the human ability to operation can be divided into three-time intervals such as an entry in the work, relative stable ability to operation, and disability to work. The first stage is characterized by comparatively low speed and accuracy of actions. The second stage depends on the higher accuracy of operator actions. And the decrease of ability to operate on the third stage is caused by fatigability. The increase of operator reliability is provided by the proper organization of work and rest, and also special training to the regulation of ability to work depending on conditions of work.

Also, the operator controlling the flight of the UAV must know the modes and control parameters of the control channel to ensure a stable flight of the device; be able to make adjustments for flight control; know the conditions for switching autopilot from manual and semi-automatic control to automatic; be able to exit the automatic control with the appropriate authorization.

The operator responsible for performing payloads must know the equipment used and its capabilities, be able to control the field of view of the video camera, be able to get useful information from the available material, and also work closely with the flight control operator.

5 Operator Evaluation Criterion

The estimated quality indicators of the operator should be attributed:

- response time t is the time that passes from the moment of perception of information to the response to it; otherwise, it is the ability to detect, process and respond to a stimulus
- the operator's accuracy ε is the degree of correspondence of the read data from the display screen by an operator to the measurement data;
- exposure τ is time for the operator have to understand the occurred situation;
- training ν, we understand the frequency of errors in the operator activity;
- stress tolerance k is the level of resistance to the negative effects of activity;
- preparedness Σ is a set of proficiency, experience, and conditions of mental and physiological faculties that determine its competence to perform certain activities with a necessary quality;

- prediction λ is the property to see or feel the events of a still unfulfilled, closer future event.

The considered set of parameters allows us to represent them as a vector with the coordinates $\theta = (t, \varepsilon, \tau, \nu, k, \Sigma, \lambda)^T$.

Then a generalized indicator of the quality operability is introduced to assess the man-operator, it called performance, which can be determined from the set of proposed indicators that written as follow

$$J = \sum_{j=1}^{M} c_j \mu_j \ , \tag{1}$$

where c_i is the ith weight coefficient, μ_i is the ith normalized parameter values, i.e.

$$\mu_j = \frac{\theta_{\max} - \theta_j}{\theta_{\max} - \theta_{\min}}, \tag{2}$$

where θ_j is a parameter, $\theta_{min} \le \theta_i \le \theta_{max}$, $j = 1,\ldots, M$, in our case $M = 7$. The weighting factors are imposed by the limitation

$$\sum_{j=1}^{M} c_i = 1. \tag{3}$$

The suitability of the operator is estimated by the ratio

$$J \ge J_{\min}, \tag{4}$$

where J_{min} is the value by which the decision is made on the admission of the operator to the intended activity. Now the task of evaluating the quality of training is reduced to determining the value J_{min} with unknown weights c_j.

Due to the fact that the introduced indicators make different contributions to the final criterion, for example, indicators such as reaction time t, accuracy (error) ε and exposure τ need to be reduced and others to increase, it makes sense to separate these factors and solve the problem of maximizing the form taking into account the equal contribution of each component

$$J_{\min} = \max_{c_i} \left(\frac{1}{n_1} \sum_{i=1}^{n_1} c_1 \theta_i^+ - \frac{1}{n_2} \sum_{i=1}^{n_2} c_1 \theta_i^- \right), \tag{5}$$

where $n_1 + n_2 = M$, for the considered parameters $\theta^+ = (c_{\bar{\nu}}, c_{\bar{k}}, c_{\bar{\Sigma}}, c_{\bar{\lambda}})$, $\theta^- = \left(c_{\bar{t}}, c_{\bar{\varepsilon}}, c_{\bar{\tau}}\right)$.

The calculation procedure is

1. We determine the values of the vector θ accepted as permissible for each parameter, $\theta \in [\theta_{min}, \theta_{max}]$.

2. We calculate the values of the coefficients c_i by the method of hierarchy analysis, involving the preparation of matrix A of pairwise comparisons of size $p \times p$, where p is the number of criteria. Set the diagonal elements of the matrix equal to 1, set the elements a_{ij} following the importance of the parameter so that the important parameter takes a number in the range from 1 to 9 so that the most important takes the value 9, and the least important 1. The element $a_{ji} = 1 / a_{ij}$.

3. We verify the fulfillment of the consistency condition for the matrix of pairwise comparisons by calculating the consistency coefficient CR

$$CR = \frac{p(p_{\max} - p)}{1.98(p-1)(p-2)} . \tag{6}$$

If CR ≤ 0.1, the level of inconsistency is considered acceptable, otherwise matrix A is reviewed.

4. Determine the value J_{min} by (5).

5. We measure the parameters of the vector θ for a particular human operator, apply (2), (1) and (4).

Corollary 1. The quantity J satisfies the condition $0 < J \leq J_{max}$.

Corollary 2. The value $J_{max} = 1$.

6 Case Study

The interaction of operator-pilot and machine can be illustrated by the scheme represented in Fig. 3 [2]. Receiving information about the system state, the operator processes this information and forms necessary influences on control units.

The operator can influence on control units of the system engineering components employing effectors. Basic human effectors are muscles of hands and legs. Control can have implemented also by the voice and changing electric potentials of a separate body point (body currents of control of manipulators for checking the physiological activity of the operator), effects of physiological activity (pulse, breath frequency).

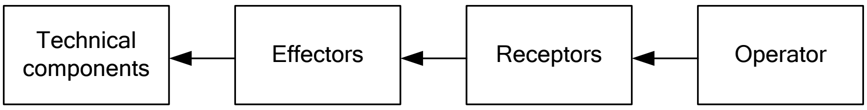

Fig. 3. Structural scheme of interaction of the operator with the technical components of the control system

The operator can influence on the technical part of the control system in two ways. For the first way, the operator is the main source of energy necessary for control. For the second way, the operator can determine the only time of implementation of the definite control unit.

It should be noted that the greatest effect of aircraft control can be achieved in the case if the operator has the so-called "sense of handle" [2]. Then the operator-pilot can correlate efforts applied to the control handle with the executed manoeuvre.

The operator-pilot carries out various functions in control systems. These functions are driving the system into action, coordination functioning different components of the control system, and also receiving, storing and converting information.

So, developing control systems it is necessary to take into consideration both technical requirements and psychological, physiological, physiological and anthropometric characteristics of the operator-pilot [17].

Indicators are of great importance in changing information between the operator-pilot and engineering facilities. This process includes optical, acoustic, mechanical and other effects. It should be noted that the system of analyzers of the operator has many channels and great possibilities for signal receiving. During using indicators, the sight analyzers of the operator-pilot have the greatest loading. Sound signalling is used with restrictions. Other analyzers are used very rarely.

So, to organize the optimal interconnection between the operator-pilot and indicators, it is necessary to take into consideration, on the one hand, basic features of human sight system first of all visual acuity, and on the another hand, – indicator parameters related with human engineering-physiological features including symbol dimensions, contrast range, dearness, alphabet type and frequency of information repetition.

During mounting indicators and control units it is necessary to carry out some principles such as priority, grouping, interaction. The priority principle lies in the location of the most important indicators and control units in optimal zones of the working place of the operator-pilot. Grouping is a combination of indicators and control units into logical blocks. Carrying out the principle of interaction means the realization of the proper and constant interconnections between every control unit and an appropriate indicator.

One of the most complex problems of the human-machine system design is a division of functions between the operator-pilot and computer. Nowadays the heuristic methods based on the experience of human-machine systems operation. One of the methods is based on the creation of lists of human-machine system functions, where every function is decided on the possibility to be carried out by the operator or computer. A decision obtained by this method is conditional and does not guarantee an absence of errors. Another method is based on the analysis of functions of the human-machine system. These functions are supplied with some parameters, for example, frequency, speed, stability, accuracy, meaning estimated by the method of expert assessments. Then, redundancy or lack of the operator or computer loading, are determined based on analytical dependencies. But using expert assessments makes this method approximate and subjective. The method based on the principle of the need to influence the operator-pilot in all cases, when the transformation of information is subjected to essential changes, has no such disadvantages. Moreover, the latter method takes into consideration the connections between system functions. This is the advantage of the method in comparison with methods, based on studying a list of system functions only.

In contrast to the above-stated methods, the proposed method of operator training is adapted to conflict situations.

The initial data taken as the norm are given in Table 1.

Table 1. Normal data.

Parameter	$\bar{t}$	$\bar{\varepsilon}$	$\bar{\tau}$	$\bar{\nu}$	$\bar{k}$	$\bar{\Sigma}$	$\bar{\lambda}$
Value	0.5	0.5	0.5	2	2	2	2
c_i	0.1976	0.4905	0.3119	0.3873	0.1397	0.2748	0.1981

Using the method of analytical hierarchy process [18-20], weighting coefficients were found that satisfy the condition for consistency of the initial matrices of pairwise comparisons.

Then, the following (5), the value of I_{min} = 0.3355. Let check the weights for other, obviously worse values of the considered parameters [20-22], for example, for data in Table.2.

Table 2. The second set of data.

Parameter	$\bar{t}$	$\bar{\varepsilon}$	$\bar{\tau}$	$\bar{\nu}$	$\bar{k}$	$\bar{\Sigma}$	$\bar{\lambda}$
Value	0.8	0.8	0.8	1.5	1.5	1.5	1.5
c_i	0.1976	0.4905	0.3119	0.3873	0.1397	0.2748	0.1981

We get the value I = 0.111, which does not satisfy the condition (4). Now we will consider the best indicators of Table 3 against the data of Table 1.

Table 3. The third set of data.

Parameter	$\bar{t}$	$\bar{\varepsilon}$	$\bar{\tau}$	$\bar{\nu}$	$\bar{k}$	$\bar{\Sigma}$	$\bar{\lambda}$
Value	0.3	0.3	0.3	2.5	2.5	2.5	2.5
c_i	0.1976	0.4905	0.3119	0.3873	0.1397	0.2748	0.1981

We obtain the value I = 0.526, which completely satisfies condition (4).

7 Conclusions

Since the scope of application of UAVs has recently been expanding, the problem of training operators to ensure the preparation, operation, and execution of tasks for the purpose is becoming acute. The paper proposes an approach in which the generalized quality indicator is a linear function of partial heterogeneous quality criteria for performing typical functions with unknown weight coefficients. The described method is a modification of the method of analytical hierarchy process based on identifying single-type indicators, the efficiency of which is confirmed by numerical examples. The considered approach can be used in the development of simulators for training operators or evaluating gamers.

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