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OPTIMIZATION OF DECISION-MAKING PROCESS IN EXTRA SITUATION ON LANDING

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Abstract. *Analyzed the decision-making process in flight extra situations. Mathematical model «airplane-crew- dispatcher -extra situation» and interaction of its main components is proposed. The criteria of optimization decision-making to prevent catastrophic emergency situation in flight is proposed*

Keywords: extra situation; decision-making process; criteria of optimization; landing; aircraft.

Introduction

Improvement of the system of operational methods is inseparably connected to automation of the most complex processes of dispatcher's work. And one of the major problems there in automation of dispatcher's work in decision making is the problem of using of computing unit in control loop. The computing unit which works as an add-on unit but does not substitute dispatcher. In other words, it comes to designing the adviser device which can provide to the dispatcher the solution of the tasks that should be formalized. In this sense, the work of computing unit can be considered as an analogue of dispatcher's work.

Among the major scientific and theoretical problems which deals with work automation the most important are: to formulate the goal of control, i. e. to determine the criteria of optimality taking into account limiting conditions; to describe control system mathematically; to develop control algorithm; to develop structural and informational scheme of algorithm implementation.

One of the possible approaches for solving those problems is based on application of system-wide work decomposition principle in the form of Global Assembly Cache (GAC) system structural analysis which allows to separate a number of typical goals in decision making. Each of these goals is characterised by its own local missions, mathematical models, methods of formalizing and solving.

The solution for the first of the mentioned problems is to formulate the criterion of ergatic system optimality. This solution is based on analysis of qualitative and quantitative characteristics of the process implemented in solving of typical task taking into account the features imposed on the GAC system as a whole by its individual elements. It is often found that rationality or, presumably, optimality of dispatcher's work in specific terms can be determined only on the qualitative descriptive level. That is why the formal description of optimal (rational) dispatcher's activity as an element of ergatic system stays relevant.

To achieve this goal can be possible with the help of theoretical-experimental approach based on the principle of assessing the final result of real work. This result can be considered in some sense as a reference. In other words, it is assumed that dispatcher in GAC system operates in optimal (suboptimal) way in the sense of some criterion of decision optimality. This criterion integrally reflects dispatcher's ideas of goals and needed results for solving the real situations tasks he faces. In this case, to formulate work optimality criterion (within which the dispatcher works) is possible with the help of solving the inverse problem of the optimal processes theory. The essence of the problem is to establish the structure and the parameters of optimality criterion on the basis of known results of solving problems for GAC. These results are assumed to reflect the extremal features of dispatcher's work under certain conditions. This assumption is obviously true when the solution of problems is made in compliance with established regulations (which define in an explicit or implicit form the list of desired goals and decision making rules), and when the content of dispatcher's commands (recommendations) corresponds to the most favourable control process development.

Although it is clear that in a general case in real situation it is possible for work optimality criteria to be unstable (changeable). This unstability is manifested in participation of various dispatchers and in unsteadiness of their professional and psychological properties and qualities.

In these conditions raise important tasks to evaluate the degree of decline the system quality due to the manifestation of the factors mentioned, and to justify the adequacy and objectivity of the created optimality criteria. The reported difficulties can be overcome if use together the methods of theory of inverse problem of optimization and methods of expert analysis.

Differences in mathematical models of typical problems' solving to a large extent determine the specificity of these methods. However, regardless of the class of the problems the proposed approach has elements in common, which can reveal the basic content and features of this trend of simulation the decision-making processes. This similarity is primarily manifested in the fact that the formalization of optimality criteria of decision making (or control) is performed using the expert evaluation methods for analysis and selection of the solutions of the inverse optimization problem for which the implementation of the decision-making process (or control) satisfies the entire set of requirements for the quality of the system as a whole, as well as for dispatcher's work.

Some peculiarities of these methods implementation can be seen in the case study of aircraft (AC) landing in bad weather conditions.

The process of GAC system functioning is repeatedly observed by group of experts and is subjected to apparatus registration.

The registration identifies evaluations of generalized control function u and vector of generalized phase coordinates q (deviations from the programmed descending trajectory). For each i th implementation on the basis of those evaluations the inverse problem of optimal processes theory is solved. In other words the generalized characteristics of i th process implementation which defines integral properties and features had in particular i th, the implementation of technical and ergatic elements of the system. With constant technical characteristics of the systems (the same type of aircraft, the same means of displaying information, etc.) it can be considered that landing control in each implementation is carried out by dispatcher using its extreme possibilities that are determined mainly by professional psychological qualities. In this sense, the generalized characteristics J_i can be considered as criterion of dispatcher's work optimality at the appropriate level of professional training and readiness to work in the i th implementation [1].

Each i th implementation of landing control process is also subjected to expert evaluation. Analysis and processing of expert evaluation results allow to divide implementations and its criteria into several classes according to the system of preferences used in expert evaluation. The parameters that form the core of the optimality criterion in each class are averaged by one of the smoothing procedures. Classes are characterized by different quality levels of the system, and therefore, are determined by different requirements to the level of dispatcher's professional training and practicing skills. The ability to make and classify criteria creates preconditions for an objective assessment of dispatchers work during approach both in learning process, and in real world. The usage of basic criteria J^S for evaluation of the system quality and work or dispatcher's training level can be built on the solution of inverse optimization problem. The result optimality criterion belongs to one of the classes according to the scheme of finding minimum distance J on basis of J^S, $(s=\overline{1,n})$ in its parameters' space.

Thus obtained optimality criteria describe dispatcher's intuitive notions (bases on test results) about rational control on the descending trajectory. Besides these criteria allow to synthesize the control equivalent to the control carried out by dispatcher when system runs normally accurate within some quantity which is determined by increasing optimality criteria value by means of averaging the results of some certain dispatchers during finding the system optimality criterion.

From a qualitative point of view, optimization of dispatcher's work during landing (in the described case) lies in the task to define optimal command content for finite sequence of time points. Herewith to get the optimality of command content (recommendations or information on aircraft position relatively to glide path) means to provide mental and physical relief of a pilot and dispatcher, and to provide an ability to stabilize aircraft on glide-path with no violation of set modes of flight during landing. Provision of mental relief for a pilot is connected with the stabilization of aircraft on the glide path. The higher is accuracy of aircraft position stabilization, the lower is possibility of mistakes (deviations) accumulation on the remaining descent segment, and therefore, the less likely is the need for dispatcher to override. Besides, pilot spends less time on information perception, decision making and motor act. While controlling by approach radar the glide slope precision depends not only on the quality of the maneuver of glide-path capturing (which is mainly determined by content and time of corrective command), but also on the time of information "On the glide path" provided by dispatcher.

Taking all the mentioned requirements into account, there appears a complex problem of multicriterion system. That's why it seems appropriate to use and develop theoretical and experimental methods for the construction of the optimality criteria based on the results of the inverse optimization theory.

It worths notice, that inverse problem theory (which takes central place in the approach under study) allows easily to get constructural solutions in case when controlling functions can be represented in the form of linear combinations of system generic coordinates. The change of these coordinates is described by system of linear differential equations. It is the condition that to a large extend determined the choice of a class of process models under study from a variety of permissible models. In general case the mathematical model of system in the process of landing approach (after making a decision of landing) is a combination of mathematical models: model of aircraft motion dynamics; system operator pilot who performs control function in the loop «crew team – aircraft»; dispatcher who performs functions of supervisions, trasfer and working out of commands and recommendations on aircraft traffic control in the loop «aircraft – approach radar – dispatcher – crew team – extra situation».

The generalized mathematical model of aircraft motion can be represented in the form of system of linear differential equations relatively to generalized coordinates q – departures of aircraft position from calculated. Herewith, there are two phases of aircraft motion process on each interval between discrete commands of dispatcher (these commands include messages about descent path error and commands on alteration of course).

The first phase for convenience can be referred to aircraft motion by the action of program control U_p. Here it is possible to observe a tendency of stable pattern of change, and, in general, stable accumulation of errors relatively to fixed descent path. This phase includes making a decision of next command content, transmission of worked out command to the crew and the beginning of the command execution. Alternation of generalized coordinates at the first approximation can be described by a system of linear differential equations with constant coefficients of such type:

$$q' = f(q_1 u_p) = Aq.$$

The next phase of aircraft motion is characterized by presence of additional stabilized control, synthesized by crew on the basis of dispatcher's command. The description of generalized coordinates alternations differs from the first phase by the fact that in the right hand of equation it has linear combinations of components of control vector function u, and each of it, in its turn, is considered as linear function of vector of system's generalized coordinates. In case when for model construction the action of vector control function is replaced by the action of scalar control function, the formalism of inverse problem solution for each decision making cycle is connected with definition of integrated quadration criterion of such type:

$$J = \int_{t_0}^{\infty} \left(q'Mq + u^2 \right) dt.$$

Coefficients of steady-on-each-cycle matrix and positive definite diagonal matrix M are defined on the basis of ratios that look alike with Riccati equation in their form.

The value of control function acts at the beginning of the first phase of each guidance cycle as a result of programmed control compositions during approach and sequence stabilized controls synthesized by dispatcher's commands. In this case the motion of aircraft can be considered optimal in the sense of compositions of integral quadratic optimality criteria

$$J'_\Sigma = \int_{t_0}^{t_1} \left(q'M^1 q + u^2 \right) dt + \ldots$$

$$+ \ldots + \int_{t_j}^{t_{j-1}} \left(q'M^j q + u^2 \right) dt + \ldots,$$

and this composition can be replaced by one criterion

$$J'_\Sigma = \int_{t_0}^{T} (q'M(q, L)q + u^2) dt,$$

with weightage matrix registering the parameters of system “aircraft – pilot – communication link – dispatcher” on different distances from runway and on different flight path errors on descending. This practically ends the formalization of the measure of dispatcher effectiveness in the process of landing approach (after making a decision of landing).

Development of complex optimality criterion which allows to formalize process of making a decision of landing, can be based on thorough analysis and on qualitative descriptions of dispatcher’s goals. Performance of those goals precedes to decision-making and is strictly connected to the mentioned above functions which characterize dispatcher’s work. If take that achieving each goal is characterized by specific effectiveness criterion, which possesses a value of “0” in case of achieving corresponding goal and a value of “1” – in other case, than the criterion of J' (which joins specific criteria of qualitative goals) can be put as

$$J' = \sum_{i=1}^{r} I_i.$$

The combination of criteria (3) and (4) gives an opportunity to finish composition of complex criterion, that allows to formalize algorithm of decision-making and control during landing.

Complex optimality criteria

$$J_\Sigma = NJ' + J'_\Sigma.$$

It is easy to notice that J_Σ possesses an optimal value only when decision of clearance to land is made and control on descent flight path is rationally (from dispatcher’s point of view) carried out.

Formalization of work of computing unit duplicating as previously stated a dispatcher means registration of specific criteria value and calculating of J' criteria value. Decision of clearance to land is made only in case if $J' = 0$, in other case when $J' \geq 1$ the command of missed approach procedure is given.

Conclusion

On descend trajectory the control is carried out in accordance with optimality criterion, the choice of which is automatically provided by synthesized range for different conditions with the consideration of aircraft type and control cycle. The functioning of adviser device can be defined as accelerated time scale simulation of aircraft motion with given for each moment initial conditions (deviations) until the time corresponding to the end of first phase of aircraft motion.

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Д. О. Шевчук. Оптимізація процесу прийняття рішень в особливих ситуаціях на етапі посадки

Проаналізовано процес прийняття рішень в умовах виникнення аварійної ситуації в польоті. Запропоновано математичну модель системи «літак-екіпаж-авіодиспетчер-особлива ситуація» на етапі виконання посадки та проаналізовано взаємодію основних її компонентів. Наведено критерії оптимізації прийняття рішень для запобігання переходу аварійної ситуаціїї у катострафічну.

Ключові слова: особлива ситуація; процес прийняття рішень; критерії оптимізації; посадка; літак.

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Напрям наукової діяльності: методи відновлення керованості літака в умовах виникнення особливих ситуацій у польоті.
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Д. О. Шевчук. Оптимизация процесса принятия решений в особых ситуациях на этапе посадки

Проанализирован процесс принятия решений в условиях возникновения аварийной ситуации в полете. Предложена математическая модель системы «самолет-экипаж-авиадиспетчер-особая ситуация» на этапе выполнения посадки и проанализировано взаимодействие основных ее компонентов. Приведены критерии оптимизации принятия решений для предотвращения перехода аварийной ситуации в катастрофическую.

Ключевые слова: особая ситуация; процесс принятия решений; критерии оптимизации; посадка; самолет.

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