MANAGING AND CONTROL OF AIRCRAFT POWER PLANT USING ARTIFICIAL NEURAL NETWORKS

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The tasks of neural networks' application in the airplane power plants automatic diagnostic systems are considered as well as their peculiarities and advantages.

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1. INTRODUCTION

The modern air engine is a complicated technical object that embodies the most progressive technologies of science and engineering. The provision of needed economic characteristics of the air engine power plant is possible by the rising the level of thermodynamic cycle operation parameters, that mostly have an influence on the air engine's resource and reliability. During the gas turbine engines operation the various tasks of aircraft power plant vital activities guaranteeing and airplane systems and energy plants functioning are solved in the onboard computer. Opportune and qualitative aircraft engine parameters' monitoring and diagnostics make it possible to realize the exploitation of the engine based on its status condition. In spite of the big number of various gas turbine engines diagnostics and monitoring methods, none of them is completely universal one. It can be explained mostly by a very high complication of the air engine: there are many parameters, links, the processes are non-linear, there are many modes of operation, etc. All it assumes the need of complex methods' application for the solving the air-engine's parameters' control and diagnostics tasks. The promising method of air engine managing and conditions' control is the neural networks' application [1-3] that grants the solving of the wide spectrum of tasks.

2. THE NEURAL NETWORKS APPLICATIONS

The main tasks that can be solved by neural networks application are the following:

- the identification of gas turbine engine mathematical models;
- the classification of aircraft power plant modes of operation;
- the control and diagnostics of aircraft power-plant status condition;
- the analysis of trends of aircraft power-plant status condition parameters, measured onboard, aimed for forecast of these parameters variation depending on the life length.

The usage of gas turbine engines mathematical models is needed for many research and practical tasks solving, for example, for the synthesis and analysis of the power-plant managing during the various regimes of flight.

The ideal mathematical model (MM) must satisfy the following mutually contradictory requirements:

- to describe adequately the connections between parameters and the processes in gas turbine engine;
- to provide the given precision of the parameters' calculation;
- to be convenient for usage in calculations and modelling;
- to be adaptable (learnable) for the individual copy of the engine, etc.

In practice usually the set of mathematical models of different complexity is used. Each model satisfies the part of requirements given above and has different areas of application.

The most precise and complicated models are non-linear gas turbine engine components' models, but they are used for the solving of research tasks and optimization of the characteristics of power-plants control system. Simplified non-linear models are widely spread, for example, regression models as well as the models with variable coefficients. But even using this approach it's not always possible to receive the universal models because of their different representation forms and the need of models' coefficients correction. Classical multidimensional functions approximation methods do not allow to realize simple mechanisms of the mathematical models structure choosing. The realization of classical interpolation methods on the base of spline-functions requires the considerable computing resources. In such a situation as a rule the providing of the calculations in the real-time is problematic.

For the air engine throttle control model the altitude-velocity and throttle performances are described by the authors using the similar modes [4]. Also in the work [4] the simple and precious mathematical model is developed.

Today in the works about the power plants management systems designing the approach of neural network usage for the mathematical model identification is proposed. The main idea of such approach usage is in the process of network learning that means the adjustment of the big number of coefficients (synaptic weights between neurons). The building of the neural network models is based on the standard procedures of the neural network structure and their learning methods. Multilayered neural network organization makes it possible to carry out the parallel calculations that support the solving of the characteristics approximation task in the real time [3].

Thermo-gas parameters of the aircraft engine (temperature, pressure, air consumption, etc.) in the different sections of the gas-air flow duct as well as mode and exit parameters (the rotor rotating frequencies, throttle, fuel consumption, etc.) are the carriers of information about the aircraft power plant condition. That's why they can be used for the definite classes of the aircraft engine conditions (properly functioning, non-properly functioning) recognizing with the aid of different mathematical models of gas turbine engines.

Using the power plant parameters trends the classes of the air-engine can be recognized by the uncovering the correlations between measured and calculated using mathematical model parameters. Statistical characteristics of the controlled parameters registration results (also caused by the appearing and developing of the defects in the aircraft power plant) make it possible to forecast the changes of the aircraft power plant condition changes during the exploitation process [5].

In the case when the number of the measurable parameters is not sufficient for the linear mathematical model development the neural network can be used as the model for the standard and defected engine's model. The analysis of the given parameters' deviations in the time is carried out by the calculation of the metrical distance between standard engine's data basing on the neural network and data received during the exploitation of the engine. The results of the quantitative modelling are evidence of complex monitoring and exploitation management possibility of the aircraft power plant using new neural network technologies. Such methods extend and expand "classical" methods that can raise the reliability of management and trustworthiness of the parameters control and aircraft engine diagnostics as well as the decision making processes efficiency on-board while "critical" conditions are detected.

3. ON THE NEURAL NETWORK'S TYPE CHOOSING

The mathematical model of the aircraft engine power plant is the model that generalizes many local models, for example, models of the flow path of the air engine. The relationship between elementary models of the physical processes can be described by the graph that makes possible to formalize the model integrity and coherence research.

Direct application of the neural network models, for example, for the diagnostic model of the aircraft power plant's flow path can be represented as multilayered perceptron with two hidden layers. Perceptron's inputs are the controlled parameters of the gas turbine engine (y_1, ..., y_n), its outputs are the controlled parameters' deviations from their nominal values $(\Delta y_1,..,\Delta y_n)$. The distinctive feature of the neural network as the diagnostic model of the aircraft power plant is that it's weight matrix is formed in the process of two-staged learning procedure basing on the models that are linear on the local aircraft engine's parameters.

The most simple example of the aircraft power plant mathematical model is the throttle characteristic of the aircraft engine in two coordinates (G_{F_coer}, n_{c_coer}), where G_{F_coer} is an adjusted value of fuel consumption in the combustion chamber, n_{c_coer} is an adjusted value of the gas turbine engine turbo compressor's rotation frequency that is represented in the relative (non-dimensional) units. As the rule the powerful deviation on the throttle characteristics' relations can be observed because of some disturbing factors (changes of the air engine's flow path geometrical parameters, errors of the main engine's parameters' and external conditions used for engine's parameters' conversion to standard atmospheric conditions measurements errors, etc.). Recent investigations show, that in the case of modes operation near maximum the measured fuel consumption's deviation from the nominal value can be up to 4,5% in the case when such an error can be caused by uniformly distributed errors of the direct measurements of the temperature and pressure as well as fuel characteristics' changes. If tolerance to the parameters' deviations is less than range explainable by random factors, then while engine parameters are regulated systematic deviations must be compensated at the expense of engine parameters' deviations from the their standard values.

Investigations carried out show that the most appropriate neural network architecture that can satisfy prescribed requirements for the aircraft power plant control quality is ensemble neural network. Such architecture in the given case is represented as the following chain: radial basis function networks (RBF) $\rightarrow$ perceptron $\rightarrow$ Kohonen's neural network (KN) (see Figure 1).

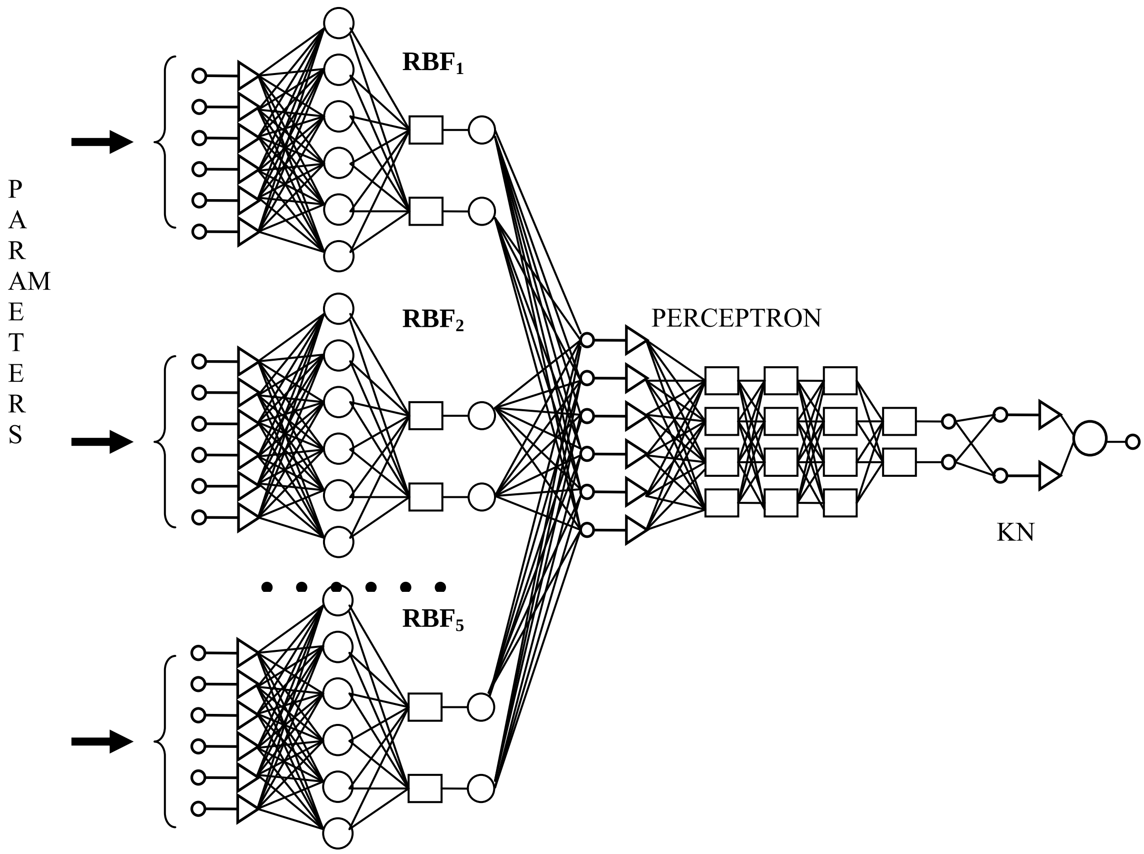

Figure 1. *Ensemble neural network architecture*

In ensemble architecture the first (input) layer filters the measured data, the second (intermediate) layer represents the thickener of the aircraft power plant status characteristics, and the output layer is the status conditions classifier.

The modelling of the given task using PC in the case of aircraft power plant's work in different modes and with different combinations of parameters let to denote 3-5 most informative parameters that maximally affect the normal functioning process of the aircraft engine. In this case the usage of five RBF networks each with five input parameters (state vector) and two output parameters (state "1"

– normal, state "0" – failure) is considered as the optimal one. Perceptron in the ensemble is the field that concentrates five RBF's outputs. Kohonen's network (classifier) has two inputs and one output. This network with a high degree of precision carries out the classification (recognition) of the aircraft power plant status condition, also in the case of partial or full uncertainty about its parameters. Computer experiment has shown that ensemble neural network recovered the absent data steady and determined the condition of the power plant. The estimation of the power plant according to its exploitation time based on neural network is carried out in the following way. The standard model of the power plant (parameters of engine) received in the process of factory development testing, which is stored in the neural network basis as the individual informational "portrait", is compared to the power plant parameters during the exploitation [6]. In the process of the comparative analysis the special metrics is calculated. Its value can be used to estimate air engine status condition and to build the separating plane. For such task solution the 3-layered perceptron (2 inputs, 14 hidden neurons, 4 outputs) is used. It is trained using the error back-propagation algorithm.

CONCLUSION

The application of the neural network apparatus is effective in the solution of many tasks: aircraft engine power plant's "image" identification, control, mode classification, diagnostics, trend analysis, forecasting, etc.

The problem of aircraft power plant and its subsystems control and diagnostics is a complicated task that is concerned with the need of taking into account many factors also the uncertainty factors. The application of the artificial intelligence methods based on the neural networks makes it possible to find new ways of this problem solving that are based on the using the knowledge and experience of the experts. These are image recognition theory, learning theory, theory of adaptation to the changing external conditions, theory of the decision making in the case of the information deficiency, etc.

Investigations considered in [7, 8] show that the neural networks using for analysis of the aircraft power plants is effective and promising.

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