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Gene identification in adaptive control systems of aviation engine

A structural approach of creation adaptive control system of aviation engine, based on gene identification of mathematical model has presented. It can be effectively applied for development of integrated control system, which includes both a priori data about the model of the object and a posteriori data about the model for the case of vector input and output in the conditions of incompleteness of information about the state, the synthesis of control of the engine.

Introduction. At present time, in connection with the development of technology, the complexity of controlled objects in developed and projected control systems significantly increases. The structure of most modern control objects is such, that an accurate mathematical description of objects either is absent or varies widely. In such conditions incompleteness information on the mathematical model imposes a significant limitation on the used methods for synthesis of control. To solve the control tasks in conditions of uncertainty are designed control systems based on robust and adaptive approaches [1], which improve reliability systems, as well as reduce the technological requirements for design.

In identification tasks, controls are often reduced to optimization of functionals task, the type of which depends on the statement of the problem [1,2]. In the more general case, the optimizable functional can have not one, but several extremum. In this case the use of gradient algorithms is advisable only after use of global optimum search algorithms, for example, algorithms include the Monte Carlo method, simulation of annealing, evolutionary algorithms. One of the most popular and proven in practice algorithms of global extremum search are genetic algorithms [2].

The goal of this research is to define the processes for identification and control of aviation engine for constructing a generalized structure of an adaptive control system with incomplete status information based on genetic algorithm.

The genetic algorithm (GA) is a heuristic the search algorithm used to solve optimization problems and modeling by successive selection, combination and variation parameters with usage the mechanisms as for biological evolution. It is a kind of evolutionary computation, where a distinctive feature is the emphasis on the use of the operator «crossing», which performs the operation of recombination of solutions-candidates, whose role is similar to the role of crossing in living nature.

One of the founders of genetic algorithms is John Holland, whose book «Adaptation in Natural and Artificial Systems» is the fundamental work in this field of research.

There are many ways to implement the idea of biological evolution in the GA. The GA, represented in figure 1 [1,2], is considered to be common.

```
BEGIN /*genetic algorithm*/
        create an initial population
        estimate the adaptiveness of each individual
```

```
        stop: = FALSE
WHILE NOT stopping TO EXECUTE
BEGIN /*create a new generation population*/
        REPEAT (size_population/2) TIMES
        BEGIN /*cycle of reproduction*/
                Select two individuals with a high
                adaptiveness from the previous
                generations for crossing

                Cross the selected individuals and get
                two descendants
                Estimate the adaptiveness of descendants

                Place descendants in a new generation
        END

        IF population converges ON stop: = TRUE
END
END
```

Fig. 1. Diagram of a typical GA.

The task is coded in such a way that its solution can be represented as a vector («chromosome»). A random number of initial vectors («initial population») is created. They are estimated using the «adaptiveness function», resulting in each the vector is assigned a certain value («adaptiveness»), which determines the probability of survival the individual represented by this vector. After this, with usage the obtained adaptiveness values are selected vectors (selection), allowed to «crossing». These vectors are «genetic operators» (in most cases the «crossing» - crossover and «mutation» - mutation), thus creating the next «generation». Individuals of the next generation are also estimated, then selection is carried out, genetic operators are applied, etc. Thus, the «evolutionary process» are simulated, continuing several life cycles (generations), until there is the criterion for stopping the algorithm is fulfilled. Such a criterion can be:

- finding a global, or suboptimal solution;
- discharge the number of generations released for evolution;
- discharge the time allowed for evolution [1].

Genetic algorithms serve, mainly, for finding solutions in very large, complex search spaces.

Gene identification. Considering the control object:

$$\begin{cases} \dot{X} = AX + BU \\ Y = CX + DU; \; X(t_0) = X_S \end{cases} \tag{1}$$

where $\mathrm{Y} = \{\mathrm{r}, 1\}, U = \{m, 1\}, X = \{n, 1\}$.

Based on the results of observations of the inputs and outputs (U, Y), it is required to restore parameters of the object (1) on the basis of genetic algorithms.

Consider the configurable model (2)

$$\begin{cases} \dot{\hat{X}} = \hat{A}\hat{X} + \hat{B}U \\ \hat{Y} = \hat{C}\hat{X} + \hat{D}U;\ \hat{X}(t_0) = \hat{X}_s \end{cases} \tag{2}$$

By forming a quality criterion for the continuous case

$$J = \sum_j \int \left(Y_j - \hat{Y}_j\right)^2 dt \tag{3}$$

where $j = 1 \ldots r$ is the number of the corresponding system output (1) or the corresponding criterion for the case of discrete measurements

$$J = \sum_j \sum_{i=1}^{N} \left(Y_j(i) - \hat{Y}_j(i)\right)^2 \tag{4}$$

where N is the number of measurements.

Having defined the «chromosome» as a vector of configurable parameters of the model (2)

$$p = \left[\hat{a}_{11}\ \hat{a}_{12}\ \ ..\hat{a}_{nn}\ \hat{b}_{11}\ .\hat{b}_{nm}\ \hat{c}_{11}\ ..\hat{c}_{rn}\ \hat{X}_{s1...}\ \hat{X}_{sn}\ \hat{d}_{11}\ ..\hat{d}_{rm}\ \right] \tag{5}$$

can be arrived at the problem of optimization

$$p = \arg\min J \tag{6}$$

Conclusion. The efficiency of defining the parameters of mathematical model the most demanding structural elements of adaptive control system the aviation engine by using GENE identification technology has been investigated and analyzed.

As the benefits of genetic and evolutionary optimization algorithms can be defined their ability to find global optima, easy parallelism, the absence of the need to calculate private derivatives (sensitivity functions). The disadvantages of GA should be attributed relatively slow convergence to the solution with respect to the gradient algorithms. Nevertheless, GA are noise-resistant methods solving inverse tasks.

References

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