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USING THE FUNCTIONAL APPROACH FOR DETERMINING PARAMETERS OF DYNAMIC MODELS OF FLYING APPARATUSES

The possibility of using the functional approach to the solving problem of determination of the characteristiscs of dynamic models of flying apparatuses is explored. The greater power of the functional approach lies in the idea that the operations may be treated just in the same way as data. The strengthes, weaknesses and problematic questions of functional approach application are discussed.

Quality of automatic control of an aircraft is one of important factors of safety of flights and competitiveness of the flying apparatus. Success of developing of the system of automatic control for an aircraft, as well as quality of its work, depend on exactness of model of aircraft as a dynamic object, which is used for creation of the control system, on plenitude and authenticity of information about the object of control (plant). The more complete and more exact is the mathematical description (mathematical model) of object, the greater effect can be got as a result of its automation and optimization. Thus, determination of parameters of mathematical model of object on the basis of watching its behaviour makes substantial part of work of designer of a control system, as well as the engineer who performs adjustment and maintenance of such a system. [1]

Mathematical models are formalized mathematical descriptions of objects, control systems and their parts, and also of their intercommunications. A model of any kind is the simplified reflection of the actual object, but it must reflect all its substantial features, that is, that complex of properties of object, the taking account of which is important for the supposed application of model. Model’s closeness to the object in terms of these properties is estimated with adequacy criteria which are based on different quantitative estimations of deviations of the state variables of the obtained model from the available experimental information. In researches, related to the construction of models of complicated objects, questions of adequacy have the special significance. Plenty of the real objects – nonlinear, non-stationary, multidimensional, with many internal reverse connections, having the distributed parameters, owning a large inertance and delay, are characterized by the large number of input and initial parameters, much from which are uncontrolled variables and/or subject to intensive disturbances. These reasons complicate building of the mathematical model, considerably adequate to the real object, in this connection there arises a requirement of model simplification.

Nowadays, there are two selected different approaches to the construction of models of the controlled objects. One approach consists in an attempt to penetrate into the “deeps” of the object operation and to set its properties and intercommunications to comprehensive physical and mathematical analysis of the phenomena and processes which take a place at its functioning. Such analytical path is very labour intensive and justifies itself only at the construction of cognitive models. Other path consists in watching and registering changes of values at the object inputs and outputs in the process of its exploitation, on its initial co-ordinates, etc, and, finally, making conclusions about the object properties and creating its mathematical model, or consistently specifying the adjustable hardware or programmatic model. Such approach, unlike the first one, is based not on theoretical, but on experimental researches of object.

Wide prospects for modification and perfection of processes of determination of parameters of models of the run-time systems are given by application of the functional approach. Usually people remember about functional approaches at the periods of technology changes, when the role of analytical and research tasks grows. It is not an accident that nowadays one often uses the term «functionality» at comparative description of the information systems.

Functional approach, and its practical mapping, functional programming, is a paradigm that originated from ideas older than the first computers. The first functional programming language celebrated its 50th birthday in 2008. Functional languages are very expressible, yet everything is achieved using a minimal number of concepts. Despite their elegance, functional languages have largely been ignored by mainstream developers until now.

Today we are facing new challenges and trends that open the door to functional approaches. We need to design systems and write programs that process large sets of data and scale to a large number of processors or computers. We want to create components that can be easily tested. We want to be able to express our logic in a declarative way which expresses results without explicitly specifying execution details – making the created structure easier to understand and reason about.

The common complication of solving problems by means of functional determinations may be overcome by aiming at formalization of basic set of objects and determination of the complete semantic system of operations applied to them. It allows to present the classes of tasks and their solutions in the form of strict formulas, which, for the sake of evidency, may be simplified by means of introduction of the extended functional characters. If necessary such characters are brought into the determination of the system of algebra which results in its expansion, and new functions are introduced, like proving lemmas and other auxiliary constructions in mathematics. Recursive and character denotations of both information and actions and any formulas, comfortable at determination functions is actively utilized.

Let us consider a procedure for determination of frequency characteristics of an aircraft directly from the records of the measured signals. Basicly, the dynamic system is supposed to be linear, with the differential equation of the following form in the time domain [2]:

$$a_n \overset{(n)}{y}(t) + a_{n-1} \overset{(n-1)}{y}(t) + \ldots + a_0\, y(t) = b_m \overset{(m)}{x}(t) + b_{m-1} \overset{(m-1)}{x}(t) + \ldots + b_0\, x(t) \quad .$$

For such signals let us apply the Laplace transform to both parts of the diferential equalization of the system:

$$L\{y_n(t)\} = Y_n(s)\ ;\ \ L\{x_m(t)\} = X_m(s);$$

$$W_{n,m}(s) = \frac{Y_n(s)}{X_m(s)} = \frac{\sum_{j=0}^{k} b_j s^j}{\sum_{j=0}^{r} a_j s^j}.$$

Let us introduce into the consideration the followings functions and operators:

the functions $F_{mn}\,(x_m(t), y_n(t))$, which characterize the system's identificability;

the functions $V_{mn}\,(x_m(t), y_n(t))$, which characterize the speed of fading of the process of identification;

the functions (functionals) $P_{mnp}\,(x_m(t), y_n(t))$, which characterize the errors of the values of the identified parameters of the system;

the functions (functionals) $E_{mnp}\,(x_m(t), y_n(t))$, which characterize the errors of control (by the output values), provided that the control is performed on the basis of the identified parameters of the system;

the identification operators $I_m(y_n(t))$;

the operator $R\{\}$ of recursive application of identification procedure;

the operator of the Laplace transform $L\{\}$;

the operator of the reverse Laplace transform $L^{-1}\{\}$;

the operators of modification of the input data $M^d_j\{\}$, $j = 1\ldots J_1$;

the operators of modification of the penalty functions $M^f_j\{\}$, $j = 1\ldots J_2$;

With the use of these denotions the problem of determination of parameters may be formulated as the problem of search of such functional operators I_m, $R\{\}$, $M^d_j\{\}$, $M^f_j\{\}$, that for the given set of input data allow to minimize the norms of functions of $P_{mnp}(x_m(t), y_n(t))$ and $E_{mnp}(x_m(t), y_n(t))$. This problem setting may be further expanded, according to the actual needs of the control system developers and their customers. Such formal expansion is conservative (every new character is determined through the old ones), while it guarantees the maintenance of all of functional properties of the source system. The minimum set of denotations in which it is possible to describe all the correct (calculated) formulas of the system, plays the role of the base of the system, realization of which is a minimum version of the system.

In realisation of such an approach, we face several problematic questions [3]. The first of them is about the effectiveness of the composed system, in comparison to the systems in which the traditional principles are applied. In order to compare the efficiencies of algorithms meaningfully, the time requirements of an algorithm must first be quantified. Although it is theoretically possible to predict the exact time taken to perform many operations, such an approach quickly becomes intractable as the system gets more complicated.

Consequently, one should sacrifice exactness in favour of an approximate but still quantitative measure of the time taken for an algorithm to execute. This approximation, the conventional notion of algorithmic complexity, is derived as an upper- or lower-bound or average-case of the amount of computation required, measured in units of some suitably-chosen primitive operations. Furthermore, asymptotic algorithmic efficiency is derived by considering these forms in the limit of infinite algorithmic complexity.

Another significant issue is interoperability. Modem scientific computing often requires many separate components to interact. These components typically use different styles, are written in different languages and sometimes even run on separate platforms or architectures. The functional approach allows programs to interact easily with other systems and even other platforms across the internet. As an example, the F# functional programming language provides a unique combination of expressive power and easy interoperability.

There is a wide variety of different software used by scientists. As the practice shows, COM and .NET applications can easily be set for interoperation with most important applications, such as Microsoft Excel, The Mathwork's MATLAB and Wolfram Research's Mathematica.

Conclusions

The power of the functional approach lies in the idea that the operations may be treated just in the same way as data. The concept of a function, unlike the classic concept of a set, partially includes a concept of time: at first arguments are calculated in order of their introduction, then in accordance with the approved algorithm the value of the function is determined – possibly, its result is obviously dependent upon the results of other functions or of the same function, but at other, before calculated, values of arguments. As usual, the values of the arguments are calculated till to them a function is used. But if in quality information not only a value but also character forms is assumed for the calculation of these values, question about time of calculation of arguments it is possible to decide not so categorically. This leads to the extended possibility of the use of recursive functions and methods of their realization.

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