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Algorithmic Synthesis of Control Systems with Changeable Structure

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Introduction

In the automatics control system regulators and corrective elements change their parameters and structure according to a certain law or the algorithm: signs of feedback links, digitally increase or decrease transition coefficients of different coordinates, values of time constants, etc. In such a system there is a possibility to make use of useful qualities of different structures or obtain new qualities, which are atypical of any of the possible structures [1, 2].

The problems of control systems of a changeable structure synthesis may be solved by means of arranging phasic portraitures and other classical methods [1, 2] when control objects are simple and have a mathematical model. Classical methods of the changeable structure synthesis have a limited sphere of application. Their application is problematic or impossible when the object is described by a complex differential equation, has a complex non-analytical mathematical model or when a mathematical model is not available at all.

The aim of the present work is to review and improve algorithmic methods of control systems synthesis initiated in works [3 – 5], as well as the software enabling the systems of a changeable structure, quasioptimal and other automatics control systems to be designed in those cases where a mathematical model of the object is complex or is unavailable at all, and when application of classical synthesis methods is impossible.

Principles of algorithmic methods of control systems of a changeable structure

In solving problems of optimization of control systems it is often necessary to determine the optimal structure and parameters of the regulator, the corrective element or any other control device, the laws of their variation, or the variation laws of control actions, which would ensure control quality set in accordance with certain criteria. All above-mentioned methods of control systems synthesis may be formulated in the form of search optimization problems.

In formulating a problem of the control system of a changeable structure synthesis, we shall form the variation Laws of parameters β_i on which the structure of the system (the regulator, the corrective element) depends [4].

Within the control interval $t_0 \le t \le t_f$ where $t_0 = 0$, by means of discrete values $i = 1,...,m$ of the components β_i, of the vector $\boldsymbol{\beta}$,

$$\begin{cases} \beta_i[jT], \ \ j = 0,...,r-1, \\ ..... \\ \beta_m[jT], \ \ j = 0,...,r-1. \end{cases} \tag{1}$$

$$\mathbf{x} = \{x_1 = \beta_1[0], x_2 = \beta_1[1T],..., x_{k-1} = \beta_m[(r-2)T], \\ x_k = \beta_m[(r-1)T]\}; \tag{2}$$

where $k = mr$-dimensional vector is introduced, T is the quantifying period $T = t_f / r$.

On the basis of the components x_i of the vector $\mathbf{x}$, functions are created by means of which variation laws of the structure and parameters are formed

$$\begin{cases} \beta_1 = \beta_1(\mathbf{x}, t), \ \ 0 \le t \le t_f, \\ ..... \\ \beta_m = \beta_m(\mathbf{x}, t), \ \ 0 \le t \le t_f \end{cases}. \tag{3}$$

Let us assume that, with the boundary conditions and limitations given, the variation laws $\beta_i^*(t)$ of the parameters β_i exist providing the minimum to the functional

$$J = \int_{t_0}^{t_f} f_0\left[y, \boldsymbol{\beta}(t)\right] dt. \tag{4}$$

Then the approximate parameters variation law $\beta_i^*(t)$ may be found in the process of search optimization.

Since the vector $\mathbf{x}$ forms the variation law $\beta(\mathbf{x}, t)$ of the parameters β_i within the interval $t_0 \le t \le t_f$, the

problem of the system of a changeable structure synthesis may be formulated in the form of a search optimization problem. It is necessary to find the vector $\mathbf{x}^*$ providing the minimum to the functional

$$J(x) = J\left[y, \boldsymbol{\beta}(\mathbf{x}, t)\right], \quad t_0 \le t \le t_f, \tag{5}$$

following the below limitations:

$$h_i\left[y, \boldsymbol{\beta}(\mathbf{x}, t)\right] = 0, \quad i = 1, ..., p < k; \tag{6}$$

$$g_j\left[y, \boldsymbol{\beta}(\mathbf{x}, t)\right] \ge 0, \quad j = 1, ..., q; \tag{7}$$

$$\mathbf{x} \in \Omega_x; \tag{8}$$

where J, h, g are the control quality indicators (the regulation time t_r, the maximum dynamic deviation σ, the control error Δy and others). The essential condition for solving the problem is experimental finding of values of the limiting functions (6) and (7) of the functional (5) in the optimization process.

The problem of the control system of a changeable structure synthesis (5) – (8) is solved in accordance with the scheme presented in Fig. 1 by applying algorithms of simplex search [3] and by using the software package *Kvazio 1* [6, 7].

We shall give an example of the solution of the problem of the control system of a changeable structure synthesis. A structural scheme of the control system of a changeable structure is presented in Fig. 2. The regulator consists of two elements: proportional and differential, connected in parallel. The coefficient of the latter $\beta_2(t)$ changes with the passing of the time therefore this element may be connected at a certain moment in the course of transitional process. When $\beta_2 = 0$, the oscillation process is shown in Fig. 3.

Applying the above presented method of the control system of a changeable structure synthesis, that is, in solving the problem (5) – (8) according to the scheme presented in Fig. 1, we can find a variation law of the

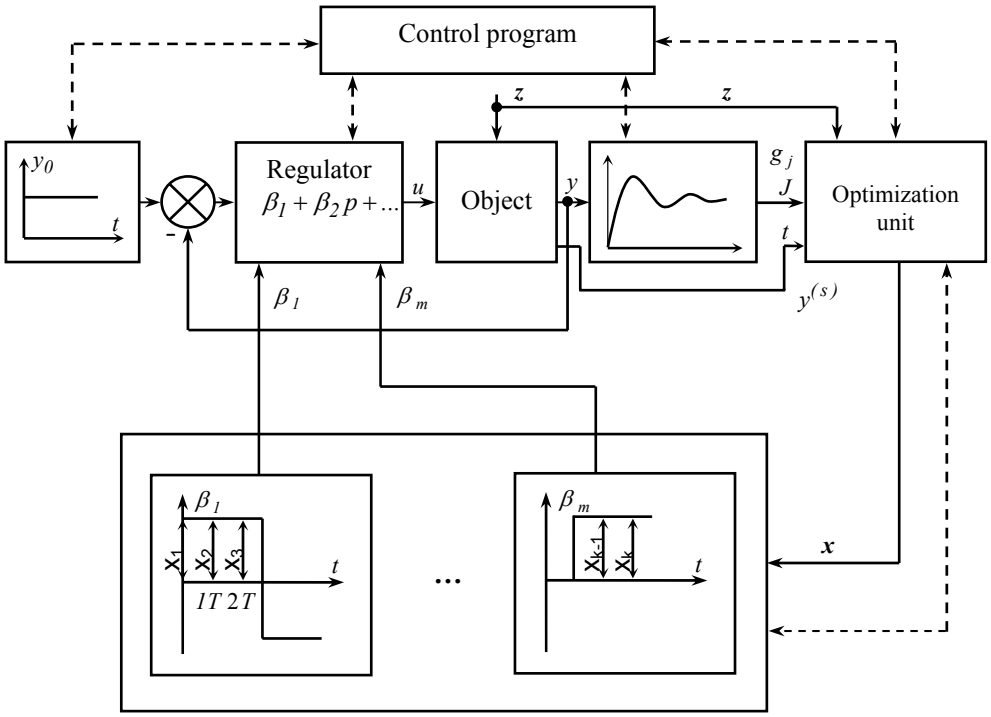

Fig. 1. A scheme of solving the problem of the control system of a changeable structure synthesis

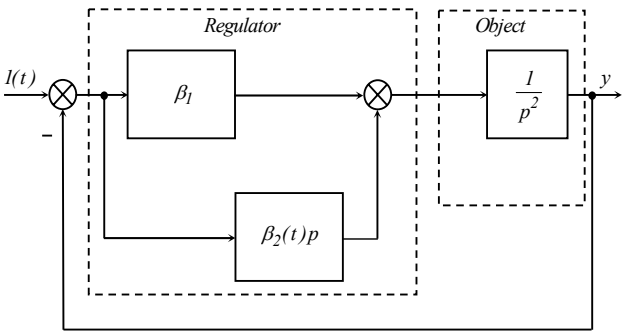

Fig. 2. Structural scheme of a control system

Fig. 3. Transitional process of the system when $\beta_2 = 0$

regulator coefficient $\beta_2(t)$ which is close to the optimal one and is presented in Fig. 4.

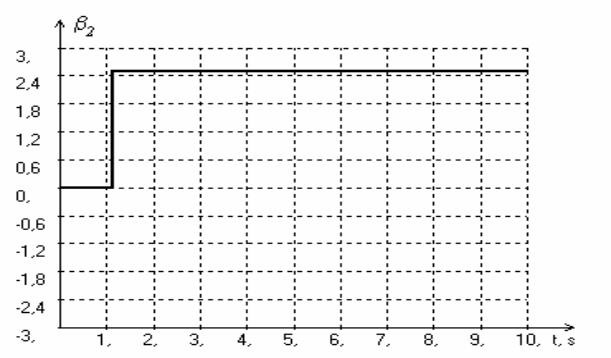

Fig. 4. Variation law of the regulation coefficient β_2 that is close to the optimal one

Transitional processes of the optimised system signal y and its derivatives $\dot{y}$ correspond to it (Fig. 5).

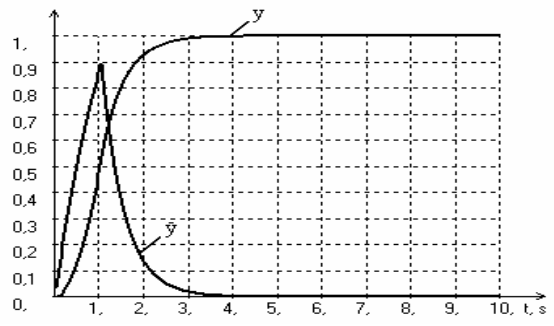

Fig. 5. Transitional processes of the system signals y and $\dot{y}$

Synthesis of control systems of a changeable structure with coordinate limitations

It is quite often that different of state coordinate limitations are found in the automatics and optimal control problems. Such limitations might appear due to the qualities of the object, the working principle, or the coordinate limitations are introduced seeking to achieve certain objectives. For example, the speed of the asynchronous engine is limited because it is slower than the synchronous speed of the engine; seeking to reduce a harmful effect on passengers, limitation on acceleration when gathering momentum or stopping the motor vehicles is introduced.

In formulating a problem of the control system of a changeable system with coordinate limitations, by means of the components x_i, the variation laws of the parameter β_i on which the structure of the system (the regulator, the correction element) depends, must be formed.

Within the control interval $t_0 \le t \le t_f$, where $t_0 = 0$, making use of $i = 1,...,m$ discrete values of the components β_i of the vector $\boldsymbol{\beta}$ (1), $k = mr$-dimensional vector is introduced (2).

On the basis of the components x_i of the vector $\boldsymbol{x}$, functions are created by means of which variation laws of the structure of the system and the parameters are established.

Let us assume that, with the boundary conditions and coordinate limitations given

$$\left|y^{(s)}\right| \le y_m^{(s)}, \qquad (9)$$

variation laws $\beta_i^*(t), i = 1,...,m$ of the parameters β_i exist, which provide the minimum to the functional (4); here s is the number of the limited derivative.

Then the approximate the variation law of the parameters of the vector $\boldsymbol{\beta}^*(t)$ may be found in the process of search optimization.

The problem may be formulated in the form of a search optimization problem. It is necessary to find vector $\mathbf{x}^*$ providing the minimum to the functional

$$J(x) = J\left[y, \boldsymbol{\beta}(\mathbf{x}, t)\right], \quad t_0 \le t \le t_f; \qquad (10)$$

following the limitations:

$$g_j\left[y, \boldsymbol{\beta}(\mathbf{x}, t)\right] \ge 0, \ j = 1,...,q; \qquad (11)$$

$$\left|y^{(s)}\right| \le y_m^{(s)}. \qquad (12)$$

The problem of the control system of a changeable structure with coordinate limitations (10) – (12) is solved according to the scheme presented in Fig. 1 by applying simplex search algorithms [3] and using the software package *Kvazio 1* [6, 8].

We shall present an example of the solution of a problem of the control system of a changeable structure with coordinate limitations using the structural scheme of the control system shown in Fig. 2. In this case we shall limit the derivative of the signal y, that is $|\dot{y}| \le \dot{y}_m = 0,4$.

When solving the problem (10) – (12) according to the scheme shown in Fig. 1, we find the variation law of the regulator coefficient $\beta_2(t)$ that is close to the optimal one (Fig. 6) to which the system of a changeable structure with the coordinate limitation $|\dot{y}| \le 0,4$ corresponds.

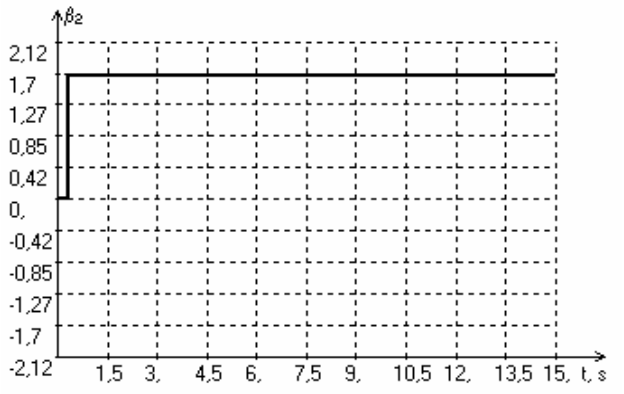

Fig. 6. Variation law of the regulator coefficient $\beta_2(t)$

Transitional processes of the signals y and $\dot{y}$ are shown in Fig. 7.

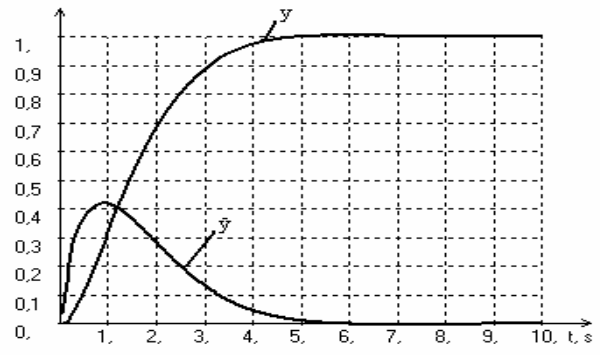

Fig. 7. Transitional processes of the signals y and $\dot{y}$ respectively

Conclusions

Universal algorithmic methods of the control system synthesis created provide the possibility, by applying the form of search optimization problems and algorithms to solve different problems of the systems of a changeable structure synthesis, to find variation laws of the structure and parameters that are close to the optimal ones even in those cases when the mathematical model of the control object is unknown, that is, when classical methods of the systems of a changeable structure and optimal control synthesis are impossible to apply.

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A. Dambrauskas, B. Karaliūnas, D. Šulskis. Algorithmic Synthesis of Control Systems with Changeable Structure // Electronics and Electrical Engineering. – Kaunas: Technologija, 2006. – No. 7(71). – P. 47 – 50.

The problems of control systems of a changeable structure synthesis may be solved by means of arranging phasic portraitures and other classical methods when control objects are simple and have a mathematical model. Classical methods of the changeable structure synthesis have a limited sphere of application. Their application is problematic or impossible when the object is described by a complex differential equation, has a complex non-analytical mathematical model or when a mathematical model is not available at all.

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А. Дамбраускас, Б. Каралюнас, Д. Шульскис. Применение методов синтеза систем управления с переменной структурой // Электроника и электротехника. – Каунас: Технология, 2006. – №. 7(71) . – С. 47 – 50.

Задачи синтеза систем упраления с переменной структурой, когда объект описывается простой математической моделью можно решать используя метод компоновки фазовых портретов и другие классические методы. Классические методы синтеза систем с переменной структурой, имеют ограниченую область применения. Их использование проблематично или невозможно, когда объект описан дифференциальным уравнением высокой степени, имеет сложную, неаналитическим путем заданную математическую модель или математическая модель совсем отсутсвует.

В данной работе рассматриваются алгоритмические методы и программное обеспечение синтеза систем с переменной структурой при ограничениях накладываемых на координаты, который может найти применение в тех случаях, когда объект описывается сложной математической моделью или эта модель неизвестна. Ил. 7, библ. 8 (на английском языке; рефераты на английском, русском и литовском яз.).

A. Dambrauskas, B. Karaliūnas, D. Šulskis. Kintamos struktūros valdymo sistemų algoritminė sintezė // Elektronika ir elektrotechnika. – Kaunas : Technologija, 2006. – Nr. 7(71). – P. 47 – 50.

Kintamos struktūros valdymo sistemų sintezės uždavinius galima spręsti naudojant fazinių portretų komponavimo ir kitus klasikinius metodus, kai valdymo objektai yra paprasti ir turi matematinį modelį. Klasikinių kintamos struktūros sintezės metodų taikymo sritys yra ribotos. Juos taikyti sunku arba neįmanoma, kai objektas aprašytas aukštos eilės diferencialine lygtimi, turi sudėtingą, neanalitiniu būdu sudarytą matematinį modelį ir kai matematinio modelio išvis nėra.

Šio darbo tikslas apžvelgti ir tobulinti kintamos struktūros ir metodiškai artimus įvairių valdymo sistemų algoritminius sintezės metodus, taip pat programinę įrangą, leidžiančią projektuoti kintamos struktūros, kvazioptimalias ir kitas automatinio valdymo sistemas tais atvejais, kai objekto matematinis modelis sudėtingas ar jo išvis nėra ir klasikinių sintezės metodų taikyti neįmanoma. Il. 7, bibl. 8 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

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