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Synthesis stages of a nonlinear non-stationary aerophotographic camera control system

A new approach to the technique is interactive for the leading developer, who at certain stages decides to repeat the iteration or move to the next stage.

Formally, the process of synthesis of a nonlinear non-stationary system can be divided into a sequence of actions (stages), the evaluation of their results is performed by the developer who makes a decision about the necessity of the stage repetition. The criterion for the convergence of iterations is empirical experience, which allows identifying of the unaccounted factors and assessing of the degree of their significance for the problem to be solved.

The technique is interactive for the leading developer, who at certain stages decides to repeat the iteration or move to the next stage. A specialist (person) cannot be excluded from the process of developing nonlinear non-stationary control systems, as the decision to repeat the stages or move to the next stages is made only by a specialist, based on his previous experience. He decides to use methods to bring the iterative process of research to the end result. Below is a step-by-step description of the technique, the block diagram of which is shown in Fig. The proposed technique can be used in the development of different classes of nonlinear non-stationary systems.

1 stage. The following phases are included: the study of a priori information; the search for analogues of the future product, similarly working units, a mathematical description of similar devices; development of requirements specifications of the project; setting goals and objectives of the proposed study; defining of the scope of the study of the constraints imposed in the development of mathematical and simulation models; determination of quality criteria and comparative characteristics of the real device and simulation model. The quality criteria of automatic control systems are determined by the requirements for the stability of the system, the values of errors, the quality of the transient process of the system with typical actions and the requirements for the dynamic accuracy of the system with continuously variable actions.

The first stage corresponds to the block number 1 (Fig.).

Stage 2. On the basis of a priori information and requirements specifications, the necessary experiments in order to obtain comparative parameters of the theoretical research are determined, as well as the methods of conducting them and further processing of the their results are developed (block 20). Experimental research is conducted and the results necessary for further research are obtained (block 21), in particular, at the initial stages of the research (in the first rounds of iterations), the results can be evaluated from the previous empirical experience of the researchers.

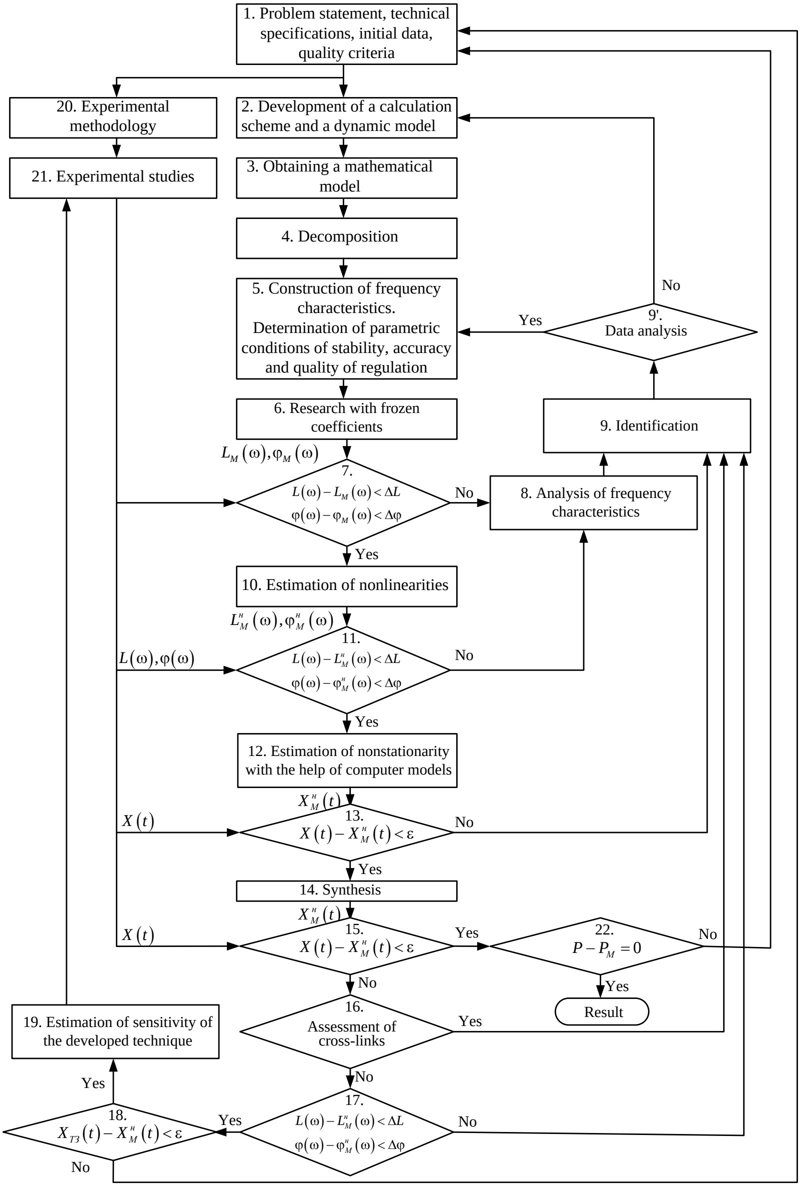

Fig. 1. Block diagram of an interactive iterative technique for the synthesis of a nonlinear non-stationary aerophotographic camera control system

Stage 3: On the basis of a priori information, imposed restrictions, developed quality criteria and comparative parameters, a calculation scheme is developed, and the primary dynamic model is built (block 2). At this stage, the designations are stipulated and the accepted assumptions are made.

Stage 4: Based on the dynamic model and taking into account the accepted notations and assumptions, a mathematical model, which should provide the ability to select mathematical models of individual nodes for decomposition of the model into isolated channels, is built (block 3).

Stage 5: The system devision into separately isolated channels is carried out (block 4).

Stage 6: Determination of the parametric conditions of stability, accuracy and quality of control for each channel is conducted (block 5). Models are built using the method of frozen coefficients to obtain the frequency characteristics of the channels and to estimate the nonlinearities inherent in the channels. Frequency characteristics for different moments of time without taking into account nonlinearities are constructed and comparison with results of the experiments (blocks 6, 7) is made:

$$\begin{aligned} &\left[L(\omega)-L_M(\omega)\right] < \Delta L; \\ &\left[\varphi(\omega)-\varphi_M(\omega)\right] < \Delta\varphi, \end{aligned} \tag{1}$$

where $L(\omega)$ - bode magnitude, obtained during the processing of experimental results for an isolated channel; $L_M(\omega)$ - bode magnitude, obtained as a result of theoretical research for an isolated channel; ΔL - bode magnitude tolerance range; $\varphi(\omega)$ - logarithmic phase frequency response curve, obtained during the processing of experimental results for an isolated channel; $\varphi_M(\omega)$ - logarithmic phase frequency response curve, obtained as a result of theoretical research for an isolated channel; $\Delta\varphi$ - logarithmic phase frequency response curve tolerance range.

Stage 7: After checking the fulfillment of the conditions (1) (block 7), a conclusion is made about the further continuation of the research (if the conditions are fulfilled) or conducting the repeated studies (if at least one condition is not fulfilled).

Stage 8: When deciding to conduct repeated studies, the analysis of frequency characteristics is carried out (block 8), and the values of the parameters for identification with the results of the experiment are reported.

Stage 9: Identification is carried out with the experimental data (block 9), and after analyzing the identification data (block 9 '), a decision is made on:

1) extention of a definition of the parametric conditions of stability, accuracy and quality of regulation. All stages are repeated, starting with the sixth one, or

2) making changes to the calculation scheme and dynamic model. All stages are repeated starting with the third one.

Stage 10: After deciding to continue the research in stage 7, the non-linearities in the isolated channels are evaluated and a decision on which nonlinearities will be included in the model is made. The frequency characteristics, taking into account non-linearities and a comparison with the results of experiments, are constructed (blocks 10, 11):

$$\begin{aligned} &\left[L(\omega)-L_M^н(\omega)\right]<\Delta L; \\ &\left[\varphi(\omega)-\varphi_M^н(\omega)\right]<\Delta\varphi, \end{aligned} \qquad (2)$$

де $L_M^н(\omega)$ - bode magnitude diagram, obtained as a result of theoretical research for an isolated channel; $\varphi_M^н(\omega)$ - logarithmic phase frequency response curve, obtained as a result of theoretical research for an isolated channel; the rest of the symbols correspond to those previously adopted.

Stage 11: After checking the fulfillment of conditions (2) (block 11), it is concluded that the research will be continued (if the conditions are fulfilled) or the research will be repeated (if at least one condition is not met), the stages will be repeated starting from the eighth.

Stage 12: After deciding to continue the research at stage 11, computer simulation models of the isolated channels are built taking into account non-stationary parameters and a comparison with the results of the experiments (blocks 12, 13):

$$\frac{1}{T}\int_0^T\left[X(t)-X_M^н(t)\right]dt \le \varepsilon, \qquad (3)$$

where T - panning cycle; $X_M^н(t)$ - the value of the controlled parameter of the isolated channel depending on time which is received by means of simulation model taking into account non-stationarity; $X(t)$ - the value of the controlled parameter of the isolated channel depending on time which is received as a result of experiment; ε - the permissible deviation of the value of the controlled parameter obtained as a result of simulation from the value of the parameter obtained during the experiment.

Stage 13: Following the results of stage 12, a conclusion about the further continuation of the research (if the condition is fulfilled) or conducting the repeated research (if the condition is not fulfilled) (block 13), repeating the stages starting from the ninth one is made.

Stage 14: After deciding to continue the research at stage 13, the synthesis of the linked system is performed and a computer simulation model of the linked system is built taking into account the non-stationary parameters and a comparison with the experimental results (blocks 14, 15) using the equation (3) taking into account the links.

Stage 15: Following the results of stage 14, a conclusion about the continuation of the research (if the condition is not fulfilled) or about the comparisons of the results with the requirements specifications (if the condition is fulfilled) (block 15) is made. Then we shift to the stage 19 (block 22) .

Stage 16: If the decision is made to continue the research, the impact of cross-links (block 16) on the individual channels is evaluated; if the influence of the links on the controlled parameters is significant, the systems are analyzed by frequency method (block 17) using the equation (2). If the influence of the cross-links is insignificant, then we return to the stage 9.

Stage 17: According to the results of the analysis of systems by the frequency method (block 17) a decision is made (block 18): if the deviation of the frequency characteristics is within the allowable, then return to the stage 9, if the deviation of the frequency characteristics is outside the allowable values, the comparison of the values of parameters with requirements specifications is carried out:

$$\frac{1}{T}\int_0^T \left[X_{TS}(t) - X_M^{н}(t) \right] dt \le \varepsilon, \qquad (4)$$

where $X_{TS}(t)$ - the value of the controlled parameter depending on time which is set in the requirements specifications according to quality criteria; ε - permissible deviation of the value of the controlled parameter which is obtained as a result of modeling from the value of the parameter specified in the requirements specifications.

Stage 18: Following the results of stage 15, a decision is made (block 18) on:

1) reviewing the task (if the condition is not fulfilled) or changing the requirements specifications or reviewing the quality criteria and repeating of all stages from the first one or;

2) the assessment of the sensitivity of the experimental technique (if the condition is fulfilled) (block 19), conducting repeated experiments and repeating of all stages, starting with the sixth, taking into account the new data of the experiments.

Stage 19: If a decision is made to compare the results with the requirements specifications, then conduct a comparative analysis of the simulation results and the requirements specifications, if the simulation results meet the requirements specifications, then a report on the work with coverage of results is made. If the simulation results do not coincide with the task and the requirements specifications, then the clerification of the requirements specification and the task is made, and all stages are repeated, starting with the first one.

The presented technique can be used for the synthesis of simple systems that do not have cross-links, or systems with a deliberately weak effect of the cross-links. To solve simplified problems, stages from 14 to 16 are excluded from the presented methodology, and as a result we shift from the thirteenth stage immediately to the nineteenth when deciding to continue research or when deciding to repeat research we shift to the eighteenth stage, before comparing the results with the requirements specifications, using equation (4).

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