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Multiple Adaptive System of Identification

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This scientific work aims to represent some elements of the theory of identification that are important for both practical use and further theoretical research in order to build logically complete basic and applied theory of identification as mathematically reasonable theory of knowledge of the cause-and-effect relationship in the objects of the real world.

For those specialists who carry out theoretical and experimental researches (technical, economic, biological, social etc) of the real-world objects with the aim of their optimal adaptive control, diagnostics of state, forecasting the consequences and so on.

It will be useful for students, postgraduates and doctoral research scholars who study the real objects.

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МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ ХАРЧОВИХ ТЕХНОЛОГІЙ

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Подано деякі елементи теорії ідентифікації, що є важливими як для практичного застосування, так і для подальших теоретичних досліджень з метою побудови логічно завершеної фундаментальної та прикладної теорії ідентифікації як математично обґрунтованої теорії пізнання причинно-наслідкового зв'язку в об'єктах реального світу.

Для спеціалістів, які здійснюють теоретичні та експериментальні дослідження (технічні, економічні, біологічні, соціальні тощо) об'єктів реального світу з метою їх оптимального адаптивного управління, діагностики стану, прогнозування наслідків тощо.

Може буде корисною для студентів, аспірантів та докторантів, які вивчають реальні об'єкти.

Рекомендовано Вченою радою НУХТ як монографію
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The Introduction

The task of increasing the accuracy of identification of complex dynamic processes, despite the significant development of these issues is still relevant: if the income $\sum^{+}$ (fig. 1) has a finite value even if the model is ideal $\left(\overline{\varepsilon}^2 = 0\right)$, the costs $\left(\sum^{-}\right)$ to obtain this model tends to infinity; so the net profit (Δ) is positive in a limited range of model complexity.

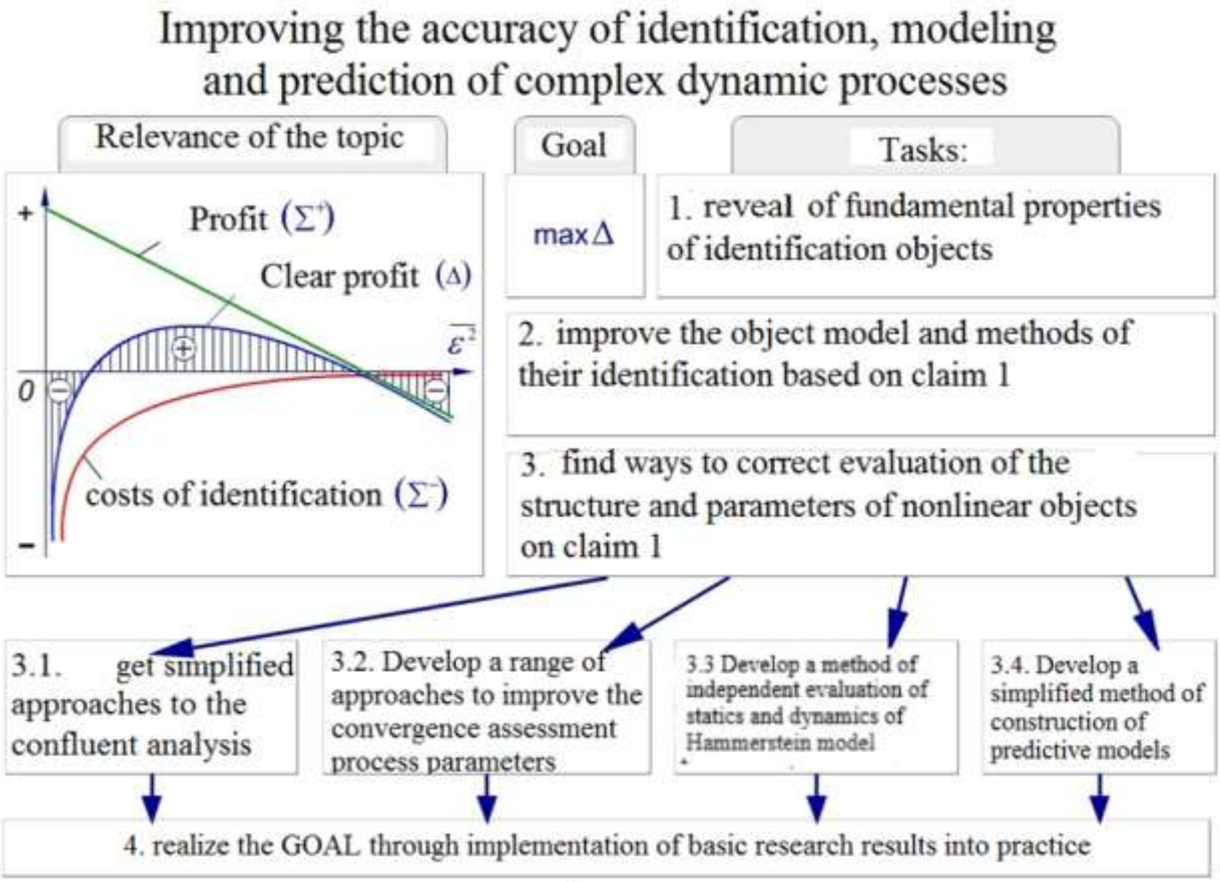

Fig. 1. The models of processes

The task is in maximizing Δ. For this purpose we need to find that fundamental property that is common to all the objects with the help of which you can achieve the goal ($max\Delta$, fig. 1), and on using this property:

1) to improve models and methods of identification;

2) to find methods of correct evaluation of structure and parameters of complex dynamic objects;

3) to get unbiased estimation methods for model parameters in terms of noisiness measurements both output and input;

4) to develop a range of approaches in order to improve the conditioning of the information matrix in terms of active and passive experiment;

5) to develop the method of independent evaluation of nonlinear statics and dynamics of Hammerstein's model in conditions of arbitrary object dynamics;

6) clearly differentiate between task of signal and parametric identification.

The properties of the real world objects are:

– non-autonomy and infinite dimensionality, and as a result there is no state of rest, because all processes are dynamic;

–limited power and natural inertia do not allow immediate change of any coordinate of the object, thus, all processes are **smooth.**

This fundamental property will be the basis of identification:

–there are not two or more identical objects, so averaging on the set gives not precise information about the parameters of a specific object;

–analogously the natural non-stationary of process limits the averaging on time;

–interrelationship and infinite dimensionality of real objects make it impossible to build a model which is isomorphic to object.

Depending on the purpose for which the model is built, infinite dimensional functional space of all state's variables of hypothetical base model (fig. 2) can be divided by the frequency feature in low - $\left(X_{LF}\right)$, middle - $\left(X_{MF}\right)$ and high - $\left(X_{HF}\right)$ frequency. Then there is the only middle frequency component in the partial model (model (1), fig. 2), (X_{LF}) is considered by quasi-stationary state of the vector $\beta(t)$ of the parameter of this model, (X_{HF}) is seen as a noise $N(t)$. We get a finite dimensional model (model (3), (4) fig. 2) for scalar *i*-th component f_i from f and limited dimensions (X_{MF}).

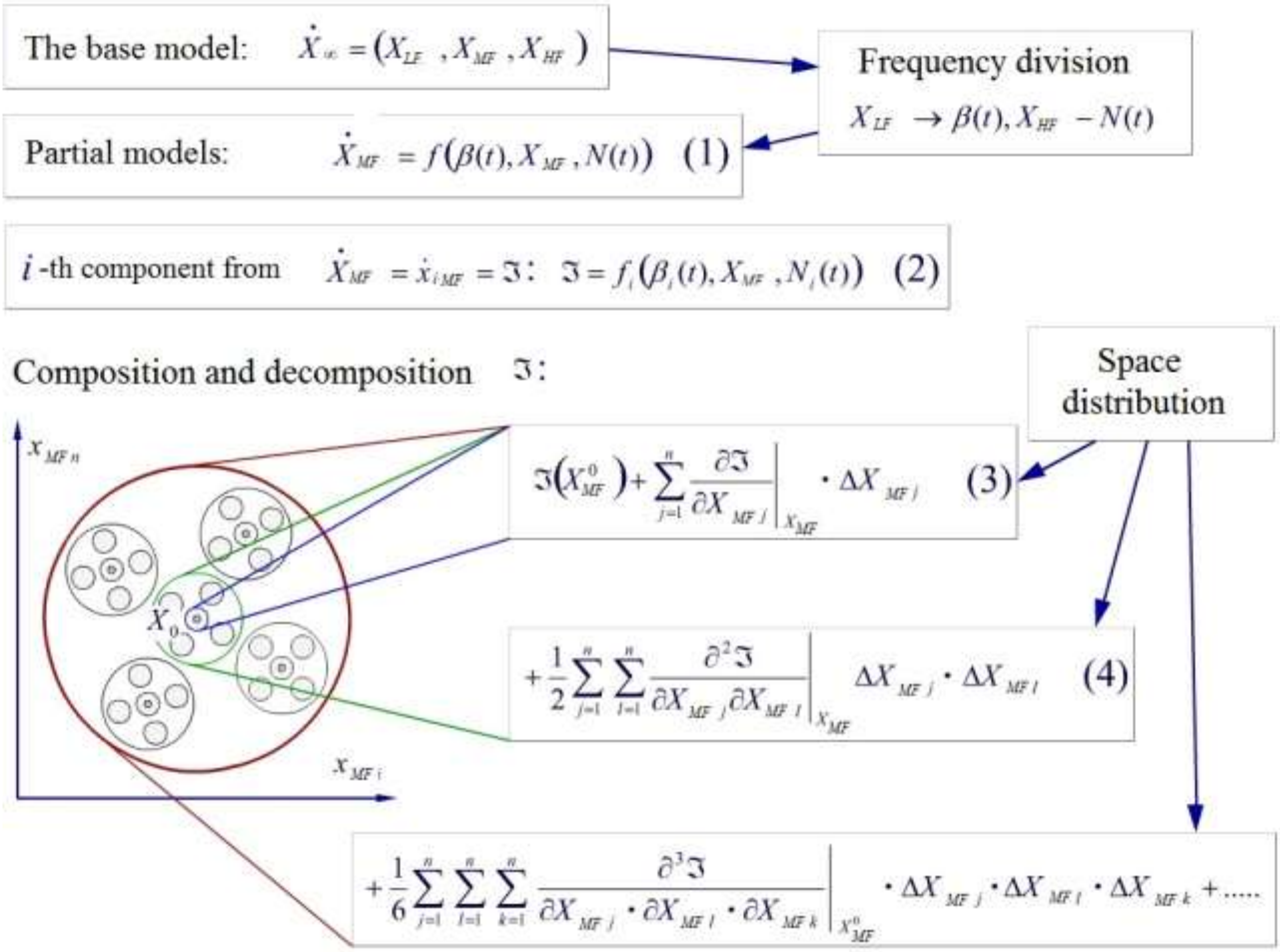

Fig. 2. The hierarchy of models

The system of identification in all is considered as a subsystem of multi-level system, where principles of decomposition, composition and optimization are used. The base model of real processes and its derivative models, modeling and forecasting solutions in the absence or presence of information about the studied process are under examination.

The issue of increasing the accuracy of identification of complex dynamic processes remains relevant. It is therefore important to find a fundamental feature common to all objects with which you can achieve this goal and on its basis to improve models and methods of identification.

The approach to structural-parametric identification of nonlinear multidimensional dependency is considered. It is based on the representation of the series (3), (4), fig. 2 as (14), fig. 3 or (15), where α is (16) for local subregions (fig. 2), it is (17) for combination of local neighboring regions; and enlarging the region further we have the model (18), next – the model (19) etc.

For $A \approx I + \Delta t \cdot A_1$, $B \approx I + \Delta t \cdot B_1$ used the following autoregressive model

AR , ARMA , ARIMA , ARCG , GARCG

Two approaches to correct composition of model

1) for nonorthogonal grid of data instead (4) have

2) for orthogonal

$$J(\beta) - J(\beta_0) = \sum_{i=1}^{n} \left\{ \frac{\partial J}{\partial \beta_i}\bigg|_{\beta_0} + \left\{ \frac{1}{2} \sum_{j=1}^{n} \frac{\partial^2 J}{\partial \beta_i \partial \beta_j}\bigg|_{\beta_0} + \left\{ \frac{1}{6} \sum_{k=1}^{n} \frac{\partial^3 J}{\partial \beta_i \partial \beta_j \partial \beta_k}\bigg|_{\beta_0} + \ldots \right\} \ldots \Delta\beta_k \right\} \Delta\beta_j \right\} \Delta\beta_i \quad (14)$$

or $\Delta y = \alpha(\beta) \cdot \Delta\beta$ (15), where $\Delta y = \Delta J, \quad \alpha \cong \frac{\partial J}{\partial \beta}\Big|_{\beta_{0r}}, \quad \Delta\beta = \beta - \beta_{0r}$ (16)

For local neighboring regions
$$\Delta y = \frac{\partial J}{\partial \beta}\bigg|_{\beta_{0p}} - \frac{\partial J}{\partial \beta}\bigg|_{\beta_{0r}}, \alpha \cong \frac{\partial^2 J}{\partial \beta^{\mathrm{T}} \partial \beta}\bigg|_{\beta_{0r}}, \Delta\beta = \beta_{0p} - \beta_{0r}, \quad p \neq r \quad (17)$$

further, increasing, we have

$$\frac{\partial J}{\partial \beta_j}\bigg|_{\beta_{0p}} \cong \frac{\partial J}{\partial \beta_j}\bigg|_{\beta_{0r}} + \sum_{i=1}^{n} \frac{\partial^2 J}{\partial \beta_i \partial \beta_j}\bigg|_{\beta_{0r}} (\beta_{i0p} - \beta_{i0r}) \quad (18)$$

Further

$$\frac{\partial^2 J}{\partial \beta_i \partial \beta_j}\bigg|_{\beta_{0k}} \cong \frac{\partial^2 J}{\partial \beta_i \partial \beta_j}\bigg|_{\beta_{0r}} + \sum_{k=1}^{n} \frac{\partial^3 J}{\partial \beta_i \partial \beta_j \partial \beta_k}\bigg|_{\beta_{0r}} (\beta_{i0k} - \beta_{i0r}) \quad (19)$$

and so on

Fig. 3. The composition of models.

The method is used for:

1) determination of the structure and parameters of the test dependence $I(\beta)$ (fig. 4, p. 1) with minor error $0{,}05\beta_2$ due to proximity of calculation $\frac{\partial I}{\partial \beta}$;

2) construction of analytical dependence of energy of the first half-wave of the discharge current of capacitor *C* in the *RLC*-circle as a function of merit βQ (fig. 4, p. 2), and determination of its optimal value. The error in determining the optimal merit was 0.05% compared to values found on the basis of numerical simulation;

3) definition of multidimensional nonlinear dependencies based on experimental data, presented in the tables (mechanic and energy objects). Here the model is consistently built as a function of one variable, coefficients of which are approximated as functions of the second variable, if there are three variables, the process continues to the third variable.

As a result of such consistent composition, nonessential components in the model are automatically reset, that is the structural identification is correct. At this the search of canonical structure of intermediate one-dimensional models does not create difficulties. The standard regression analysis with brute force of structures is substantially more complex, especially if vector of variable β has large dimension *n*.

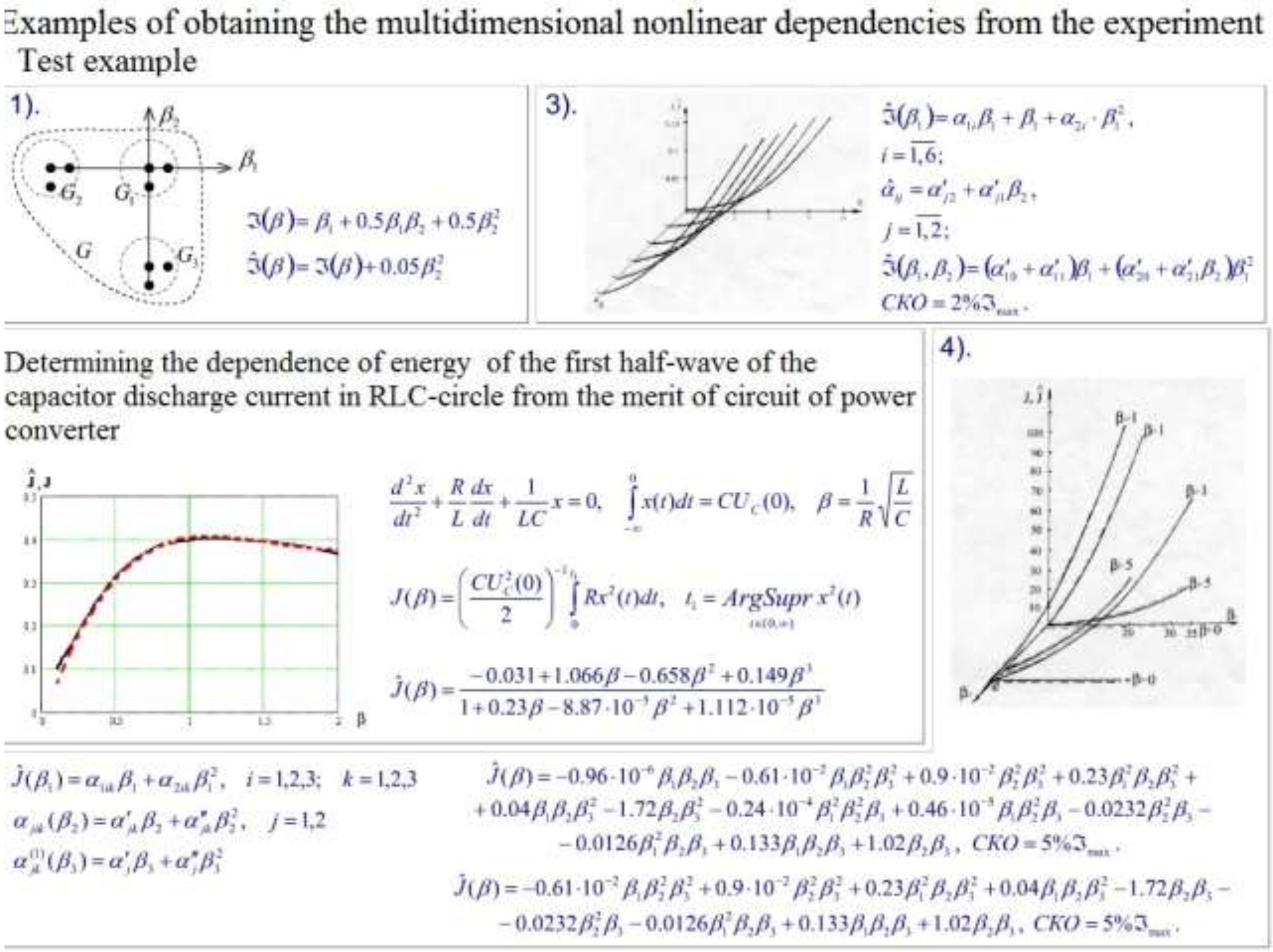

Fig. 4

If the information about the structure of the model is absent, the problem of identification as the problem of approximation has many solutions, but the only one solution will be effective relating to the problem of prediction at a certain time τ.

The test example was considered in fig. 5, p. 1÷4. The unknown dependence is approximated on the interval [0, *T*] by degree polynomials of the Ist, IInd, IIIrd degrees. The higher the degree is, the more accurate approximation is. We can say that the prediction error is proportional to the product of dimension model “*n*” on the interval of the forecast τ: the more “*n*' is', the less τ it needs. The academician A.G. Ivakhnenko proposed to introduce the external criterion to select the structure of forecast model, for example, "regularity" criterion (fig. 5, p. 3).

The perfect I and the “external” criterion are compared in the table (fig. 5, p. 4) for the above test. The criterion of "regularity" was not mistaken in choosing the optimal structure for $\tau = 0{,}2$ and $\tau = 0{,}5$. In order to increase the accuracy of the forecast it is proposed to create a base of canonical models ordered on the set of attributes.

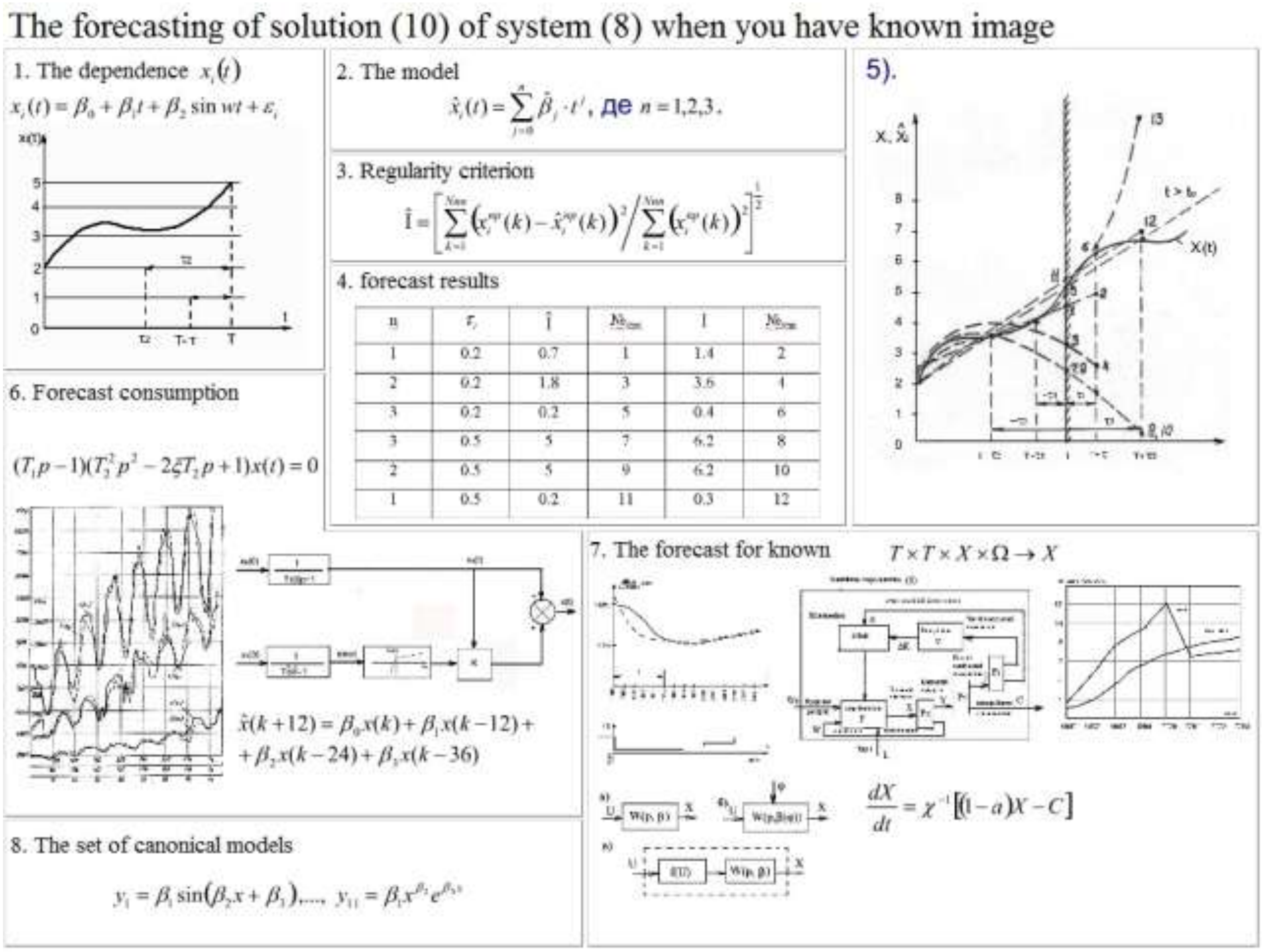

Fig. 5

Then the problem of structural identification will be reduced to a problem of image recognition. The nonius approximation is possible with the choice from the base of models at every step of the appropriate specifying supplement (fig. 5, p. 8).

If we have information regarding the structure of the model (fig. 5, p. 6,7), it should be considered in the forecasting models. Thus, the process of energy consumption is determined by the aperiodic trend with seasonal fluctuations that are superimposed on it. This corresponds to a continuous model (fig. 5, p. 6) and its difference analogue in increments of 1 year. The block diagram can be put into compliance with this process (fig. 5, p. 6).

The nonlinear dynamic models, for example Hammerstein's models, take into account the properties of real objects more accurately. In the case of the parameterization of non-linearity $f(u)$ of the model such approach requires the definition of a large number $(n+m+r)$ of interconnected (through an information matrix) unknown parameters.

In order to separate non-parametric estimation of nonlinearity $f(u)$ and dynamic component, the proposed method aims to use the fundamental property - the *smooth* of processes, which is extended to nonlinearity in real objects.

Using the results of arbitrary dynamics of an object we will find the nonparametric model of nonlinear dependence $f(\upsilon)$ or $f(z)$ provided to a minimum of mean square of $(r+1)$-th- derivative from f to υ or to z, or equivalent to its relevant difference of $(r+1)$-th order in accordance to optimized parameters of linear dynamic component. Further, having a model $\hat{f}(\upsilon)$ or $\hat{f}(z)$ we find coefficients of linear component of Hammerstein's models.

The method is used to determine the nonlinear dependences on the dynamic processes of field test of aircraft, electric drive and tare characteristics of thermistor meters TP 100 of gas temperature in main gas pipelines.

The possibility of improving the efficiency of solving the problem of time series' prediction using the main criterion, the extension of the set of identification methods, the use of the set of canonical models are investigated.

The importance of the optimization of natural experiment for the objective determination of the parameters of a mathematical model of dynamic object is presented.

The necessity of a clear division of tasks of the parametric and signal identification is indicated.

The examples of systems of identification and optimization of technological processes of spinning the quartz tube and training on a computer simulator are given.

The following material is only fragments of the theory of identification; it may be effectively used in practice and for the further development of the theory of identification – the mathematically formalized the theory of knowledge of the real world objects.