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PROBLEM SOLVING BY SIMULATION

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CONTENTS

Control System Robustness: Modelling and Simulation

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ABSTRACT - *The aim of the paper is to present some results of the computer package for MIMO system stability robustness testing.*

1. INTRODUCTION

The ability to keep the system desired performance in the presence of some bounded system disturbances is called *the system robustness*. The majority of publications which have appeared on system robustness have considered *the robustness of stability*. It is interesting to pose the following questions: How is modelling uncertainty to be measured ? What magnitude uncertainty is admissible if system stability is to be preserved?
The answers are given by *the robust stability tests* which generally come down to statement that the system preserves stability if the uncertainty measure of the nominal model is less then the *robustness measure*.

2. MODELLING UNCERTAINTY

For the frequency representation, $G_o(s)$ - a nominal transfer matrix, the unstructured uncertainty has usually the form:

additive case: $$\left\{G_p(s)\right\}_\Delta = \left\{G_o(s) + \Delta(s) \,\middle|\, \bar{\sigma}[\Delta(j\omega)] \le e(\omega) \quad \forall\omega \in \mathbb{R}\right\} \tag{1}$$

multiplicative case: $$\left\{G_p(s)\right\}_\delta = \left\{(\mathbb{I} + \delta(s))G_o(s) \,\middle|\, \bar{\sigma}[\delta(j\omega) \le \delta_o(\omega) \quad \forall\omega \in \mathbb{R}\right\} \tag{2}$$

where $\bar{\sigma}(\cdot)$ denotes the maximum singular value of the matrix.

For the time domain the models with uncertainty are given:

$$\dot{x}(t) = (\mathbb{A} + \mathbb{E})\, x(t) \tag{3}$$

where $\mathbb{A} \in \mathbb{R}^{nxn}$ is nominally stable closed-loop system state matrix and $\mathbb{E} \in \mathbb{R}^{nxn}$ is a perturbation matrix. We can know $\|\mathbb{E}\|$ or maximum perturbation in the elements e_{ij} only. Basing on auxiliary matrices - $\mathbb{U} \in \mathbb{R}^{nxn}$ $[\mathbb{U}_{ij} = \varepsilon_{ij}/\varepsilon, \varepsilon = \max_{ij} \varepsilon_{ij}, \varepsilon_{ij} = \max_t e_{ij}(t)]$ and $\mathbb{P} \in \mathbb{R}^{nxn}$ for solving the Lyapunov matrix equation: $\mathbb{P}\mathbb{A} + A^T\mathbb{P} + 2\mathbb{I} = 0$ some *robustness measures* are formulated and presented at table 1, where $\mathbb{P}_m$ denotes a matrix formed of the absolute value of every entry of $\mathbb{P}$ and $\mathbb{Q}_s$ denotes the symmetric part of $\mathbb{Q}$, i.e. $\mathbb{Q}_s = \frac{1}{2}(\mathbb{Q}+\mathbb{Q}^T)$

3. ROBUSTNESS MEASURES (RM)

The indicators estimating the available extent of modelling uncertainty to maintain the system stability are called robustness measures.

Table 1. Some stability robustness measures and computer results

uncertainty type	robustness measure	tests	computer results: RM values	computer results: ε
(1)	$\mu_a(\omega)=\underline{\sigma}[1+G_o(j\omega)]\ \forall\omega\in\mathbb{R}$	$e(\omega)<\mu_a(w)$		
(2)	$\mu_m(\omega)=\underline{\sigma}[1+G_o^{-1}(j\omega)]\ \forall\omega\in\mathbb{R}$	$\delta_o(\omega)<\mu_m(w)$		
(3)	$\mu_Y = 1/\bar{\sigma}(P_m U)_s$	$\varepsilon < \mu_Y$	0.076	0.238
	$\mu_P = \sum_{c=1}^{k-1} \mu_c;\ E=\varepsilon E^*$	$\varepsilon < \mu_P$	0.284	0.238
$(P_m)_c$ from Lyapunov eq. for $A_c = A+\sum_{i=0}^{c-1}\mu_i E$	* $\mu_c = 1/\bar{\sigma}[(P_m)_c E^*]_s$			

4. SIMULATION RESULTS AND FINAL REMARKS

Computer program package has been used to test the MIMO systems robustness. The results of simulations are grouped in columns 4 and 5 of Table 1. The nominal plant has two inputs and two outputs and all entries of matrix $G_o(s)$ are of the type: $k_{ij}/(sT_{ij}+1)$ where $k_{11}=2$, $T_{11}=6$, $k_{12}=5$, $T_{12}=13$, $k_{21}=4$, $T_{21}=9$, $k_{22}=1$, $T_{22}=5$. The uncertainties are $\Delta k_{11} = 2$, $\Delta T_{11} = 1$, $\Delta k_{12} = 1$, $\Delta T_{12}=1$, $\Delta k_{21}=1$, $\Delta T_{21}=2$, $\Delta k_{22}=0$, $\Delta T_{22}=0$. In the column 4 of the Table 1 the RM computed after transforming frequency model to time domain and closing the unity feedback loop are presented. In the column 5 we have the values of the extent of the example's uncertainty; stability condition is satisfied for the last measure only: $\mu_P>\varepsilon$. The results point out the problem connected with the so-called conservatism of RM. The simulated system is stable in the face of the uncertainties despite the unsatisfactory result of the robustness tests based on μ_Y.

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ON THE SIMULATION OF ASYNCHRONOUS LOGICAL CONTROL

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Modern control systems involve, as their subsystems, sophisticated logic that performs necessary switching functions for the control of discrete-event processes. Such processes, whose major features are event-orientedness, causality, asynchrony and parallelism, are activated and idled by generating the discrete, usually binary, values at control variables, and manifest their operation milestones through the corresponding values of sensor variables.

A wide range of models for logical control includes such as Petri nets, signal-transition diagrams, systems of logical equations. All such models, provided that they are supplied with a given initial state, can generate the behavior of the process control which must meet certain design properties. Since the models, in many applications, may be very complex, there is hardly a way for complete analytical proving of these properties. Therefore, it is necessary to simulate their behavior in terms of the model operation semantics. One of the most important design properties, which has adequate interpretations in the above formalisms, is stability. Our specific characterisation of stability here, which is called persistence, implies the possibility to change each control variable only if the previous value, or change, has been indicated either through the "front-end" actuator variable or through a particular sensor signal. Therefore, in addition to the structural correctness provided by the switching conditions satisfying the initial process control specification, we ensure a form of temporal correctness, which essentially depends on the time parameters, delays, of both the control components and processes controlled.

We present a technique for simulating asynchronous logical control which uses a relation-based temporal framework and suggests a unified simulation/design methodology which allows the designer to vary the time parameters of the control components until a satisfactory solution is achieved. Such solution may often lie between two ultimate timing settings: one, the strong timing conditions, presumes all the components having equal delays, and the other, the weak timing assumptions, appears to be a delay-insensitive logic. We illustrate our approach with a number of instructive examples of digital control simulation.

1. Asynchronous Logical Control Specification

The closed-loop logical control system, as a subclass of discrete-event systems, consists of a controlled process (plant) and a controller. This system has the structure which is described by a set of components $X = \{x_1, x_2, \ldots, x_n\}$. The components are discrete variables, which, in the present domain, are binary variables defined on set $\{0,1\}$. X consists of both the control signals initiating some events in the controlled process and the response signals generated by the process. The operational specification of logical control system may be made using, for example, a Petri net.

Traditionally, Petri nets have been used for simulation purposes mainly in such areas where the behavioral semantics of Petri nets is related to the modeling of material or data flow in a system. The simulation process gives essentially quantitative results (histograms, maximum queue sizes, maximum usage rates etc), and the designer is supposed to derive all necessary qualitative predictions in the form of relations between the simulation results and given requirements, in order to proceed to the optimization stage. An efficient software is commercially available for such applications.

Here, we persue another way of using Petri nets – for specification of control flow semantics, with the possibility to extract, through the simulation process, a more qualitative information, which may be produced by applying some reasoning rules that map quantitative results of runing the model onto some relational framework. The latter can be an effective source for making some qualitative design decisions. For these purposes, we consider so-called signal-transition labeled Petri nets (STPN). Formally, an STPN is a triple (N, DX, L) where N is an ordinary Petri net, $N=(P,T,F,M^\circ)$, with P and T as sets of places and transitions, respectively, $F \subseteq (P \times T) \bigcup (T \times P)$, as a flow relation, and initial marking M°; DX is the set of signal transitions, i.e. $DX = \bigcup_i \{+x_i, -x_i\}$, where $+x_i$ $(-x_i)$ stands for the "0–1" ("1–0") transition of variable x_i; and $L{:}T \to DX$ is a labeling function which associates the transitions of the net with the signal value transitions.

An alternative way of specifying logical control system is using the set of logical equations of the form

$$x_i = f_i(X) = f_i(x_1, x_2, ..., x_n)$$

where variables x_i are associated with the control and response signals. Furthermore, some control signals can be self–dependent, thus meaning the presence of local feedbacks. In order to have a consistent interpretation of self–dependence, each component represented by the corresponding variable x_i is modeled as a combination of a delay–free f_i–function element and an inertial delay (of a finite value) attached to the function element.

2. Relational Semantics and Persistence Property

A straightforward way of modeling the behavior of the control system, with subsequent analysis of properties, is to generate, for a given STPN or a system of logical equations, the state space or the set of execution sequences, a language on set DX, and check some design criteria: for example, proving this language fits in another language, which represents a desirable behaviour of the system.

In many respects this technique may be ineffective for establishing some properties concerned with qualitative logical analysis. A better framework, much more compact, is provided by the partial order semantics of model execution. This relational framework contains information about concurrency between transitions in an explicit form.

An important property of asynchronous logical control is the persistence of control signals. Formally, it means that for any component x in X in every execution there should always be a strict ordering between mutually opposite changes of its value. This guarantees that the event activated in the controlled process, by applying a new value at the control signal x, would remain controllable – the subsequent change of x is performed only after the controller has accepted some acknowledgement of the previous change either (both) through global or (and) local feedback. The lack of persistence may result in a logically non–deterministic behavior of the whole system. It is clear that persistence requires using the relational framework of the system operation.

3. Simulation Process Organization

The simulation process is organized by applying some quantitative, temporal, attributes to the original non–temporal specification. The type of these attributes may range from some fixed timing parameters for all transitions to the set of randomly distributed (within some intervals) time magnitudes, for some transitions expressing the stochastic operation conditions. For a given temporal assignment the simulator runs the event–driven execution of the model and produces a sufficient number of execution sequences. The final extraction of relational semantics, in which all transitions of variables in X are partially ordered, can be done using the following rule. Two transitions, a and b, are in the "independency" relation if there is at least one pair of execution sequences, in one of which a precedes b and in the other b precedes a, or there is at least one sequence where both a and b are executed simultaneously. The simulator may also produce a quantified degree of independence, by using some statistics of precedence relation between pairs of transitions in DX. The relational framework can also be used for establishing other important effects of system operation.

4. Related Work

The execution sequence framework can use both syntax and semantics of descrete–event systems of [1]. The relational framework for checking persistence may be organized on either event structures[2] or causal automata [3]. Similar technique is provided by the timed signal graphs [4]. The idea of persistence in logical control was inspired by the Muller's theory of speed–independent circuits [5].

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FORMATION AND USAGE OF KNOWLEDGE IN SITUATION CONTROL SYSTEMS

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Intelligent control of a complex system in fluctuating selforganizing environment requires significant computational resources for simulation of situations. Situation control algorithms (SCA) based on processing of previously accumulated knowledge of complex system behaviour in a finite set of situations may largely reduce computational efforts.SCA include situation identification using an information - and - measurement subsystem; selection of a current goal from a set of currently attainable ones and respective control action aimed at its attainment. To formalize knowledge representation within situation control systems, a number of definitions and relations is introduced.

Evolution of a complex system and environment is treated as sequential process P in space of states S(V) on set of state variables V initiated by action function F from set of initial situations S^o:

$$P = \langle S, F, S^o \rangle \qquad (1)$$

Development of process P is observed in discrete time t whose qu antum is determined by resolution of the information-and-measurement subsystem. Introduction of time t allows to determine space of states ST(V,t) and evolution equation:

$$V_{n+1} = F(V_n, t_{n+1}) \qquad (2)$$

In set V, we define the following subsets:
X, subset of variables describing the state of complex system ($X \subset V$);
W,subset of variables describing the state of environment ($W \subset V$);
C, subset of variables available for modification in control of complex system ($C \subset X$);
K, subset of variables reflecting determined processes in environment ($K \subset W$).
Equation (2) may be transcribed to include explicit control function $f_c(C)$and function of determined processes in environment $f_d(K)$:

$$\begin{cases} X_{n+1} = F(f_c(C_n), X_n, W_n, t_{n+1}) \\ W_{n+1} = F(f_d(K_n), X_n, W_n, t_{n+1}) \end{cases} \qquad (3)$$

Situation metric T is defined by resource vector R including variables of energetic, information, and intelligent resources from set X, by complex system entropy vector E including variable states and their derivatives which determine the measure of chaotic state of the complex system evolution in the environment, by coordinate vector Y characterizing space and time relations in the sublect area under consideration:

$$T_{s} = \langle R,\ E,\ Y \rangle \qquad (4)$$

In general, knowledge Z on the situation includes, besides situation metric T, set of currently attainable situations SD ($SD \subset ST$) and metric of situation T_G whose attainment is the global goal of situation control:

$$Z = \langle T,\ SD,\ T_G \rangle \qquad (5)$$

Selection f_c for Eq.(3) is implemented by a certain goal function G depending on entropy modification during the transition to new situation $E + \triangle E$, deviation $\triangle N$ from ideal trajectory of movement to situation T_G and correlation FC (W) weighing situation from SD depending on variable values W:

$$f_c = G(\triangle E, \triangle N,\ FC(W),\ Z) \qquad (6)$$

Equations (5) and (6) are a basis for formation of algorithms and knowledge base for intelligent control of a complex system. Knowledge base is completed with the data obtained as a result of goal-oriented model experiments. The mathematical model is aimed at distributed calculations and includes an array of state variables of complex system D, experiment control programmes L, and component modelling programmes A:

$$M = \langle D,\ A,\ L \rangle \qquad (7)$$

Combination of the distributed or concentrated implementation of each element M defines 8 different organizations of the modelling process using a distributed computer system. With any organization of distributed calculations, synhcronization is achieved on the event-to-event basis (asynchronically). Due to this approach, the maximum parallelism is obtained, observing the desired real-time scale.

COGNIZANT ADAPTIVE SIMULATION SYSTEM FOR APPLICATIONS IN NUMEROUS DIFFERENT RELEVANT AREAS*

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TO WHOMSOEVER IT MAY CONCERN!

"Cassandra, in Greek mythology, the daughter of Priam, the last king of Troy, and his wife Hecuba. Cassandra was loved by the god Apollo, who promised to bestow on her the power of prophecy if she would comply with his desires. Cassandra accepted the proposal, received the gift, and then refused her favours. Apollo revenged himself by ordaining that her prophecies should never be believed."

The New Encyclopædia Britannica
Micropædia Ready Reference Vol. 2.
Encyclopædia Britannica, Inc.
Chicago, 1988, p. 924

CASSANDRA, presented here, is a *demon controlled simulation system* that is able to predict events in various fields of life (natural sciences, technology, economy, etc.) using AI controlled modeling. Based on the results supplied, useful knowledge about complex systems might be gained and the outcome of many situations can be improved.

* This work is partly sponsored by the National Committee for Technical Development.

C ognizant
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is a novel approach to modeling and simulation, a breakthrough in providing really customized tools specialized for users' requirements in a wide range of applications.

CASSANDRA enhances the effectivity of simulation by automating the control of simulation experiments using *demons* (utilizing knowledge base and inference engine, i.e. methods of artificial intelligence) [1][2][3].

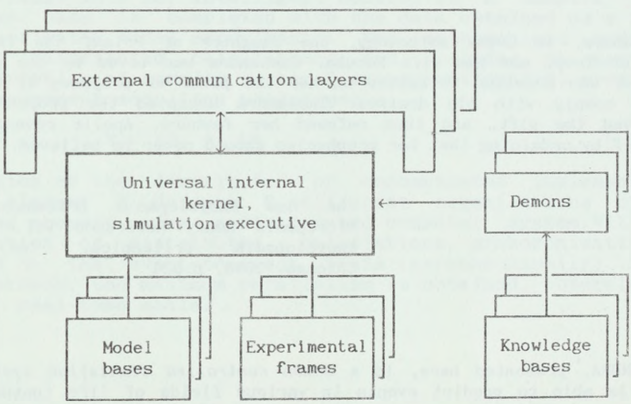

Figure 1 Structure of the CASSANDRA simulation system

SOME OF THE MOST IMPORTANT FEATURES OF THE CASSANDRA SYSTEM

* A *universal kernel* is provided based on which *problem oriented simulators specially customized* for special requirements and man-machine communication style of the given application fields can be supplied within a short time and at reasonable cost.
  (This overcomes the not-user-oriented approach of general purpose tools as well as high costs and long development time of specialized systems.)

* *Automated control of modeling.* The entire recursive process of the simulation experiment is controlled by methods of *artificial intelligence. Demons* using knowledge bases and inference engines evaluate the results of dynamic simulation continuously and modify the
  - experimental conditions
  - model structure
  - model parameters

  as required to achieve the goals intended.

* Non-procedural models revealing the topological structure of the model described as a network of model elements (and not in the form of the conventional procedural program description). This means that the model is not represented as a single sequence of instructions, but rather as such a structure in which parallel interacting procedures occur the handling of which in simulated time the simulator automatically takes care of. In this way a model directly conforming to the real modelled system is obtained, revealing the original one in a natural way.

* Separate model building and dynamic simulation phases ensure the investigations of the same model under different conditions as well as investigating different models under the same conditions.

* Handling of both *level type* events that can be described by variables and *entity type* events that can be described by the location of mobile elements within the model structure. In other words, in a real system the events can be classified into these two subclasses. The output level of a logic circuit or the traffic light can be regarded, for example, as *level type,* while the location of a lorry in a transport system or a message in a computer network can be regarded as an *entity type* event.

* Possibility for implementing arbitrary discrete model elements (open system structure).

* Monitoring the process of dynamic simulation with *demons* using *knowledge bases* and *inference engines* to automate the simulation experiment by:
  a) modifying the experimental conditions,
  b) modifying the model structure (topology),
  c) modifying the model parameters.

  This means that demons are inserted in the model and these demons investigate its dynamic behaviour continuously and, in case of the fulfilment of prescribed conditions, modify the model and/or the experimental conditions.

* Interactive/menu type input.

* Postprocessing, data collecting, graphic output procedures.

* Model base, experimental frame, knowledge base libraries.

POSSIBLE FIELDS OF APPLICATION

- Investigation and designing of FMS's (Flexible Manufacturing Systems)
- Logistics
- Strategy of controlling transport systems (road, rail, air) of both cargo and passengers
- Optimizing urban traffic systems
- Investigating information processing systems (multiprocessor computer structures)
- Computer networks, protocols
- Economic problems at enterprise or national level
- Management on various levels
- Social problems
- Ecology
- Biology, medical problems

etc.

CONCLUDING REMARKS

The CASSANDRA system the first experimental version of which is presented and demonstrated on this conference is an open system and in further development.

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THE SIMULATION RESEARCHES OF PARAMETRIC FILTERS OF CONSTANT COMPONENT

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There is necessity of average value determination in real time for different measured signals in many industrial,measurement and other processes.The average value of stationary and ergodic stochastic process can be calculated as averaged in time one optional realization x(t) of the process.Assuming that x(t) is the sum of constant component $\bar{x}$ and variable component $\tilde{x}(t)$, it can be proved that when $t \to \infty$ the value of component $\bar{x}$ equals to average value of that realization,and (basing on ergotic theorem) equals to expected value of the process.Ideal result makes the time of calculation $t \to \infty$, when certain filtration error is assumed (for instance 5 per-cent) the result can be obtained quite quickly.The boundary values of spectral-reponse characteristic of filter which pass-band is reduced to $\omega = 0$ (filter of constant component) were assumed.The stop-band was limited by frequency Ω, such that $|K(j\Omega)| = \alpha = 0{,}05$ [1].

The spectral assumptions allowed the searching of optimal structure of filter.The assumed quality coefficient was the product of transient state time and functional,which described spectral characteristic of module.It can be written as:

$$k = t_w \cdot \sqrt{\int_0^{\infty} |K(j\omega)|^2 \, d\omega} \qquad \ldots(1)$$

The results have been refered to period of boundary frequency Ω. It made the comparison of different filter structures possible. Basing on well-known filters with constant parameters it was decided,that better filter quality would be searched by making their parameters variable (in time). Introductory calculations and estimations were made for I-st order system with assumed functions of parameter variability.The functions were chosen according to simplicity of their technical realization.For obtaining the filter with minimum value of quality coefficient k the simulation researches on model described by equations

$$[\omega_0(t)]^{-2} y''(t) + 2\beta(t)[\omega_0(t)]^{-1} y'(t) + y(t) = x(t) \qquad \ldots(2)$$

$$\omega_0(t) = \mathcal{L}^{-1}\left\{\frac{1}{s}\left[1 - \frac{k_1}{\frac{s^2}{\omega_{0_1}^2} + \frac{2\beta_1 s}{\omega_{0_1}} + 1}\right]\right\} \qquad \ldots(3)$$

$$\beta(t) = \mathcal{L}^{-1}\left\{\frac{\beta_p}{s}\left[1 + \frac{k_2}{\frac{s^2}{\omega_{o_2}^2} + \frac{2\beta_2 s}{\omega_{o_2}} + 1}\right]\right\} \qquad \ldots(4)$$

were undertaken.
Optimization was done for assumed space of variable parameters ω_{o_1}, β_1, k_1, ω_{o_2}, β_2, k_2. During researches the "apparent paradox" was observed : shortening of transient state time was obtained together with decreasing value of frequency Ω to Ω_k. Quotient $n = \Omega/\Omega_k$ can be determined as multiplication of "filtration reserve" of spectral-response characteristic of constant component filter module. The minimum value of quality coefficient k obtained for given filter was compared to the best filters with constant parameters (according to criterion given above) and to filter of II-nd order with variable parameters [1]. It is shown on the figure 1.

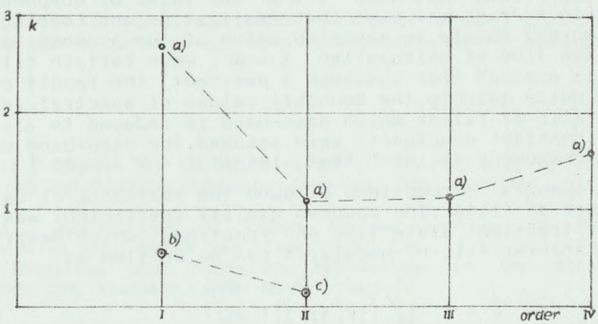

Figure 1. Value of quality coefficient k :
a) for constant parameters filters
b) for parametric filter of I-st order
c) for investigated parametric filter of II-nd order.

It is easy to observe that a big improvement of filtration quality of constant component was achieved. It was possible thanks to simulation researches.

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THE SIMULATION RESEARCHES OF PROTOTYPE CONTROL SYSTEM FOR TRACK BREAKSTONE CLEANING MACHINE

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The operation of track machine for breakstone cleaning can be described as follows.During slow continuous running (speed about 0,2 m/s) the 20 meters long section of rails with sleepers, limited by machine fore and back wheels, is lifted up and the process of track breakstone scooping takes place.The next is operation of mechanical cleaning of breakstone. Clean breakstone is dumped on the ground and levelled out by means of levelling beam. Afterwards rails together with sleepers are laid on the levelled breakstone foundation. The back wheels press down the rails into "new" breakstone foundation and in that way the operation is finished.

The measuring and control system of cleaning machine should guarantee high final accuracy of rails laying out.It means, that difference between track formation lines before and after breakstone cleaning should not be greater than ± 2 per milles.The track superelevation after cleaning operation should not be changed more than 0,02 radians. During the cleaning process part of crumbled breakstone is thrown away.The loss of breakstone is not controlled and that is why it has to be treated as random and most significant cause of disturbances. The deflections of frame of machine caused by weight of rails and vibrations of frame are additional disturbances acting on measuring and control system.

The idea of measuring and control system for described track machine has been presented in [1]. It results from [1], that required positions of final control units are given by:

$$K_{Lo} = G_o - 0,5\, d_k\, W_R - Q\,(N_R - N_P) \qquad (1)$$

$$K_{Po} = G_o + 0,5\, d_k\, W_R - Q\,(N_R - N_P) \qquad (2)$$

$$B_{Lo} = G_o - T_o - 0,5\, d_B\,(W_P/T_o/ - W_R) - Q\,(N_R - N_P) \qquad (3)$$

$$B_{Po} = G_o - T_o + 0,5\, d_B\,(W_P/T_o/ - W_R) - Q\,(N_R - N_P) \qquad (4)$$

where K_{Lo} - position of left trough for breakstone scooping, K_{Po} - position of right trough for breakstone scooping, B_{Lo}-position of left end of levelling beam, B_{Po} -position of right end of levelling beam, G_o - mean thickness of breakstone layer taken up by scooping troughs, T_o - required mean thickness of clean breakstone layer, d_B - span of levelling beam, d_k - span between left and right trough, Q - distance between fore wheels of machine and the levelling beam (about 15 meters), N_P - track formation line angle before breakstone cleaning, N_R- formation line angle of chosen part of frame of machine, W_R- superelevation of part of frame over the place where levelling beam is fastened, $W_P/T_o/$ - delayed superelevation of track before cleaning operation (T_o = Q/v , where v is machine speed).

Positions given by Eqs. (1) - (4) are set values for the four independent position control servo-systems. Every servo-system contains hydraulic servo-motor operated by electromagnetic valves. Basing on experimental and catalogue data the simplified models of servo-motors have been worked out. The obtained models for levelling beam servo-motor and trough servo-motor have the form of strongly non-linear system of differential equations of second order.

So called "trajectory of drive" and "trajectory of breaking" have been found by means of simulation of both servo-motor models. The equation of servo-system time-optimal or time-suboptimal feedback controller can be easy determined if "drive" and "breaking" trajectories of controlled plant are known.

The verification of efectiveness of algorithms for suboptimal controllers in "nearly real" conditions of cleaning machine opera-tion has been the second task of simulation researches. In order to prove the usefulness of obtained suboptimal control algorithms the models of servo-system for both types of servo-motor have been investigated. Set values of servo-systems have been "generated" in accordance with Eqs. (1) - (4), where $W_R(t)$, $W_P(t)$,$N_R(t)$, $N_P(t)$ have been replaced by suitable recordings of signals made during real run of earlier type of machine for breakstone cle-aning.

The simulation researches have been done by means of program Symul (designer Progel, Szczecin) for IBM PC/AT (MS/DOS 3.10). Some results of simulation researches have been used by ZNTK Works during the designs of prototype of Ot -800 track machine for breakstone cleaning.

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APPLICATION OF SIMULATION IN THE RESEARCH OF THE PROPULSION SYSTEM OF NAVY SHIP

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ABSTRACT
Following the example of the propulsion system of a certain navy ship,this paper discusses the necessity of studying the system Combined Diesel or Gas Turbine propulsion plants (CODOG) and Controllable-Pitch Propeller(CPP) using the simulation technology, as well as the studying method, contents,the problems sloved and results.

INTRODUCTION

The system of CODOG and CPP is an effective propulsion mode used by middle-sized naval ships,with many conspicuous virtues in reliability,economy and manoeuvrability. But the system needs a high automatic control system so as to meet the demands of control number, speed and accuracy over all cases of manoeuvres while maintaining the machinery load within the acceptable limits , and also give a good steady and transient state performance. As we are short of ready-made design and operation experiences for the steady state cooperation and transient response of the system, digital simulation technology becomes a necessary and fundamental means to study such propulsion system.

STUDY TARGET AND SIMULATION METHODS

The study target of this paper is a naval ship with two shafts. Each CPP is drived by one gas turbine or one diesel engine via the combining gearbox and self-synchromesh clutch in either shaft.By mans of the theoretical study and analysis of the results of model test,the simulation models of the system are established as follows:

1.Motion Model of Ship Body

Referred to M.M.G. model for single shaft and single rudder,we establish the motion model of ship body through theoretical analysis and experiment modification , which includes three freedom motion of advance, side slip and turning.The model is showed to be believable for the naval ship with two shafts and two rudders.

2.Model of Drive Train System and CPP

The model of this sub-system mainly expresses the relation between torque and speed. And it includes the variations to system simulation structure due to the engagement and disengagement of self-synchromesh clutch.The model of hydraulic control system of CPP is established according to analysing its structure and principle, but the hydraulic model of CPP is set up in the light of model test.

3.Model of Engines

As the internal working processes of engines is very complicated,the model of engines which consist of two diesel engines and two gas turbines and their control system,is established using quasi-steady state method by means of the " Grey Box " theory . It simplifies the work of simulation and ensures the calculating accuracy in large change of working conditions.

4.Model of the Propulsion Control System

In order to obtain a good steady state and transient cooperation for the propulsion system,the propulsion control system is emphatically studied by simulation.Firstly,we supposed a model on the basis of the similar propulsion system,then we defined all of the parameters which are suitable for this propulsion control system by means of computer simulation and result analysis.

With the exception of this,the interactions of CPP and body and its effects are considerated in the simulation.

SIMULATION METHOD AND PROGRAM

As the motion inertia of ship body in this system is far larger than the turning movement inertia of its shafting,this system is a stiff system.Therefore , the STIFF integration method and Runge-Kutta method with small step are used . The calculating module and logical decision module of the general simulation program cann't satisfy the needs of simulation of this system.On the basis of ZFX program,we have extended and modified its functions and gained a complete program which is suitable to simulation of CODOG system of naval ship.It is written with standard FORTRAN , faces the simulation structure and runs in COMPAQ 386 microcomputer.And it can determine automatically the initial values of parameters.In process of simulation,the variation of ten parameters can be tracked and monitored.At the end of simulation,the results can be saved in the hard disk,or be drawed on the screen or paper according to our needs.

APPLICATION OF SIMULATION

1.Steady State Analysis of the Propulsion System

According to the steady state simulation,we have obtained the relations among shaft speed,ship speed , fuel rack position of gas turbine and diesel engine,and pitch of CPP.On the basis of this,we have infered the relations of pitch of CPP, PLA of gas turbine and shaft speed along with the power demands , and the ambient temperature compensation,the pitch window schedule , the load control schedule of diesel engine and the load control line.

2.Transient Analysis of the Propulsion System

By means of simulation of the dynamic performance ,we have anlysed and determined the optimal fast idle power of gas turbine,maximum astern PLA, pitch anticipation, maximum astern pitch ,integral power trim,limit on speed error ,limit on output,low shaft speed controller datum gain and the variations to demands of PLA, pitch,diesel engine speed along with PCL.The control settings are showed to give satisfactory dynamic performance while maintaining the load within safe limits.According to the settings,the transient performance of propulsion system over a range of conditions and manoeuvres is checked and predicted.The results of study provide complete steady state and transient informations for the engineers who design the system.

3.Analysis of Engine Changeover

The dynamic responses of changeover from one engine to another are simulated many times on the condition of different control settings and rates.By means of analysing results,we find the reasonable and safe changeover schedules and control settings.

4.Analysis of Ambient Temperature Effect and Load limiting Cases

The transient responses of the system are examined on the supposition of various ambient temperature and critical working conditions.The results provide the transient performance under critical conditions for the designer and the operator,and give some recommendations how to avoid the crises and methods how to deal with the crises after happened.

SUMMARY

By means of simulation,we provide the detailed steady state and transient performance and the recomendated control schedules and control settings of the CODOG propulsion system for the designers.In other word,we have carried out a lot of"real" experiments in the computer without any money and dangers.Furthermore,the simulation results will play an important role in the sea trial of naval ship . Therefore , the simulation technology is an important and essential tool in the design of modern naval ship.

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TURBOSET CONTROLLER SETTING SENSITIVITIES

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Control system optimization is usually based upon simulation. In many cases the optimal controller design is based on constant values of the system parameters. In practice, operating conditions cause that several parameters deviate from their nominal values and the results of the optimization may not be practicable. Hence it is important to keep the optimal controller settings insensitive to variations of the controlled plant parameters or to know how to change them during system operation.

The growth of electric power systems causes that optimal operation of the turboset control systems becomes more and more important to maintain satisfactory turboset performance under all operating conditions. The new sensitivity factor, the optimal controller setting sensitivity has been used in evaluation of the optimization results. It was earlier defined by the author [1]. It indicates whether any changes of controller settings are needed after system parameters deviation from their nominal values, in order to preserve the optimal performance of the control system.

If we consider the basic control system which consists of a plant and a controller and which is assumed to be optimal, the controller setting sensitivity is defined as follows:

$$S_{ij} = \left.\frac{\partial \beta_i}{\partial \alpha_j}\right|_{\alpha_0} \qquad \begin{array}{l} i=1,2, \dots m \\ j=1,2, \dots n \end{array}$$

where $\alpha_1, \alpha_2, \dots \alpha_n$ denote the plant parameters and $\beta_1, \beta_2, \dots \beta_m$ the controller settings. The subscript α_0 indicates that this partial derivative is taken at the nominal parameter values.

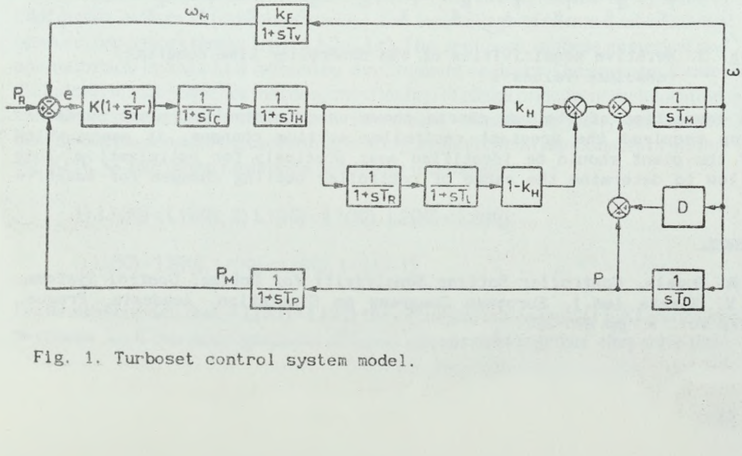

Fig. 1. Turboset control system model.

A turboset control system was considered. It consisted of a steam-flow controller, steam turbine and a synchronous generator connected to a large electric power system. The block diagram of the analyzed control system is given in Fig. 1.

The turboset controller setting sensitivities with respect to all turbine and generator parameters have been computed. The results are shown in the form of bar charts in Fig. 2 and 3.

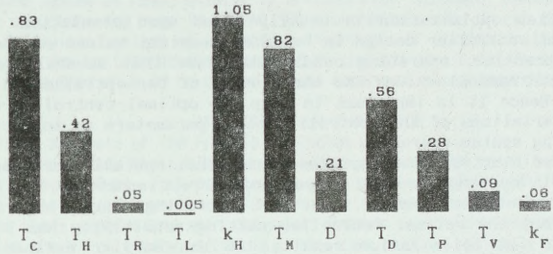

Fig. 2. Relative sensitivities of the controller gain (absolute values).

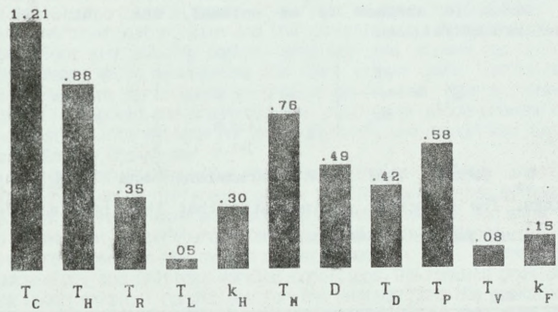

Fig. 3. Relative sensitivities of the controller time constant (absolute values).

An inspection of the bar charts shows which controlled plant parameter deviation required the greatest controller setting changes, it means which part of the plant should be identified most precisely for optimization. They also allow to determine the range of controller setting changes for adaptive control.

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Structural analysis and optimization of electronic system.

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Modern analog electronic systems for signal transduction are based an integrated circuits. These circuits are characterized by large rejection of parameters in different crystals.High level of their stability and to lekable characteristics deviation during the lot production is usualy produced by means of structural methods, e.g. by means of feedback and parameter compensation. The article deals with method of analysis and optimization of the system structures. These system structures are discribed by means of lenear and quasilinear equations represented as transfer function **P(s)=P(s)+M(s)**, where P(s) and M(s) - are **Laplasian S** polynomials with coefficients calculated as the result of solution of approximation probleme [1].

For exemple, many variants of the probleme structure **K=(K1,K2,..Kl)** are to be synthesized according to the algorithms [1] during its design period. Each variant **Ki** has its own transfer function Ki(s)=B(s)/A(s).The function polynomial coefficients are described by means of expressions containing the system elements parameters.Polynomials themselves also have the same form, as polynomials **P(s)** and **M(s)**.During the parameter synthesis the parameter elements are to be formulated so that equation P(s)=B(s), M(s)=A(s) produced the minimum error. The parameter elements synthesis process is in fact long labour-consuming one if the execution of these equations may be achieved only the equation above and taking into account these exploitation condisions and technology requirements, also the price and reliability are to be considered.

· That is why it is suitable to choose such subset **Kr <K** circuits that will meet all the limits mentioned above before the parameter synthesis. These limits are to have the suitable form for their using during such period of the process, when it is impossible to obtain the system numerical characteristics (exept the few limit evaluation) but it is possible to compare relatively the circuits **Ki** and **Kj** by some of their quality indexes Lt (criteria of quality). The assemblage of system quality indexes produce the vector criteria L=(L1,L2,...,Lr). The sequence of these numerical and non-numerical indexes Lt is defined by development engineer.The engineer locates the indexes in such sequence that determinates first of all the principe of their location, then the implementation method and its variants considering the system specific qualities.Let us consider that according to lexographical circuit relationship of prefering $Ki \overset{lex}{>} Kj$ one of the r following conditions is fulfieled

1) L1(Ki)<L1(Kj); 2) L1(Ki)=L1(Kj), L2(Ki)<L2(Kj); ...

r) Lt(Ki)=Lt(Kj), Lr(Ki)<Lr(Kj), t=(1,r-1).

Let us also consider, that, if L(Ki)=L(Kj) the circuit are equivalent $Ki \overset{lex}{>} Kj$ according to criteria **L**. If two lexicographical different circuits exist together they selve the lexicographical problem of optimization

$$\underset{Kr \in K}{\text{lex min}}\ L(Kr) \qquad (1)$$

Let us show for exemple the discription of quality criteria, which is connected whith parameters reliability. The probability of the system reliable werk has its maximum, when the expressian

$$Lt(x) = \sum_{i=1}^{u} (S_{xi}^{F})^2 + \sum_{i=1}^{u} (S_{xi\cdot xi}^{F})^2 + \sum_{i,j=1}^{u} (S_{xi\cdot xj}^{F})^2,$$

- where F -system characteristic and xi,j -parameters of its elements i,j and

$$S_{xi}^{F} = xi\cdot dF/(F\cdot dxi); \qquad S_{xi\cdot xj}^{F} = xi\cdot xj\cdot d^2F/(F\cdot dxi\cdot dxj) -$$

relative sensivities of the first and the second powerhas, its minimum.

Its is impossible to calculate Lt(x) directly,becouse x parameters are yet unknown. So let us consider anothe criteria $Lt(x) \overset{lex}{\approx} Lt(x)$ based on the well known connection betwen the system stability reserve of element xi and relative sensivity-the stability reserve increases, while the sensivity decreases (when the stability reserve is infinitely large the sensivity has its limit meanings 0 or ±1 in dependce of the system configurations).

Consequently, for comparing the circuits Ki and Kj by their sensivities it is possible to compare their stability reseves formulated by means of Hurwitz stability criteria. For exemple, Hurwitz determinant for system $A(s)=A4\cdot s^4+A3\cdot s^3+...+A0$ performs

$$Dh = A1 \cdot A2 \cdot A3 - A0 \cdot A3^2 - A4 \cdot A1^2$$

Using feedback in the system causes increasing or decreasing of one/few coefficients Ai.

Evidently two systems Ki and Kj although the have only one difference-feedback in Kj increases only A4 and feedback in Ki increases only A2 - have qreat difference in their stability reserve, e.g. $Ki \overset{lex}{>} Kj$.

So for comparing the systems by Li one can only determinate what direction and coefficients A(s) would change different feedbacks. Thus it is possible sometimes even not to produce the system feell analysis.

Systems analysis algorithms contain algebraic symbols operations, differentiation operations, algorithm of system graph analysis, database Dh for solution of problem (1). Algorithms of toplogical structure synthesis [1] allow to create the circuits data bank synthesized by designing system. Toplogy circuit, all quality criterinon defined by designing system are stored in the bank. This allows to make the synthesis process more easy after system have accumulated sektain expirience.

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THE ALLOCATION AND DEVELOPMENT PROBLEMS OF LARGE SCALE COMMUNICATION SYSTEMS

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INTRODUCTION. A comprehensive design of large scale systems requires solving optimal allocation problems of their subsystems and communications. A heavy investments to transportation and communication systems require the use of more adequate mathematical models and more precise algorithms to solve the problems.

Authors are engaged in more exactly defining of mathematical models of transportation systems and working out of effective algorithms and computer codes for their analysis and synthesis.

A class of a mathematical region models has been augmented. Choice recomendations of region model for solving of transportation communication design problems have been advanced.

The following methods have been worked out: 1) structure synthesis of a set of interaction systems, 2) tree network optimal allocation, 3) optimal allocation of mutually connected extended objects, 4) transportation communication design under uncertainty.

STRUCTURE SYNTHESYS OF SET OF INTERACTION SYSTEMS is the problem which can be represented as

$$F(x) \to \min , x \in X,$$

where X is a finite set, and it is possible to introduce monotonically coordinated particular criteria

$$U_i(x) \to \min, i \in [1,m].$$

Particular criteria are monotonically coordinated if in the case $x',x'' \in X$, $U_i(x') \leqslant U_i(x'')$ $\forall i \in [1,m]$ we have $F(x') \leqslant F(x'')$.

A Class D is NP-hard problems for wich are monotonically coordinated particular criteria and particular problems

$$U_i(x) \to \min, x \in X \quad \forall i \in [1,m]$$

belong to a class P. Algorithm which makes possible giving approximate (with lower and upper estimations) solution assumed the D problem is described in [1].

TREE NETWORK OPTIMAL ALLOCATION is an extremal problem

$$f(\phi)= \sum_{j \in J} c(j, \phi(j)) + \sum_{[i,j] \in E} \{b([i,j],\phi(i),\phi(j)) +$$

$$+ b([i,j],\phi(i),\phi(j))\} \to \min, \quad \phi: J \to V,$$

where tree $G=(J,E)$, a finite set V, mappings $b:E \times V^2 \to R$ and $c:J \times V \to R$ are given [2]. The algorithm of this problem is proposed.

Suppose that $n=\mathrm{card}(J)$, j_n is a root of graph the G, the set $J=\{j_i\}$, $i=1,2,\ldots n$, is numbered by a back round order of the graph G, a graph $G(K)$ is a subgraph of the graph G on node set $K \subset J$, $\phi(*)|X$ is a restriction on X map ϕ, $F(j_l)=j_k$: $([j_l,j_k] \in E$, $l<k)$. The algorithm is based on construction of a problem sequence $\{\theta_i(G_i,V,b,c_i)\}$, $i=1,2,\ldots n$, in which $G_1=G$, $c_1=c$, and problems θ_{i+1}, $i=1,2,\ldots,n-1$ are derived in the following way:

$$G_{i+1} = (J_{i+1}, E_{i+1}) = G_i(J_{i+1});\ J_{i+1} = J_i \setminus \{j_i\};$$
$$(\forall j \in J_{i+1} \setminus \{F(j_i)\},\ \forall v \in V)\ (c_{i+1}(j,v) = c_i(j,v));$$
$$(\forall v \in V)\ \Big[c_{i+1}(F(j_i),v) = c_i(F(j_i),v) +$$
$$+\min\Big[c_i(j_i,k) + b([j_i,F(j_i)],k,v) + b([F(j_i),j_i],v,k)\Big],\ k \in V\Big].$$

T h e o r e m. There are decisions ψ_i of problems θ_i, $i=1,2,\ldots,n$ so that $\psi_i = \psi|J_i$, $f(\psi_i) = f(\psi_{i+1})$, $i=1,2,\ldots,n-1$;

$$\psi(j_n) = \mathbf{arg\ min}\ c_n(j_n,k),\ k \in V;$$

$$\psi(j_i) = \mathbf{arg\ min}\Big[c_i(j_i,k) + b([j_i,F(j_i)],\ k,\ \psi(F(j_i))) +$$
$$+\ b([j_i,F(j_i)],\ \psi(j_i),\ k)\Big],\ k \in V, \quad i=1,2,\ldots,n-1 \ ∎$$

The algorithm execution consists of two stages. At first stage the problem sequence $\{\theta_i\}$, $i=1,2,\ldots n$ is constructed. At second stage the meanings $\psi(j_n)$, $\psi(j_{n-1})$, ..., $\psi(j_1)$ are found in accordance with the theorem.

The algorithm time and space complexity is $O(\mathbf{card}^2 V\ \mathbf{card}\ J)$. Mainly the memory capacity is used for the map b storing. For a number of applied network problems the algorithm space complexity may be decreased to $O(\mathbf{card}\ V\ \mathbf{card}\ J)$ due to an algorithmic representation of the map b. In this connection the algorithm time complexity is not increased and may be decreased.

OPTIMAL ALLOCATION OF MUTUALLY CONNECTED EXTENDED OBJECTS It stands to reason to replace the allocation problem by the non-atomic allocation problem in case there exists a great number of objects. The paper [3] deals with optimal allocation, in a specified region D, of certain continuum Ω. The extent of objects $\omega \in \Omega$ is modelled by a measure on the σ-algebra of subset from Ω. It is required to find an invective mapping $\psi: \Omega \to D$ which maintains the measure and minimizes the functional dependent on ψ and denoting the mean cost of communications linking elements from Ω. Examples are considered.

STRUCTURE SYNTHESIS OF COMMUNICATION SYSTEMS UNDER UNCERTAINTY. Cases of internal and external unsertainty of mathematical model is considered. Interval numbers and fuzzy sets are used for uncertainty simulation. Scalar and vector preferences on the set of interval and fuzzy alternatives are introduced. Generalization of decomposition scheme from [1] are used to solve a structure synthesis problems under uncertainty.

COMPUTER CODES COMPLEX has been worked out. It is used for synthesis and development control of oil deposit transportation and communication networks.

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THE INTERACTIVE FIXED CHARGE INHOMOGENEOUS FLOWS OPTIMIZATION PROBLEM

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An optimization problem of interactive inhomogeneous flows (Steiner multicommodity network flow problem)[3,4] is formulated. The problem main characteristic is a fixed charge change when combining multicommodity communications. We propose a method for solving this problem which to restrict the search on the feasible domain reduces the original problem to a concave programming problem in the form: $\min\{f(x) \mid x \in X\}$ where $f: \mathbb{R}^n \to \mathbb{R}$ is a concave function, $X \subset \mathbb{R}^n_{\geqslant 0}$ is a flow polytope defined by network transportation constraints. For practical large-scale problems arizing from planning transportation networks on inhomogeneous surfaces defined by a digital model a method of local optimization over a flow polytope vertices set is proposed which is far more effective in comparison with the method [1] under polytope strong degeneracy conditions.

DEFINITION OF THE PROBLEM. Network planning conditions are defined with the help of a non-oriented *elementary communication graph* (ECG) $G=(V, E)$; $\Pi=\{1; 2;\ldots; K\}$ is a product set. For each product $k \in \Pi$ from the vertex set V of the graph G chosen are a set of sources $Q^{(k)} \in V$ with predeterming positive capacities $\{b^{(k)}(q) \mid q \in Q^{(k)}\}$ and a destination $q_0 \in V \setminus Q^{(k)}$ with the capacity $b^{(k)}(q_0^{(k)}) = -\sum_{q \in Q^{(k)}} b^{(k)}(q)$. In a set of 2^Π of all the subsets of the product set Π given is a fixed charge function $w_{ij}: 2^\Pi \to \mathbb{R}_{\geqslant 0}$, describing a fixed charge interaction and satisfying the following conditions:

$$w_{ij}(\emptyset) = 0 \; ; \tag{1}$$

$$\forall \mathcal{A}, \mathcal{B} \subseteq \Pi: \;\; \mathcal{A} \subseteq \mathcal{B} \Rightarrow w_{ij}(\mathcal{A}) \leqslant w_{ij}(\mathcal{B}) \; . \tag{2}$$

If a flow interaction along an edge (i, j) in any combination does not lead to a fixed charge increase (decrease), i.e. multicommodity communication combinations are encouraged (punished), then an additional submodularity (3) (supermodularity (4)) condition is imposed on the fixed charge function :

$$\forall \mathcal{A}, \mathcal{B} \subseteq \Pi: \;\; w_{ij}(\mathcal{A}) + w_{ij}(\mathcal{B}) \geqslant w_{ij}(\mathcal{A} \cup \mathcal{B}) + w_{ij}(\mathcal{A} \cap \mathcal{B}) \; ; \tag{3}$$

$$\forall \mathcal{A}, \mathcal{B} \subseteq \Pi: \;\; w_{ij}(\mathcal{A}) + w_{ij}(\mathcal{B}) \leqslant w_{ij}(\mathcal{A} \cup \mathcal{B}) + w_{ij}(\mathcal{A} \cap \mathcal{B}) \; . \tag{4}$$

The transportation cost of $y_{ij}^{(k)}$ units of the kth product along an edge (i, j) is described by a concave non-decreasing transportation cost function $\psi_{ij}^{(k)} : \mathbb{R}_{\geqslant 0} \to \mathbb{R}_{\geqslant 0}$ satisfying the condition of $\psi_{ij}^{(k)}(0)=0$. An *edge cost function* (ECF) $\varphi_{ij} : \mathbb{R}^K_{\geqslant 0} \to \mathbb{R}_{\geqslant 0}$ is obtained as follows ($y_{ij} = (y_{ij}^{(k)} \mid k \in \Pi)$):

$$\varphi_{ij}(y_{ij}) = w_{ij}(\{k \in \Pi \mid y_{ij}^{(k)} > 0\}) + \sum_{k \in \Pi} \psi_{ij}^{(k)}(y_{ij}^{(k)}), \tag{5}$$

The interactive fixed charge inhomogeneous flow optimization problem can be written down in the form:

$$\min \{ \varphi(y) = \sum_{(i,j) \in E} \varphi_{ij}(y_{ij}) \mid y \in Y = \otimes_{k \in \Pi} Y^{(k)} \} \tag{6}$$

where $Y^{(k)}$ is a feasible k^{th} product flow set on a graph G, defined by the conditions similar to ordinary network transportation constraints for oriented graphs.

PRECISE SOLUTION METHODS. An objective function of problem (6) is a concave , but the feasible set Y is non-convex. We show the way to pass from problem (6) to an equivalent in some sense problem of searching an optimal flow on the directed graph with a concave objective function and a convex feasible domain:

$$\min_{x\in X}\left\{f(x)=\sum_{(i,j)\in E}\varphi_{ij}(x_{ij}+x_{ji}) \mid x=(x_{ij} \mid (i,j)\in E),\ x_{ij}=(x_{ij}^{(k)} \mid k\in\Pi)\right\} \quad (7)$$

where $X=\bigotimes_{k\in\Pi} X^{(k)}$, $X^{(k)}$ $(k\in\Pi)$ is a convex polyhedral set (flow polytope) defined by network transportation constraints.

Problem (7) falls into the class of concave generalized separable function minimization problems on a convex polyhedron. Precise methods can be divided into 3 groups [2]: 1) branch and bound methods, using objective function generalized separability and constructing objective function convex envelopes for underestimating; 2) methods using linear minorant; 3) methods using cone splitting procedure and *Tuy's* cuts [5].

We consider the applicability of all of the 3 groups of methods to problem (7). The 3rd group methods can't be applied to problem (7) directly as to do so an objective function f must be defined over the whole of space $\mathbb{R}^n$ (or there must be a concave extension f on $\mathbb{R}^n$). The ECF φ_{ij} becomes discontinuous of the bound of a non-negative octant $\mathbb{R}^{2K}_{\geq 0}$ which leads to emptiness of a set of all function f concave extensions with $\mathbb{R}^{2K|E|}_{\geq 0}$ over $\mathbb{R}^{2K|E|}$. We show the possibility of an ECF modification to avoid non-extensibility with concavity preservation under the condition of preservation of a substitution equivalence.

LOCAL OPTIMIZATION ON A FLOW POLYTOPE VERTICES SET. In practical large-scale networks design problems [3, 4] flow polytope is strongly degenerate. The strong polytope degeneracy doesn't allow to use the known technique (potentials method) for local optimization. For this case we propose an algorithm which is an extension of [1] and is highly effective.

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THE REAL-TIME SIMULATION FOR REACTOR NEUTRON KINETIC PROCESS

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ABSTRACT

In this paper, the methods of calculating neutron kinetik equation are discussed. The conventional methods should select quite short time step, because the equation is stiffness problem.

Based on the principle of the discrete similar, the difference equation is derived, and the time step increment size can be greatly increased. under the given conditions the stepsize could be enlarged to the third power of 10. There fore much computing time can be saved. Numerical examples confirm that the model being built need not be a complicated one but, however, should be representative enough to draw conclusion for more detailed models such as conventional methods.

This calculation method can be applied to the real-time simulation in reactor neutron kinetics.

Ⅰ. INTRODUCTION

The one of the most important porblems in simulation of dynamic characteristics of the reactor in the training simulator for nuclear power plant is to set up the math model of simulation for neutron kinetic eguations.

This paper, based on the principle of the discrete simular, e.g. using Laplace method transfers the neutron kinetic eguation and then by means of discretization to get the discrete solution of the eguation. Under the given conditions the stepsize could enlarged to the 2-3th power of 10, and the calculation could be much decreased for one stepsize, so that with the reguired accuracy much time for calculation would be saved (1).

Ⅱ. DISCUSSION

Variation of the neutron power in reactor can be expressed by the following neutron kinetic eguations:

$$\frac{dn}{dt} = \frac{\Delta\rho - 1}{l / \beta} n + \sum_{i=1}^{6} \lambda_i C_i + q \qquad (1)$$

$$\frac{dc_i}{dt} = \frac{\beta}{l} n - \lambda_i c_i, \quad i = 1, 2 \cdots\cdots 6 \qquad (2)$$

After the Laplace transformation of equation (2)comes:

$$sc(s) - c(0) = -\lambda c(s) + \frac{\beta}{l} n(s)$$

$$c(s) = \frac{1}{s+\lambda} c(0) + \frac{1}{s+\lambda} \frac{\beta}{l} n(s) \qquad (3)$$

Using counter-Laplace transformation and volume integration the results of state equations of continuous system are given:

$$C(KT) = e^{-\lambda KT} C(0) + \int_0^{KT} e^{-\lambda(KT-\tau)} \frac{\beta}{l} n(\tau) d\tau \qquad (4)$$

$$C((K+1)T) = e^{-\lambda(K+1)T} C(0) + \int_0^{(K+1)T} e^{-\lambda((K+1)T-\tau)} \frac{\beta}{l} n(\tau) d\tau \qquad (5)$$

With (5)-(4)$\times e^{-\lambda T}$goes to:

$$C((K+1)T) = e^{-\lambda T} C(KT) + \int_{KT}^{(K+1)T} e^{-\lambda((K+1)T-\tau)} \frac{\beta}{l} n(\tau) d\tau \qquad (6)$$

Because of the independence of the integration of the right part of Eqs. (6) on value k the discrete result of Eqs. (2) can be given:

$$C\,[(K+1)T] = e^{-\lambda T}C(KT) + (1-e^{-\lambda T})n(KT) \qquad (7)$$

Deriving calculation model for simulation of dynamic process in reactor based on dynamic behaviour theory of adiabatic point reactor, differential Eqs. become algebra Eqs (2) .

Ⅲ. CALCULATION EXAMPLE

Using above derived simulation math model and running the relative program on computer a series of calculations were carried out and the different results were showed and compared with classical results in table (1).

TABLE(1)

Comparison of the Classical Method and Discrete Method

Δρ	t	classical method Ts=0.001	discrete method		
			Ts=0.25	Ts=0.5	Ts=1.0
0.003463	2.0	1.0040	1.0036	1.0032	1.0025
	4.0	1.0046	1.0040	1.0036	1.0030
	6.0	1.0051	1.0045	1.0039	1.0033
	8.0	1.0057	1.0049	1.0043	1.0035
	10.0	1.0062	1.0053	1.0047	1.0038
0.006925	2.0	1.0081	1.0072	1.0065	1.0049
	4.0	1.0092	1.0081	1.0073	1.0060
	6.0	1.0103	1.0090	1.0080	1.0066
	8.0	1.0114	1.0099	1.0087	1.0071
	10.0	1.0125	1.0107	1.0094	1.0076

note: Ts-stepsize of time (second)

When inserted reactivity equals 0.006925(dollar) the maximum absolute error is 0.0049, maximum relative error is 0.49% within 10s. Then because of the great increase of stepsize for intergration by 2-3 power of 10 with the discrete similar method and reduction of operational quantity needed between two samplings . This method is usefull for the trnaining simulator of the nuclear power plant.

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COMPUTER REALIZATION OF THE SIX-DIMENSIONAL MATCHING OF THE BEAM PARAMETERS IN LINEAR ACCELERATOR

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A problem of the six-dimensional matching of the beam phase space to the linac acceptance is certainly very important in a high average current ion accelerator because of the restrictions on the beam losses level [I]. In connection with the design of the RFQ booster accelerator from 400 KeV to 750 KeV for the INR linac the necessity of the beam matching between the RFQ and Alvarez tank arises.

Due to the energy spread of the RFQ output beam there is a fast growth of bunch length on the drift space. In order to keep the longitudinal parameters the rf-buncher between RFQ and Alvarez tank is used. The change of the bunch density distribution along the transport channel results to the strong dependence of the six-dimensional matching conditions upon the transverse and longitudinal space charge forces.

The solving of the six-dimensional matching problem can be achieved by using the r.m.s. envelope equations including space charge [2]:

$$R'' + (K_u - Q_u)R_u - \frac{E_u^2}{R_u^3} = 0\ , \quad u=x,y,z \qquad (I)$$

where K_u (K_z=0) are coefficients depending of the external linear focusing fields; Q_u are the coefficients depending of the internal linearized space charge fields; R_u are the r.m.s. envelopes of the beam defined as the second moments of the particle phase space distribution in the corresponding planes;

E_u are the r.m.s. emittaces. Solving the system (I) jointly the beam r.m.s. characteristics at the transport channel exit are found. Knowing this data we can determine the objective function [2] which should be minimized. At the longitudinal phase plane the minus unit transformation of the phase space ellipse must be fulfilled. The problem is the definition of the global minimum of the objective function with boundary conditions by the method of the flexible polyhedron [3].

Computer simulation was done and the beam behaviour in the optimized transport channel is shown in Fig. I. Finally, the suitable six-dimensional matching was achieved with the objective function value less then 10^{-6}.

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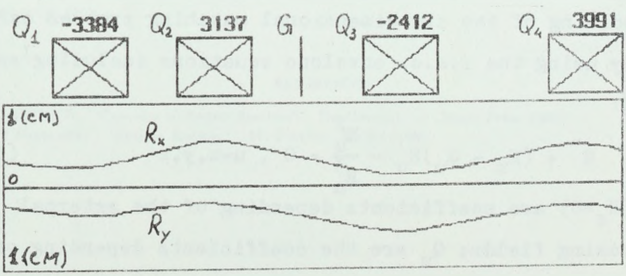

Fig. I. Beam envelope behaviour along the transport channel Q_i, i=I,...,4 are the quadrupoles with gradients in (Gauss/cm); G is the gap of buncher.

SIMULATION OF THE CLOSED ORBIT REGENERATION AND CORRECTION IN THE MMF STORAGE RING

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Closed orbit (CO) regeneration and correction is one of the main problem of the circular accelerator tuning. The closed orbit distortions (COD) are caused by the imperfections of storage ring magnetic lattice. The monitors are located along ring to measure beam position. Using these data an amplitude of COD can be decreased by means of the correctors. COD simulation and methods of the CO regeneration and correction applied to Moscow Meson Factory (MMF) Storage Ring [1] are presented.

The linearized transverse particle motion is described by Hill's equation [2]:

$$y''(s) + K(s)\cdot y(s) = F(s), \qquad (1)$$

where y, s are transverse and longitudinal coordinates, C is the circumference, K(s+C)=K(s) is the focusing function, F(s) is a perturbation function.

The solution of Eq.(1) can be written in the form: $y(s) = C(s)\cdot y_o + S(s)\cdot y'_o + U(s)$, where C(s)and S(s) are two independent solutions of the homogeneous equation and U(s) is a particular solution inhomogeneous equation.

CO exists if the periodic boundary conditions $Y_{co}(s+C) = Y_{co}(s)$, $Y'_{co}(s+C) = Y'_{co}(s)$ is fulfilled. Using Twiss parameters β and μ [3] CO can be determined as [2]:

$$Y_{co}(s) = \sqrt{\beta(s)}/(2\cdot\cos\pi Q)\cdot\int_s^{s+C} F(t)\cdot\sqrt{\beta(t)}\cdot\cos(\pi\cdot Q+\mu(s)-\mu(t))\cdot dt,$$

where Q is the betatron oscillation frequency. y(s) and y′(s) are expressed through the initial conditions y_o, y'_o [2]:

$$\begin{pmatrix} y \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} C & C' & U \\ S & S' & U' \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} y_o \\ y'_o \\ 1 \end{pmatrix}.$$

The transfer matrix can be easy calculated for separate structure element such as dipole and quadrupole magnets and drift space [2]. The ring transfer matrix M(s) is the product of elementary matrices. Thus the CO is defined by equation:

$$(Y_{co}, Y'_{co}, 1)^t = M(s)\cdot(Y_{co}, Y'_{co}, 1)^t.$$

Unperturbed matrix ($U = U' = 0$) is used for orbit fitting between monitors: $y(s) = C(s)\cdot y_i + S(s)\cdot(y_{i+1} - C_{i+1}\cdot y_i)/S_{i+1}$, where y_i is COD measured by i-th monitor.

Corrector contribution in COD can be taken into account by right-hand side of the Eq.(1) $F(s) = \sum \theta_j \cdot \delta(s - s_j)$ as a kick θ_j in the corrector position. The corrector excitations can be received by minimization of measured norm $\sum(y_i - Y_{co\,i})^2$.

The other method is a harmonic correction. For normalized coordinates $q = y/\sqrt{\beta(s)}$, $\phi = 1/Q\cdot\int_0^s dt/\sqrt{\beta(t)}$ the solution of Eq.(1) in frequency domain becomes: $q_k = Q^2/(Q^2-k^2)\cdot f_k$, $f(q) = \sum f_k \cdot e^{ik\phi} = Q^2\cdot\beta^{3/2}\cdot F(s)$. The kicks θ_j is defined by matrix equation: $(q_k) = (a_{kj})\cdot(\theta_j)$, $a_{kj} = 1/2\pi\cdot Q\cdot\sqrt{\beta_j}/(Q^2-k^2)\cdot e^{ik\phi_j}$.

COD is calculated by matrix method with the random distribution of errors: magnet misalignments - 10^{-4} m; magnet tilts - 10^{-3} rad; field deviations - 10^{-2} %; COD measurement errors - $2.5\cdot10^{-4}$ m. Averaged maximum value of COD obtained by Monte-Carlo method is $\langle y_{max}\rangle = 4.3$ mm, $\sigma = 2.2$ mm.

Two methods have been used to simulate the orbit correction: (1) optimizing strategy by solving least-square problem for different combinations of eight correctors; (2) correction for four maximum harmonic amplitudes received by FFT of the regenerated orbit. The correction coefficient $\langle y_{max}\rangle/\langle y_{max\ cor}\rangle$ for different number of correctors N_{cor} is listed in Table 1.

Table 1

N_{cor} =	1	2	3	4	5	6	7	8
Method (1)	3.9	7.5	10.4	12.2	14.0	14.2	14.2	14.2
Method (2)	-	-	-	-	-	-	-	8.7

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SIMULATION OF GIBBS POINT PROCESSES WITH STRONG CLUSTERED PROPERTIES

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INTRODUCTION

The Gibbs point processes are the stochastic models well-fit to decribe natural systems of interacting particles. Even a simple class of these processes may produce point patterns with qualitatively different properties, from regular to clustered patterns. The distribution of these processes is given by a potential function.Thus if the potential is known the process can be simulated. An estimated potential function may serve as a descriptor of the data, and with some experience an interpretation is possible.
A Monte Carlo realisations of the Gibbs point processes can be obtained by running for long enough the corresponding spatial birth-and-death processes which have these point processes as their equilibrium distributions.
Simulation of point patterns with strong clustered properties is delicate problem relating to the loss of stationarity of a birth-and-death point process.
Several authors [5,6] have tried to model highly clustered point patterns by using Gibbs distributions with attractive potentials. Some of these potentials violate a stability condition. In [3] test allowing to reject a simulation pattern when it is far from a typical sample of the given process is proposed.
In this paper the class of the Gibbs point processes is introduced which allows to generate point patterns with tight clusters.

MODEL

Let N be the space of all locally finite counting measures Φ on $[R^d,\mathcal{B}^d]$ and $\mathfrak{N}$ the corresponding σ-algebra of subsets of N.
A point process P is a distribution on $[N,\mathfrak{N}]$.
The reduced Campbell measure $C_P^!$ of P is a measure on $\mathcal{B}^d\otimes\mathfrak{N}$ defined by

$$C_P^!(B\times Y) = \int\int 1_Y(\Phi-\delta x)\Phi(dx)P(d\Phi).$$

The measure Λ_P on $\mathcal{B}^d$ defined by

$$\Lambda_P(B)=C_P^!(B\times N)=\int\Phi(B)P(d\Phi).$$

is called the intensity measure of P. If P is homogeneous then there exists a constant λ such that $\Lambda_P = \lambda\cdot\nu$ (where ν is the Lebesgue measure on $[R^d,\mathcal{B}^d]$).
If the intensity measure Λ_P is σ-finite, then for Λ_P-a.e. $x\in R^d$ there exists uniquely determined distribution $P_x^!$ on $[N,\mathfrak{N}]$ with

$$C_P^!(B\times Y) = \int P_x^!(Y)\Lambda_P(dx)$$

is called the reduced Palm distribution of the point process P with respect to the point x.
Denote by Q the Poisson process with intensity measure Λ_Q. The point process P is a Gibbs point process with weight process Q iff $C_P \ll \Lambda_Q\times P$ [4]. Then for $(\Lambda_Q\times P)$-a.e. $(x,\Phi)\in R^d\times N$

$$\frac{dC_P^!}{d\Lambda_{q\times P}}(x,\Phi) = exp(-E(x,\Phi)).$$

The function $E:R^d \times N \to [-\infty,\infty)$ is called the local energy and it can be presented as

$$E(x,\Phi) = \alpha + \sum_{\substack{x_1 \in \Phi \\ x \neq x_1}} \Psi_1(x,x_1) + \sum^*_{\substack{x_1,x_2 \in \Phi \\ x \neq x_1,x_2}} \Psi_2(x,x_1,x_2) + \cdots + \sum^*_{\substack{x_1,\ldots,x_k \in \Phi \\ x \neq x_1,\ldots,x}} \Psi_k(x,x_1,\ldots,x_k)$$

($\sum^*$ denotes summation over pairwise different points).
Here α is chemical potential and Ψ_i are interaction potentials. Functions Ψ_i are symmetric in x, $x_1,\ldots,x_i$ and non-null iff each pair of points is of interacting points. In the cases of i=1 and i=2 Ψ_i are called a pair potential and a triplet potential respectively.
If the local energy E of a Gibbs point process is generated by only a pair potential Ψ_1 then the Gibbs process is called a pairwise interaction point process. Clustered point patterns can be simulated by a pairwise interaction point process if a pair potential posseses a hard-core distance R^*, i.e. $\Psi_1(x,y)=\infty$ for $\|x-y\| < R^*$. If R^* is much less than an interaction distance R defined as $\Psi_1(x,y) = 0$ for $\|x-y\| > R$) then we can simulate clustered patterns which do not deviate far from Poisson patterns.
Much more highly clustered point patterns one can obtained if to use a local energy of the form

$$E(x,\Phi) = \alpha + \sum_{\substack{x_1 \in \Phi \\ x \neq x_1}} \Psi_1(x,x) + \sum^*_{\substack{x_1,x_2 \in \Phi \\ x \neq x_1,x_2}} \Psi_2(x,x,x)$$

By means of a triplet potential Ψ_2 we can control the size and density of clusters without violenting a stability conditions.

PARAMETER ESTIMATION

The estimation procedure is based on parametrization of interaction potentials Ψ. To estimate parameters of potential functons we used the pseudo-likelihood method [1]. Pseudo-likelihood estimates θ are obtained by maximization of a pseudo-likelihood function

$$L_P(\theta) = \sum_{1=1}^{n} log\ \lambda(x_i\,|\Phi\cap W) - \ log \int_W \lambda(x|\Phi\cap W)dx,$$

where $\lambda(x|\Phi\cap W) = exp(-E(x,\Phi))$ and $(x_1,\ldots,x_n)$ are points in a sample window W.

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AGGREGATION IN SIMULATION OF LARGE SCALE THERMIC PROCESSES

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The goal of our study is to propose an iterative method of rapid calculation of the large thermic processes which will be applicable in real time to the on-line control. This method is based on the controls aggregation and in each iteration we have the aggregated problem with small number of the control parameters ahd a set of independent subproblems of small dimension. The convergence properties of the method are discussed in [1].

The first problem studied concerns the optimal control of a vertical oven having 12 heating zones. This system of 12 controls presents great internal couplings due to the naturalconvection in the chimney and to thermal conduction. Following Lang and all [2] we consider the simplest representation of the linearized process as a 24 dimensional localized constants model in classical form

$$J=\alpha\int_0^T\sum_{i=1}^{12}(z_i(t)-z_{id})^2dt+\beta\int_0^T\sum_{i=1}^{12}(u_i(t)-u_{id})^2dt\to\min$$

$$\dot{y}=Ay+Bu,\ y(0)=y_0,\ t\in[0,T],\ z=Cy, \tag{1}$$

$$(z_i(T)-z_{id})^2\le\delta,\ i=1,2\ldots12.$$

where $y(t)$ is the state vector, $u(t)$ the control vector and $z(t)$ the output vector (temperature at the observation points). The dimensions of this vectors are 24,12 and 12, respectively. The objective is to maintain a prescribed distribution of temperature z_d on a vertical object placed in the chimney, while limiting energy consumption.

In order to solve the problem (1) we use both spatial and time aggregation of the controls. The time interval $[0,T]$ is divided into L equal subintervals $[t_{j-1},t_j]$ of the length $h=T/L$, $j=1,2\ldots L$, $t_0=0$, $t_L=T$.

We introduce L scalar aggregated controls U_j $j=1,2\ldots L$ and weighting elements $\alpha_0(t),\alpha_i(t)$, i=1,2...12. Weighting elements $\alpha_i(t)$ respect to spatial aggregation and $\alpha_0(t)$ respects to time aggregation. Let us define the set A of weighting elements;

$$A=\{\alpha_i(t),\alpha_0(t)\mid\int_{t_{j-1}}^{t_j}\alpha_0(t)dt=0,\ j=1,2\ldots L,\ \sum_{i=1}^{12}\alpha_i(t)=0,\ t\in[0,T]\} \tag{2}$$

For any given $\alpha\in A$ define the disaggregated controls in the form

$$u_i(t)=U_j/12h+\alpha_0(t)+\alpha_i(t),\ t\in[t_{j-1},t_j] \tag{3}$$

From Eqs. (2),(3) we have the following relation between the original and the aggregated controls:

$$U_j=\int_{t_{j-1}}^{t_j}\sum_{i=1}^{12}u_i(t)dt,\ j=1,2\ldots L \tag{4}$$

Thus the aggregated control U_j is the total energy consumption during the j-th time subinterval. Fixing $\mathring{\alpha} \in A$ and substitute Eq.(3) in the original problem (1) we form the aggregated problem. It has L scalar control variables U_j $j=1,2...L$ and therefore is an ordinary finite dimensional mathematical programming problem.

Denote by $\theta(\alpha)$ the extremal-value functional of the aggregated problem, depending on $\alpha \in A$, and consider the auxiliary problem

$$\min\{\theta(\alpha) \mid \alpha \in A\} \tag{5}$$

It was shown in [1] that if $\mathring{\alpha}$ is a local extremal solution of the problem (5) and U is the optimal solution of the aggregated problem with $\alpha = \mathring{\alpha}$, then the disaggregated solution $\mathring{u}(t)$ calculated in accordance with Eq.(3) for $\alpha = \mathring{\alpha}$, is the optimal solution of the original problem (1). In order to solve the auxiliary problem (5), we may use the first-order optimisation method such as gradient projection. Note that due to the simple structure of the set A, the projection on A decomposes into L+1 independent projection, calculated analitically. In order to find the gradient $\nabla\theta(\mathring{\alpha})$ one may use the marginal value theorem and get $\nabla\theta(\mathring{\alpha}) = \partial L/\partial\alpha$ where L is standard Lagrange function for the aggregated problem with $\alpha = \mathring{\alpha}$.

Thus, each iteration of the proposed decomposition-aggregation method consists of the following steps. Fixing $\mathring{\alpha} \in A$ and solve the aggregated problem. Form the Lagrange function for the aggregated problem and find $\nabla\theta(\mathring{\alpha})$ in accordance with the marginal value theorem. Then find L+1 independent projections and calculate the new values of weighting elements.

Numerical experiments done on IBM PC-XT with INTEL-8088 processor for the same values of $A, B, C, y_0, z_{id}, u_{id}$ as in [2] and $\delta = 0.01$, $L=12$. In order to solve the aggregated problem we use discrete net with 25 nodes in the time interval $[0,T]$ and the augmented Lagrangian method. The stopping rule was

$$\|\alpha^{\ell+1} - \alpha^{\ell}\| \,/\, \|\alpha^{\ell}\| \le 0.001$$

The number of iterations in the auxiliary problem necessary for convergence is 4÷5 and the time C.P.U. of the calculatios is around 4 minutes per iteration. The total C.P.U. time practically independent on the value α/β and considerably depends on δ i.e. the accuracy in the terminal constraints.

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SIMULATION OF HEAT EXCHANGE PROCESSES WITH IDENTIFICATION OF THERMAL PARAMETERS

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The distribution of a thermal system in time and, especially, in space presupposes, during investigation of its thermal state, the need for taking into account heat exchange parameters distributed along the object cutout (e.g.coefficients of heat exchange or thermal flows changing along the boundaries of the zone under investigation). While carrying out the identification of local heat exchange parameters in terms of control theory (e.g.with the help of the suggested adaptive iterative filter) we actually construct closed circuit of control. In each of the above circuits one may identify the corresponding control parameter (or its analog).

All circuits under consideration at the algorithmic level join in a united, multiply connected system of automatic control, the number of closed circuits being determined by the number of the sections on the surface under investigation with constant heat exchange parameters. It should be noted here that for local parameters determination one should take into account the correlation between all control circuits, i.e.allow for the mutual influence of all local parameters under identification. The last circumstance supposing the inclusion of the characteristic temperatures of each of the local zones into the measurement vector is allowed for with the help of covariance error matrix of the identified equations. It is striking that one can observe a qualitative leap of the results accuracy, the difficulty of iteration break at each step of the recurrent algorithm and regular characteristics of the procedure in going from two local quantities to a larger number of them. This is likely due to the fact that with large number of interacting correlation moments a small change of one of them gives rise to changes in many others provoking, in its turn, a drift of the corresponding identified evaluations. Everything taken together requires some special tricks during identification procedure.

As an initial model we use partial differential parabolic equations with corresponding boundary conditions.

The purpose of this paper is to investigate the capabilities of the adaptive iterative filter in identification of local (more than 2 in number) thermal parameters for models and problems of different complexity. The algorithm of adaptive iterative filter can be written in the following way [1] :

$$\hat{\vec{Z}}^{(j)}_{K/K} = \hat{\vec{Z}}^{(j-1)}_{K/K} + K^{(j)}_{K}\left[\tilde{\vec{Y}}_{K} - \hat{H}^{(j)}_{K}\hat{\vec{Z}}^{(j-1)}_{K/K}\right];$$

$$K_K^{(j)} = P_{K-1/K-1}\left[\hat{H}_K^{(j)}\right]^T\left\{\hat{H}_K^{(j)} P_{K-1/K-1}\left[\hat{H}_K^{(j)}\right]^T + R_K\right\}^{-1};$$

$$P_{K-1/K-1} = \left[\bar{I} - K_{K-1}^{(i)}\hat{H}_{K-1}^{(i)}\right] P_{K-2/K-2}\left[\bar{I} - K_{K-1}^{(i)}\hat{H}_{K-1}^{(i)}\right]^T + \qquad (1)$$
$$+ K_{K-1}^{(i)} R_K \left[K_{K-1}^{(i)}\right]^T,$$

where $\hat{\bar{Z}}_{K/K}^{(j)}$ is evaluation of the desired parameters vector at jth iteration of the Kth time step obtained in terms of $\bar{Y}_K$ measurements; K_K is weight matrix; $P_{K-1/K-1}$, P_K are covariance filter matrices; i - is the last iteration of the (K -1)th step.

Low (in terms of the desired parameters number) filter dimensionality and actual absence of round-off error accumulation (the method functions in the framework of the stochastic simulation algorithms) makes it possible to adopt, if necessary, single-purpose personal computers.

It should be noted that in the filter iterative modification the role of the mathematical model of the thermal system under study is played by the linearized matrix-vector equation in the form

$$\hat{\bar{X}}_K^{(j)} = \Phi_{K,K-1}^{(j-1)}\hat{\bar{X}}_{K-1}^{(i)} + F_{K,K-1}^{(j-1)}\hat{\bar{U}}_K^{(j-1)} + G_{K,K-1}^{(j-1)}\bar{W}_K, \qquad (2)$$

which described all thermal processes in the systems and variable transient matrices $\Phi_{K,K-1}$, $F_{K,K-1}$, $G_{K,K-1}$ were used in the filter computational algorithms to search for the prediction of temperature vector $\bar{T}$ or extended state vector $\bar{X}$ (temperature pattern and unknown parameters $\bar{Z}$) and prediction error covariance matrix. Since algorithm (1) functions in the space of desired parameters the account of mutual influence of temperature pattern and heat engineering parameters carried out in the iterative filter [1] with the help of transient matrices, is presently made employing nonstationary measurement matrix $\hat{H}_K$.

Model problems solved in the paper and conducted investigations allow to pass on to the identification of any number of local thermal parameters in actual heat engineering systems with the aid of adaptive iterative filter efficient algorithm.

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SIMULATION OF STRUCTURE AND PROPERTIES OF RANDOM COMPOSITES

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As an example of a random composit a high temperature solid electrolyte based on dioxyde of zirconium, possessing impurity disorder is studied. Such specimens being composed of grains of a few micrometers obey high oxygen ionic electrical conduction. Inner microstructure of a grain, being part of a monocristal, was simulated.

Dioxyde of zirconium is stabilized to cubic fluorite phase when doping cations of lower valency: bivalent calcium, magnesium or trivalent yttrium, strontium. The doped cations lie in the sites of cations sublattice, replaycing ions of zirconium. The electrical neutrality of system is achieved thanks to the vacancies in oxygen sublattice. The concentration of doped cations, providing the maximal electrical conductivity is about 10-12% for bivalent and of 16-20% as to monovalent cations, whereby the concentration of vacancies in the oxigen sublattice is of 4-6%. So the whole structure is highly disordered. For forcasting its properties it is important to know the characteristics of mutual distribution of doped cations as well of vacancies.

For simulating the defects subsystem (doped cations and vacancies) the Monte-Carlo Method was used. Zirconium dioxyde base system influence is taken into account by means of effective defect charges and dielectric penetrability, entering into the Coulomb interionic potential [1]. The adopted lattice model allows effectively take account of repulsion between ions, being at small distances. The system included from 32 to 96 particules.

The results of simulation showed the short range order in defect distribution, which was exhibiting in two or three nearest coordination spheres. The mutual defect distribution at higher distances was completly random, what shows the screening of charges. When temperature decreasing the short range order becomes more evident. In systems of bivalent cations the defect clustering can be observed, what causes the low electrical conductivity of systems in comparison with systems of trivalent cations.

A special characteristic of elasticity deformation of dispersal and composit materials, being microstructural medium, consists in simultaneity of deformation and microdestruction. The character of deformation, especially by stress close to limits, permits to make analogy with phase transition, for its simulation the theory of percolation can be used.

It is proposed to present the elasticity modulus aş splains, obtained as result of sewing of well-known asymptotics: after the theory of effective medium or according to Bruggeman equation and the percolation function, describing the states near to critical. Due to such interpolate dependences elasticity modulus have a smooth transition (without the first derivative rupture) within the whole range of intact bonds from percolation threshold to 1.

To obtain the deformation porosity range is a percolation problem. The connection between the volume part of pores and the bonding function is proposed. For bonding function the asymptotic scaling expression close to percolation threshold is known.

Sometimes the microphysical analyses of elasticity modulus by deformation presents difficulties because of lack of technical possibility to indicate the change of intact bonds part by an independent way. Nevertheless it is necessary to take into account the fractal structure of destruction process. That is why the porosity presents the parameter more available for measuring. Percolation correlations, obtained during the studies, show, that critical deformation index is equal to the standart critical deformation index divided on the first percolation critical index, if the porosity is used as a structural variable. This can explain, why experimental data and some theoretical evaluations of critical index are very different.

The first critical percolation connection index for different kinds of lattices is known fairly reliable. So it is equal to 0.46 for a simple cubic lattice. In accordance with critical threshold values of intact connection's proportion the experimental data of colloidal cristal analyses gives 2.0 for critical deformation index [2]. There are also evaluations of 2.25 for the conductivity according to the theory of effective medium. The analyses of casualy perforated deformed foil gives the index of 3.7 and 3.3 by constant load in dependence of specific hole proportion [3]. The values of 3.2-4 are obtained in result of studying deformed sintered metals, having different volume proportion of pores[3]. So it can be concluded, that the critical index values obtained in [3] do not contradict the evaluations in [2] and theoretical values of 4.4, the connection between them is to be determined by the obtained expression.

Using the idea of penetration depth of a new particle into the cluster and for maintaining the stability of the aggregates but not of a single particle, a sufficient condition of fractal cluster formation is formulated. This condition allows to determine the critical dimensions of particles for any kinds of fractal structures by different structure formations: diffusal, cluster-cluster, with linear and brown trajectories. The elasticity distribution low modulus in such clusters is obtained.

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MATHEMATICAL MODEL OF THE MATTER SELF-ORGANISATION PROCESS AND RESULTS OF ITS ANALYSIS

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We have used the following suppositions and incomplete equations, connecting the parameters of micro-macro- and megasystems.

1. In any arbitrarily chosen space of R_o radius is going on the quasicyclic process of the photons and nucleons transformation. A generalized proton-neutron complex (i) transforms at T T_b into a generalized neutron-proton complex (j). The neutron-proton complex transforms at T_b T T_a into a proton-neutron complex. The term "generalized" is attributed to the mean values of these quantities in a space of R_o radius. The ratio of protons number (N_p) to neutrons number (N_n) in generalized complexes $(N_p/N_n)^p_i$ and $(N_p/N_n)_j$, are determined by equation

$$(N_p/N_n)_i-(N_p/N_n)_j=(m_n-m_p)/m_e$$

2. Energy of the generalized photon is reduced in accordance with equation

$$E = E_o/\exp(Ht)$$

Owing to existence of the unstable elementary particles a geometrical complex with energy $E_f=\sqrt{E_aE_b}$ arise. The "electrical" (E_a) and "magnetic" (E_b) constituents of this complex satisfy the equations:

$$e^2=\lambda_o E_a\exp(HR_o/c); \quad (E_o-E_2)1\varphi/c = E_b t_\mu;$$
$$E_b t_\mu = E_a t_n; \quad E_1(m_{\pi^+}-m_{\pi^o})/m_e=\sqrt{E_aE_b};$$

3. A mean-geometrical complex also exists in the form of a "Habbl's particle" with inertia force $F_v = m_v Hc$ equal to a force of gravitational interaction between two such particles at distance r_v one from other.

4. A space is possessed a latent mass by amount m_f on each mean-geometrical complex. A total latent mass $M_f=m_f N_f(4/3)\ R_o^3$, where $N_f=1/\ ^3_f$.

5. A process is going on in accordance with equations:

$$[(E_oR_1/E_aR_o)-M_o/M_c](E_oR_1/E_aR_o)^{-1}=R_3^3R_9^{-2}R_3^{-1}-1$$
$$[(M_o/M_c)-(E_oR_1/E_aR_o)](E_oR_1/E_aR_{o1})^{-1}=R_{32}^3R_o^{-3}$$
$$[(E_oR_1/E_aR_2)-M_o/M_c](E_oR_1/E_aR_o)^{-1}=R_3^3R_9^{-2}R_3^{-1}$$
$$[(M_o/M_c)-(E_oR_1/E_aR_2)](E_oR_1/E_aR_o)^{-1}=R_3^3R_o^{-3}-1$$

We have elaborated 81 incomplete equations, which include 25 new parameters and 4 known parameters with unsufficiently defined values (H,R_o,M_o,M_c). The following calculation results were recieved on the basis of consecutive approximation:

$E_a=1.615\times10^{-15}$erg; $E_b=6.747\times10^{-7}$erg; $E_f=3.301\times10^{-11}$erg; $\lambda_f=0.123$ cm; $H=1.674\times10^{-18}s^{-1}$; $E_o=3.767\times10^{-12}$erg; $R_o=1.791\times$

$x10^{28}$cm; R_1=4.478x10^{26}cm; E_1=3.675x10^{-12}erg; R_2=0.895x10^{28}cm; R_3=1.241x10^{28}cm; m_f=1.884x10^{-32}g; m_v=3.690x10^{-32}g; r_v=1.92x 10^{-16}cm; T_a=2.9 K; T_b=2.1x10^7K; N_f=537.63 cm^{-3}; $(N_p/N_n)_i$= =7.389; $(N_p/N_n)_j$=4.859. Thus $R_2=0.5R_o$; $m_v=0.5E_f/c^2$; $\lambda_f=hc/E_o$; $E_f=m_fc^2+0.5m_vc^2$; $m_v=2m_f$; $M_f=0.983M_o$.

The calculated values of some parameters coincide with the known data: E_a= mean value of microwave photons energy; T_a= temperature of microwave background; T_b= low limit of nuclear synthesis temperature; $(N_p/N_n)_i$=mean ratio of the proton and neutron numbers in cosmic gases; R_1,R_2,R_3= parameters of large-scale structure of the Universe [1] ; r_v= radius of electro-weak interaction. The parameters H, R_o, M_o define the constants $G=Hc/(M_o/R_o^2)$ and $h=(m_e^2/m_\mu)$ Hl_f^2. This constant may presented as follows:

$h=E\lambda/c=mc^2\lambda/c=mc\lambda=mHR_o\lambda_o=mHl^2=mc^2Hl^2/c^2=EHl^2/c^2=Et'$, where $t'=Hl^2/c^2$; $c=HR_o$; $m=E/c^2$; $R_o\lambda=l^2$; $\lambda=hc/E$.

As quantity λ/c in Planck's formula $E=hc/\lambda$ may be replaced by the expression Hl^2/C^2 and both quantities have a dimension of time, at the equality of numerical values l and c the last expression defines quantity $t'=t_f$, which is a natural scale of time, $t_f=Hl_f^2/c^2$, where l_f is a natural scale of length.

The values E_aR_o, E_aR_2, E_oR_1, M_o, M_c make up endless decimal fractions, which have the dimensionless quantities (-1/3) and (+2/3) as their limits.

The quantity E_f in $(m_n-m_p)/m_e$ times less then energy uncertainty $\Delta E_c=h/\Delta t_{\pi^0}=h/t_{\pi^0}$ and in $(m_{\pi^+}-m_{\pi^0})/m_e$ times more then E_o. Therefore the unstable elementary particles are formed a basis of a dynamic euilibrium between mean-geometrical complexes [2] and "Habbl's particles". A relatively great latent mass is one of the main factors of negentropic stage of the matter self-organisation process.

<u>Notation:</u>

t=time; c= speed of light in vacuum; h=Planck's constant; G=gravitational constant; H=Habbl's constant; e=elementary electrical charge; m_v= mass of "Habbl's particle"; t_μ, t_n=mean lifetimes of muon and neutron; l_f=natural scale of length; λ_f=linear size of a structural element with latent mass m_f; $E_o,E_1,R_1,R_2,R_3,T_a,T_b$=new parameters; $m_e,m_n,m_p,m_{\pi^+},m_{\pi^0}$=masses of elementary particles; $M_c=M_o-M_f$.

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MATHEMATICAL SIMULATION OF THE OPTICAL FIBRE DRAWING PROCESS

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ABSTRACT

The results of solution of interconnected hydrodynamic and thermal problems in the case of the optical fibre drawing process are given. The algorythm of the process stability's investigation is proposed, its effectivity is illustrated by corresponding numerical data

Most optical fibres are produced from a fused silica, or a doped silica preform rod, by peripherelly heating and drawing the rod along its axial direction [1] . These conditions yield a "neck-down" shape of the melting glass region within which velocity and viscosity vary both along and normal to the rod axis. To compute the axially symmetric fields of velocities and temperatures (viscosity dependence on temperature is unique and known) as well as unknown a priori boundary surface its necessary to solve Navier-Stokes and energy equations simultaneously.

To find the solution of the steady-state problem for the above-mentioned coupled equations the following iterative scheme is used. First, an arbitrary boundary surface is assumed - for example, from empirical data - for a given set of drawing conditions. So, the energy equation is solved to determine the temperature field within the adopted region and, hence, the corresponding viscosity field (due to known dependence between the temperature and viscosity). The next step is solving of the Navier-Stokes equations with known viscosity distribution. The determined velocities are substituted into the continuety equation to obtain an iterated boundary surface, calculations are repeated from the very beginning, and so on until solution converges.

Both energy and Navier-Stokes equations are solved with utilization of boundary integral equation method (BIEM) based on the theory of potential [2] . Thanks to BIEM we can, at first, avoid the discretizationof the problem in whole and act as more analytically as possible to establish a general relationships between the boundary values, and after that introduce an approximations. It is found that four or five iterations are sufficient when the numerical scheme begins an empirical shape as the arbitrary shape of the boundary surface. The results of computed temperature and velocity fields as well as corresponding neck shapes are obtained for the wide range of boundary conditions.

The investigation of the process's stability is conducted in the classical hydrodynamic sence:the reaction of the process to infinitesimal perturbations is determined [3] . According to proposed algorythm based on indirect BIEM, the eigenvalue problem for the linearized (about steady state) fundamental differential equations is reduced to the eigenvalue problem for Fredholm integral equation. The effectivity of this method is illustrated by numerical data represented in the plane of the process's dimentionless parameters: so-called draw ratio (fibre speed to rod speed ratio) and viscous forces to surface tension forces ratio. These results yield the possibilities for the statements of the process's optimization problems.

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Computer Model of Cluster in Crystal

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The all properties of the crystals and ceramic solid state in particular with high temperature superconductivity determine by the their electronic structure. The perfect crystalline lattice approximation for real crystals and so on can not be used and we must develope thy approach.

In our publications[1-3] we developed the cluster's analysis of the investigation of electronic structure (ES) of doped and defect crystals. Basic of the theory is the considere tion of ES of Cluster it include the central ion such as ions of iron, lanthan, actinium etc. groups (in shot nl-ions, where nl = 3d, 4f, 5f) and surroundings (ligand) ions. In first step we contain in Cluster only immediate surronding with explane of consideration for all cluster.

The mathemetical procedure of ab initio ES calculation is self-consistent field theory for clusters was developed by author [3-4] .

The foundations of our consideration are the next:

1. Choise of wave function of our cluster as antysymmetrical product of the ions wave functions. This wave function transform as the line or row of matrix of irreducible representation of definite point group.
2. Determination of expession for clusters energy.
3. Minimization of energy expression in one electron approximation and calculation of one elctron radial part of wave function.
4. Calculation of electronic density, energy and so on.

If the ligand-ligand interaction are neglected the wave function of our cluster are the following:

$$\Phi(n_1l_1^{N_1}\, n_2l_2^{N_2}\Gamma) = \hat{A}\,\varphi(n_1l_1^{N_1}\Gamma)\,\chi(n_2l_2^{N_2}\,\Gamma) \qquad (1)$$

and using the orthonormal basis of wave functions we can write down the expression for Clusters energy as:

$$E = E_1 + cE_2 + c'(E_z + E_c + E_{exc}) \qquad (2)$$

E_1 and E_2 are the free-ion energy of impurity and ligand, c - is the number of ligand. Expression for E_z, E_c and E_{exc} can be obtained using the theory of fractional parentage coefficient.

Minimization of expression (2) with boundary conditions of Vigner-Zeitsallow to put equations for radial parts of one electron wave functions. Common equation received in [3] . In this approximation calculated the optacal prooerties of doped crystals and ceramic with high corresponding to experiment

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A CLASS OF EXPLICIT MULTISTEP METHODS SUITABLE FOR INTEGRATING ODE's WITH LOW ACCURACY AND LARGE STEP

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Real-time simulation systems constantly requir numerically integrating the following nonlinear initial value problem

$$y'=f(t,y),\ y(t_0)=y_0,\quad y,f\in R^m,\ m\geqslant 1. \tag{1}$$

In this class of simulation systems, the accuracy requirment for numerical solution is not generally high, but there are real-time requirements for integration. Considering economic benifit and saving the expenses of computer hardware as much as possible, we have derived a class of explicit methods suitable for integrating Eq.(1) with low accuracy and large step, based on the assumption : the stiffness ratio of Eq.(1) is not very large.

Consider the general explicit linear 3-step methods of order 3

$$y_{n+3}-(a+b+1)y_{n+2}+(a+b+ab)y_{n+1}-aby_n$$
$$=h\left(\left(\frac{3-a-b-ab}{2}+d\right)f_{n+2}+\left(\frac{3ab-a-b-1}{2}-2d\right)f_{n+1}+df_n\right), \tag{2}$$

where a and b are real numbers or conjugate complex numbers which satisfy $|a|\leqslant 1$, $|b|\leqslant 1$, $a\neq 1$, $b\neq 1$ and that if $|a|=|b|=1$, then $a\neq b$, d is an arbitrary rea number.

Theorem 1. Let a and b be given, then if

$$d=d_1=-\frac{(a-b)^2+3(1-ab)^2}{4(3+a+b-ab)}, \tag{3}$$

the method (2) has the longest absolute stability interval which is

$$\left(-2\cdot\frac{3+a+b-ab}{3-a-b-ab},\ 0\right). \tag{4}$$

The error constant C_3 (Lambert [1], p.26) of the corresponding method satisfies $0 < C_3 < 1$ and when $a \longrightarrow 1$ and $b \longrightarrow 1$, $C_3 \longrightarrow 1$ but

$$\overline{C}_3 = \frac{C_3}{(1-a)(1-b)} \longrightarrow +\infty ,$$

where $\overline{C}_3$ is the error constant of the method in the sense of Henrici'definition ([2], p.266).

Observe that when a and b tend to unit, the interval (4) tend to ($-\infty$, 0), which means that the methods with sufficient large absolute stability interval can be obtained.

If a and b are given, then there exist an interval $\Delta(a,b)$ such that if $d \in \Delta(a,b)$, then stability regions of the methods (2) are simply connected regions, therefore we are interested in getting such d_2 and d_3 that

$$S(a,b,d_2) = \max_{d \in \Delta(a,b)} S(a,b,d), \tag{5}$$

$$Ih(a,b,d_3) = \max_{d \in \Delta(a,b)} Ih(a,b,d), \tag{6}$$

where for the methods which are given by a, b and d, S(a,b,d) and Ih(a,b,d) denote the area of the stability regions and the maximum height of the stability regions along the imaginary axis, respectively.

According to [3], the stability property of the methods which are derived by (5) or (6) is optimal in the sense of (5) or (6). We have numerically solved the problems (5) and (6) and have obtained some methods with better stability properties.

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A CLASS OF IMPLICIT LINEAR MULTISTEP METHODS
WITH A(α)-STABILITY PROPERTIES

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Consider the general implicit linear 3-step methods of order 3

$$y_{n+3} - (A+1)y_{n+2} + (A+B)y_{n+1} - By_n = h\left(\left(\frac{5+5B+A}{12} - d\right)f_{n+3} + \left(\frac{2-4B-2A}{3} + 3d\right)f_{n+2} + \left(\frac{-1+23B-5A}{12} - 3d\right)f_{n+1} + df_n\right), \quad (1)$$

where $A=a+b$, $B=ab$ and a and b are real numbers or conjugate complex numbers which satisfy $|a| \leq 1$, $|b| \leq 1$, $a \neq 1$, $b \neq 1$ and that if $|a| = |b| = 1$, then $a \neq b$. d is an arbitrary real number.

Let

$$q_1 = 1-11B-A, \quad q_2 = 1+B+2A, \quad q_3 = 1-A+B, \quad q_4 = (5+5B+A)(1-3B+A),$$

$$q_5 = -11(1+B^2)+26B+A^2-2A(1+B)$$

and two restricted conditions for a, b and d are

$$\text{(i)} \quad q_5 \leq 0, \; q_2 \geq 0, \; -\frac{q_4}{24q_3} \leq d \leq -\frac{q_1}{24},$$

$$\text{(ii)} \quad q_5 > 0, \; q_5^2 < 96(1-B)^2 q_2 q_3, \; \frac{q_5^2}{576q_3^2(1-B)} - \frac{q_4}{24q_3} < d \leq -\frac{q_1}{24}.$$

Then the following results have been derived.

Lemma 1. If the methods (1) are A_0-stable, then $|a| < 1$ and $|b| < 1$.

Theorem 1. The methods (1) are A_0-stable if and only if a, b and d satisfy the restricted condition (i) or (ii).

Corollary 1. The implicit linear 3-step methods of order 3

$$y_{n+3} - (a+1)y_{n+2} + ay_{n+1} = h\Big(\Big(\frac{5+a}{12} - d\Big)f_{n+3}$$

$$+ \Big(\frac{2-2a}{3} + 3d\Big)f_{n+2} + \Big(\frac{-1-5a}{12} - 3d\Big)f_{n+1} + df_n\Big) \qquad (2)$$

are A_0-stable if and only if a and d satisfy

$$-\frac{1}{2} \leq a < 1, \quad -\frac{(1+a)(5+a)}{24(1-a)} \leq d \leq -\frac{1-a}{24}. \qquad (3)$$

Theorem 2. If a and d satisfy

$$-\frac{1}{2} < a < 1, \quad -\frac{a^2+a+1}{12} \leq d < -\frac{1-a}{24}, \qquad (4)$$

then the methods (2) are $A(\alpha)$-stable.

According to theorem 2, we can consider the following problems. Let $\alpha(a,d)$ and $\Delta(a)$ denote the α of $A(\alpha)$-stability for the methods (2) which be given by a and d and the interval

$$\Big[-\frac{a^2+a+1}{12}, -\frac{1-a}{24}\Big),$$

respectively. Then for $a \in (-\frac{1}{2}, 1)$, defined

$$\alpha(a) = \max_{d \in \Delta(a)} \alpha(a,d) \qquad (5)$$

It can be shown that when $a \longrightarrow 1$, $\alpha(a) \longrightarrow \frac{\pi}{2}$ and the error constant $C_4 \longrightarrow -\infty$.

We have numerically solved the problems (5) and have computed the coefficients and some parameters of the corresponding methods, such as

$a= -0.4$	$\alpha(-0.4)=51^\circ 51'$	$C_4= -0.06310$	$d= -0.06333$
$a= 0$	$\alpha(0) =78^\circ 28'$	$C_4= -0.11100$	$d= -0.06933$
$a= 0.6$	$\alpha(0.6) =88^\circ$	$C_4= -0.30500$	$d= -0.05533$
$a= 0.8$	$\alpha(0.8) =89^\circ 21'$	$C_4= -0.62167$	$d= -0.04933$
$a= 0.95$	$\alpha(0.95)=89^\circ 55'$	$C_4= -2.51920$	$d= -0.04471$

Remark that for the backward differentiation method of order 3, $a= \frac{7+i\sqrt{39}}{22}$, $b= \frac{7-i\sqrt{39}}{22}$, $\alpha=88^\circ 27'$, $C_4= -0.25$.

HOW TO MAKE A "HOME-SIMULATOR"

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There are some well-known simulation languages (for example CSMP) for studying the transient behaviour of continous dynamical systems. These languages can be used easily also by people, who aren't too much familiar with the technics of mathematical modeling. If somebody is able to create and to program the state-space models of his subsystems, he can also put them together with a short program.

On this poster a simulation processor will be shown - containing less then 100 FORTRAN statements. It can connect "r" number of subsystems, described with the general

(1) $\dot{\underline{x}}_i(t) = \underline{f}_i\,(t,\ \underline{x}_i(t),\ \underline{u}_i(t))$ (state eq.)

(2) $\underline{v}_i(t) = \underline{g}_i\,(t,\ \underline{x}_i(t),\ \underline{u}_i(t))$ (output eq.)

nonlinear state-space models (i=1,2,...,r). (In the present version dead-time is not allowed, but it can be extended easily to that.)

The principle of simulation is that there exists a final system of differential equations, describing the motion of the connected dynamical system. If it would exist explicitely, then a RUNGE-KUTTA method could be simply used for its numerical solution. But there is also an implicit way for that.

The connections are defined by the generally nonlinear

(3) $\underline{u}_i(t) = \underline{h}_i\,(t,\ \underline{v}_1(t),\ \ldots\ ,\underline{v}_j(t),\ \ldots\ ,\underline{v}_r(t))$

input equations in which the external input signals are represented by the single "t" variable. For example:

(4) $u_{3,1}(t) = \sin(t) + \mathrm{abs}(v_{1,2}(t)) * \exp(-t*v_{5,4}(t))$

where the first index refers to the subsystem, while the second index shows the vector-component.

By successive substitution of (2),(3) and (1) equations (eliminating now the dyrect $\underline{u}_i$ -dependence in eq.(2)) :

(5)
$$\dot{\underline{x}}_i = \underline{f}_i\,[t,\ \underline{x}_i,\ \underline{h}_i(\ t,\ \underline{g}_1(t,\underline{x}_1),\ \ldots\ ,\underline{g}_r(t,\underline{x}_r))] =$$
$$= \underline{f}_i^{o}\,(t,\ \underline{x}_1,\ \ldots\ ,\underline{x}_i,\ \ldots\ ,\underline{x}_r) = \underline{f}_i^{o}\,(t,\ \underline{x})$$

which shows, that the total $\underline{x}$ state-vector may occour in every subsystem's model. These equations (i=1,2,...,r) form together the the total state-space model of the connected systems.

The starting points of subvectors are stored in the LX, LU and LV pointer-vectors. For example:

(6)
$$\underline{x}^T = [\ \overbrace{\underset{\substack{\uparrow \\ LX(1)}}{x_{1,1}},\ \ldots\ ,x_{1,n_1}},\ \ \ldots\ldots\ \ \overbrace{,\underset{\substack{\uparrow \\ LX(r)}}{x_{r,1}},\ \ldots\ ,x_{r,n_r}}\ ]$$

Using the possibility of FORTRAN array-handling, we can localise the user's subroutines to the subsystem's vectors. For example:

```
      CALL OUTPUT (i, t, x(LX(i)), u(LU(i)), v(LV(i)))
C          ======                               -
```

which counts the eq.(2) for the i-th subsystem. And what the user writes:

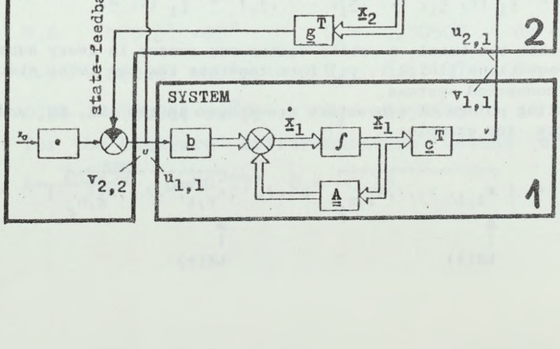
```
      SUBROUTINE OUTPUT (i, t, x, u, v)
C     ---------- ======            -
      DIMENSION  x(1),u(1),v(1)
C     -------------------------------------------------
      GOTO       (L1, ... ,Li, ... ,Lr), i
C     -------------------------------------------------
           :
           :
  Li  CONTINUE
      v(1) = x(2) + 15 * u(3) ...
      v(2) = ...
           :
      RETURN
```

The v(1),v(2),... values will be written to the appropriate places in the final $\underline{v}$ hypervector !

In the case of large subsystems, this statements may be replaced with the calling of a subroutine. Similar technics must be used at the INPUT (for eq.(3)) and at the FUNCT (for eq.(1)) subroutines, and at other three user-written communication segments.

The system below will be explaind in details on the poster.

This method can be regarded as state-space oriented one. It was developed to model the nonlinear dynamic behaviour of a boiler. Of course the principle can be realised also in other high-level programming languages.



SIMULAITION OF A NEW LOGISTICS SYSTEM

(R.Rafes, ARIAE, Vilnius, USSR)

Lecture deals with investigation into main control components in production-shipping-transportation-storage line, disclosing in the production-sales system reserves caused by poor optimization of interaction between these two sectors and developing methods for practical usage of the investigation results.

J.Apple, F.Bencovics, Y.Yuxiao, H.Stabenau, D.Atkins were engaged in separate aspects of this problem.

The strategy for solving a comprehensive problem of flow control is developed, theoretically substantiated and approved.. The quantitative dependences of relationship between order and product lot tonnage on the one hand extensive-intensive aspects of production transportation and supplies on the other hand are derived. The genesis of contract delivery with minimal costs duties execution problem is revealed and the stratified description of the problem is given, the abovementioned items allowed to select and substantiate the concept and structure of the system management. Proceeding from the conclution that industry-to-industry disconnection of enterprises is one of the main reasons for order execution level reduction a new management and control mechanism for improving performance co-ordination between works and service centres that expands the system abilities without additional capital investment is offered and substantiated in the work. The mechanisms is oriented to current costs saving in the system with efforts applied to the uniformity of flow rate. The tools for solving the problem that include the library of models, algorithms and software of tasks supporting systems control functions are offered.

The simulation model of the production-sales system functioning, models for products flow chart optimization, selection of a delivery form by a customer, order distribution from month to month, monthly planning for different variants of a system structure are developed. This is necessary for elaboration of the special class of CIM and Expert systems.

OPTIMIZATION OF MEASURING SYSTEM PARAMETERS IN GODYS PC SIMULATION LANGUAGE

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INTRODUCTION

The development of computer technique and the extension of its application to industrial systems of diagnosis and automatic control was followed by extended application and increased capabilities of industrial measuring systems. Measuring systems can measure more new quantities and the introduction of digital-circuit and microcomputer techniques makes the application of new measuring methods possible. Common application of measuring systems is related to the problem of introducing automatic designing of such systems. It should be based on computer analysis and optimization of mathematic system models. The introduction of this type of designing is conditioned by:measuring equipment unification, determination of practically useful quality criteria and the creation of proper software.

METHODOLOGY

The following work presents the methodology of computer- aided designing of measuring systems which has been applied by the author. The methodology is underlied by structural modelling of measuring systems and by the analysis and optimization of these models in GODYS PC simulation language. Accuracy criteria defined in the sense of total error, determined on errors of separate channels with regard to the goal of system functioning, were taken as quality criteria of modelled systems.

For example, quality criteria of n - channel measuring system may take the form of a sum or a maximum of every channel errors. However, if the system is assigned for the identification of model parameters of the measured object, other criteria taking into account identification process may be used as quality criteria, e.g. identification quality, parameter measurability etc.

GODYS PC language is a new implementation, on IBM PC computers, of the simulation language for dynamic continuous systems with discrete events. It was worked out in 1980 for simulation of measuring system models, including digital ones, too. The language possesses 52 standard operation selected in the way which would allow model simulation in the form of ordinary differential, linear and nonlinear equations. It also has models of impulse and digital parts in a structural form. Standard operation make it possible both to introduce optional inputs into the system and to realize quality criteria. Simulation results are presented in various graphic forms and in the form of a file which may be processed in other language.

GODYS PC language is equipped with an optimization up to five modelled system parameters according to the determined criterion. At present, there are two optimization methods (MGS and DSC). It is intended to complement them with some new ones.

EXAMPLE

A measurement system for d.c. motor identification has been modelled. Six parameters: field voltage, exiting current, current and voltage of rotor, rotational velocity and torque have been measured. During the simulation in GODYS PC language metrological characteristics system´s channels and several total errors were evaluated. On the base of criterion - system´s total sum error - an optimal choice of five parameters a measurement system was made. There were: separators limit frequency, word length of AD converter, nonlinearity class of rate generator, two resistances of multiplexer and sample-hold circuit. In simulation investigation a usage of GODYS PC language for computer optimization parameters of measurement system has been shown.

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