Prof. Dr. PAUL CONSTANTINESCU
Conf. Dr. Eng. EDUARD RĂDĂCEANU
"Ştefan Gheorghiu" Academy

The MIS as a Model of "Management and Managed System" in Class S_2

In the paper there is presented the Management Informatic System (MIS) as a system with two control loops, its properties (controlability, observability, stability), and some methodological notes regarding the MIS analysis, design and implementation for a satisfactory management of economic processes, and even more complicated systems, as socio-economic systems.

1. MIS STRUCTURAL DESCRIPTION

The MIS is considered in the paper as a model of the pair "management-managed system".

A scheme to represent the MIS in which are acting the principal aspects of the management atributes (prevision*), organization, personnel coordination and control) is given in Fig. I, where:

w_1 are inputs (perturbations) at the strategic-tactic level;
w_2 are inputs (perturbations) at the operational level;
x_1 is the state of the system at the strategic-tactic level;
x_2 is the state of the system at the operative level;
y is the output of the system at the strategic-tactic level;
y_1 is the output of the strategic-tactic level to the operative level;
y_2 is the output of the system at the operative level;
S_1 is the model of the controled system, at the strategic-tactic level, by consideration of the basic indicators;
S_2 is the model at the operative level of the controled process;
BD_1 is the decision block at the strategic-tactic level;

* By prevision we mean forecasting (long term), planning (medium term), and programming (short term).

BD_2 is the decision block at the operative level;

u_1 is the comand from the decision block BD_1;

u_2 is the comand from the decision block BD_2;

In this scheme S_1 and S_2 are images (models and data) of the managed system, and BD_1 and BD_2 reprezent all procedures for the comand synthesis

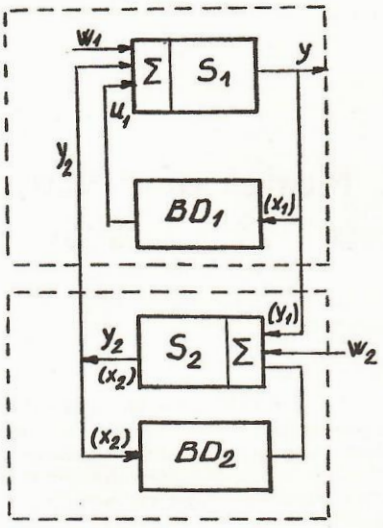


Fig. 1

(models), to build-up a program (trajectory) and for tracking the satisfactory trajectory.

In this way principal functions of the data base are the reprezentation of the system, and the procedures for the comand synthesis (using special models for that).

The MIS includes also means for gathering, transmision and data processing, and specific procedures for a satisfactory control of the system in real time.

In a management informatic system there are three phases:

— the choice of the objectives;

— the programming (by simulation) of possible evolutions and identification of the satisfactory trajectory accordingly with the objectives;

— the tracking of the trajectory in the real evolution.

These phases suggest the two loops structure (Fig. 1) of the management informatic system, each loop with its dominant function: trajectory programming and tracking respectively.

Such a system with two loops will be called a system in the class S_2.

In Fig. 2 we have transposed Fig. 1 by consideration of the data base and the decident's place in the MIS structure.

y represents the output of the MIS

w keeps the significance from Fig. 1

y_1 is the output spaced-out to the operative level

y_2 is the agreggated output to the strategic-tactic level

i_p is the informatic image of events in the controled process (maintenance of the data base)

i_s represents the maintenance and the interogation of the data base at the strategic-tactic level

i_0 as i_s but at the operative level.

u_1 is part of y, the comand from the strategic-tactic decision block acting via the decision block of the operative level

u_2 the same significance as in Fig. 1.

The first loop will be concerned with the evolution programming (plan proposed) and the control of the evolution at the strategic-tactic level, after the plan was adopted.

The second loop is concerned with the programming on shorter horizon and the tracking of the programmed evolution at the operative level. Here

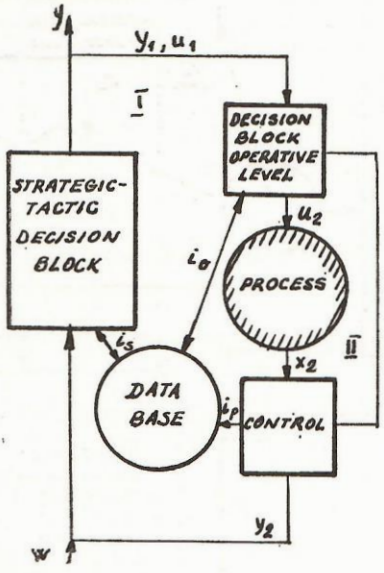


Fig. 2

differences from the programmed trajectory, or tendencies to be produced such differencies, call regulating actions (Fig. 3).

The synthesis of the trajectory is made at the strategic tactic level using inputs w_1 and agreggate reports (y_2) from the operative level, proving in this way the adaptive character of the scheme.

The connections between the system parts and the system and its environment (as y_1, y_2, w_1, w_2) are made through the data base (*BD*).

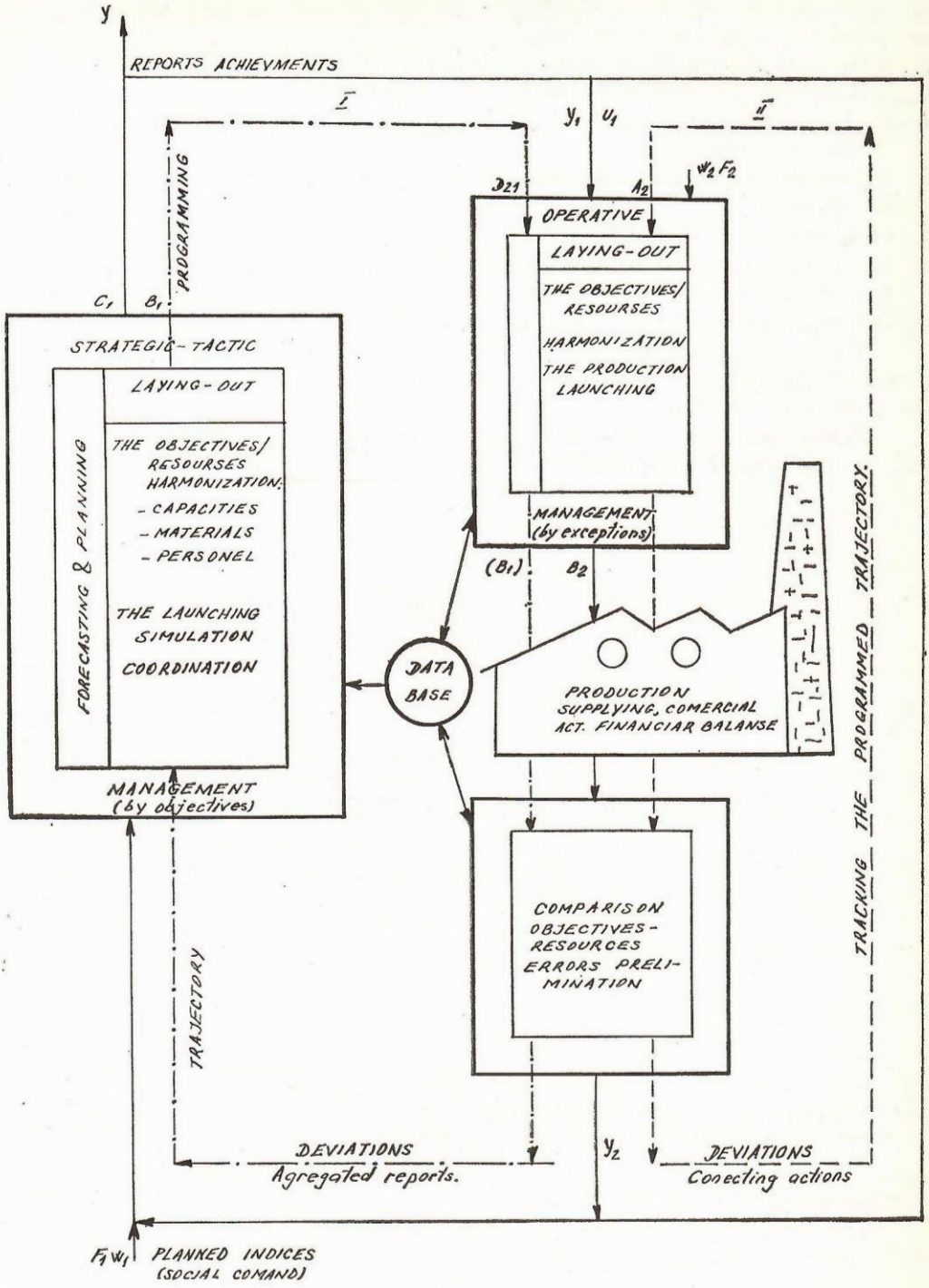

y
REPORTS ACHIEVMENTS
I
II
PROGRAMMING
C1
B1
STRATEGIC - TACTIC
LAYING - OUT
THE OBJECTIVES/ RESOURSES HARMONIZATION:
- CAPACITIES
- MATERIALS
- PERSONEL
THE LAUNCHING SIMULATION
COORDINATION
FORECASTING & PLANNING
MANAGEMENT (by objectives)
y1 u1
D21
A2
ψ2 F2
OPERATIVE
LAYING - OUT
THE OBJECTIVES/ RESOURSES
HARMONIZATION
THE PRODUCTION LAUNCHING
MANAGEMENT (by exceptions)
(B1)
B2
DATA BASE
PRODUCTION SUPPLYING, COMERCIAL ACT. FINANCIAR BALANSE
COMPARISON OBJECTIVES - RESOURCES ERRORS PRELIMINATION
TRACKING THE PROGRAMMED TRAJECTORY
TRAJECTORY
DEVIATIONS
Agregated reports.
y2
DEVIATIONS
Conecting actions
F1 ψ1
PLANNED INDICES
(SOCIAL COMAND)

Fig. 3

The first loop can be described in the first approximation as a linear system given by the equations (Fig. 3):

$$x_1(t_{k+1}) = A_1(t_k)x_1(t_k) + B_1u_1(t_k) + F_1w_1(t_k) + D_{12}y_2(t_k)^*$$

$$y_1(t_k) = C_1X_1(t_k)$$

where:

$x_1(t_k)$ represents the state of the system at the moment t_k;
$u_1(t_k)$ represents the comand which must be synthetised;
$y_2(t_k)$ is the output at the operative level at the moment t_k;
$w_1(t_k)$ is the perturbation at the strategic-tactic level (imposed inputs, a.s.o.);
$A_1(t_k)$ is the state variable processing matrix at the moment t_k
B_1 is the matrix which represents the control information filtering to act upon the state vector;
F_1 is the matrix corresponding to the perturbation gathering and filtering to act on the state vector;
C_1 is the matrix giving the output from the state vector;
D_{12} is the connection matrix between the first and the second loop (by agregation process).

Because the data and information gathering and transmision is determined by a structure which is more stable than the processing algorithms and data, we shall consider B_1, C_1, F_1 to be constant in the first aproximation.

We shall assume the pair "management — managed system" can be described by linear equation in first approximation.

The system represented by the second loop is described by the equation

$$X_2(\tau_{k+1}) = A_2(\tau_k)X_2(\tau_k) + B_2U_2(\tau_k) + F_2w_2(\tau_k) + D_{21}y_1(\tau_k)$$

$$y_2(\tau_k) = C_2X_2(\tau_k)$$

$y_1(\tau_k)$ will be assumed to be $y_1(t_k)$ if $t_k \leqslant \tau_k < t_{k+1}$

where A_2, B_2, C_2, F_2 are analogous to A_1, B_1, C_1, F_1, D_{21} is the connection matrix between the two loops (by spacing-out process).

S_I and S_{II} have different tact, $(t_k - t_{k-1})_1 > (\tau_k - \tau_{k-1})$, and it is considered these tacts to be divisible each other*.

By the notation $x = \begin{pmatrix} x_1 \\ x_2 \end{pmatrix}$, $y = \begin{pmatrix} y_1 \\ y \end{pmatrix}$, $u = \begin{pmatrix} u_1 \\ u_2 \end{pmatrix}$, $w = \begin{pmatrix} w_1 \\ w_2 \end{pmatrix}$

---

* This is allways possible, τ_i can represent a week or a decade eg., and t_j will be in this case the month, the quarter of a year, or the year, a.s.o.

So, in the equation of the first loop, $y_2(t_k)$ can be considered, for exemple, to be $y_2(t_k) = \sum_{i=1}^{n} \alpha_i y_2(\tau_{k_i})$ a sum of weighted values $y_2(\tau_{k_i})$ of the output y_2 on the time interval $t_{k+1} - t_k$; this form will represent the mechanism of spacing-out and aggregation.

we obtain:

$$\begin{pmatrix} x_1(\tau_{k+1}) \\ x_2(\tau_{k+1}) \end{pmatrix} = \begin{pmatrix} A_1(\tau_k) & 0 \\ 0 & A_2(\tau_k) \end{pmatrix} \begin{pmatrix} x_1(\tau_k) \\ x_2(\tau_k) \end{pmatrix} + \begin{pmatrix} B_1 & 0 \\ 0 & B_2 \end{pmatrix} \begin{pmatrix} u_1(\tau_k) \\ u_2(\tau_k) \end{pmatrix} + \begin{pmatrix} 0 & D_{21} \\ D_{12} & 0 \end{pmatrix} \begin{pmatrix} y_1(\tau_k) \\ y_2(\tau_k) \end{pmatrix} +$$

$$+ \begin{pmatrix} F_1 & 0 \\ 0 & F_2 \end{pmatrix} \begin{pmatrix} w_1(\tau_k) \\ w_2(\tau_k) \end{pmatrix}, \quad y(\tau_k) = \begin{pmatrix} y_1(\tau_k) \\ y_2(\tau_k) \end{pmatrix} = \begin{pmatrix} C_1 & 0 \\ 0 & C_2 \end{pmatrix} \begin{pmatrix} x_1(\tau_k) \\ x_2(\tau_k) \end{pmatrix}, \quad y(\tau_k) = \begin{pmatrix} C & 0 \\ 0 & 0 \end{pmatrix} \begin{pmatrix} x_1(\tau_k) \\ x_2(\tau_k) \end{pmatrix}$$

$A(\tau_k) = E$ for $t_k < \tau_k < t_{k+1}$ B_1, F_1, C_2 are considered only at the moments t_i, $i > 1$

$A(\tau_k) = A(t_k)$ if $\tau_k = t_{k+1}$, D_{12} is considered to act at the moments t_i, corresponding to the aggregated reports.

or,

$$(S_2) \begin{cases} x(\tau_{k+1}) = A(\tau_{k+1})x(\tau_k) + Bu(\tau_k) + Dy(\tau_k) + Fw(\tau_k) \\ y(\tau_k) = \bar{C}x(\tau_k) \end{cases}$$

or

$$(S_2) \begin{cases} x(\tau_{k+1}) = (A(\tau_k) + D\bar{C})\, x\,(\tau_k) + Bu(\tau_k) + Fw(\tau_k) \\ y(\tau_k) = \bar{C}x(\tau_k) \end{cases}$$

The equations (S_2) will be considered within the MIS in the class S_2 definition.

The condition for controlability is the matrix

$$(B\,(A + D\bar{C})B\;\; (A + D\bar{C})^2B \quad\; (A + D\bar{C})^{n-1}B)$$

to be nonsingular.

The condition for observability is the matrix

$$(\bar{C}\;\; (A + D\bar{C})^+\bar{C} \quad (A + D\bar{C})^{+(n-1)}\bar{C})$$

to be nonsingular.

The nonsingularity conditions can be found using the Hadamard's theorem.

The lemma if a matrix has negative dominant diagonal, all characteristic roots have negative real parts, can be used to find stability conditions for a system in the class S_2.

It is allmost obvious now that the principal task at the strategic-tactic level is to meet the objectives resources equilibrium and to programme the satisfactory trajectory, management by objectives being dominant at this level (Fig. 4a); at the operative level the tracking of this trajectory is done by management by exception method especially, to maintain the dynamic stability and good results in evolution (Fig. 4b), where x_0, x_f are the initial and final state, respectively:

..... is the trajectory designed at the strategic-tactic level by simulation,

———— is the trajectory programmed at the tactic level,

ε is the distance that ensures the dynamic stability.

The programming action at the tactic level is done by laying-out the tasks that result from general objectives established by the strategic management and by considering the resources allocated for every objective.

A scheme which represents the management atributes action is given in Fig. 5. It was necessary to consider differences between specific actions at

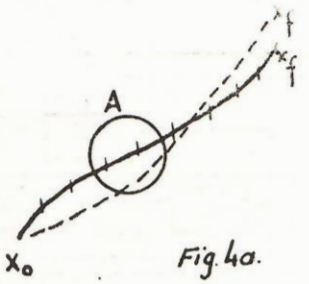


Fig. 4a.

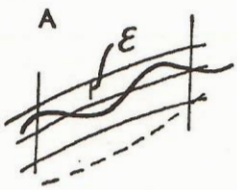


Fig. 4b.

every level of the hierarchical structure corresponding to a MIS (as a model of the pair management-managed system) as a start point for the mathematical modelling.

The management atributes at the strategic level can be found as objectives of the first loop, and those of the operative management are presented as objectives of the second loop level.

For a satisfactory management (trajectory) it is necessary and sufficient the resources/objectives harmonization (equilibrium).

The tracking of the programmed trajectory made mainly at the operative level, can be strict or only approximative. A strict tracking can lead to a rigidization of the management activities and can impede current development actions, or can on the contrary, to overload, may be in not an effective manner, the system components if the equillibrium between objectives and resources is frequentely altered.

Therefore it is desirable to be allowed to adjust on longer horizons than that of the operative level the programmed trajectory, to meet the needs of the resources/objectives harmonisation.

This action could be made by the tactic part of the management and is an important way in which it ensures the tracking ("glissage") of the satisfactory trajectory established by simulation at the strategic level.

Concerning the reports at the strategic-tactic level, they are made by data aggregation, synthetising data at the operative level in form of global indicators that describe at the level the controled object (enterprise, central, a.s.o.).

The hierarchization and descentralization described here have two aspects.

— ensure an operative and efficient management for every part of the system;

— ensure the harmonious operation of the system as a whole.

In Fig. 5 is given the structure of the controled system — its organisation corresponding to the action of blocks BCT_k — *whose function can be divided between BCS and* BCO_k — *and* BCO_k.

Concerning the informatic system design, we shall take care about the principle of the independence of this system and structures it serves, confering maleability by the possibility of different ways of aggregation and laying-out corresponding to different structures.

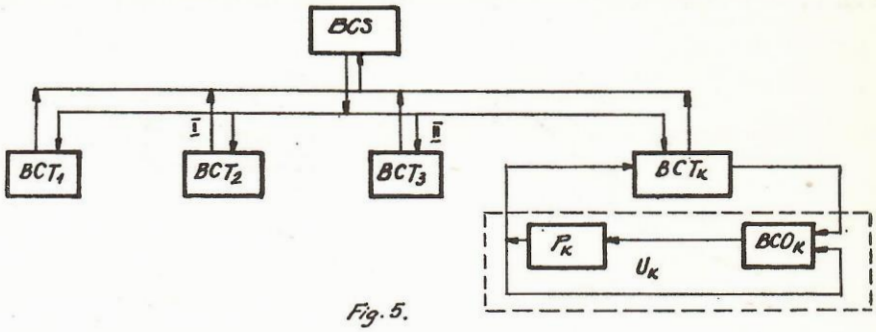


Fig. 5.

I... links of aggregation type
II... links of laying-out type
U_k ... tracking loops at the operative level
BCS ... strategic block with functions
- — the design by simulation of the system trajectory
- — the rebuilding of the system image as a whole for the coordination.

BCT_k ... tactic control block, corresponding to the part P_k of the process, which programmes the trajectory corresponding to this part of the system and to its specific objective given by the laying out process.
P_k ... part of the controled process
BCO_k ... block for operative control
U_k ... tracking loop for the part P_k of the controled process.

For complex systems this scheme may correspond only to a part of the informatic system consisting in a combination of such structured parts.

The MIS we propose (Fig. 2, 3), having associated the equations (S_2) lead to the integration of these levels of decision via data-base and the sequence models in the three blocks which are figured.

The MIS model must ensure also the link of the tactic level and the operative level.

Fig. 4, 5 argue once more the two loops structure adopted for MIS.

2. FORMAL DESCRIPTION OF MIS

In order to formalize structure of MIS we give the following definitions

Definition 1

We shall call vertical laying (spaceing-out) operation the set of transformations $\bar{x} = T_A^V x, \bar{u} = T_B^V u, \bar{y} = T_C^V y, \bar{w} = T_F^V w$ where the matrices T_A^V, T_B^V, T_C^V T_F^V, T_D^V are nonsingular (if necessary previously squared)* and perform the transformation of the matrices A, B, C, D, F from the equations (SI) or (SII) in the following matrices respectively.

* or for which we shall consider to exist the generalized inverse (e.g. in Penrose's sense).

$$\mathcal{A} = \begin{pmatrix} \bar{A}_1 & \\ & \bar{A}_2 \end{pmatrix}, \mathcal{B} = \begin{pmatrix} \bar{B}_1 & 0 \\ 0 & \bar{B}_2 \end{pmatrix} \mathcal{D} = \begin{pmatrix} 0 & \bar{D}_{12} \\ \bar{D}_{21} & 0 \end{pmatrix}, \mathcal{F} = \begin{pmatrix} \bar{F}_1 & 0 \\ 0 & F_2 \end{pmatrix}, \mathcal{C} = \begin{pmatrix} \bar{C}_1 & 0 \\ 0 & \bar{C}_2 \end{pmatrix}$$

The vector dimension is generally increased.

Definition 2

We shall call vertical aggregation the inverse operation of the vertical space-out operation.

Definition 3

We shall call horizontal space-out operation the set of transformations

$$z = T_A^h x,\ v = T_B^h u,\ w = T_F^h w,\ \gamma_{1(2)} = T_D^h y_{1(2)},\ \gamma_{2(1)} = T_C^h y_{2(1)}$$

$$\text{where } T_A^h = \begin{pmatrix} T_{A_1}^h \\ T_{A_k}^h \end{pmatrix}, T_B^h = \begin{pmatrix} T_{B_1}^h \\ T_{A_l}^h \end{pmatrix} a \cdot s \cdot o;\ T_A^h,\ T_B^h,\ T_D^h,\ T_C^h$$

admit the generalised inverse.

Definition 4

We shall call horizontal aggregation the inverse operation of the horizontal space-out operation.

By space-out model we understand a vertical and/or horizontal space-out operation.

By aggregation model we understand a vertical and/or horizontal aggregation.

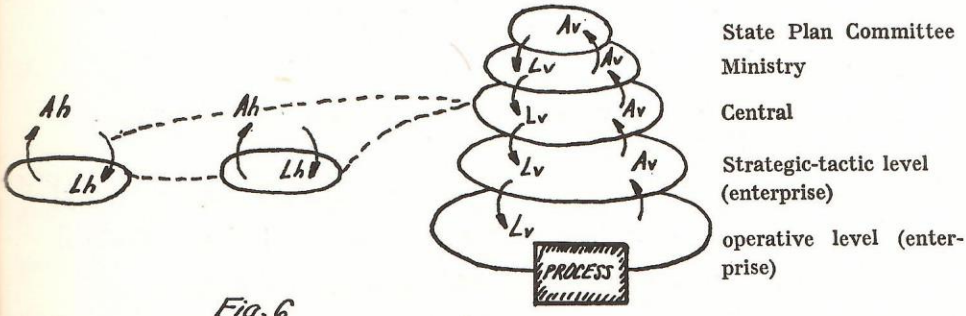


Fig. 6

Definition 5

We shall call MIS in the class S_2 a MIS structured as in Fig. 3 having associated the equations (S_2) and two subsystems having associated the equations (SI) and (SII) connected by the space-out and aggregation models.

If we consider the managed system (e.g. enterprise) at the most inferior loop we have usually to deal with chains of loops as in Fig. 6.

Considering this figure we can see that in respect with a loop of SII type at any level which is tracking a trajectory given by spaceing (laying)-out (L) all the superior loops can be assimilated with a single loop of SI type in which is designed the trajectory.

Conversely, at any level, in respect with a loop of SI type all the loops up to the operative level which includes the managed system can be assimilated with a single loop of SII type due to the A_v and L_v models.

Also we can see that a SII loop has always a single SI master loop, but each SI loop has several SII loops which can be assimilated as a single SII loop by the Lh and Ah models.

These remarks lead us to the result that we can consider the MIS in class S_2 as an implementing methodology of MIS.

We shall prove this result in the following propositions:

Lemma 1

The vertical spaceing-out and aggregation keep the S_2 (SI and SII) system equations invariant.

Lemma 2

The horizontal spaceing out and aggregation keep the S_2 (SI and SII) system invariant.

The proof of these two lemmas is given in the apendix; concerning planar conections between S_2 systems we can prove the following theorem about the invariance of the S_2 type equations.

THEOREM I

The cascade, parallel and bridge combination of S_2 systems rest in the S_2 system class.

Proof

Let prove that two S_2 systems linked in cascade give a S_2 system.

Let S_{21} and S_{22} be S_2 systems, given by the equations

$$(S_{21})x_1(t_{k+1}) = A_1x_1(t_k) + B_1u_1(t_k) + F_1w_1(t_k) + D_1y_1(t_k);\ y_1(t_k) = C_1x_1(t_k)$$

$$(S_{22})x_2(t_k) = A_2x_2(t_k) + B_2U_2(t_k) + F_2w_2(t_k) + D_2y_2(t_k);\ y_2(t_k) = C_2x_2(t_k)$$

For the cascade linkage we consider $w_2(t_k) = Hy_1(t_k)$

so
$$x_2(t_{k+1}) = A_2x_2(t_k) + B_2u_2(t_k) + F_2Hy_1(t_k) + D_2y_2(t_k)$$

$$y_2(t_k) = C_2x_2(t_k).$$

By the notation $x = \begin{pmatrix} x_1 \\ x_2 \end{pmatrix}$, $u = \begin{pmatrix} u_1 \\ u_2 \end{pmatrix}$, $A = \begin{pmatrix} A_1 & 0 \\ F_2HC_2 & A_2 \end{pmatrix}$, $B = \begin{pmatrix} B_1 & 0 \\ 0 & B_2 \end{pmatrix}$, a.s.o.

we obtain: $x(t_{k+1}) = Ax(t_k) + Bu(t_k) + Fw(t_k) + Dy(t_k)$

$$y(t_k) = Cx(t_k).$$

which are S_2 system equations.

The proof is analogous for input-parallel connection ($w_1(t_k) = Gw_2(t_k)$), output-paralel connection ($y = y_1 + Ky_2$) or bridge connection ($\tilde{w}_2 = w_2 + Ly_1$, $\tilde{w}_1 = w_1 + My_2$)

The 1st consequence

From lema 1, lema 2 and theorem I results the invariance of the S_2 system equation.

The 2nd consequence

The invariance of the S_2 system equation allows the reduction of a n-levels hierarchic system created by aggregation and laying-out process to a S_2 system (by considering the strategic-tactic, respectively the operative loop a S_2 system).

3. THE CHOICE OF THE PERFORMANCE INDEX AND THE OPTIMAL SYNTHESIS

We assume that the evolution between the initial and the final state is made in n steps and the overall cost of the data base and models utilization is a quadratic function of the difference between the actual state and the final target state, and of the decision effort, which depends on the same diference.

Therefore we adopt for the first loop the performance index

$$J_1(x_1, u_1, t_0, t_n) = \frac{1}{2}\, x_1'(t_n)\Lambda_1 x_1(t_n) + \frac{1}{2}\sum_{i=0}^{n}[x_1'(t_i)Rx_1(t_i) + u'(t_i)Qu(t_i)]$$

where Λ_1, R_1, Q_1 are quadratic positive definite matrices.

For the tracking mode of the system we adopt the performance index

$$J_2(x_2, u_2, \tau_0, \tau_n) = \frac{1}{2}\,(y_2(\tau_n) - y_{2d}(\tau_n))\Lambda_2(y_2(\tau_n) - y_{2d}(\tau_n)) + \frac{1}{2}\sum_{i=0}^{n}[(y_2(\tau_i) -$$

$$- y_{2d}(\tau_i))R_2(y_2(\tau_i) - y_{2d}(\tau_i)) + u_i(\tau_i)Q_2u_2(\tau_i)]$$

where $y_2(\tau_i)$ represents the programmed output at the moment τ_i and $y_{2d}(\tau_n)$ is the desired output at the moment τ_i.

R_1, R_2, Λ_1, Λ_2, Q_1, Q_2 are in the data base. These matrices reflect the process of data and information aggregation and laying out.

The matrices A, B, C reflect the actualizing, and respectively, maintenance process of the data base and respectively the gathering and the process of the state information.

The matrices R_1, R_2, Λ_2, Λ_1, Q_1, Q_2 are very important in the optimal synthesis and reflect the cost of the transition from the initial state to the final state. This cost depends upon the equipment (hardware) and the software used.

The S_2 structure of the MIS leads to a descentralization of the management and to two level hierarchization in the same time, which integrate and

polarize dynamicaly the management atributes; the principal task of the strategic-tactic management is not only to coordinate the subsystems of the whole system (as in [7,] [8] but to realize an important part of the prevision and control at this level as well.

The control at the operative level is made by the operative management.

The satisfactory management is realized by the harmonization of objectives and resources and by keeping performance index at a satisfactory value.

The hierarchization can be made with a greater number of levels but it can be proved that exist an optimal number of levels (by analogy with [11]; by using lemma 1, lemma 2, and theorem I, we obtain the results that for satisfactory management S_2 is invariant at any level we design and implement a MIS, that is a multilevel system built up using the aggregation and space-out (laying-out) processes, can be reduced to a S_2 system.

Keeping the S_2 system definition equations, the optimal comand low for the trajectory programming mode is:

$$u_{1k} = -(Q_1 + B_1' P_{1n-k} B_1)^{-1} B_1' (P_{1,\,n-k-1} A_1 x_{1,k} + v_{1,k});\ x_{1k} = x_1(t_k),$$

$$u_{1,k} = u_1(t_k) \text{ a.s.o}$$

where P_1 is the solution of the equation corresponding in the discret case to the Riccati equation (used in the continue system case): $P_{1,\,n-k} = R_1 +$

$$+ A_1'\ P_{1,\,n-k} A_1 - A_1' P_{1,\,n-k-1} B_1 (R_1 + B_1' P_{1,\,n-k-1} B_1)^{-1} B_1' P_{1,\,n-k-1} A_1$$

with the final condition $P_{1,0} = \Lambda_1$. $v_{1,k}$ verifies the equation $v_{1,\,n-k} = [A_1 +$

$$+ P_{1,\,n-k} B_1' (Q_1 + B_1' P_{1,\,n-k} B_1)^{-1} B_1'] v_{1,\,n-k-1} - P_{1,\,n-k-1} AFW_{n-k-1} -$$

$$- P_{1,\,n-k-1} A_1 D_{12} y_2,\ v_{1,n} = 0.$$

For the tracking mode (the second loop) the optimal comand low is

$$u_{2,k} = -(Q_2 + B_2' P_{2,\,k+1} B_2)^{-1} B_2' (P_{2,\,k+1} A_2 x_{2,k} + v_{2,\,k+1})$$

where $P_{2,k}$ is the solution of the equation

$$P_{2,k} = C_2' R_2 C_2 + A_2' P_{2,\,k+1} A_2 - (B_2' P_{2,\,k+2} A_2)(Q_2 + B_2' P_{2,\,k+1} B_2)^{-1} B_2 P_{2,\,k+1} A_2,$$

$$P_{2,n} = C_2' \Lambda_2 C_2$$

and $v_{2,k}$ is the solution of the equation

$$v_{2,k} = C_2' R_2 y_{2d,k} + [A_2' - A_2' P_{2,\,k+1} B_2 (Q_2 + B_2' P_{2,\,k+1} B_2)^{-1} B_2')] v_{2,\,k+1} +$$

$$+ P_{2,\,k+1} A_2 F_2 w_{2,\,k+1} + P_{2,\,k+1} A_2 D_{21} y_{1,k};\ v_{2,n} = C_2' \Lambda_2 y_{2d,n}.$$

For both operating modes the comand low can be synthetised by a linear regulator (the low is linear in the state variables).

4. THE S_2 SYSTEM AND THE MANAGEMENT ATTRIBUTES FOR SATISFACTORY MANAGEMENT

We defined S_2 systems to be able to realize mainly the attributes of prevision and control, because the informal parts associated to the organization and personnel coordination are still important.

It seems that the design of the MIS as S_2 system is a necessary condition for an efficient management.

Because for harmonizing objectives-resources, that is for a good prevision of the satisfactory evolution, we need the trajectory synthesis (when perturbations occur) and then it will be necessary to track this trajectory, it is obvious that the MIS must have a structure able to realize these two major attributes.

Can a single decision block, in an one loop system, realize these functions?

For not complicated systems, for which the state vector has few components — that implies a low dimmension of the matrices A, B, C as well, the both functions of a S_2 system can be embeded in a single loop; we can reflect such situations in designing and implementing MIS systems.

For complex systems (the complexity of the system can be evaluated by the state vector dimmension) for which the agregation and laying out are necessary, the hierarchization become necessary.

Now, by using theorem I (the invariance of S_2 system), we can prove the *theorem II*:

The necessary and sufficient condition to realize the management attributes is the S_2 — type structure of the MIS

The definition of R, Q, Λ can be made by simulation, using a data base corresponding to the system we have to study, starting from different initial states and applying different input perturbations.

The cost of the state transition of the system will allow to appreciate, for a certain hardware and software and a certain data base, what R, Q and Λ represent, and if we are in the range of the satisfactory management.

We conclude that the theoretical base for a modularized design of the MIS can be ensured by the invariance of the S_2 equation

$$x(\tau_{k+1}) = Ax(\tau_k) + Bu(\tau_k) + Fw(\tau_k) + Dy(\tau_k)$$

$$y(\tau_k) = Cx(\tau_k)$$

which allow a typical analysis and design, by defining X, A, B, C, R, Q, Λ of the model; the implementation has to start with the first loop which will lead to a satisfactory management, gradually including the operative level, keeping for the performance index the satisfactory value.

Acknowledgement: The authors are in debt to prof. A. Halanay from Central Institute of Mathematics — Bucharest for useful remarks concerning this work.

APPENDIX

The proof of Lemma 1

The application of the spaceing-out operation between the loop of strategic-tactic type (SI) and a (SII) loop correspond to intermediate management levels creation.

The equation of the *SI* loop:

$$x_1(t_{k+1}) = Ax_1(t_k) + Bu_1(t_k) + Fw_1(t_k) + Dy_2(t_k)$$

$$y_1(t_k) = Cx_1(t_k)$$

after the change of variable $\bar{x}_1 = T_A^V x_1$, representing part of spacing-out operation (in the state space), becomes:

$$T_A^{V+}\bar{x}_1(t_{k+1}) = AT_A^{V+}\bar{x}_1(t_k) + Bu_1(t_k) + Fw_1(t_k) + Dy_2(t_k)\,*$$

$$y_1(t_k) = CT_A^{V+1}\bar{x}_1(t_k)$$

or $$\bar{x}_1(t_{k+1}) = T_A^V A T_A^{V+}\bar{x}_1(t_k) + T_A^V B u_1(t_k) + T_A^V F w_1(t_k) + T_A^V D y_2(t_k)$$

$$y_1(t_k) = CT_A^V\bar{x}_1(t_k)$$

or finally: $\bar{x}_1(t_{k+1}) = Ax_1(t_k) + T_A^V B u_1(t_k) + T_A^V F w_1(t_k) + T_A^V D y_2(t_k)$

$$y_1(t_k) = CT_A^{V+}\bar{x}_1(t_k).$$

By changing the variable $\bar{u}_1 = T_B^V u_1$ and the others ($\bar{w}_1 = T_F^V w_1$, $\bar{y}_2 = T_D^V y_2$). the equations become:

$$(*)\begin{cases}\bar{x}_1(t_{k+1}) = A\bar{x}_1(t_k) + T_A^V B T_B^{V+}\bar{u}_1(t_k) + T_A^V F T_F^{V+} w_1(t_k) + T_A^V D T_D^{V+}\bar{y}_2(t_k)\\ y_1(t_k) = T_C^V C T_A^{V+}\bar{x}_1(t_k).\end{cases}$$

If T_A^V, T_B^V, T_C^V, T_D^V, T_F^V are chosen to fulfill the following conditions

$$T_A^V A T_A^{V+} = \mathcal{A} = \begin{pmatrix} A_1 & 0 \\ 0 & A_2 \end{pmatrix} T_A^V B T_B^{V+} = \mathcal{B} = \begin{pmatrix} B_1 & 0 \\ 0 & B_2 \end{pmatrix}$$

$$T_A^V F T_F^{V+} = F = \begin{pmatrix} F_1 & 0 \\ 0 & F_2 \end{pmatrix} T_A^V D T_D^{V+} = D = \begin{pmatrix} 0 & D_{12} \\ D_{21} & 0 \end{pmatrix}$$

$$T_C^V C T_A^{V+} = C = \begin{pmatrix} C_1 & 0 \\ 0 & \bar{C}_2 \end{pmatrix}$$

we can rewrite (*) as SI and SII coupled loops equations obtained by vertical spaceing-out operation, that is, as S_2 system equations. The same way can be used for vertical spaceing-out at the SII level loop. To keep in mind that at the every inferior loop created by the spaceing-out operation the tact τ will be divisor of the tact t; let be $t_{k-1} \leqslant \tau_i < t_k$, $i = 1, \ldots n$, if there are n tacts at the SII level for a tact at the SI level. So $y_1(\tau_i) = y_1(t_{k-1})$ if $t_{k-1} \leqslant \tau_i < t_k$, a.s.o.

The vertical aggregation is the inverse of the vertica lspacing-out. We are to prove that starting with an S_2 system we can write equations for SI and/or SII loops.

The S_2 system equations:

$$x(t_{k+1}) = \mathcal{A}x(t_k) + \mathcal{B}u(t_k) + \mathcal{F}wt_k) + \mathcal{D}y(t_k)$$

$$y(t_k) = \mathcal{C}x(t_k)$$

---

* Because of the possible change of the dimension of vectors x, u, w, y, the inverse T_A^V ,a..s o are taken as generalized inverse (e.g. in Penrose sense $T \cdot T_{\,} = E$

with $\mathcal{A}$, $\mathcal{B}$, $\mathcal{C}$, $\mathcal{D}$, $\mathcal{F}$, defined by:

$$\mathcal{A} = \begin{pmatrix} A_1 & 0 \\ 0 & A_2 \end{pmatrix}, \mathcal{B} = \begin{pmatrix} B_1 & 0 \\ 0 & B_2 \end{pmatrix}, \mathcal{C} = \begin{pmatrix} C_1 & 0 \\ 0 & C_2 \end{pmatrix}, \mathcal{D} = \begin{pmatrix} 0 & D_{12} \\ D_{21} & 0 \end{pmatrix}, \mathcal{F} = \begin{pmatrix} F_1 & 0 \\ 0 & F_2 \end{pmatrix}$$

By considering $F_2 w_2 = D_{23} y_3 + \tilde{F}_2 w_2$, where y_3 can be seen as the connection between SII loop of the system and its subordinate loop (if it exists), the equations of the SII loop becomes:

$$x_2(\tau_{k+1}) = A_2 x_2(\tau_k) + B_2 u_2(\tau_k) + F_2 w_2(\tau_k) + D_{23} y_3(\tau_k) + D_{21} y_1(\tau_k)$$

$$y_2(\tau_k) = C_2 x_2(\tau_k)$$

The SI loop equations are:

$$x_1(t_{k+1}) = A_1 x_1(t_k) + B_1 u_1(t_k) + F_1 w_1(t_k) + D_{12} y_2(t_k).$$

$$y_1(t_k) = C_1 x_1(t_k).$$

We want to prove that the initial S_2 system is equivalent with a SI loop of a S_2 system whose SII loop is the subsystem whose output is y_3.

By coupling the S_2 equations:
with the equations:

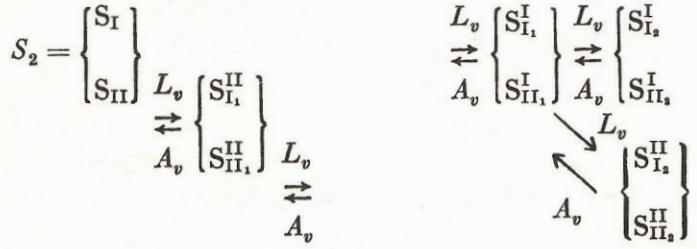
$$(**) \quad \begin{cases} x_3(\bar{\tau}_{k+1}) = A_3 x_3(\bar{\tau}_k) + B_3 u_3(\bar{\tau}_k) + F_3 w_3(\bar{\tau}_k) + D_{32} y_2(\bar{\tau}_k) \\ y_3(\bar{\tau}_k) = C_3 x_3(\bar{\tau}_k) \end{cases}$$

and considering $\tilde{\mathcal{F}} w = \mathcal{F} w + D_{31} y_3$ and $\tilde{\mathcal{F}} x = \mathcal{A} x + \mathcal{D} y = (\mathcal{A} + \mathcal{C}\mathcal{D})\ x$ we obtain:

$$(*^*_*) \quad \begin{cases} x(t_{k+1}) = \tilde{\mathcal{A}} x(t_k) + \mathcal{B} u(t_k) + \tilde{\mathcal{F}} w(t_k) + \mathcal{D}_{21} y_2(t_k) \\ y(t_k) = \mathcal{C} x(t_k) \end{cases}$$

which together with (**) form a S_2 equations set.
But $(*^*_*)$ can be considered as SI loop equation. *QED*
In the same way we can prove that S_2 system can be considered as SII loop, which illustrates the meaning of vertical spaceing-out and aggregation.

In Fig. 7 this concept is represented:



Where the superior index shows the origin loop of the S_2 system formed by laying-out operation and the inferior arabic number shows the ranck of the operation.

A_v means vertical aggregation

L_v means vertical laying (space)-out

A pair $\begin{Bmatrix} S^i_{I_j} \\ S_{II_j} \end{Bmatrix}$ represent a S_2 system created at the jth application, $i = $I or II, of the spacing-out operation at the S_i type loop.

Similarly we can represent the horizontal spacing-out and aggregation (Fig. 8).

$$S_2 = \begin{Bmatrix} S_I \\ \\ S_{II} \end{Bmatrix} \begin{matrix} L_h \\ \rightleftharpoons \\ A_h \end{matrix} \begin{Bmatrix} S_I \\ \\ S_{II_1} S_{II_2} \dots S_{II_k} \end{Bmatrix}$$

where $SII_1 \dots SII_k$ are SII type loops obtained by spacing-out at the SII oop level.

A_h represents the horizontal aggregation

L_h represents the horizontal spacing-out.

The proof of the 2nd Lemma

The S_2 system equations are written by coupling SI and SII loops.

Let
$$\begin{cases} x_2(\tau_k) = Ax_2(\tau_k) + Bu_2(\tau_k) + Fw(\tau_k) + Dy_1(\tau_k) \\ y_2(\tau_k) = Cx_2(\tau_k) \end{cases}$$

be the SII loop equations.

By horizontal spacing-out in the state space (by definition, the change of variable $z = T^h_A x$*) we obtain:

$$T^{h+}_A z_2(\tau_{k+1}) = A T^{h+}_A z_2(\tau_k) + Bu_2(\tau_k) + Fw_2(\tau_k) + Dy_1(\tau_k)$$
$$y_2(\tau_k) = C T^h_A z_2(\tau_k).$$

or,
$$z_2(\tau_{k+1}) = T^h_A A T^{h+}_A z_2(\tau_k) + T^h_A B u_2(\tau_k) + T^h_A F w_2(\tau_k) + T^h_A D y_1(\tau)$$
$$y_2(\tau_k) = C T^{h+}_A z_2(\tau_k)$$

We note:

$$v_2(\tau_k) = T^h_B u_2(\tau_k),\ w_2(\tau_k) = T^h_F w_2(\tau_k),$$
$$\gamma_1(\tau_k) = T^h_D y_1(\tau_k),\ \gamma_2(\tau_k) = T^h_C y_2(\tau_k).$$

Then,

$$\begin{cases} z_2(\tau_{k+1}) = T^h_A A T^{h+}_A z_2(\tau_k) + T^h_A B T^{h+}_B v_2(\tau_k) + \\ \quad + T^h_A F T^{h+}_F w_2(\tau_k) I T^{h+}_A D T^{h+}_D \gamma_1(\tau_k) \\ \gamma_2(\tau_k) = T^h_C C T^{h+}_A z_2(\tau_k) \end{cases}$$

---

* Here if T^h_A, T^h_A, a.s.o. are square T^{h+}_A, T^{h+}_B a.s.o. will be taken as true inverse T^{h-1}_A, T^{h-1}_B, a.s.o.

By the notation

$$T_A^h A T_A^{h+} = \mathcal{A} = \begin{pmatrix} A_1 & & 0 \\ & A_2 & \\ & & \ddots \\ 0 & & A_k \end{pmatrix}$$

$$T_A^h B T_B^{h+} = \mathcal{B} = \begin{pmatrix} B_1 & & 0 \\ & B_2 & \\ & & \ddots \\ 0 & & B_k \end{pmatrix}$$

$$T_A^h F T_F^{h+} = \mathcal{F} = \begin{pmatrix} F_1 & & 0 \\ & F_2 & \\ & & \ddots \\ 0 & & F_k \end{pmatrix}$$

$$T_A^h D T_D^{h+} = \mathcal{D} = \begin{pmatrix} D_1 & & 0 \\ & D_2 & \\ & & \ddots \\ 0 & & D_k \end{pmatrix}$$

$$T_C^h C T_A^{h+} = \mathcal{C} = \begin{pmatrix} C_1 & & 0 \\ & C_2 & \\ & & \ddots \\ 0 & & C_k \end{pmatrix}$$

we obtain

$$(*) \quad \begin{cases} z_2(\tau_{k+1}) = \mathcal{A} z_2(\tau_k) + \mathcal{B} v_2(\tau_k) + \mathcal{F} w_2(\tau_k) + \mathcal{D}\, \gamma_1(\tau_k) \\ \gamma_2(\tau_k) = \mathcal{C} z_2(\tau_k) \end{cases}$$

where $z_2 = \begin{pmatrix} z_{21} \\ \vdots \\ z_{2k} \end{pmatrix}$ $z_{21}, \ldots, z_{2k}$ being vectors of certain dimensions.

Eq. (*) represents the set of SII type loops obtained from initial SII loop by the spacing-out operation.

As $\mathcal{D}\gamma_1 \sim D y_1$, the combination of SI loop with the (*) system gives S_2 system.

The proof for aggregation is immediate.

Given the set of SI type loop equations:

$$(**)\quad \begin{cases} z_{2i}(\tau_{k+1}) = \mathcal{A}_i z_{2i}(\tau_k) + \mathcal{B}_i v_{2i}(\tau_k) + \mathcal{F}_i w_{2i}(\tau_k) + \mathcal{D}_i \gamma_{1i}(\tau_k). \\ \gamma_{2i}(\tau_k) = \mathcal{C}_i z_{2i}(\tau_k) \qquad i = 1, \ldots, k. \end{cases}$$

The aggregation is the transformation of the set of vectors z_{2i}, or the aggregate vector $z_2 = \begin{pmatrix} z_{2i} \\ \vdots \\ z_{2k} \end{pmatrix}$ into the vector x_2, by applying the operator T_A^{h}, $x_2 = T_A^{h+} z_2$.

The set of k equations of the (**) type can be written

$$\{ z_2(\tau_{k+1}) = \mathcal{A} z_2(\tau_k) + \mathcal{B} v_2(\tau_k) + \mathcal{F} w_2(\tau_k) + \mathcal{D} \gamma_1(\tau_k)$$

$$\gamma_2(\tau_k) = \mathcal{C} z_2(\tau_k)$$

where $\mathcal{A} = \begin{pmatrix} A_1 & & & 0 \\ & A_2 & & \\ & & \ddots & \\ 0 & & & A_k \end{pmatrix}$, $\mathcal{B} = \begin{pmatrix} B_1 & & & 0 \\ & B_2 & & \\ & & \ddots & \\ 0 & & & B_k \end{pmatrix}$, $\mathcal{F} = \begin{pmatrix} F_1 & & & 0 \\ & F_2 & & \\ & & \ddots & \\ 0 & & & F_k \end{pmatrix}$,

$$\mathcal{D} = \begin{pmatrix} D_1 & & & 0 \\ & D_2 & & \\ & & \ddots & \\ 0 & & & D_k \end{pmatrix}.$$

By applying T_A^{h+} transformation we obtain:

$$T_A^{h+} x_2(\tau_{k+1}) = \mathcal{A} T_A^{h+} x_2(\tau_k) + \mathcal{B} v_2(\tau_k) + \mathcal{F} w_2(\tau_k) + \mathcal{D} \gamma_1(\tau_k)$$

$$\gamma_2(\tau_k) = \mathcal{C} T_A^{h+} x_2(\tau_k)$$

or,

$$\begin{cases} x_2(\tau_{k+1}) = T_A^h \mathcal{A} T_A^{h+} x_2(\tau_k) + T_A^h \mathcal{B} v_2(\tau_k) + T_A^h \mathcal{F} w_2(\tau_k) + T_A^h \mathcal{D} \gamma_1(\tau_k) \\ \gamma_2(\tau_k) = \mathcal{C} T_A^h x_2(\tau_k). \end{cases}$$

If we note $T_A^h \mathcal{A} T_A^{h+} = \mathcal{A}_2$ and take into account the changes of variables $v_2 = T_B^h u_2$, $\omega_2 = T_F^h w_2, \gamma_1 = T_D^h y_1$

we obtain: $(*^*_*)$ $\begin{cases} x_2(\tau_{k+1}) = \mathcal{A}_2 x_2(\tau_k) + \mathcal{B}_2 u_2(\tau_k) + \mathcal{F}_2 w_2(\tau_k) + \mathcal{D}_{12} y_1(\tau_k). \\ y_2(\tau_k) = \mathcal{C}_2 x_2(\tau_k) \end{cases}$

where $B_2 = T_A^h B T_A^{h+}$, $F_2 = T_A^h F T_A^{h+}$, $D_{12} = T_A^h D T_D^{h+}$, $C_2 = T_c C T_A^+$.
The eq. $(*^*_*)$ combined with the SI loop equation give S_2 equation. So we can conclude that the spacing-out operation and aggregation at the SI or SII loop level mentain the transformed system as a system in S_2 class. This fact can have important consequences in the structural design of complex MIS.

REFERENCES

1. BEIU J., CONSTANTINESCU P., RĂDĂCEANU E., STĂNCIOIU I.: *Unele caracteristici ale concepției sistemice pentru conducerea unităților economice.* (Some Characteristics of the Systemic Conception for Management of Economic Units). Conducere-Decizie, no. 9—10, 1974, CIDSP.
2. BEIU J., RĂDĂCEANU E., STĂNCIOIU I.: *Considerații privind organizarea și conducerea întreprinderii socialiste.* (Considerations Regarding the Organization and Management of the Socialist Enterprises). Analele Academiei Ștefan Gheorghiu, vol. III, 1974.
3. CONSTANTINESCU P.: *Proiectarea și organizarea sistemelor de conducere cu mijloace de prelucrare automată a datelor.* (Designing and Organizing the Management Systems Using Automatic Means of Data Processing). Curs-Academia de Studii Economice, 1973.
4. CONSTANTINESCU P.: *Elemente tipizate utilizate în cadrul proiectelor de sisteme informatice* (Tipyfied Elements Used for the Design of Information Systems). Conducere-Decizie, no. 3, 1974.
5. CONSTANTINESCU P., EFTIMIE R.: *Structura bazei de date a sistemelor informatice din unitățile economice.* (The Structure of Data Base of the Information Systems Within the Economic Units). Conducere-Decizie, no. 6, 1974.
6. CONSTANTINESCU P., RĂDĂCEANU E.: *Caracterizarea sistemelor informatice în clasa S_2* (Characterizing the Informatiou System in S_2 Class) Analele Acad. Ștefan Gheorghiu vol. III 1974.
7. MESAROVIC M.: *A Conceptal Framework for the Studies of Multilevel Multigoal Systems.* Report SRS 101, 1—66—43, Case 1966.
8. MESAROVIC M., PEARSON J. D., MACKO D., TAKAHARA Y: *On the Synthesis of Dynamic Multilevel Systems.* Paper 40B, IFAC, London, 1966.
9. RĂDĂCEANU E.: *Contribuții la coducerea satisfăcătoare a sistemelor complexe.* (Contributions for the Management of Complex Systems). Teză de doctorat, 1970. Institutul de Energetică al Academiei.
10. RĂDĂCEANU E.: *Implicații ale abordării sistemice în analiza și proiectarea sistemelor informatice.* (Implications of the Systemic Approach in Analysing and Designing the Information Systems). Revista CEPECA, no. 4, 1973.
11. STRASZAK A.: *On the Structure Synthesis Problem in Multilevel Control Systems.* Proc. IFAC, Tokyo, Symp. 1965.
12. BELEA C., CĂLIN S.: *Sisteme automate adaptive și optimale.* (Automatic Adaptive and Optimal Systems). Editura Tehnică, 1972.

SYSTEME INFORMATIQUE POUR LA DIRECTION (SID) — MODELE DE LA DIRECTION ET DU PROCESSUS DIRIGE DANS LA CLASSE S_2

Les auteurs présentent le système informatique en tant que système dans la classe S_2, ses propriétés (possibilités de contrôle, d'observation et de stabilité dynamique) et certaines considerations d'ordre méthodologique concernant l'analyse, la synthèse et leur application en vue d'obtenir une direction adéquate des processus économiques.

ИНФОРМАТИЧЕСКАЯ СИСТЕМА УПРАВЛЕНИЯ (ИСУ) — МОДЕЛЬ В КЛАССЕ S_2 УПРАВЛЕНИЯ И УПРАВЛЯЕМОГО ПРОЦЕССА

В настоящей статье представлены информатическая система как система в классе S_2, ее свойства (контролируемость, наблюдаемость и динамическая устойчивсть) и некоторые соображения методологического порядка в отношении анализа, синтеза и улучшения их с целью удовлетворительного руководства экономическими процессами.

28 I. 1975