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HIERARCHY OF INFORMATION PROCESSING IN ORGANIZATIONAL SYSTEMS

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Abstract. An attempt to explain a basic nature of the information processing hierarchy in Organizational Systems is made. A framework for intelligent information processing at managing is presented. Organizational System (Enterprise) as the framework of so called elementary management cycles is decomposed. The structure of elementary management cycle (EMC) is presented and its properties discussed. A taxonomy of information processing hierarchies is based and presented. Such considerations seems to be important for the design of intelligent management information systems.

Key words: information processing, hierarchy, Enterprise, elementary management cycle.

1. Introduction. Although the term "hierarchy" is widely used in the area of information processing in the Organizational Systems it is rarely given a systemic analysis of that (Elzas, 1986; Mesarovic, 1970; Ackoff, 1971; Gudas, 1989). We shall offer an attempt at systemic investigation of information processes hierarchy in Organizational Systems which is oriented toward a pragmatic incorporating of intelligence into management information systems. Thus, the structural model of information units and their interactions at managing of Enterprise is needed. Such framework should include the hierarchical system of interactions between data, knowledge and objective items as well as between technological objects. It seems that investigation of the hierarchy of information processes in the Organizational System should have influence for the problem of intelligence of information systems as well as for the problem of artificial intelligence on the whole.

2. Peculiarities of Organizational System modelling. The analysis of information flow in Organizational Systems is complicated due to such features of that systems:

a) two interrelated technologies – technology of materials and energy processing (TMP), and technology of information processing (TIP) – are interacted;

b) both technologies can be conceptualized adequately only as multilevel hierarchical systems;

c) it seems that hierarchies of several types (for example, layers, stratas and echelons as presented by Mesarovic (1970) may be singled out;

d) processing of information is considered to be a complex item which consists of data, knowledge and objective components;

e) information manipulations at managing of Enterprise are intelligent because includes syntactic as well as semantical and pragmatical aspects of information.

Recently the requirements for the intelligence level of information systems are going up. Thus, a comprehensive frameworks for modelling of information processing in Organizational Systems are necessary. A systemic view to the management of Organizational Systems as to the hierarchical structure of information processing seems to be the one of possible points of view.

In order to make adequate decomposition of information processing in Enterprise the concept of Space of Processes (SP) was introduced (Gudas, 1991). The choice of three-dimensional SP was predetermined as a mean for representation of data, knowledge and objective items in all three aspects of information manipulations (syntactic, semantical, pragmatical) at managing of Organizational System. Some results of investigation based on such approach are presented in this paper.

As the basic unit of the management model presented in this paper an elementary management cycle (EMC) is introduced. The EMC is considered as the "systemic factor" in this approach, and may be considered as the "gene" of properties of the whole Organizational System. The EMC is supposed to be the smallest part

in partitioning the body of management process (a unit of management). A hierarchy of information processing in Enterprise as the structure of EMC is presented. Departments of Enterprise are considered to be "devices" for information processing and administrative hierarchy. Hierarchy of echelons (Mesarovic, 1970) as the sequel of information processing hierarchy is supposed.

3. Elementary management cycle as a unit of hierarchical structure. The elementary hierarchical cycle (EMC) is considered to be basic structural unit in the framework of information processing at managing of Enterprise. Formally the structure of EMC can be defined as diagram in notations of the theory of categories (Gudas, 1989) and is presented in Fig. 1.

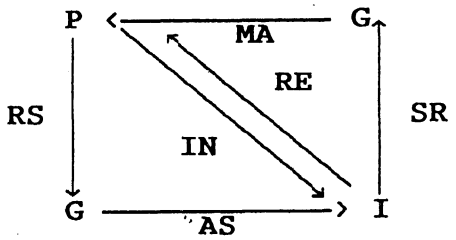

Fig. 1. The diagram of elementary management cycle.

The elementary management cycle consists of following elements: model of material-energy processing TMP (category P); model of information processing TIP (category I); structure of goals (objectives) of Enterprise (category G); process of restructuring of TMP in accordance with definite goal (morphism RS); process of aspectisation of TMP, i.e., semantisation of TIP in accordance with definite goal (morphism AS); process of interpretation as composition of RS and AS (morphism IN); process of decision structuring (morphism SR) and implementation of it (morphism MA) in accordance with definite goal; process of realization (morphism RE) as composition of SR and MA.

Suppose that all units of EMC are necessary – the managing of Enterprise doesn't fit within the quality if the lack of any unit of any EMC occur.

Decomposition of the EMC in the so called Space of Processes (Gudas, 1991) makes the data, knowledge and objectives interactions at managing evident (Fig. 2). The technology of material-energy processing (TMP) is related with technology of information processing (TIP) by feedback loop created by the interpretation (IN) and realization (RE). IN and RE are complex processes closely related with objectives of Enterprise located on the plane (AG, GE).

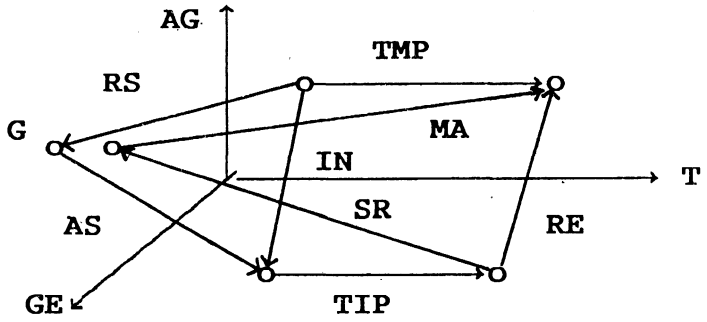

Fig. 2. Elementary cycle of management in the Space of Processes.

Interpretation (IN) of situation in TMP consists of the following two stages: restructuring (RS) of TMP (real world) to the set of equally important entities making no structure; aspectisation (AS), i.e., transformation of a set of entities into a certain semantic frame in accordance with a definite goal of investigation.

Realization (RE) of some managing solution consists of the following two stages: structuring (SR) of the managing solution in terms ("language") of some adequate subgoal, and materialization (MA), i.e., changing the state of TMP.

The principal feature of the Organizational System – the intelligence of information processes at management – is emphasized by this decomposition. This is confirmed by the character of such information manipulations as interpretation IN and realization RE. Namely the essence of interpretation is the acquisition of data and

knowledge from the real world (TMP) – semantic model of reality is established adequately to definite subgoal of managing. The realization of some managing solution is considered as the manipulation when semantic of solution by the way of its materialization is transformed adequately to the fixed goal (subgoal) of Enterprise (or department) and influence to the state of TMP is made. So all three aspects of information – syntactic, semantical and pragmatical – are included in information processing at management.

4. Organizational System as the hierarchy of elementary management cycles. The processes of aggregation (AG) and generalization (GE) divide the set of the EMC into levels and in this way two different types of EMC hierarchies arise in the Space of Processes: hierarchy of aggregation and hierarchy of generalization of EMC. Formally in such case each EMC is identified by two indexes: i – the number of aggregation level, and j – the number of generalization level. Naturally, the third index r for the type of activity of Organizational System must be included. The graphical representations of EMC hierarchies are presented in Fig. 3–5. In the Fig. 3 all activities $r, r+1, \ldots, r+n, \ldots, r+m$ are on the same level i of aggregation. Every mark $j, j+1, \ldots$ on the axis GE notes the level of generalization of EMC. Each single activity r may be managed by different number of EMC of various levels of generalization. Besides the generalization level of the same activity r may be different on different levels of aggregation as presented in Fig. 4.

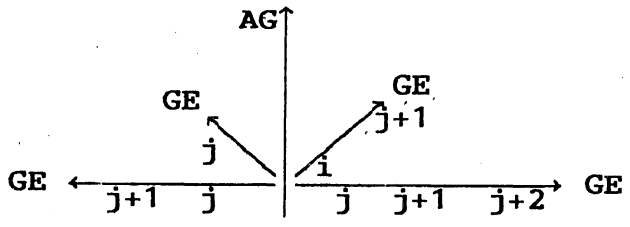

Fig. 3. The set of EMC of the same level i of aggregation.

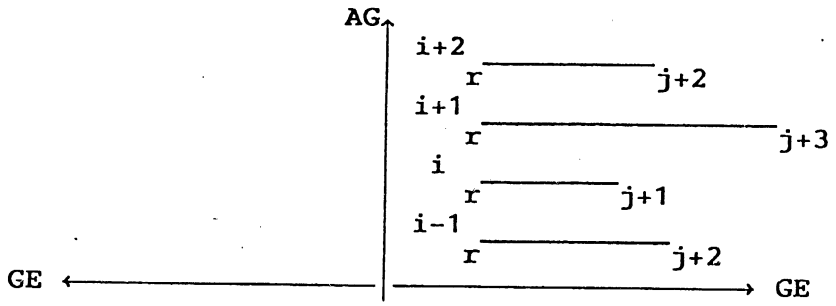

Fig. 4. The different level of generalization of the same activity r in different levels of aggregation.

And, finally the Organizational System as a system of EMC hierarchies is presented in Fig. 5. This is the graphical model of information processing hierarchy in Organizational Systems decomposed in the Space of Processes.

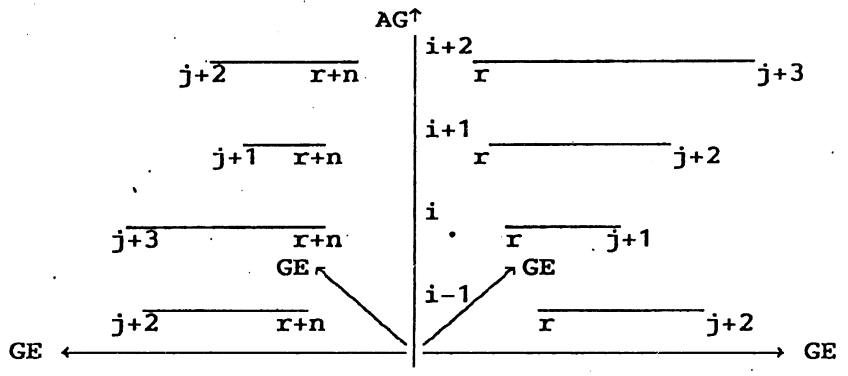

Fig. 5. The hierarchy of EMC as the model of management of Organizational System.

Several important features of the such hierarchical system of EMC must be outlined:

1. An interaction between two different EMC in this hierarchy may be realized as interface between any components of EMC

(Fig. 1). Thus, one EMC can make influence to another EMC through such its components:

a) technology of material-energy processing P;

b) interpretation IN;

c) data processing DP;

d) decision making DM;

e) realization RE;

f) structure of goals G;

g) data structures D of model I;

h) knowledge structures K of model I.

2. Every component of EMC forms its own hierarchies in directions if the axes AG, GE and T, so the hierarchy of aggregation, the hierarchy of generalization and the hierarchy of time levels arise.

3. The location of every EMC in the Space of Processes is characterized by: the number i of aggregation level; the number j of generalization level; the number t of time item. Thus, anyone EMC may differ from any other EMC by the level of aggregation, level of generalization and number of time period.

4. A set of EMC is implemented in Organizational System by a set of departments (or other units of administrative system). In general the correlation between the EMC and departments may be as follows:

a) a single EMC is carried out by one department;

b) a part of the EMC is carried out by one department, i.e. a set of departments implements one EMC;

c) some EMC are implemented by one department.

5. Information which is used for management of Organizational System can be divided into three diverse components: data, knowledge and objectives (goals). Every component has its own place in the Space of Processes: data and knowledge structures are closely related and placed (Fig. 2) on the plane (AG, T) and the plane (GE, T). The structure of objectives of Enterprise is placed on the plane (AG, GE) as separate structure, which is related with TMP and TIP by the processes of interpretation IN and realization RE.

Table 1. Taxonomy of hierarchies

	The units of EMC									
	IN		I		G	DP	DM	RE		P	
	RS	AS	D	K				SR	MA	TMP	TIP
AG	H_{IN}^{AG}		H_{I}^{AG}		H_{G}^{AG}	H_{DP}^{AG}	H_{DM}^{AG}	H_{RE}^{AG}		H_{P}^{AG}	
	H_{RS}^{AG}	H_{AS}^{AG}	H_{D}^{AG}	H_{K}^{AG}				H_{SR}^{AG}	H_{MA}^{AG}	H_{TMP}^{AG}	H_{TIP}^{AG}
GE	H_{IN}^{GE}		H_{I}^{GE}		H_{G}^{GE}	H_{DP}^{AG}	H_{DM}^{GE}	H_{RE}^{GE}		–	
	H_{RS}^{GE}	H_{AS}^{GE}	H_{D}^{GE}	H_{K}^{GE}				H_{SR}^{GE}	H_{MA}^{GE}	–	–

5. Taxonomy of hierarchies. The set of hierarchical relation types which take place in model of information processing shown in Fig. 5 is presented in Table 1.

Consequently, hierarchical structures of the following types may arise in the direction of aggregation process (Fig. 2):

– aggregation hierarchy of interpretation processes H_{IN}^{AG}

– aggregation hierarchy of data processing H_{DP}^{AG};

– aggregation hierarchy of decision making processes H_{DM}^{AG};

– aggregation hierarchy of realization processes H_{RE}^{AG};

– aggregation hierarchy of material units of technologies (products technology TMP and information technology TIP) H_{P}^{AG};

– aggregation hierarchy of H_{I}^{AG} of information elements of model *I*, which can be decomposed into two separate hierarchies of data items H_{D}^{AG} and knowledge items H_{K}^{AG}.

Theoretically several EMC may be located on the same aggregation level *i* for managing of the same object. In this way the generalization hierarchy for every stage of EMC arises. That may occur then several methods of different levels of abstraction are used to solve the same problem. Thus, the following taxonomy of generalization hierarchies of information units at management arises in Enterprise:

– generalization hierarchy of interpretation H_{IN}^{GE} which defines the abstraction levels of interpretation rules and procedures;

– generalization hierarchy of data processing H_{DP}^{GE} which defines the levels of abstraction of data structures and procedures;

– generalization hierarchy of decision making H_{DM}^{GE} which includes data, knowledge structures and procedures;

– generalization hierarchy of decision realization processes H_{RE}^{GE};

– generalization hierarchy H_{I}^{GE} of information elements of model I, which can be decomposed into separate hierarchies of data items D and knowledge items K: H_{D}^{GE} and H_{K}^{GE};

– generalization hierarchy of goals H_{G}^{GE} of Organizational System.

Complex processes IN and RE are compositions of RS, AS and SR, MA adequately (Fig. 1, 2), and so, hierarchies H_{RS}^{AG}, H_{AS}^{AG}, H_{RS}^{GE}, H_{AS}^{GE} and H_{RS}^{AG}, H_{AS}^{AG}, H_{RS}^{GE}, H_{AS}^{GE} are included in taxonomy (Table 1).

The taxonomy of hierarchies given above can be compared with that by Mesarovic (1970). For example, the hierarchy of layers can be expressed as both the aggregation hierarchy H_{DM}^{AG} and generalization hierarchy H_{DM}^{GE} of decision making; the strata's hierarchy is adequate for the aggregation hierarchy H_{P}^{AG} of technologies units. Other types of EMC hierarchies would be named too in order to outline the matter of them. For example, H_{IN}^{AG} may be named "the hierarchy of competence". H_{DP}^{AG} – "the hierarchy of decision support"; H_{RE}^{AG} – "the hierarchy of decision executives".

6. Hierarchical relations between departments. A set of EMC is implemented in Organizational System by a set of departments (or other units) of administrative system. The correlation between the EMC and departments can be various: a single EMC is carried out by one department; a set of departments implements one EMC; some EMC are implemented by one department. So, a set of the different types of information relations arises between departments.

For example, a set of types of relations between two departments when each of them implements all steps of EMC is presented in Table 2.

Table 2. The set of relation types between departments

N.	The basic types of hierarchical relations													
	H^{AG}_{IN}	H^{AG}_{I}	H^{AG}_{G}	H^{AG}_{DP}	H^{AG}_{DM}	H^{AG}_{RE}	H^{AG}_{TMP}	H^{AG}_{TIP}	H^{GE}_{IN}	H^{GE}_{I}	H^{GE}_{G}	H^{GE}_{DP}	H^{GE}_{DM}	H^{GE}_{RE}
1	+	−	−	−	−	−	−	−	−	−	−	−	−	−
2	−	+	−	−	−	−	−	−	−	−	−	−	−	−
...														
14	−	−	−	−	−	−	−	−	−	−	−	−	−	+
15	+	+	−	−	−	−	−	−	−	−	−	−	−	−
...														
16382	+	+	+	+	+	+	+	+	+	+	+	+	+	−
16383	+	+	+	+	+	+	+	+	+	+	+	+	+	+

The total number of different types of relations between two departments is very high: $2^{14} - 1 = 16383$. This is the best illustration of complexity of information processes at management.

7. Relation between the hierarchy of departments and generalization level of information. A set of departments of administrative system of organization usually is presented as equilateral triangle and the number of departments decreases as the level of their hierarchy (the level of aggregation) increases. What can be stated about the regularity of information generalization in different levels of administration? It seems it would be complicated to define the precise dependence, but some characteristic cases can be picked out (Table 2).

The level of generalization of information in Fig. 6a goes up together with the aggregation level of departments. It seems to be the most natural case in managing of Organizational System. It can be supposed that lower levels of generalization of information in the departments of the higher levels are not important and so, can be regarded (Fig. 6b). In the Fig. 6c the level of "competence" decreases as the aggregation level of departments increases (in organizations with the distinct bureaucratic character). The competence of the departments in middle levels of organization is the reason for efficiency (Fig. 6d) and the obstacle for improvement

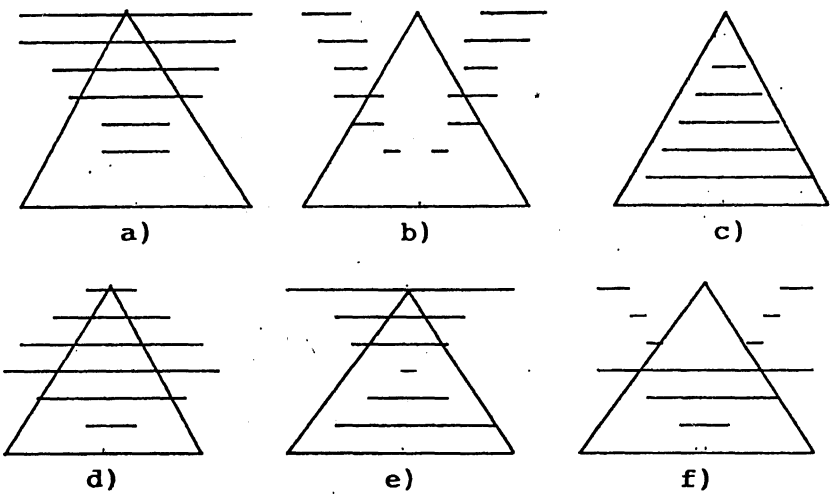

Fig. 6. The relation between the administrative hierarchy and the generalization level of information.

(Fig. 6e) of the situation. The Fig. 6f picks up the difference between information used in functional (specialized) departments on lower levels and in administrative departments on the higher levels of aggregation hierarchy.

8. Conclusions. This is the attempt at a theoretical foundation of framework for information processing in Organizational Systems which is oriented to incorporating intelligence into management information systems (MIS). The decomposition of information processes of management in the Space of Processes picks up that the interfaces of different information structures in management includes all three aspects of information: syntactic, semantical and pragmatical. It seems that this feature of information processing is nearly the basic for the intelligent processes. Thus, the framework discussed above emphasizes the main conceptual elements of intelligent information systems and interfaces between them.

The basic results of the approach to the problem of hierarchy of information processes in Organizational Systems presented in this paper are as follows:

1. The concept "hierarchy" has a sense only if the concrete space is considered. For example, the hierarchies of aggregation, of generalization and of time units are separated in the Space of Processes.

2. The reason for hierarchy in Organizational Systems are the processes of aggregation and generalization of information – data, knowledge and goal items. The administrative departments are supposed to be the bearers ("hardware") for these information processes ("software").

3. The elementary management cycle (EMC) is considered to be the basic unit of information processing hierarchy in Organizational Systems. Thus the Organizational Systems is supposed to be the hierarchy of EMC for various activities. All departments which implements the steps of one EMC are on the same levels of both hierarchies – the hierarchy of aggregation and the hierarchy of generalization.

4. The co-ordination of EMC located on the different levels of aggregation and generalization hierarchies are necessary to obtain the global goal of Organizational System. The co-ordination can be implemented by influence to everyone element of EMC in two different directions: along the axis of aggregation (AG) and along the axis of generalization (GE).

5. The framework of information processing hierarchy in Organizational Systems given above seems to be the structure suitable for the development of intelligent information systems.

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