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A Contribution to IS General Taxonomy

The term "Information System" has been used for a great number of different products of human mind designed to enable man to understand and control the events in his surroundings. Numerous classifications of ISs have been designed so far. They are based on various forms and characteristics of the existing systems, but they do not explain their origin and growth. In this study, preceded by a brief survey of the existing classifications, a new genetic taxonomy of IS is presented. It is based on those characteristics of ISs, which are important for their development and design. It also shows how the principles of genetic taxonomy can be applied to evaluate the complexity of new IS development and thus improve the understanding between IS designers and users.

Key words: information system, real system, business processes, taxonomy, classification.

1. Definition of the problem

Each scientific and professional field tries to arrange and classify objects of interest for study. By noticing common characteristics of apparently different objects, classification enables us to generalize the knowledge acquired by studying individual cases, thus being an extremly important procedure of scientific synthesis in a certain field. However, a single classification can not include all possible characteristics of some phenomena and that is why many scientists face the complex task of selecting classification characteristics of importance to a specific kind of research. In other words, each classification is made on the basis of a specific point of view and has a clearly defined goal which is determined by the nature of research.

As in other scientific fields, a number of different classifications have been designed in the field of IS. In the following section we are going to see that they are all related to the visible characteristics of the IS which has been completed. There is no doubt that all such classifications are relevant to the user of IS, since they explain its functional characteristics and internal structure. However, in order to design, develop and implement IS successfully, it is necessary to explain those characteristics of IS which describe the purpose of its existence, general process of its development and its genesis. So it seems necessary to develop a classification of the afore mentioned characteristics that will meet the needs of IS designers in a better way. This paper suggests the approach which, due to its origin is, called "genetic[1] taxonomy". The aim of this taxonomy is better understanding of the essence of IS (which is always a subsystem of the real system), developing an IS be more appropriate to the demands of the real system, built more quickly and efficiently and implemented with better effectiveness.

2. A brief look at the existing taxonomies

The influence of information technology (IT) on the whole range of economic and social activities has resulted in a great number of new types of ISs. Despite a lot of new classifications and taxonomies appearing to overcome the problem of classification of new types of ISs, it was often very difficult to make a broad range of new ISs fit in a little number of predetermined patterns. *Reed* and *Barrier* [Reed 94] point out the problem of as classification too narrow for such a great number of IS types. They broaden the classification by suggesting a two-dimensional matrix classification. In the rows of that matrix they put the type of support that the IS gives to a user (data processing, communications, supply of information and decision support) and in the columns we find system users (singleuser or individual, department or institution). The earlier example of two-dimensional classification was developed by *Scott* [Scot 85], but some new types of ISs cannot be fully included with in this taxonomy made more than ten years ago. Namely, *Scott* classifies ISs only according to the type of the problem (structural, nonstructural) and the level of management activity (operative, tactical, strategic).

An example of one-dimensional classification according to the time of its development, (in this way indirectly related to the level of used IT) was given by Ein-Dor and Segev [EinD 93]. This taxonomy (which gives 17 different IT types) can be considered as the one designed for business executives, providing the general insight into current developments in this field.

A complete review of the existing taxonomies is given in a postgraduate research paper at the *Faculty of Organization and Informatics* [Kozi 95] and in the already mentioned article by *Reed* and *Barrier* published in *Journal of Information Technology*.

The common characteristic of the afore mentioned taxonomies is their focus on technological, functional and working features of completed IS, such as they appear after their development and use. Hence, in accordance with the underlined note in the previous section, they could be called *descriptive taxonomies*. By no means trying to diminishi their value and importance for good understanding of functioning of IS in working environment, we must conclude that purely descriptive taxonomies are not sufficient to IS designers clarifying the reasons for developing IS and their origin.

[1] The term genetic has been chosen according to the term "genetic method". This is a philosophical approach oriented at analisyng and understanding some phenomenon in terms of its genesis or origin (as opposed to "descriptive method", which describes an object as it is).

They are not sufficient for understanding the initial and decisive life-cycle stage of their development.

3. Genetic definition and taxonomy of IS

Classification and systematization of certain objects is possible and reasonable only if a group of objects is uniquely defined by some common characteristics and the classification criteria are prevously determined. That is why we shall first discuss the definition and meaning of an *information system*, not only describing this object and its working behaviour when it is developed and implemented, but considering the reasons for its existence, development, source and origin.

3.1 Genetic definition of IS

The reason for the existence of an IS, its development process and its way of functioning can be properly and fully explained only if we start with examining the real system in which IS operates. As the model for discussion that follows in this paper, the most complex systems ever made will be taken: goal-oriented, dynamic, multi-level hierarchical systems with information-feedback and control, acting in unstable environmental conditions, having the characteristic of learning and self-organizing. Functioning, attributes and qualities of such systems have been well described many times in literature on this subject, e.g. in [Mesa 72] or [Habe 74]. This class of systems is sometimes called *organizational systems* by some authors that give a more detailed theory about their behaviour and functioning in an unstable environment [Burk 81]. Without going into a more detailed theoretical discussion we shall think of enterprises, banks, governmental, military and social institutions etc. as organizational systems. Each organizational system includes people, business processes and certain technical equipment (resources) and operates within some unstable environment in order to achieve some specific goals. In order to reach the previously defined set of goals, organizational systems carry out a great number of different (but mutually interlinked) processes, which shall be referred to as business[2] processes or *business technology*.

The principles of genetic taxonomy are based on the hypothesis, proved in previously mentioned literature, that for a purposeful and effective organizational system management a separately designed information subsystem is needed. The predetermined goals and the way of achieving them (or business processes in wider sense), as well as the internal organizational structure of the real system, determine its information subsystem. Therefore we can conclude that the tasks of information subsystem arise from the organizational system general model functioning, as shown in *Figure 1*.

[2] Business process is a set of mutually connected activities and decisions undertaken to achieve some specific parts of a common goal of the organizational system, for performing of which some resources and time are necessary.

Generally speaking, according to *Figure 1*, the total activities and decisions made in any organizational system and being mutually interrelated make a set of its business processes, which can be classified in to three levels:

- processes on the **decision** level,
- processes on the **management** level and
- processes on the **operational** level.

On the *operational level* a set of basic activities of a real organizational system is performed. These activities are visible from outside and make the system recognizable to the observer, e.g. transforming raw materials into end-products in a manufacturing firm, clients' money transactions in banks, diagnosis and patient treatment in hospitals etc. Through processes on the operational level *input flows* **I** are transformed into *output flows* **O**, and these flows represent the organizational system for its environment. In manufacturing systems these flows are of material nature, while within others they are financial (banks e.g.) or immaterial (schools, governmental institutions e.g.). The aim of each system is to *increase the efficiency* of this transformation i.e. to accomplish a task with a minimum loss of resources (material, energy, work, time, etc.). Speaking of enterprises, on this level profit is being made, depending not only on work efficiency on the operational level but also on the effectiveness[3] of the enterprise as a whole.

On the *management level* work is planned and organized, needs for resources are planned, their use is approved, the level of organizational system efficiency observed and the activities for removing disturbances (coming from the environment or from elements of internal structure of the real system on the performance level) are undertaken. For these activities management requires feedback-information about operational level activities I_a, information on system output effects I_o' as well as external disturbances. Based on this information and the set of goals N_d from the decision level, through the processes on management level the orders (or guidelines) N_o for work performance and use of entering resources N_r are given. The efficiency of organizational system as a whole depends on management quality. Speaking of an enterprise, the criterion for measuring efficiency is the profit made in the previous business year to be spent in the current year or in the course of the medium-term period.

Concerning the system management, a remark must be made stressing the fact that control and management would not be necessary if the processes on the operational level were fully determined and the external disturbances had no influence on them. But in that case we would have an automatic slot-machine (it means that for each given input a known output noned be obtained) instead of an organizational system. Further more, the notion of disturbance I_d should be taken here as any disturbance (or *noise*, technically speaking) coming from the environment and not only the one that diminishes the value of the output. As far as we think of disturbance in this way, it

[3] In this study *effectiveness* refers to the ratio between total output from the real system and total input in the real system, both variables being measured by the same unit (e.g. money).

could have a positive influence on organizational system, like e.g. increase in demand for products of a certain company.

On the *decision level* the goals, necessary for management processes are set in the form of principal decisions N_d. For a manufacturing firm it could be a decision about gained profit share, new product development or entering new markets. Information on the firm's business profile and transactions I_b and influence of environment I_e on it (e.g. market trends, financial sources, technologies available etc.) is needed for decision-making . The stability of any organizational system and its future growth and development depend on decision-making level quality.

There is a lot of data on organizational system state and its environment'; some of which are redundant, some incomplete and some unreliable. All data are liable to getting out of date, considering dynamics of changes in the system and its environment. The data must be collected, stored, the important ones selected, grouped and dispatched according to processes on the operational level; in other words, processed into information suitable for the management and decision-making level and, thus processed, sent to adequate levels. If there is a great amount of data and a great number of processes that need them, if algorithms of their transformation into information are complex and the time for decision-making short, a special subsystem of the real system must be built to carry out property and effectively all this work. The subsystem defined in this way is called an *information subsystem* of the real system. Its genetic definition therefore would be: ***An information subsystem is a subsystem of the organizational system, whose task is to link processes on the operational, management and decision-making level and the goal of which is improving performance efficiency, supporting good quality management and increasing decision-making reliability.***

Figure 1 shows that information subsystem is composed of a set of different flows symbolically marked by a group of arrows. It should be noticed that there are at least three different flows in the real system: **information**[4] **flow**, **orders**[5] **flow** and **resource flow**. On the other hand, in an information system these three flows are reduced to only two: *information flow* and *orders flow*. Namely, an information subsystem does not involve physical flows of resources but information on these flows (e.g. in an information system we do not deal with materials but with information on the flow of materials).

[4] *Information*, according to the theory of information, is a message with specific meaning for the receiver. The receiver decides if it is necessary, and how to take appropriate action.

[5] The *order* is information which obligates the receiver to particular action.

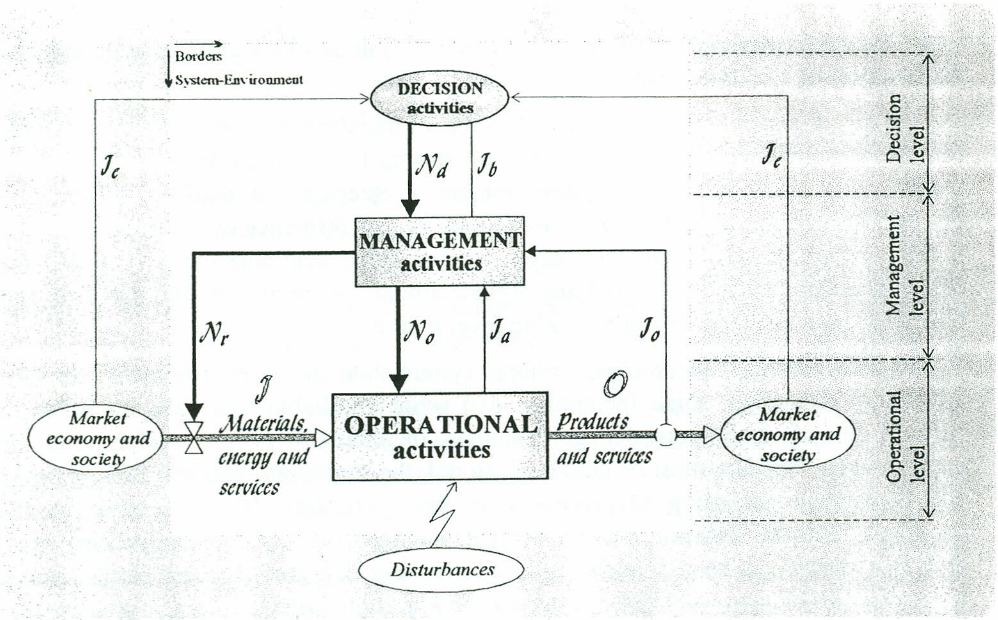

Figure 1: ***Organizational system and its information subsystem***

At this point certain dichotonomy occurs arising from the use of the term "information subsystem" and the usual term "information system". Do these expressions have the same or different meanings? The explanation should be based on the principles of the general theory of systems, which proves that each group of interlinked elements can be studied as a separate system, an condition that its bounds and links with the environment can be determined. Therefore, according to the genetic approach, the term "information subsystem" is correct because it implies it is being a part of the organizational system. On the other hand, it is acceptable to use the term "information system" (abbreviation IS) always when specific rules for its design, development, implementation and use are studied, on condition that its belonging to organizational system is constantly and undoubtedly clear. In accordance with this, we shall continue to use the term information system or the abbreviation IS but this will always imply that it is a subsystem of the real system.

In order to recognize the value of the genetic definition, let us go back to the *descriptive* definition of IS, which says: *Information system is a group of activities and procedures for collecting, storing, retrieving, processing and dispatching of information.* This definition describes IS through its functions, but tells nothing about its fundamental purpose and genesis; thus no matter how useful it is for the user it is still incomplete for the IS designer. Taking into consideration only these descriptive definitions, designers of IS's are in danger of implemeting a purely technological approach to IS development. In our opinion that is one of the significant reasons for inadequate efficiency of many IS during their application.

In accordance with the real-system organization, shown in *Figure 1*, the complete IS of an enterprise will consist of three linked subsystems, each of them supporting one process level. They are:

- operational information subsystem (OIS),
- management information subsystem (MIS) and
- decision-making information subsystem (DIS).

Information subsystem objectives are in principle different for each of the three realsystem levels, outlined in *Table I.* Understanding the nature of processes on each level of the realsystem and the special objectives of corresponding information subsystems is of essential importance for correct design of IS as a whole.

Table I: ***Characteristics and goals of IS's on different levels in the structure of the real system***

Information subsystem level	Information subsystem goals
OPERATIONAL- basic transformation processes	Improving the work efficiency
MANAGEMENT- organizing, monitoring and control	Improving the effectiveness of the real system as the whole
DECISION - setting the goals	Supporting the stability of the present real system, his future growth and development

The following conclusions, based on the previous discussions and patterns given in *Figure 1* and *Table I*, are of importance for a genetic approach to information system development and design:

a) An information system cannot exist by itself. It is always a subsystem of some real system. Each real system has its distinctive IS, which enables the optimal functioning of that particular system.

b) Each organizational system must have its information (sub)system, otherwise it would not be able to function, not to mention its growth and development. That is why IS design is most often described as the improvement of the existing one and very rarely (i.e. only when the fundamental goals of the real system are changed or a completely new one is being built) as a new IS development.

c) An IS is always a model of some organizational system business processes (or business technology). Thus a bought IS is successful by used only business processes in question are identical to the model used in developing the bought IS.

d) IS can be built on different technologies. Computer technologies are the most efficient, but not the only technological IS support. So far no IS has been built exclusively on computer technologies. The planned IS efficiency can be achieved only by well-coordinated and economical balancing between computer technology and other Kinds of support.

e) A considerable knowledge of organizational system structure and functioning is *conditio sine qua non* for its IS design, a fact too aften neglected. It often results in the fact that the design of a new (or the improvement of the existing) system begins by choosing new hardware or by programming and not with the analysis of the real system objectives, its business technology and its processes and data modelling.

3.2 Principles of genetic taxonomy

According to *Figure 1*, all IS subsystems do not have the same internal organization, since they do not have the same goal and do not support the processes of the same type. Generally speaking, three types of processes can be recognized in organizational systems:

- **determined processes with expected sequence** (e.g. delivery is followed by making invoices and both processes are determined by their contents, resources and performance time) which in business technology of organizational systems are most often well-determined by their form

- **determined processes with unexpected sequence** (e.g. new material ordering, its delivery into production or writing-off old stocks are disjunctive processes, one of which follows material stock checking etc.)

- **inventive type processes**, which are not determined in advance by their content and are of unpredictable occurrence and duration (e.g. replacing some materials in product structure).

Thus, the type of process to be supported by IS may be selected as the **first criterion** for its taxonomy and classification.

The task content and ways of completing these tasks on each level (the usual term is “function”) of the organizational system (operational, management, decision making) differ a lot. Indeed, many authors (see e.g. in [McLe 93] and others) have noticed that on each of these three levels of the organizational system “pyramid” all three types of processes are performed, but their share differs according to the level. For instance on the operational level, *determined processes with expected sequence* prevail, with some exceptions where the performer has to choose the mode of further performance. Modern principles of management, which are based on the principles of the initiative, authority and responsibility of smaller working groups, certainly include choice and decision making. On the other hand, the function of decision making cannot be based only on inventiveness of the one who makes decisions, without gathering facts. It seems that mixing up different types of processes on different levels was one of the obstacles in all previous IS classifications. Instead, we suggest the matrix picture of these relations, which explains why the functional levels (described as operational, management and decision-making), were selected as the **second criterion** for IS taxonomy.

The level of computer involvement in the processes and activities of the organizational system was selected as the **third criterion** for taxonomy. As a matter of fact the powerful IT development expands daily the list of computer supported processes, but some activities there are organized (this being a permanent tendency in some cases) by using classic technologies. Therefore, it is justified to select technological equipment as a separate criterion for IS taxonomy. Considering this, at least three technological levels can be distinguished:

- processes supported by non-computer technologies (*classic technologies*),

- processes supported by information technologies, where computers are used for collecting, storing, processing and dispatching of data and information (or *computers with data-base technologies*) and

- processes in which computers are bearers of knowledge necessary for performing different processes in the organizational system (or *computers with knowledge- base technologies*).

If these criteria are shown on a three-dimensional matrix, on orthogonal axes of three-dimensional Cartesian system, we get "**genetic taxonomy space**" (GTS) of information systems, or three-dimensional **v-r-t** space (where **v** stands for type, **r** for level and **t** for technology), shown in *Figure 2*.

Each of these 27 partial subspaces of genetic taxonomy space represents one group of information systems whose atributes differ from information systems, in other subspaces in three fundamental (genetic) characteristics. Reposition of each cube in genetic taxonomy space, here referred to as **genetic-taxonomical order** (GTO), of each IS is unequivocally determined by the value of three coordinates of genetic taxonomy space. In *Table 2* some typical and well-known developed information systems are mentioned with the determined genetic-taxonomical order ($R_{v,r,t}$). Thus e.g. classic system for computer-supported stock management (**M**aterial **R**equirements **P**lanning-MRP) is taxonomically determined by the set of elements whose classification parameter value is $R_{v,r,t}$ =[1,2,2] and new resources management system for manufacturing companies (**M**anagement **R**esource **P**lanning-MRP II) has the value of $R_{v,r,t}$ =[2,2,2]. For computer-supported **A**ccounting **I**nformation **S**ystem (AIS) is $R_{v,r,t}$ =[1,1,2]. Expert system for equipment maintenance can have $R_{v,r,t}$ =[2,2,3], while **A**rtificial **I**ntelligence systems (AI), based e.g. on neural networks, can reach the value $R_{v,r,t}$ =[3,3,3].

The basic characteristics of the proposed genetic taxonomy are its **openness** and **applicability in IS strategic planning**. Its openness is shown as external and internal. *External openness* enables extension on each of three GTS-axes by adding new discrete values to each classification parameter. These values are not necessarily integer, which is a point briefly elaborated in section 4 of this paper. *Internal opennes*, which is at this point manifested as all GTS subspaces vacancy in *Table 2*, enables determining genetic taxonomy order even for an IS not completed. In this respect the afore mentioned taxonomy reminds of D.I.Mendeleev's periodical system of elements.

Genetic taxonomy *applicability to IS strategic planning* is manifested as a possibility of selecting the values of certain classification parameters at the moment of approaching new IS development. By setting the classification parameter values it is possible to determine the goals of new IS in advance with more precision, and with less possibilityes of misunderstanding. In way chances for better understanding between an IS-designer and an investor are enhanced.

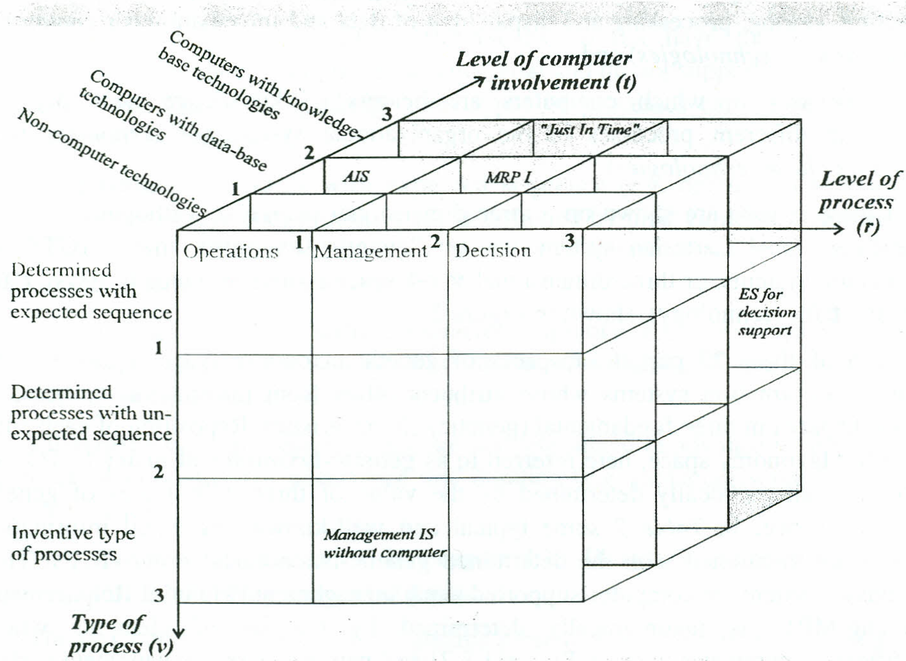

Figure 2: ***Genetic taxonomy space for different information systems***

Table II: ***Genetic-taxonomical order (GTO) for some information systems***

v	r	t	The name of information system	GTO-value
1	1	1	Accounting, not supported by computer	[1,1,1]
1	1	2	Accounting Information System (AIS)	[1,1,2]
1	1	3		
1	2	1		
1	2	2	MRP (Material Requirements Planning)	[1,2,2]
1	2	3	Japanese manufacturing concept "Just-In-Time"	[1,2,3]
1	3	1		
1	3	2		
1	3	3		
2	1	1		
2	1	2		
2	1	3		
2	2	1	Manufacturing control, not supported by computer	[2,2,1]
2	2	2	Manufacturing Resource Planning (MRP II)	[2,2,2]
2	2	3	Aeroplane or missile flight control (without pilot)	[2,2,3]
2	3	1		
2	3	2		
2	3	3	IS for equipment maintenance	
3	1	1		
3	1	2	Computer Aided Design (CAD)	[3,1,2]
3	1	3		
3	2	1		
3	2	2	Management Information System (MIS)	[3,2,2]
3	2	3		
3	3	1		
3	3	2		
3	3	3	Artificial Intelligence systems (AI)	[3,3,3]

4. Genetic taxonomy as a base for the assessement of IS development complexity

The space of IS genetic taxonomy, shown in *Figure 2*, is divided by discrete classification criteria values, placed on three orthogonal axes of the co-ordinate system. The basic metrics was chosen in such a way that the increase in value of each classification parameter is proportionate to the increase in complexity of planned IS, which should meet the set criterion. It is justified to surmise that the classification criteria are not necessarily the discrete integer values in the closed interval [0,3], but they could assume any value within this domain. IS whose development is to be approached, may be planned in the way that it mainly supports the processes on the operational level, but partly entering the decision-making level. In that case value greater than 1 e.g. $r = 1.25$ can be attached to classification criterion which refers to the level of process. In general, each classification criterion may be considered as the vector which lies in the direction of one co-ordinate axis, and whose absolute value expresses the degree of IS complexity which should meet the set criterion.

If we suppose that the complexity of development, design and implementation of a new IS depends on requested complexity of each classification criterion but also on their interaction, the common complexity S of a planned IS can be expressed as a *box product* of vectors that represent demands according to particular classification criteria, in other words:

$$S = (v \times r) \cdot t$$

Vector analysis has shown that such a box product gives space volume which is closed by three vectors. Thus we can conclude that the common IS complexity is proportionate to volume closed by classification criteria in the space of genetic taxonomy. Such an approach to development complexity assessement of a planned IS, based on analysing a set of independent factors, is similar in its concept to the so-called "Function Point Analysis" (FPA) which is, thoroughly, described in [Sall 95]. FPA has in fact become the international standard for planning new software and for the complexity assessement of the existing software, but is not applicable to predicting complexity of a new IS as a whole, which is still at the planning stage and must be developed. The authors believe, that here by proposed approach can also cover this problem.

5. Conclusion and guidelines for further research

The brief review of research given in this paper has shown that it is possible to conceive a new IS taxonomy which would start from the basic purpose of their development and genesis and technology level used for their accomplishment. The proposed three-dimensional genetic taxonomy is open because it includes not only the developed systems but also the ones not developed yet but possible in taxonomic space. According to its conception, semantics and content, it is more suitable for IS designers than the existing, descriptive taxonomies. Besides, it is suitable for the assessement of the expected development complexity of a new IS in the same way FPA is suitable for software development complexity assessement. The suggested genetic taxonomy enables the setting of objective parameters for IS to be developed, so improvement in designer-investor cooperation can be expected.

Further research related to IS genetic taxonomy should be directed towards solving the following problems:

- defining the rules for detailed and consistent metrics of classification parameters, with emphasis on their noncardinal values, in order to improve the exactness of complexity analysis for planned information systems

- collecting the data about a lot of already developed ISs, and defining their GTO in order to evaluate the correctness, consistency and usefulness of the proposed genetic taxonomy and

- validating usefulness of the proposed genetic taxonomy in setting the goals at the new IS strategic planning stage.

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Brumec J. Prilog općoj taksonomiji informacijskih sustava

Sažetak

Naziv "Informacijski sustav" koristi se za velik skup raznovrsnih proizvoda ljudskog uma izgrađenih s ciljem da čovjeku omoguće uvid i upravljanje nad zbivanjima u njegovom okruženju. U svezi s tim razvijene su brojne klasifikacije IS-a. One polaze od različitih oblika i svojstava postojećih sustava, ali ne objašnjavaju njihovo podrijetlo i nastanak. U radu je nakon kraćeg pregleda nekih postojećih klasifikacija izložena nova, genetička taksonomija IS-a. Ona polazi od onih svojstava IS-a, koja su značajna za njihov razvoj i izgradnju. Prikazano je također kako se načela genetičke taksonomije mogu primijeniti pri procjeni složenosti razvoja novog informacijskog sustava i tako poboljšati razumijevanje između projektanata i korisnika informacijskih sustava.