Knowledge representation in controlling sub-system

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Abstract—**The paper presents issues related to knowledge representation in controlling sub-system in integrated management support system. In the first part of article, a controlling sub-system is characterized. Next, the formal definition of knowledge structure is presented. This structure can be used, for example, to integration of knowledge. The final part describes an example of use of the elaborated structure in practice.**

I. Introduction

CONTEMPORARY economy forces companies to operate in a very turbulent environment. In order for the companies to become competitive, the decision makers are forced to make quick yet effective decisions. Without a doubt, the effectiveness of those decisions influences performance and results obtained by companies. To run the decision-making process correctly, companies increasingly employ the process of controlling, defined as performance-oriented operation, executed through planning, control and reporting [9]. Professional literature considers controlling in two aspects: strategic controlling which is aimed at coordinating all sub-systems of strategic management, i.e. strategic planning, control as well as strategic information feed [5]; and operational controlling which should put the company in control over its income, expenses, thus achieving the assumed profit, and financial liquidity [2]. In order to ensure full integration of business processes within a company, supporting the tasks of both strategic and operational controlling should be executed within a sub-system of an integrated management information system (IMIS) [1]. It should be noted that the function of controlling sub-system for analysis, planning or control generates new knowledge which should be used by the decision makers on an ongoing basis.

However, so far professional literature has not defined formal representation structure of the knowledge in a controlling sub-system, considering all elements of the controlling system. Such structure might prove useful, e.g. to compare items of knowledge generated with different methods of analysis.

Therefore, the purpose of this article is to devise a formal definition of knowledge structure in IMIS controlling sub-system.

The research has been realized through the following stages:

1. Analyzing of the existing solutions in knowledge representation and integration and controlling area using such research methods like the literature studies, the observation of phenomena in the enterprises, the case studies of different practical application of IMIS.

2. Developing the definition of the knowledge structure. The quantitative methods and the case studies have been used in this stage.

II. Knowledge representation and integration techniques

A knowledge representation structure must be capable of representing the broad spectrum of knowledge types categorized by Feigenbaum including [11]:

- objects - information on physical objects and concepts,
- events - time-dependent actions and events that may indicate cause and effect relationships,
- performance - procedure or process of performing tasks,
- meta-knowledge - knowledge about knowledge including its reliability, importance, performance evaluation of cognitive processors.

The literature of subject presents many different methods for knowledge representation. The main of them include internal-symbolic representation, first-order predicate logic, multi-valued logic, fuzzy logic, tuples, relational tuples, partitions and coverings, trees, rule-based systems, artificial neural networks, frame representation, ontologies such as semantic web and semantic networks, multi-attributes and multi-values structures, multi valued logic includes a three valued logic and a fuzzy logic.

Internal-symbolic representation requires a common symbol language, in which knowledge can be express.

The first-order predicate logic (and its extensions), multi-valued logic and fuzzy logic approach is a symbolic-

cognitive approach and results from general assumptions [14]:

- the knowledge representation is independent of physical media,
- system's internal states are related to the objects of external environment,
- the knowledge representation consist of symbols forming the structure,
- reasoning is based on the manipulation of these structures to derive other structures.

Often the tuples, relational tuples, partitions and coverings are used for knowledge representation [15]. Trees, instead, are the graphs which represent hierarchical knowledge [12], [26].

A rule based system uses rules as the knowledge representation for knowledge coded into the system. A rule-based system consists of a set of IF-THEN rules, a set of facts and some interpreter controlling the application of the rules, given the facts [13].

Artificial neural networks are generally defined as systems of interconnected "neurons" which can compute values from inputs, and are capable of machine learning as well as pattern recognition thanks to their adaptive nature [18].

Frame representation provides a concise structural representation of useful relations, and support a concise definition-by-specialization technique that is easy for most domain experts to use. In addition, special purpose deduction algorithms have been developed that exploit the structural characteristics of frames to rapidly perform a set of inferences commonly needed in knowledge-system applications. the taxonomic relationships among frames enable descriptive information to be shared among multiple frames (via inheritance) and because the internal structure of frames enables semantic integrity constraints to be automatically maintained. [19].

The Semantic Web allows searching not only information but also knowledge. Its main purpose is introducing structure and semantic content in the huge amount of unstructured or semi-structured distributed knowledge available on the Web, being the central notion behind the Semantic Web that of ontologies, which describe concepts and their relations in a particular field of knowledge [16].

The paper [17] instead, presents the semantic net with node and links activation level (the "slipnet") to represent knowledge. This type of representation allows the processing both knowledge represented in a symbolic way and knowledge represented in a numerical way. Thus it is possible to determine a certainty level of semantic relations between nodes (topics).

Often knowledge is represented as multi-attribute and multi-value structure consist of different number of different types attributes. It allow for representing the real word environment in wide scope of objects features. Such structures are used, for example in case of weather

forecasting multiagent system [15] or supply chain management multiagent system [10], [25].

Integration of knowledge is considered in different ways and on different levels. Previous attempts tended to predict group performance based on some statistic involving members' performances. For example [20] reported that group performance is an average of individual performance. Wolley [21] measured the collective knowledge. They experimentally proved that collective knowledge and intelligence is not strongly correlated with the average or maximum individual intelligences of group members but is correlated with the average social sensitivity of group members, the equality in distribution of conversational turn-taking, and the proportion of females in the group. In works [22], [23], [24] a formal mathematical model for knowledge integration is presented, in which the consensus-based knowledge functions for generating integration of knowledge have been defined.

III.   CHARACTERISTIC OF A CONTROLLING SUB-SYSTEM

Operational management of a company requires employing a reliable and effective controlling system, which depends on proper organization of an integrated management system. Controlling sub-system is a component of IMIS, collecting big amounts of data from other sub-systems, thus generating information for the management. The information is then the basis for making a decision. Therefore, the reliability of the sub-system is dependent upon the reliability of the entire IMIS. It is also imperative to provide support for the controlling system through maximally automated circulation of documents, which allows for an ongoing data feed for management purposes; through a register of events taking place in a company, that enables to control, and through issuing up-to-date and solid analyses and reports for the management. Such solutions are made possible through the use of domain bases of each of the employed IMIS sub-systems, and the use of data warehouses along with other Business Intelligence tools. Summary of sample information used by the controlling sub-system in order to the planning function, control and inspection presented table 1.

Considering the controlling sub-system and its efficient operation, it is vital to decentralize the management system in a company and one of the ways to do that is to designate certain responsibility centers in the company [8]. The starting point for such division is an assumption that the entire activity conducted by the company can be divided into many integrated sub-categories, each of them having its own individual characteristic and requiring an individual approach [6]. Dividing a company into smaller units and assigning specific targets to them is a crucial condition for introducing a reliable controlling system and making unit managers account for the accomplishment of assigned tasks and targets [8].

Fig 1 presents the functional architecture of controlling subsystem. From the knowledge processing point of view,

TABLE I.
EXAMPLES OF THE USE OF EVENT RECORDS IN OTHER SUB-SYSTEM IN ORDER TO THE CONTROLLING FUNCTIONING IN ENTERPRISE

The name of the sub-system	Automatic records of events supporting the work of the controlling
ACCOUNTING SUB-SYSTEM	– automatic generation posting and transfer automatically after payment, – automatic posting costs and financial income resulting in exchange rate differences, – automatic decreeing and posting payroll generated in human resources management sub-system, – automatic aggregation and post inventory documents.
HUMAN RESOURCES MANAGEMENT SUB-SYSTEM	– information about the amount of the salaries paid in individual organizational units, – information about the differences in salaries on individual positions, – information about the differences in wages on individual positions, – information about skilled workers needed to perform specific jobs by company, – automatic creation of the collator salary costs on projects/organizations units on the basis of the records of working time.
LOGISTIC SUB-SYSTEM	– information on current inventory values, broken down by types of materials or their economic usefulness, – receiving/issuing of goods from the warehouse on the basis of the barcode (automatic records), – carry out inventory using barcodes or technology (Optical Character Recognition/ Intelligent Character Recognition/ Optical Mark Recognition), – automatic generation of an inventory documents.
CRM SUB-SYSTEM	– generate information about the current state of the debt, thanks to the automatic generation of invoices, – the ability to create reports based on customer segmentation or Pareto principle, – information on complaints made by customers.
MANUFACTURING MANAGEMENT SUB-SYSTEM	– identify needs of material of a specific production order, – determine necessary for the order execution the man-hours, – analysis of the use of the working time of machines and equipment on the basis of the automatic reading of their work time.

the reports module and internal consultant module are very important. The first of them facilitate monitoring of the business organization processes. It is very important tool for management supporting. After determining the limit values for a given process the module reports values of each event and informs about tasks, which have to be perform. The second module, instead, suggests the optimal solutions for a given decision-making problem. For example, the tasks performed by module are as follows:

- performing the effectivity analyses,
- supporting in the costs calculation rules,
- supporting in the costs settlement.

When implementing the controlling sub-system in a company, it is vital to remember the specific needs of each organization and their uniqueness. Therefore, it is necessary to precisely define targets and expectations put forth to the controlling process by management staff from each company at pre-implementation stage. This will allow obtaining an efficient tool, adapted perfectly to the information needs of a company. One can honestly state that there are no identical controlling systems, as there are no identical companies.

Distinct characteristics of production processes, distinct organization methods and different management methods make each company one of a kind [3, 4].
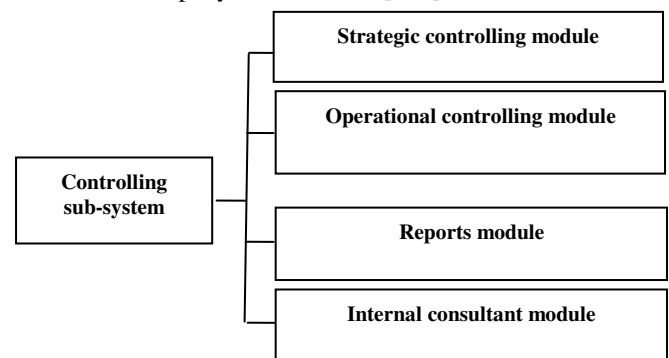

Fig 1. The functional architecture of a controlling sub-system.
Source: self-elaboration.

Consequently, each company has its own uniquely organized controlling system, although the system contains commonly used solutions and tools, based on two basic assumptions:

- all action taken in the company is aimed at the main target – to optimize profit made in a given environment,
- to increase the efficiency of all centers of responsibility, so that they contribute to achieving the main target of the company to the highest degree possible.

As a result of the analysis and conclusion process, the controlling sub-system generates new knowledge concerning business processes. The knowledge is subject to structuration process, therefore it should be represented as unitary structure which will be defined later in the article. The computer system should provide the controlling unit with all necessary information from sub-systems operating in the company, including the financial-accounting or production management sub-systems and allow analyzing received data in various lay-outs and cross-sections.

IV. DEFINITION OF THE KNOWLEDGE STRUCTURE

In order to allow for the representation of knowledge in controlling sub-system as a single structure, it is necessary to define it formally. On the basis of the characteristics of the sub-system control made in the previous paragraph, the knowledge structure can be defined as follows:

The structure of knowledge in controlling sub-system is called following sequence:

$$WCO = \left\langle \{D\}, \{P\}, \{W\}, \{AN\}, \{J\}, \{K\}, \{R\}, \kappa, \omega, SP, DT \right\rangle$$

Where:

1) $D = \{d_1, d_2, \ldots, d_i\}$ - denotes set of data, for example, record of production orders, a list of the materials ordered from vendors, list of cost items and revenue which undertaking the subject to the budgeting by each of the organizational units, or bill of the customers or vendors,

2) $P = \{p_1, p_2, \ldots, p_i\}$ - denotes set of plans prepared for a specific period, in scope of data of D set,

3) $W = \{w_1, w_2, \ldots, w_i\}$ – denotes set of values related to the implementation of the established size plans by individual organizational units operating in the enterprise,

4) $AN = \{a_1, a_2, \ldots, a_i\}$ - denotes set of analysis made on the basis of plans and implementation, and calculated on the basis of the analysis the values of deviations are presented in reports,

5) $K = \{k_1, k_2, \ldots, k_i\}$ - denotes set of controls, where $k_1 .. k_i$ mean procedures of controls, allow to detect irregularities in the use of production factors by, for example, comparison of standards with real values; an example would be control of fuel consumption in transport vehicles in relation to established standards of consumption, or quality control of finished products on each stage of production;

6) $J = \{j_1, j_2, \ldots, j_h\}$ – denotes set of organizational units to evaluate using the tools of controlling, with its manager about specific responsibilities and competence necessary to drive organizational unit,

7) $R = \{r_1, r_2, \ldots, r_h\}$ - denotes set of reports generated by system, both of the checks carried out and in terms of presentation of information resulting from the analysis carried out,

8) SP - denote s the degree of certainty of the reports, in particular, in relation to reports on the nature of the „ex ante". Degree of certainty can be, for example, calculated on the basis of the probability of a change in interest rates by the central bank, changes in inflation rates and different sizes for the purchasing power of money,

9) $DT = \{CT, CW\}$ - where CT denotes transaction time, instead CW the right time of the reports performing, e.g. report performed 2013-01-23 showing an enterprise state of the day 2012-12-31.

In addition to the defined attributes of the knowledge structure includes the following features:

10) $\kappa: D \times P \times W \times K \to R$ - is at least partially a function of control, that mirrors elements of the Cartesian product $D \times P \times W \times K$ in elements of R set. Function κ will be partially, when only selected elements of the Cartesian product $D \times P \times W \times K$ will be as its arguments. This function, on the basis of the data, plans, implementation and control, creates a report with the controls.

Function κ satisfies the following conditions:

1) $(D = \varnothing) \vee (P = \varnothing) \vee (W = \varnothing) \vee (K = \varnothing) \Rightarrow \kappa = \varnothing$

- if any of function's arguments is an empty set, then the function result is also an empty set.

2) $(D \neq \varnothing) \wedge (P \neq \varnothing) \wedge (W \neq \varnothing) \wedge (K \neq \varnothing) \Rightarrow \kappa \neq \varnothing$.

- if each of function's arguments isn't an empty set, then the function result also isn't an empty set.

11) $\omega: D \times P \times W \times AN \to R$ - is at least partially a function of knowledge, that mirrors elements of the Cartesian product $D \times P \times W \times AN$ in elements of R set. Function ω will be partially, when only selected elements of the Cartesian product $D \times P \times W \times AN$ will be as its arguments. This function, on the basis of the data, plans, implementations and analysis, creates a report.

Function ω satisfies the following conditions:

1) $(D = \varnothing) \vee (P = \varnothing) \vee (W = \varnothing) \vee (AN = \varnothing) \Rightarrow \kappa = \varnothing$

- if any of function's arguments is an empty set, then the function result is also an empty set.

2) $(D \neq \varnothing) \wedge (P \neq \varnothing) \wedge (W \neq \varnothing) \wedge (AN \neq \varnothing) \Rightarrow \kappa \neq \varnothing$

- if each of function's arguments isn't an empty set, then the function result also isn't an empty set.

The knowledge structure of controlling sub-system defined in this article is a multi-attributes and multi-values structure (it consist of different types of attributes). This structure can be using to representation of knowledge generated as a result of analysis of implementation established in the plans of the values.

Next part of the paper presents using a defined structure in practice implementation.

V. THE EXAMPLE OF USING THE FORMAL DEFINITION OF KNOWLEDGE STRUCTURE

The use of the knowledge structure is illustrated in the example companies of financial industry that take care of the free of debts the hospitals. The knowledge structure, automatically generated by controlling sub-system, can, in this case, present itself as follows:

1) D={list of hospitals operating on an interesting enterprise area, list of hospitals with which the enterprise has established cooperation, list of costs and revenues necessary for the proper preparation of the company's budget}.

2) P={prepared plans for the period of the financial year, broken down by 4 calendar months. The plans consist of:
- sales budget prepared on the basis of both the hospitals with which you are already working, as well as new units, the enterprise should acquire in the indicated period,
- cost budget broken down by individual business units, i.e. the marketing department, dales department, accounting department, controlling department and the others,
- expected results associated with the free of debts the specific hospital}.

3) W= { the value corresponding to a plan, resulting from the actual implementation of the previously established plans}.

4) AN={analyses consist of comparison plans and implementation the individual scheduled values included in set W}.

5) K={the control concerning of liquidity loss prevention in connection with the activities of large outflows of funds in the form of a credit for hospitals and the cyclical (for example, monthly or quarterly) a relatively small influence on behalf of the bank account}.

6) J={marketing department, dales department, accounting department, controlling department, Hospital 1, Hospital 2....Hospital n}.

Therefore, a set J, in this example, is a set of organizational units of the enterprise, but also the hospitals, z with which the enterprise cooperates to the clearance of the efficiency of the investments carried out,

7) R={reports on the implementation of budget plans and the results of the analysis of deviations and evaluation report on funding opportunities further hospitals based on the company's own or with the possibility to organize a bank loans intended for this purpose }.

8) SP =0.7.

9) DT ={01.09.2012, 31.12.2012};

The enterprise is considering financing the business development based on hospitals 1, 2, 3 and 4 with 5-year bank loan. The 700 thousand loans will ensure the financial liquidity in the investment period. The detailed calculations are presented in the table 2.

The parameters of automatic function of control and its results may present as follows:

κ (planned receipts and cash outflows) = {planned cash receipts, collected at the moment funds along with the loan had entered for the purpose of carrying out the activities and the planned financial resources allocated to free of debts the hospitals; result of a control: planned receipts and expenses are possible provided under condition to ensure the operational functioning of the company and to cover the cost of raising capital};

Instead, parameters and results (in the form of reports, which can contain both the information and the conclusions drawn in automatically[1]) of the function of knowledge generated by the sub-system may present as follows (the number of the tables was given for the order by the authors – it is not generated by the sub-system):

ω(D, P,W,AN)= {results are presented by Table 2 and Table 3}.

TABLE 2. PLANNED CASH FLOWS ASSOCIATED WITH THE LENDING AND REPAYMENT INSTALLMENTS BY HOSPITALS

The name of project	Year	Month	Payment term	Cash flows [thousands]	Balance [thousands]
Loan				**700**	**700**
Hospital 1	2012	9	2012-09-03	-150	550
Hospital 2	2012	9	2012-09-08	-380	170
Revenues	2012	9	2012-09-15	45	215
Operating costs	2012	9	2012-09-30	-20	195
Financial costs	2012	9	2012-09-30	-10	185
Revenues	2012	10	2012-10-30	55	240
Hospital 3	2012	10	2012-10-03	-120	120
Operating costs	2012	10	2012-10-31	-17	103
Financial costs	2012	10	2012-10-31	-14	89
Revenues	2012	11	2012-11-15	66	155
Operating costs	2012	11	2012-11-30	-20	135
Financial costs	2012	11	2012-11-30	-20	115
Revenues	2012	12	2012-12-15	66	181
Hospital 4	2012	12	2012-12-25	-140	41
Operating costs	2012	12	2012-12-31	-20	21
Financial costs	2012	12	2012-12-31	-21	0

Conclusions: Following the presented juxtaposition, one might initially state that a company is able to fund the planned projects through the planned amount of bank loan. Significant financial expenses of the bank loan make the company management worried about the profitability of such investment. The revenues, expenses and profits in the described period are presented in the table 3.

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[1] The data mining techniques and expert systems are used in this purpose

TABLE 3. PLANNED REVENUES, COSTS, PROFITS OF ENTERPRISE FUNCTIONING

	2012/09	2012/10	2012/11	2012/12
Revenues [thousands]	45	55	66	66
Costs [thousands]	30	31	40	41
Profit [thousands]	15	24	26	25
Cumulative Profit [thousands]	15	39	65	90

Conclusions: As one may notice the profit margin of the investment amounts to 38% and allows sustainable growth of the enterprise and repayment of the bank loan within agreed period.

Generating data from the chart by the controlling sub-system is possible due to its cooperation with the sales sub-system, because it contains all information regarding concluded agreements, their amount and payment schedule. The juxtaposition may function as final or be the basis for creating an overall plan of money flow through the controlling sub-system that considers all revenues, costs and profits of company's operation (table 3).

The similarly structures of knowledge can be automatically generated by the controlling sub-system with regard to, for example, other periods, or new hospitals acquired by the company. Thanks to the formal representation of knowledge it can be easily compared, verified and integrated.

VI. CONCLUSION

The operation of the controlling sub-system in IMIS is connected with generating knowledge which is extremely useful e.g. from the perspective of company competitiveness. Operational efficiency is not only influenced by flexibility and the ability to satisfy customers' needs, but also by keeping proper financial liquidity in the company. Note that economic decisions are usually made with risk and uncertainty, therefore knowledge generated by the controlling sub-system is often heterogeneous by nature. That is why it is crucial to store the knowledge with the use of unitary structure whose formal definition has been devised in this article. Representing knowledge with the use of such structure enables its comparison as well as detection of conflicts resulting from the knowledge – for instance, one can obtain a report from the controlling sub-system, which states that within a given period of time it will be more profitable for the company to produce product A for customer K1, however, production of product B for customer K2 within the same period of time will ensure higher financial liquidity. Such a situation is defined as conflict of knowledge which hinders the process of making a final decision, and should be resolved by man or by an automated system [25].

The representation of knowledge in the controlling sub-system as unitary structure may thus lead to higher

effectiveness of all decisions made by decision makers, based on reports generated in the controlling sub-system.

The further research works may relate to elaborate a structure of knowledge with functional dependencies between attributes, formal definition of knowledge conflict appearing in controlling sub-system and the methods of these conflicts resolving.

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