DISTRIBUTED COGNITIVE RESOURCES AS A BASIS FOR SOLVING OPERATIONAL MANAGEMENT PROBLEMS

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ABSTRACT

The research is aimed at finding solutions for better operational management of geographically distributed companies. We offer a management solution based on innovation knowledge of distributed cognitive resources (DCR) regardless of their geographical location. Then we describe a corporal structure model adjusted to DCR, a model of a management problem and management synthesis algorithm invariant to the number of management objects. We also suggest a management structure implementing the designed models and algorithms on the basis of multi-agent system.

KEY WORDS: Knowledge management;Decision making;Expert systems for economics.

1. INTRODUCTION

Globalization brought about serious changes in business environment. The market became more global with growing competition and shorter life-cycles of business processes (Kidd et al.,2006; Senge et al., 2010). Trying to adapt to new conditions, companies change their structures. Geographically distributed structures with hundreds of subdivisions in countries with favorable economic conditions and qualified personnel turned out to be the most successful (Gruber,1993; Studer et al., 1999; Kidd et al., 2006; Ablameico et al., 2007). The growth of competition gave way to constant improvement of business processes via innovation knowledge. Short life-cycle made the plan tasks shrink and operational management tasks expand. The general tendency is that the principal competitive advantages in post-industrial environment are won by operational management based on innovation knowledge. Operational efficiency provides for fast response to environment changes and innovations give better products than the ones supplied by the competition (Horsky, 2008; Kidd, 2006; Ablameico et al., 2007). Yet, these advantages are hard to attain with computer technologies offered by the IT market for the following reasons:

1) traditional management systems like MRP-ERP-CRV solve plan tasks using information from stationary data bases (DB);

2) expert systems can solve quite a narrow range of plan tasks and also use stationary media - knowledge bases (KB);

3) operational management system OLAP applies Data Mining and Knowledge Discovery methods that are not always efficient and also use DB.

The above mentioned systems are not efficient in solving real operational problems, as DB information promptly goes out of date in the conditions of dynamic environment and management based on this information is seldom successful.

Various approaches are recommended to improve the quality of operational management (Lafta,2002; Novikov,2005; Kidd,2006). We think that one of the most promising of them is the use of innovation knowledge regardless of its location (Krasnoproshin et al.,2004; Ablameico et al.,2007). The practical application of this idea needs new technologies related not to DB that get out of date too fast, but to the distributed innovation sources often referred to as distributed cognitive resources (DCR). DCR include experts, consultants and other persons having the information (newest for the moment) necessary to solve a problem. Various authors have presented a number of DCR methods, but their findings are fragmentary, which makes it hard to put them into practice (Novikov,2005) .

Our research describes an integrated solution of an operational management problem by distributed companies on the basis of DCR knowledge and offers the corresponding architecture of computer systems.

2. PROBLEM DEFINITION

Firstly, DCR should be divided into two groups: internal and external. The internal DCR include resources that make part of the company's administration: the center and remote subdivisions. The external DCR imply experts from other firms and other persons whose knowledge is outsourced for finding a solution. To make it simple let's thinks that the knowledge of just 1 expert is used. Taking into account this implication, the problem definition goes as follows.

Fancy there is a company OS, consisting of the Center, distributed subdivisions P^1, P^2,…, P^k and an expert E. The company solves a management synthesis problem S of the management U = f (D), with: U – management D – knowledge, f – function of conversing

D into U. The expert E and head of subdivisions P^1, P^2,…,P^k have the knowledge D = D^E,D^{P1},...,D^{Pk} for solving the problem.

A technology should be designed for: 1) receiving knowledge D, relevant to the semantics of S; 2) conversion of knowledge D into management U during the time t.

The principal requirement to the solution: invariance of the time of synthesis of U to the number of subdivisions, that is $t \approx const$ with $k \rightarrow \infty$.

While analyzing the problem definition we can select 3 aspects of the solution: organizational, communication and algorithmic components. The first one includes a model of an organization providing access to DCR. The second provides for Center-E and Center-P information exchange aimed at receiving DCR knowledge and the third aspect is related to algorithms of conversing the knowledge into management. The integrated application of these aspects is rather complicated as they are studied by different science disciplines: theories of organization, communication, artificial intellect and management. To avoid this difficulty we applied ontological approach (Gruber,1993), which allows describing complicated problems and specify the solution successively from a concept to a program code.

3. DECISION

Organizational component. The implementation of the organizational component implies making a model of a virtual organization providing access to DCR knowledge. Various studies suggest a number of such models, but they are limited by 2-3 levels and ignore the infrastructure properties of global environment, which makes them hard to carry out, especially in case of distributed organizations (Novikov,2005; Horsky,2008).

To make a universal model of a distributed organization, it is suggested to unite the elements of the organization theory and infrastructure options of global environment (Internet) within a graph theory.

Let's represent the one-to-one mapping of the company's administrative structure in a graph of a tree type. The administration of the company is the root of graph, its multitude of subdivisions and experts are the nodes and communication is the arcs.

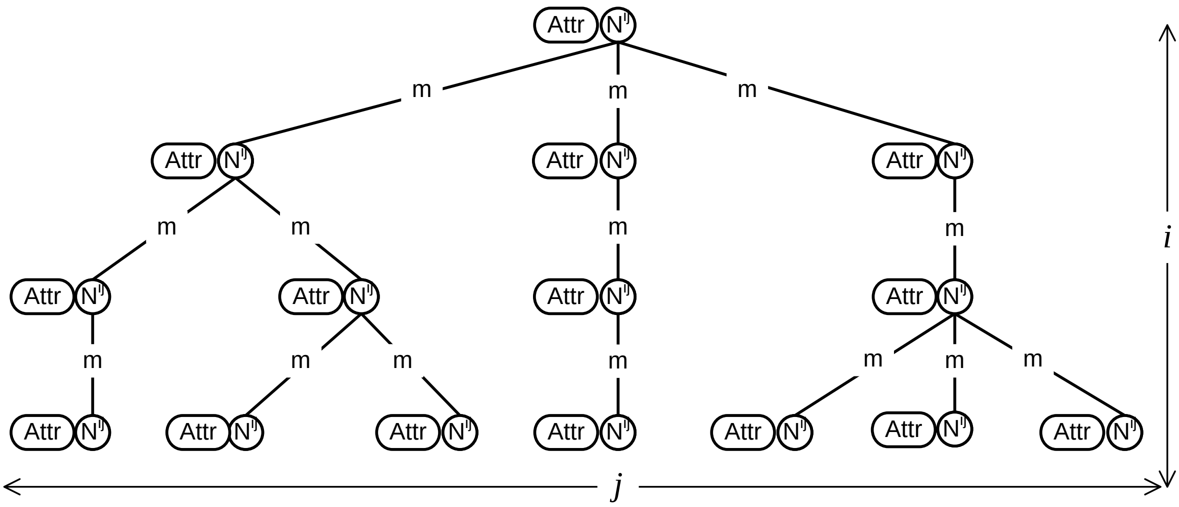
The organization of DCR communication primarily requires identification of the participants of dialogue in local and global environment. Local identification solves the problem of fast visualization of the organization structure of any degree of complexity and size on PC screen. Global identification is necessary for searching DCR in the Internet. Do this:

1) mark nodes of graph. Let's mark them by number (N^{ij}) to make local identification of graph nodes;

2) assign each node to the finite aggregate of objects (attributes - attr), identifying nodes in global environment and performing some other functions;

3) associate each arc with a mediator m, providing for information exchange between the nodes.

The result is an attributed tree presented on Figure 1.



i – number of the level; *j* – number the node on the level

Figure 1 - Model of distributed company

Thus, the model structure of company is represented in the form of the connected attributed tree G =(V,E), its nodes stand for DCR and their properties and the arcs stand for a broker in information exchange. The difference of this model from similar ones is a possibility of arbitrary specification of the attributes. As a result they can be adjusted to any structure in global or local net.

Specify the general graph model by creating ontological models of the company, center, expert, subdivisions and broker taking into account the specificity of Internet infrastructure, organization of dialogues and information security requirements:

OS = (Center, P^1, P^2,…,P^n, E, broker, structure, com)

Center = (A^{GC}, A^{LC}, nameC, signC, R^E, Q^E, mem, status)

P = (A^{GP}, A^{LP}, nameP, signP, R^P, Q^P, mem, status)

E = (A^{GE}, A^{LE}, nameE, signE, R^P, Q^P, mem, status) with: A^{G*} – address of DCR in global environment (A^{G*} = address email); A^{L*} – DCR address in the organization ($A^{L*}=N^{ij}$); name* – name of decision-maker; sign* – electronic signature; R*,Q* – center- expert and center- subdivision dialogue tool; mem – memory for storing the results of the dialogue; status – DCR status (whether it takes part in the solution or not).

Thus, we have got a working graph model of a distributed company and a model of its participants. In total they provide access to DCR in global environment.

Software implementation of the graph model provides for DB (See DB1 on the figure 2), including all available DCR. Practical application of DB requires a mediator to represent the communication component. A variant of such a broker, which can be applied in global and local nets, goes as follows.

Communication component. The classical function of any mediator (broker) is transferring a message (information) from originator to recipient. The list of functions in our case should be expanded. Firstly, the center should receive information D from recipients (E, P). Consequently, a remote dialogue function is necessary. Secondly, the information can be stolen or distorted and, therefore, a function of protection (coding and decoding) should be added.

There is enough literature providing researches of broker models for stiff architectures like COM and DB as information sources. Flexible models of architectures with intellectual sources are not studied enough (Krasnoproshin, 2004; Novikov, 2005). The following broker model is aimed at bridging this gap:

$$broker = (A^{from}, A^{to}, R^*, Q^*, mem, guard)$$

with: A^{from} – originator address A^{to} – recipient address; R*, Q* – dialogue; mem – memory; guard – information security product (automatic coding and decoding).

In total, the process of receiving DCR knowledge via mediator (broker) includes five steps:

1) center analyses problem S;
2) center chooses an expert E and subdivisions P taking part in the solution of S;
3) broker is created and sent (A^{GC},A^{GE},R^E,Q^E, mem=Ø, guard) to expert E;
4) broker is received by expert E, who receives its knowledge within the dialogue R^E,Q^E , after that broker (A^{GE}, A^{GC}, R^E, Q^E, mem= $<R^E, Q^E>$, guard) is returned to the center;

5) broker is sent (A^{GE}, A^{GC}, R^P, Q^P, mem=Ø, guard) to subdivisions P. Their knowledge is received within the framework of dialogue R^P, Q^P and broker is returned to the center (A^{GP}, A^{GC}, R^P, Q^P, mem = <D>, guard).

Thus, broker forms data base D (See DB2 on the figure) from two types of DCR: expert E and subdivisions P, necessary for the synthesis of management U. Let's specify the structure of D and algorithm of management synthesis.

Algorythmic component. There are many methods of management synthesis based on the theory of management, image discrimination theory, fuzzy sets theory, etc. (Zadeh, 1994; Krasnoproshin, 2004; Novikov, 2005). In total, they can be divided into 2 groups: formal methods of managing artificial (mechanical, electronic, etc.) systems and subjective methods for management of organizational systems (companies). Historically, the methods of the first group are better developed, as they were demanded by military and space industries. Nevertheless, it could be suggested that both methods are based the classical formula of a management theory:

$$U = \boldsymbol{F}\,(X,<X>,V)$$

with: U – management; X – diagnostic indicators that characterize the state of the object being diagnosed; ***F*** – synthesis algorithm of management U, relevant to <X>and V. As a rule, an object exposed to diagnostics is represented by univariate value vector of the attributes, the state of the object and the corresponding management are represented by ranged sets of standard vectors:

$$X = X^1,X^2,\ldots,X^k$$

$$V = V^1,V^2,V^h$$

$$U = U^1,U^2,U^h$$

The classical approach suggests receiving values X, V, U by sensors, controllers and other devices that can fix signals. In case of DCR, the value of these variables should be created by remote expert E, remote subdivisions P should communicate this meaning. Thus, the center should make a task S to expert E within the dialogue R^E, Q^E. The expert should inform the center on the value and number of indicators, a multitude of possible conditions V and managements U, as well as the corresponding variant of dialogue R^P, Q^P for obtaining the values <X> by the heads of subdivisions. Via dialogue R^P, Q^P the center receives current values <X> of indicators X from heads of subdivisions P. Managements U based on X, <X>, V are synthesized with the help of algorithm F. This is the general scheme of the solution. Its implementation is not difficult, as the theory of artificial intellect includes a wide range of methods of acquiring expert knowledge for creating dialogue R*, Q* and forming D. Yet, the choice of synthesis algorithm F is one of the unsolved problems. In order to find a way out of the situation we suggest: synthesis of management by any of the existing algorithms and specifying it by expert assessments. To this end, it is necessary to supply the dialogue R^P, Q^P with bifurcation variables $X \in \mathbf{X}$ and the corresponding scale-step for changing the results of the algorithm F: V=V+-step. Bifurcations are meanings of the variables changing the state of diagnostics objects regardless of the other (non-bifurcation) variables. Bifurcations are chosen by the experts. That is why they can be regarded as correction of formal results due to expert assessments during the process of synthesis. In total, the algorithm of management synthesis includes the following steps:

1) sampling values X,<X>,**X**, step, V, U in D;
2) sampling distances between <X> and vectors V^2,V^m (the first stage of F);
3) fixing number i and vector V^i with the minimal distance (the second stage of F);
4) analysis of bifurcation values with a $\mathbf{X} \neq \emptyset$ and the corresponding correction of the number i to the value- step: i = i +-step (the third stage of F);
5) choice of management U^i (the fourth stage of F).

The architecture of a computer system applying the organization, communication and algorithmic components goes as follows.

4. SYSTEM ARCHITECTURE

The elements of computer system architecture are defined by the processes of problem solution. In our case three processes can be singled out: organizational, communication and algorithmic components. Besides, one should take into account typical system processes: initialization of every new problem and integration of DCR information into a single knowledge base. The processes are distributive, as DCR are distributed and information exchange between them is carried out by a broker using Internet channels. In order to apply such processes it is necessary to use the agent approach, initially meant for net application. (Dunin-Keplicz, 2010). Consequently, the architecture of the target system will include 5 program agents. Their integrated action in the Internet will result in synthesis of managements for subdivisions (see the figure 2).

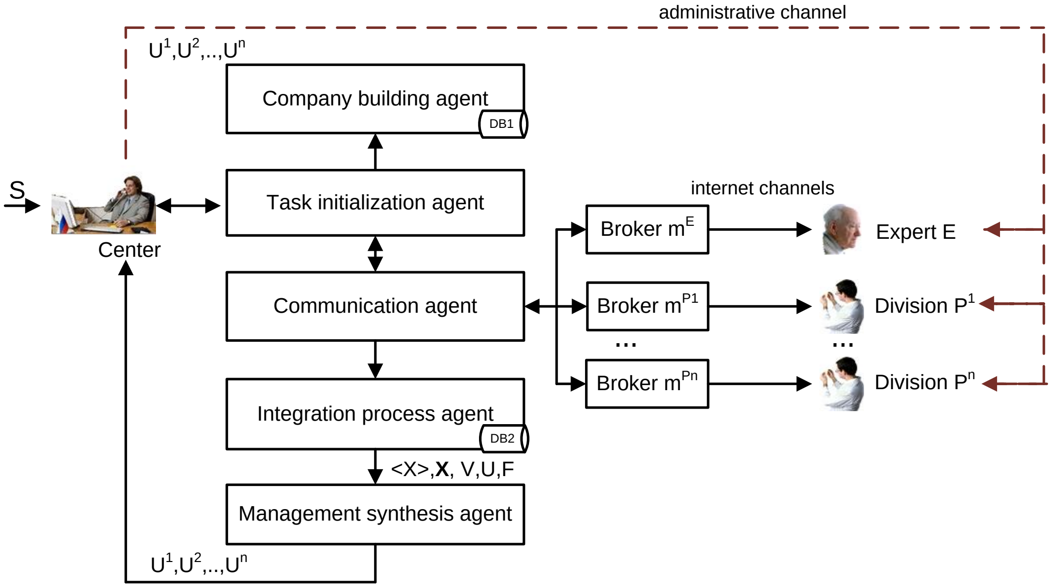


Figure 2 – Architecture of operational management system

The given architecture is universal, user-friendly and can be implemented both via specialized (LQML, ACL) and common high level programming languages (say, Jawa, C++). We implemented it as a library of agents on C# language of Microsoft .Net platform and used it for a number of applied systems of the operational management of distributed companies and building environmental and medical monitoring systems.

5. CONCLUSIONS

The study represents results of researching the methods of operational management of the distributed organizations on the basis of DCR. It suggests an integrated solution including:

– flexible graph model of a distributed organization, providing access to DCR. Unlike rigid models based on DB, it gives room for fast replacement of HRH and parallel acquisition of knowledge from them;

– model of a management problem with its elements formed not from DB like traditional technologies present, but from distributed cognitive resources;

– algorithm of management synthesis invariant to the number of management objects and uniting the advantages of formal and expert approaches;

– multi-agent system architecture providing for parallel acquisition of DCR knowledge, forming DB and synthesis of the corresponding solution.

The principal result of the study is development of methodic software providing for fast construction of inexpensive, protected and easy-to-work operational management systems, which make outside competent knowledge contribute to the solution of internal operational problems.

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