Cognitive map as representation of knowledge structure

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Abstract—**Tacit knowledge management requires a special approach because of the complexity of verbalization, explanation and formalization. The purpose of the article is to substantiate the approach to the tacit knowledge management, which allows integrating concepts from different fields of knowledge on the basis of systems methodology. Problems and tasks of tacit knowledge management are considered in the context of social interaction of individuals. This raises the problem of mutual understanding and communication barriers. The challenge of understanding depends on the quality of knowledge, the way knowledge is presented and the coherence of knowledge among themselves. An interdisciplinary approach based on systems methodology and soft systems thinking is proposed. The structuring of knowledge occurs through the construction of a collective cognitive map, which is a conceptual systems model of knowledge of a group of individuals. The elements of the model are ideas, assumptions, judgments, opinions of individuals, and the process of construction is considered as a way of organizing social interaction, which is based on the formation of a shared understanding. Priority directions of further research include the development of methods of analysis, verification and evaluation of the credibility of models based on collective cognitive maps.**

I. Introduction

Problem solving in human activity is associated with the organization of various types of knowledge. The issues of supporting human intellectual activity are studied in various fields (cognitive psychology, knowledge engineering, knowledge management, management sciences, system analysis, etc.). However, there is still a shortage of relatively simple and convenient tools for managing them, especially when solving real life problems. For quite a long time, the field of knowledge management has been associated with IT technologies, whose development has been promising over the past few decades. It seemed that the formalization of organizational knowledge, the creation of corporate knowledge bases, portals can effectively manage knowledge and provide support for intellectual activity. However, in solving real life problems and tasks, it was found that knowledge management is not only and not so much the creation of knowledge bases or portals. It turned out that the most valuable knowledge needed for supporting intellectual activity is tacit knowledge. Tacit knowledge is individual in nature and largely depends on the cognitive character-istics of individual. In addition, this kind of knowledge is difficult to formalize, and therefore is almost impossible to spread it through "uploading" to corporate knowledge base. Obviously, management of tacit knowledge requires a different approach to knowledge management [1].

The term "knowledge" and, as commonly used with it "information", are polysemantic. Depending on application they are interpreted differently, and are often used on an intuitive level. Studies in psychology show that a person actively processes information, creating certain meaningful conceptual structures, which are considered as knowledge. Conceptual structures are considered as a "special level of cognitive organization", in which an individual version of the world picture is constructed, that determines the activity in typical conditions. [2]

II. On some problems and tasks of tacit knowledge management

Traditionally, the "bottleneck" in knowledge management is the extraction, representation of knowledge and conceptual analysis (or knowledge structuring) [3]. Along with this, the spread and exchange of knowledge is also difficult. Spread of tacit knowledge involves the exchange of ideas, experiences; an explanation of the logic that was used to solve problems or tasks in the past in order to help other people solving other problems and tasks in the present or future. From this perspective, the exchange and spread of knowledge is based on communication between individuals and is considered as social interaction. In this case, in the social interaction of a group of individuals, the problem of mutual understanding arises, which depends on the knowledge, their quality, ways of presentation and coherence of knowledge among themselves [4]. The communication barriers arising from this are due not only to differences in knowledge, but also to the subjectivity of judgments and assessments that reflect the cognitive characteristics of a person: perception, interpretation, understanding of the surrounding world. In the areas related to the development of new products, communication barriers are defined as knowledge boundaries: syntactic, semantic, and pragmatic. They are manifested through differences in the knowledge, experience, views and interests of group members [5].

Based on this the research task is not only to identify and conceptualize tacit knowledge of an individual, but also to organize the processes of spread and share knowledge between individuals. This leads to the task of organizing the processes of communication and social interaction in a group of individuals.

A. Systems methodology and tacit knowledge management

The tasks of knowledge elicitation and conceptualization are usually solved on the basis of systems methodology. The wide application of systems approach in the second half of the 20th century for solving various problems in socio-economic systems, where the role of the active elements of the system is played by people, whose individual and collective behavior determines the essential aspects of the behavior of the system as a whole, revealed some limitations of its application. The traditional systems approach, called later "hard" or *"hard systems thinking"*, seeks to bring scientific rigor to problem solving and aims to produce objective results that are free of the personal aspect. The recognition of the significance of the "human factor" and the associated risks has led to the creation and development of "soft" systems approach or *"soft systems thinking"*. Soft systems thinking considers a person and his perception, beliefs, values and interests as basic components of system. The main task, which is solved with the help of soft systems thinking, is to identify world views and system of assessments that people use to understand and construct reality. From this perspective soft systems thinking has been designed to overcome the shortcomings of hard systems thinking.

At present among the well-developed and widely applicable soft system methodologies can be distinguished "Soft Systems Methodology" (SSM), developed by P. Checkland, "Strategic Options Development and Analysis" (SODA) by C. Eden and "Strategic Choice Approach" (SCA) by J. Friend.

Thus, the second research issues consists in finding adequate forms of system representation, the components of which are perception, beliefs, values and interests of actors. More broadly we can talk about adequate forms of elicitation and representation of the knowledge structures of an individual and/or a group of individuals. From this it follows that the system methodology should be complemented with concepts of cognitive science.

B. The aid of cognitive science

In cognitive science knowledge structures are usually considered as mental representations. The concept of "mental representation" refers to the number of key concepts of cognitive science and is defined as "...the actual mental image of a particular event (that is, the subjective form of "vision" of what is happening). ... mental representations are an operational form of mental experience, they change as the situation and intellectual efforts of the subject change, being a specialized and detailed mental picture of the event" [6, p. 98]. The recognition of the presence of representation is the recognition of the existence of an "internal" reality, i.e. the representation of reality in the consciousness of the individual. Features of representation formation determine the nature of intellectual activity. Mental representation is a "built" reality in certain conditions and for certain purposes. At the present stage, representation is considered not only as a form of knowledge storage, but also as a tool for applying knowledge to certain events, objects of reality. The role of the representation of information is most clearly manifested in the processes of solving problems and consists in creating an adequate conceptual understanding of the problem situation, which, in turn, serves as foundation for integrating and transforming information.

III. COGNITIVE MAP AS TOOL FOR CONCEPTUALIZATION KNOWLEDGE

To spread knowledge it is necessary not only to identify them, but also to represent (visualize) them in the most convenient form for human perception. To date, various methods of knowledge visualization have been created and are widely used (e.g. [7 - 9]). Along with this effective method of visualization are different types of cognitive maps. The definition of the concept "cognitive map" is rather vague [10, 11] and depending on the field of study or application is used for distinguishing between mental representation, which exists only in mind, and its external representation; or, according to R. Axelrod [12] map is not "cognitive map", but "map of cognition". C. Eden [13] uses this concept in a completely different way: a cognitive map is not a "map of cognition", but a "map created to help cognition". In the field of artificial intelligence a similar to R. Axelrod approach is used to map the knowledge of experts, but combined with fuzzy logic to build fuzzy cognitive maps.

It is obvious that the term "cognitive map" has such an intuitive application that new researchers appear with new ideas or mapping techniques for completely new and different purposes.

The cognitive mapping technique is based on the position of existence of cognitive functions of information processing, which directly affect human behavior and actions. Cognitive mapping is a technique of graphic representation of various individual views on the issues under consideration. In general, mapping techniques can be divided into two large classes:

1) to represent the cognitive processes of the individual;
2) to represent cognitive processes at the group level.

In order to solve the problem of knowledge spread it is necessary to aggregate external representations of cognitive structures and processes of individuals. In this

case, we are not talking about a simple aggregation of individual knowledge structures, but about creating a collective knowledge structure and its visualization.

A. The aid of conceptual modeling

Another aspect of the "bottleneck" in knowledge management is knowledge structuring. The solution to this problem is found with the help of conceptual modeling. Conceptual modeling can be defined as a way of deciding what to include in the model and what to exclude from the model [14]. Unfortunately, this type of modeling is not well understood. The main reason for this is probably due to the fact that conceptual modeling is more an "art" than a "science". Therefore, it is difficult to define methods and procedures, and the skills of conceptual modeling are acquired for the most part only through experience in solving practical problems. Among the key aspects of conceptual modeling, the following can be highlighted: iterativeness, independence from the software or development environment used, significance of the positions and points of view of both the model developer and the client.

Thus, conceptual models are a visualization tool and have been designed for formation of primary knowledge and their holistic perception. These models are a convenient tool for structuring and representing knowledge, especially in the early stages of the study of the subject area, and allow to describe it in the form of concepts and relationships between them. Conceptual models are used not only for the representation and integration knowledge, but also for training, knowledge transferring and share.

Since the spread of knowledge is communication and social interaction, the methods of group modeling were developed for supporting these processes. Group model building methods allows to coordinate and collect scattered knowledge of the participants in the system model. The model is considered as a form of representation (visualization) different points of view, judgments and assumptions of group members, and the process of building a model is a way of organizing social interaction. At the same time, the identified primary ideas (knowledge) of the participants in the process of refinement, coordination are transformed in such a way that a new integrated knowledge is created, which none of the members of the group had previously possessed.

Thus, the task of spread (also transferring and share) knowledge is reduced to the construction of a collective conceptual system model of the issue under consideration.

B. Oval Mapping Technique for building collective cognitive map

At the stage of knowledge conceptualization the Oval Mapping Technique (SODA methodology) seems to be quite convenient. The method is based on the construction of a collective causal map in the form of a directed graph, the nodes of which are related causality or influence concepts (expressing ideas, assumptions, judgments, opinions). [15] The process of building includes the steps of concepts elicitation, clarification, coordination, structuring. The created model has a hierarchical structure, which greatly facilitates reading and analysis of map.

However, in situations characterized by novelty and uncertainty building of causal models is very difficult because of cognitive limitations of individuals – in conditions of uncertainty it is extremely difficult for an individual to build causal relationship. Under these conditions, at the initial stage, it is proposed to build maps of influence - to determine only the impact of concepts on each other, without specifying the type and strength of influence. Further, to the extent of clarifying the language and meaning of concepts and their coordination (this may require to elicit additional concepts) it becomes possible to determine the type of links between them. [16]

From the perspective of creation collective knowledge, the processes of refinement, coordination and accommodation are of interest. At the heart of the transformation of individual knowledge and their aggregation in the form of a model is the formation of a *shared meaning* and *shared understanding* – notions that are the subject of research of social psychology.

A model built using group model building techniques visualizes a holistic shared view of a group of individuals about the issue under consideration. For creating a common image of a system as opposed to the individual one it is necessary to form shared understanding of elements and their interrelation in the model. The *shared understanding* can be defined as "the overlap of understanding and concepts among group members" [17, p. 36]. For collaborative modelling shared understanding is seen as "the extent to which specific knowledge among group members of concepts representing system elements and their relations overlaps" [18, p. 249]. For creating overlap of knowledge the participant not only need to exchange information about the elements of the model and their interrelation but also to form a shared meaning of these elements and their interrelation. The formation of *shared meaning* is usually viewed from the point of view of *sensemaking*, understood as "the ongoing retrospective development of plausible images that rationalize what people are doing" [19, p. 409].

Although the mechanisms of formation of shared meaning and shared understanding are not sufficiently studied, poorly understood, nevertheless, reliance on them can partly solve the problem of verifying the adequacy and credibility conceptual model.

IV. CONCLUSION

The author's application of cognitive mapping methods for solving real life problems [20] has shown that

in addition to the mastery of conceptual modeling, is required knowledge from various fields (system analysis, cognitive science, etc.) both for the practical application of methods based on cognitive maps, and for the theoretical justification of the building technology and obtained results. The further development of this area requires not even an interdisciplinary approach, but a transdisciplinary one, which may create a common conceptual space for different areas of knowledge, thereby, if knowledge boundaries are not removed, then significantly reducing them. Among the priorities for further research can also be identified the development of methods of analysis, verification and evaluation of the credibility of models based on collective cognitive maps.

REFERENCES

[1] McDermott R. Knowing in community. *IHRIM*, 2000, no. 19. pp. 19-26.
[2] Velichkovskij B.M. *Kognitivnaya nauka: Osnovy psikhologii poznaniya [Cognitive science: Fundamentals of cognition psychology]*, Moscow: Smysl, 2006, (in Russian).
[3] Gavrilova T.A., Leshcheva I.A., Strahovich E.V. Ob ispol'zovanii vizual'nyh konceptual'nyh modelej v prepodavanii [On the use of visual conceptual models in teaching]. *Vestnik Sankt-Peterburgskogo universiteta [Bulletin of St. Petersburg University]*, 2011, no. 4, pp. 124-150 (in Russian).
[4] Abramova N.A. Refleksivnyj podhod i problema vzaimoponimaniya [Reflexive approach and the problem of mutual understanding]. *Chelovecheskij faktor v upravlenii [Human factor in management]*, Moscow: KomKniga, 2006, pp. 52-82 (in Russian).
[5] Carlile R.P. A pragmatic view of knowledge and boundaries: Boundary objects in new product development. *Organization Science*, 2002, no. 1, pp. 442-455.
[6] Holodnaya M.A. *Psihologiya intellekta: Paradoksy issledovaniya [The psychology of intelligence: Paradoxes of research]*, St. Petersburg: Piter, 2002. 272p. (in Russian).
[7] Gavrilova T.A., Gulyakina N.A. Vizual'nye metody raboty so znaniyami: popytka obzora [Visual methods of working with knowledge: an attempt to review]. *Iskusstvennyj intellekt i prinyatie reshenij [Artificial Intelligence and Decision Making]*, 2008, no. 1, pp. 15-21 (in Russian).
[8] Gavrilova T.A. et al. About one method of classification of visual models [About one method of classification of visual models]. *Biznes-informatika [Business Informatics]*, 2013, no. 4 (26), pp. 21–34 (in Russian).
[9] Gavrilova T.A., Alsuf'ev A.I., Grinberg E..YA. Vizualizaciya znanij: kritika Sent-Gallenskoj shkoly i analiz sovremennyh trendov [Knowledge visualization: criticism of the St. Gallen school and analysis of modern trends]. *Biznes-informatika [Business Informatics]*, 2017, no. 3 (41), pp. 7–9 (in Russian).
[10] Doyle J.K., Ford D.N. Mental models concepts revisited: some clarifications and a reply to Lane *System Dynamics Review: The Journal of the System Dynamics Society*, 1999, v. 15, no. 4, pp. 411-415.
[11] Kitchin R.M. Cognitive maps: What are they and why study them? *Journal of environmental psychology*, 1994, v. 14, no. 1, pp. 1-19.
[12] Eden C. Analyzing cognitive maps to help structure issues or problems. *European Journal of Operational Research*, 2004, v. 159, no. 3, pp. 673-686.
[13] Axelrod R.*Structure of decision: The cognitive maps of political elites*, Princeton, NJ: Princeton University Press, 1976. 400 p.
[14] Robinson S. et al. (ed.). *Conceptual modeling for discrete-event simulation*, CRC Press, 2011. 490 p.
[15] Ackermann F., Eden C. Strategic options development and analysis.*Systems approaches to managing change: A practical guide*, Springer, London, 2010. pp. 135-190.
[16] Zbrishchak S.G. Sistemno–kognitivnyj podhod k organizacii sovmestnoj deyatel'nosti gruppy zainteresovannyh storon [System–cognitive approach to the organization of joint activities of a group of stakeholders]. *Ekonomika i upravlenie: problemy, resheniya [Economics and Management: problems, solutions]*, 2017, v. 3(66), no. 6, pp. 155-158 (in Russian).
[17] Mulder I., Swaak J., Kessels J. Assessing learning and shared understanding in technology-mediated interaction. *Educational Technology and Society*, 2002, no. 5(1), pp.35-47.
[18] Renger M., Kolfschoten G.L., de Vreede G.J. Challenges in collaborative modelling: a literature review and research agenda. *International Journal of Simulation and Process Modelling*, 2008, no. 4(3-4), pp. 248-263.
[19] Weick K.E., Sutcliffe K.M., Obstfeld D. Organizing and the process of sensemaking. *Organization science*, 2005/ no. 16(4), pp. 409-421.
[20] Zbrishchak S.G. Reshenie problemnyh situacij v menedzhmente na osnove kollektivnyh kognitivnyh kart [Solving problem situations in management on the basis of collective cognitive maps]. *Ekonomika i upravlenie: problemy, resheniya [Economics and Management: problems, solutions]*, 2017, v. 4(63), no. 3, pp. 235-245 (in Russian).

КОГНИТИВНАЯ КАРТА КАК РЕПРЕЗЕНТАЦИЯ СТРУКТУР ЗНАНИЙ

Збрищак С.Г.

Управление неявными знаниями требует специального подхода в силу сложности вербализации, объяснения и формализации. Цель статьи состоит в обосновании подхода к управлению неявными знаниями, позволяющий интегрировать положения из различных областей знаний на фундаменте системной методологии. Проблемы и задачи управления неявными знаниями рассматриваются в контексте социального взаимодействия индивидов. При этом возникают проблема взаимопонимания и коммуникативные барьеры. Проблема достижения взаимопонимания зависит от качества знаний, способов представления и согласованности знаний между собой. Предложен междисциплинарный подход на основе построения коллективной когнитивной карты. Методологической основой служит системная методология в части мягкого направления, а структурирование знаний происходит посредством построения коллективной когнитивной карты, которая представляет собой концептуальную системную модель знаний группы индивидов об исследуемой предметной области. Элементами модели служат идеи, предположения, суждения, мнения индивидов, а процесс построения рассматривается как способ организации социального взаимодействия, в основе которого лежит формирование совместного понимания посредством совместного придания смысла. Приоритетные направления дальнейших исследований включают задачи развития методов анализа, проверки и оценки достоверности моделей на основе коллективных когнитивных карт.