Knowledge Representation in Intelligent Collaborative Educational Systems

Sabina Katalnikova, Leonids Novickis, Natalya Prokofyeva

Riga Technical University, Riga, Latvia
{sabina.katalnikova, leonids.novickis, natalija.prokofjeva}@rtu.lv

Abstract. In this paper, the concept of collaborative intelligent educational system is presented. Different knowledge representation models are compared in the context of their use in collaborative intelligent educational systems. Advantages of semantic networks for knowledge representation in such systems are described. Main advantages of extended semantic networks are shown and a set of basic operations regarding them is drawn up.

Keywords: intelligent collaborative educational system, knowledge worker, extended semantic network.

1 Introduction

In today's world, a shift from technology based on energy investing to technologies based on knowledge and information has taken place. Knowledge plays a special role in post-industrial evolution. Leading experts in the field of practical implementation of the basic principles of sustainable development strategy – Peter Drucker [1], Alvin Toffler [2], James Brian Quinn [3] – independently proclaimed human entry into a new economy society – knowledge society, in which knowledge is the basic economic resource. Thus, regeneration of this resource has great importance, which is impossible without developing a conception of representation, acquisition, analysis and use of knowledge.

On the other hand, contemporary society faces new challenges – how to organize educational process in such a way that graduates become so called knowledge workers in the full sense of this term [4]?

The purpose of this article is to choose a possible model for knowledge representation in intelligent collaborative educational system as a basis for preparation of knowledge workers in today's society.

2 Knowledge Workers and Intelligent Collaborative Educational Systems

The leading social groups of the knowledge society will be 'knowledge workers' – knowledge executives who know how to allocate knowledge to productive use [5]. Knowledge work includes the work of all participants of the production process to achieve optimal results through combination of each employee's individual skills. A knowledge worker must constantly learn innovative knowledge to be competitive, and on the other hand – he or she cannot do without teaching. Thus, employee training function is one of priorities of staff management functions in modern organizations. But in global virtual organizations employees are scattered around the world.

Changes that occur each time and complexity of electronic technology society that uses a new type of electronic communication devices have resulted in continuing growth in the amount, diversity and service activities carried out in all fields [6]. Thus, in today's society, the concept of collaborative systems has emerged.

A collaborative system is a system in which many users or agents are engaged in a shared activity, often in distanced locations. In the large family of distributed applications, collaborative systems are distinguished by the fact that the agents work together to achieve a common goal and have a great need to interact with each other in the sense that they share information, change requests, etc. [7]

An educational system is a set of interrelated educational and innovative processes and the management of these processes. There exist general laws of development of educational systems. These are: focus on the ultimate objective, development of measures for precise system functioning, compliance of the sub-objectives with the ultimate objective, availability of resources, consistency, and safety.

Collaborative systems are applied in the educational field and aimed at evaluating and enhancing the performance of educational process [8]. Collaborative learning helps knowledge workers to carry on deeper conversations, create multiple perspectives and develop reliable arguments. This is the main reason why collaborative groups facilitate greater cognitive development than the one that the same individuals can achieve while studying alone [9].

An intelligent collaborative educational system applies methods of artificial intelligence to provide better support for the users of educational systems and is based on three elements: interconnection (a resource sharing technology education), instrumentation (accumulation of necessary data) and intelligence (making decisions that enhance the learning process) [10]. The architecture of an intelligent collaborative educational system can be described as is shown on Fig. 1. User Module effects interface between the system and the user. Management Module collects information from other modules, analyses and processes it, supplies other modules with information obtained from analysis. Domain knowledge module manages a number of educational objects and provides users with appropriate objects. Collaborative Educational Module procures strategies in accordance with the common goal of education. Control Module affords user tasks and tests and verifies their execution according to its model.

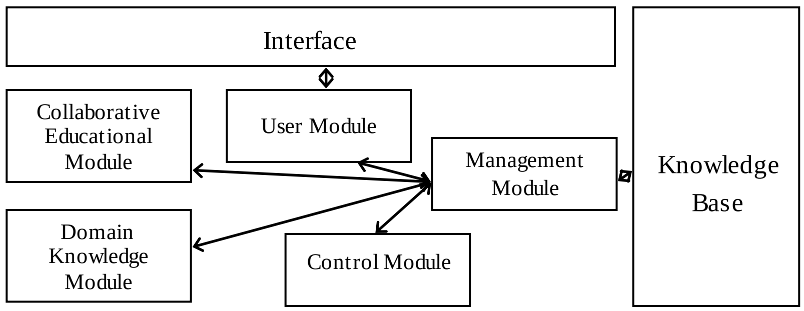

Fig.1. Structure of intelligent collaborative educational system

3 Related Works

Many research articles in the world and in Latvia are dedicated to the problem of intelligent collaborative educational system development. Though the idea of "intelligence" has built a long tradition in learning systems, it has only relatively recently entered the domain of collaborative learning.

For example, in [11] it is emphasized that computer-supported collaborative learning is focused on how collaborative learning supported by technology can enhance peer interaction and work in groups, and how collaboration and technology facilitate sharing and distribution of knowledge and expertise among community members.

In [12] it is defined that an intelligent educational system aims to provide learner-tailored support during the problem-solving process, as a human tutor would do. The comparative analysis of a large amount of publications resulted in a classification scheme, which is proposed as a comprehensive tool for analyzing and interconnecting the major design principles applied in the area of intelligent systems for collaborative learning support. Intelligent systems for collaborative learning support can be classified and their design and operation can be analyzed in the following dimensions:

- Pedagogical objective: the general pedagogical objective of the system.
- Target of intervention: the focus of the intelligent support.
- Modelling: modelling techniques implemented in the system.
- Technology: the kind of technology used to implement the intelligent operation of the system.
- Design space: how the intelligence-based intervention is presented to the partners.

Similar problems are described in many articles: development of intelligent tutoring systems based on knowledge workers' personal knowledge of management systems [4, 13], use of concept maps in adaptive and intelligent knowledge assessment [14-16], multiagent techniques, development of agent based intelligent tutoring systems [17-18], possibilities of extending the agent oriented software engineering methodology to make it usable for the development of other agent oriented systems [19]; development of web-based collaborative e-learning systems [20]. Paper [21] presents a method for agents' knowledge representation by using semantic network; paper [22] surveys graph based knowledge representation and reasoning, observations are presented highlighting suitability of the surveyed graph models for contemporary scenarios; in [23, 24] various tools and languages for knowledge representation using ontology are described, examples of tasks are listed; paper [25] defines the structure and the main applications of ontology.

However, it should be noted that the problem of development of directly collaborative educational systems for knowledge workers considering a set of their attributes has not been paid the attention it deserves in the scientific community.

4 Models of Knowledge Representation

Solving the problem of knowledge representation in general involves ensuring adequate display of knowledge stored in a variety of knowledge sources as formalized representations, automated processing of which will allow to effectively solve problem tasks from the domain under research to obtain results that are not qualitatively inferior to results obtained by highly qualified specialists of this domain in dealing with such problems [26].

At present, the most common models of knowledge representation in intelligent systems are the following:

- logical models (knowledge is represented as a set of correctly formed formulas of any formal system);
- production models (central element of this model is a set of products and rules of inference, instead of logical inference characteristic of logical models the conclusion based on knowledge is used);
- frame-based models (foundation of this knowledge model is the concept of frame – a data structure that represents some conceptual object or standard situation);
- network models in which the domain is considered as a set of objects and their relationships. Semantic networks are the most common network model of knowledge representation.

In the applied systems of artificial intelligence in fields like medicine, bioinformatics, semantic web etc., ontologies are widely used for knowledge representation. In working with ontologies, special languages of ontology representation (RDFS, OWL etc., [23-25, 27, 28]) are used to supplement traditional languages of knowledge representation.

Based on the set of general requirements traditionally imposed on models, it is possible to formulate some requirements for models of knowledge representation in intelligent collaborative educational systems [12, 26, 29, 30]:

- visuality of construction and display of logical connections and semantic relationships of investigated domain, taking into account the main components of an intelligent educational system, i. e. interconnection, instrumentation and intelligence;
- knowledge representation in terms of natural language pertinent to the studied domain, possibility to describe a set of the competences of each employee in the language of the model, possibility of taking into account in the model the individual attributes of each member of the cooperative learning group;
- obtaining holistic image of represented knowledge in the framework of hypotheses accepted in the construction of models, which allows to take into account all essential objects, their properties and relations involved in the problem to be solved, as well as to neglect the insignificant ones;
- preservation of information contained in the original and obtainment of new information;
- accessibility of the model for research;
- representation of both declarative and procedural knowledge;
- conceptual structure consisting of concepts and relationships between concepts should be unequivocal and unique.

Let us consider the comparison of properties of the basic models of knowledge representation based on the aforementioned requirements.

Table 1. Comparison of Properties of Basic Models of Knowledge Representation [26]

Requirements for Knowledge Representation Models	**Knowledge Representation Models**			
	Logical Model	**Production Model**	**Frame-Based Model**	**Semantic Network**
Knowledge representation in terms of natural language	±	+	+	+
Declarative knowledge representation	+	+	+	+
Procedural knowledge representation	+	+	+	–
Representation of logical connections in the domain	+	+	–	–
Representation of semantic relations in the domain	+	±	+	+
Visibility of knowledge description	–	–	–	+
Integrity of knowledge structure representation	–	–	–	+

The data presented in Table 1 ("+" symbol indicates the presence of corresponding properties in the representation model, “±” symbol – partial presence, “–” symbol – absence) shows that semantic network model meets the greatest number of requirements. As a result, the model of knowledge representation to be developed should be based on this model taking into account development of its logical and procedural properties. Extended semantic network is one of the varieties of this improved semantic network models. Extended semantic networks have been developed to eliminate heterogeneity of the usual semantic networks, which is caused by presence of the aggregates of objects linked by ties of relations, interconnected relations and other factors [31]. An important aspect of extended semantic network is its ability to represent procedural knowledge and also logical constructions.

5 Extended Semantic Networks

The concept of semantic networks of knowledge representation is based on the idea that all knowledge can be represented as a set of objects (concepts) and links (relations) between them.

The main advantages of semantic networks are as follows:

- proximity of the network structure to the semantic structure of phrases in natural language;
- visuality of knowledge system represented graphically;
- versatility achieved by selecting an appropriate set of relations;
- possibility to connect different network fragments;
- definition of operations performed on objects;
- for each operation on data or knowledge, it is possible to allocate a certain part of network that covers the essential characteristics of request.
- Semantic models also have some disadvantages:
- an arbitrary structure and different node and relation types complicate information processing;
- semantic networks have no special means to determine time dependencies;
- complexity of exception handling;
- representation, usage, and modification of knowledge and description of systems at the level of complexity corresponding to that of reality is a time-consuming procedure;
- processing of network models requires a special apparatus of formal withdrawal and planning.

In extended semantic networks, nodes can correspond not only to objects or concepts, but also to relations, logical components of information, complex objects and others. To everything that can be regarded as an independent unit, its own node must correspond. Thus, nodes of different type are entered – nodes corresponding to names of relations, as well as a special composite element called connection node. They are connected by marked edges with nodes taken from the array of above-mentioned nodes. As a result, a fragment appears that corresponds to elementary situation, i.e. objects that are bound by relation. Such a fragment is called an elementary one [31].

The basis of extended semantic networks is a set of nodes from which elementary fragments D_0 (D_1, D_2, ... , D_k / D_{k+1}) are compiled, where D_0 stands for relation name; D_1, D_2, ... , D_k – for the objects participating in relation; D_{k+1} – for the connection node denoting the whole array of objects participating in the relation; this node is also called c-node of elementary fragment; $D_0, D_1, D_2, \ldots, D_{k+1} \in D$, $\kappa>0$ [32].

Extended semantic networks are considered as a finite set of elementary fragments. Names of relations play the role of objects and can enter into relations. This defines high homogeneity of the model. Connection node of elementary fragment can be part of other elementary fragments but not as a c-node.

The set of nodes is partitioned into three disjoint subsets [33]:

$$D = G \cup X \cup E\ ,$$

where G stands for detected nodes (definite components); X – for undetected nodes (variable components, their roles are defined in further processing of the model; E – for special nodes (used in the production description).

In its turn, the G set consists of three subsets:

$$G = R \cup A \cup \{t,f\}\ ,$$

where R stands for an array of relation names (corresponding to D_0); A – for an array of concepts; {t,f} – for logical component D pointing to the truth or falsity of the relations of the represented relation, t – true, f – false.

Let us represent, for example, the most common view of intelligent collaborative educational system in the form of a fragment of extended semantic network. We shall use a reduced image of the elementary fragment. At first, we don't draw the node {t,f} with its edges. We assume that if this node is not connected to connection node by dint of corresponding fragment, true (t) relations are represented. It will simplify the drawing. Secondly, we put a special character of the empty space (_) in compliance with unimportant or unessential components. This symbol is required to represent relations for which not all components are specified but only the necessary ones.

As already mentioned, a collaborative intelligent educational system (CIES) is based on four elements: interconnection (IC), instrumentation (INST), intelligence (INT) and shared activity (SA). Thus, we can write the following expression:

Based on (CIES, IC, INST, INT, SA /_):

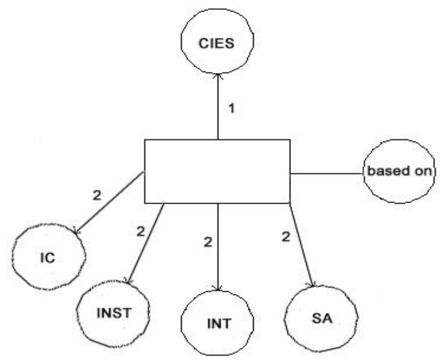

Fig.2. A fragment of description of a collaborative intelligent educational system

Operations on elementary fragments can be expressed by the objects themselves. The following nodes are entered into R to represent operations [33]:

- for set-theoretic relations – $\{\cap, \cup, \in, \backslash\} \subset R$;
- for arithmetic expressions – $\{+, -, *, :\} \subset R$;
- for logical constructions – $\{\wedge, \vee, \neg\} \subset R$;
- for the language of predicate logic – $\{\forall, \exists\} \subset R$;
- for queries – node $? \in R$;
- for representation of productions – nodes corresponding to cause-effect and part-whole relations allowing to represent the dynamic of changes of objects and strategy of their behavior.

For processing of knowledge represented by extended semantic networks, the principle of matching pattern in the form of two network overlay method is used. It is based on identification of rules allowing to bind nodes and compare networks in accordance with laws of logic [33].

The authors think that it is necessary to modify a set of operations on elementary fragments to use extended semantic networks for solving the problem of collaborative intelligent educational system development, because the whole domain of logical connections cannot be represented in existing extended semantic network models. The future work of the authors will be devoted to this issue.

6 Conclusions and Future work

In this paper, concepts of knowledge worker and collaborative intelligent educational systems have been considered, basic models of knowledge representation have been reviewed. The authors have briefly described advantages of extended semantic networks for knowledge representation in these systems and have shown that these networks meet the requirements more fully. Thus, the authors think that use of extended semantic networks in their future work is expedient. Future work will focus on the evolution of extended semantic network models, the general scheme of the improvement and detailed elaboration of collaborative intelligent educational systems, their practical implementation as a prototype and approbation in real conditions of modern higher education institutions.

References

1. Drucker P. F. Post-Capitalist Society. HarperBusiness, USA, 1994. 240 p.
2. Toffler A. The Third Wave. Bantam Books, USA, 1980, 537 p.
3. Quinn J.B. Intelligent Enterprise: A Knowledge and Service Based Paradigm for Industry.: The Free Press, New York, 1992, 1992, 473 p.
4. Grundspenkis, J. The Conceptual Framework for Integration of Multiagent Based Intelligent Tutoring and Personal Knowledge Management Systems in Educational Settings // Workshops

on Business Informatics Research: International Workshops and Doctoral Consortium, 2011, pp. 143-157.
5. Drucker P. F. Post-Capitalist Society. Harper Business, USA, 1994. 240 p.
6. Yi-Chen Lan. Global information society: operating information systems in a dynamic global business environment. Idea Group Publishing, 2005. [Online] available at http://books.google.lv/
7. Dobrican O. An Example of Collaborative System // International Workshop Collaborative Support Systems in Business and Education, Cluj-Napoca, 2005, pp.48.
8. Ciurea C., Batagan R. Collaborative Educational Systems // Oeconomics of Knowledge, Volume 2, Issue 4, 4Q 2010, pp.13-22
9. Różewski P., Jankowskia J., Bródka P., Michalski R. Knowledge workers' collaborative learning behavior modeling in an organizational social network. Computers in Human Behavior, Volume 51, Part B, October 2015, pp. 1248–1260.
10. Batagan L., Boja C., Cristian I. Intelligent Educational Systems, Support for an Education Cluster // Proceedings of the 5th conference on European computing conference, pp. 468-473
11. Lipponen L. Exploring Foundations for Computer-Supported Collaborative Learning // Proceedings of the Fourth Computer Support for Collaborative Learning Conference: Foundations for a CSCL Community, 2002, pp.72-81
12. Magnisalis I., Demetriadis S., Karakostas A. Adaptive and Intelligent Systems for Collaborative Learning Support: A Review of the Field // IEEE Transaction on Learning Technologies, Vol. 4, No. 1, January-March 2011, pp. 5-20
13. Grundspenkis, J., Ciekure, J. The Conceptual Framework for Integration of Intelligent Tutoring and Knowledge Management Systems in Education Settings // Perspectives in Business Informatics Research: 10th International Conference, 2010, pp. 242-250.
14. Grundspenkis, J. Concept Map Based Intelligent Knowledge Assessment System: Experience of Development and Practical Use. No: Multiple Perspectives on Problem Solving and Learning in the Digital Age. New York, Dordrecht, Heidelberg, London: Springer Science+Business Media, LLC, 2011. pp. 179-198.
15. Anohina-Naumeca, A., Grundspenkis, J. Concept Maps as a Tool for Extended Support of Intelligent Knowledge Assessment // Proceedings of the 5th International Conference on Concept Mapping: 5th International Conference on Concept Mapping, 2012, pp. 57-60.
16. Anohina-Naumeca, A., Graudina, V., Grundspenkis, J. Using Concept Maps in Adaptive Knowledge Assessment // Advances in Information Systems Development: New Methods and Practice for the Networked Society. Vol.1. New York: Springer, 2007, pp. 469-480.
17. Lavendelis, E., Grundspenkis, J. MIPITS - An Agent based Intelligent Tutoring System // Proceedings of 2nd International Conference on Agents and Artificial Intelligence, 2010, pp. 5-13.
18. Lavendelis, E., Grundspenkis, J. MASITS Methodology Supported Development of Agent Based Intelligent Tutoring System MIPITS // Proceedings of 2nd International Conference on Agents and Artificial Intelligence, 2010, pp. 119-132.
19. Lavendelis, E. Extending the MASITS Methodology for General Purpose Agent Oriented Software Engineering // Proceedings of the 7th International Conference on Agents and Artificial Intelligence, 2015, pp. 157-165.
20. Novickis, L., Rikure, T. Intelligent Tutoring Systems // Proceedings of IST4Balt International Workshop "IST 6th Framework Programme – Great Opportunity for Cooperation & Collaboration", 2005, pp. 35-40.
21. Hernes M. The Semantic Method for Agents' Knowledge Representation in the Cognitive Integrated Management Information System // Position Papers of the Federated Conference on Computer Science and Information Systems, 2015, Vol. 6, pp. 195–202

22. Rajangam E., Annamalai C. Graph Models for Knowledge Representation and Reasoning for Contemporary and Emerging Needs – A Survey // I.J. Information Technology and Computer Science, 2016, Vol. 2, pp.14-22
23. Jain S., Mishra S. Knowledge Representation with Ontology // Proceedings of International Conference on Advances in Computer Engineering & Applications, 2014, pp. 1-5.
24. Korshikov D., Lakhin O., Noskova A., Yurygina Yu. Development of Knowledge Representation Techniques for use in Modelling // Proceedings of International Conference "Open Semantic Technologies for Intelligent Systems", 2015, pp. 3-7
25. Gontier, E.M. Web Semantic and Ontology // Advances in Internet of Things, 2015, Vol. 5, pp. 15-20
26. Yalovets A.L. Representation and Processing of Knowledge from the Point of View of Mathematical Modeling. Naukova Dumka, Kiev, 2011. p. 339 [In Russian]
27. Gruber T.R. A Translation Approach to Portable Ontology Specifications // Knowledge Acquisition, 1993, Vol. 5(2), pp. 199–220
28. Verkhoturova Yu.S. Ontology as a Model of Knowledge Representation // Buryat State University Gazette, 2012, 5(2), Vol.15, pp. 32-36 [in Russian]
29. Clark P. Requirements for a Knowledge Representation System. [Online] http://www.cs.utexas.edu/users/pclark/working_notes/010.pdf.
30. Schank R.C. Conceptual Information Processing. American Elsevier Publishing Company, Inc., New York, 1975
31. Kuznetsov I.P. Semantic Representation. Nauka, Mockow, 1986, p. 296 [In Russian]
32. Kozerenko E.B., Kuznetsov I.P. Evolution of Linguistic Semantic Presentations in the Intelligent Systems Based on the Extended Semantic Networks // Computer Linguistics and Intelligent Technologies, 2010, Vol. 9, pp. 205-211
33. Bashmakov A. Intelligent Information Technology. MSIT, Moskow, 2005. 302 p. [In Russian]