Application of the Fuzzy Knowledge Base in the Construction of Expert Systems

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***Abstract*—This article describes a formal model of the fuzzy knowledge base based on the analysis of contexts of the subject area. Also, the article describes the architecture of the fuzzy knowledge base. In addition, the article describes application of the knowledge base model in developing an expert system for diagnosing the level of development children of early age.**

Keywords—ontology; fuzzy ontology; knowledge base; temporary context; space context; expert system

I. Introduction

At present, artificial intelligence methods are used to solve various problems in the field of business process automation. The use of methods of artificial intelligence allows computing systems to solve intellectual problems approximately at the human level. However, intelligent systems solve specific problems and cannot completely replace a person.

Intellectual systems should have knowledge of the problem area (PrA) and methods for solving the tasks assigned. Now, for "learning" of intelligent systems the following methods are used:

- methods of machine learning;
- methods of knowledge engineering.

The methods of machine learning assume the use of different versions of neural networks. Neural networks allow to identify patterns and use them to solve set tasks. However, neural networks require serious attention to architecture and teaching methods. Trained neural networks solve only specific tasks.

The methods of knowledge engineering describe the features of the PrA in the form of a semantic network. The resulting semantic networks can be extended and adapted to solve a wide range of problems. However, the construction of semantic networks requires a lot of time and labor.

Ontologies are used as a form of representation of knowledge base in intelligent systems based on the methods of knowledge engineering. Ontology is a formalized representation of the features of the PrA. A large number of foreign and Russian researchers use ontologies to learn intelligent systems: F. Bobillo, U. Straccia [1], M. Gao, C. Liu [2], D. Bianchini [3], N. Guarino [4], G. Guizzardi [5], R.A. Falbo [6], G. Stumme [7], T.R. Gruber [8], A. Medche [9], T.A. Gavrilova[10], V.N. Vagin [11], V.V. Gribova [12], Yu.A. Zagorulko [13], A.S. Kleschev [14], I.P. Norenkov, D.E. Palchunov, S.V. Smirnov [15].

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At the moment Web Ontology Language version 2 (OWL) is used to describe ontologies. It became a recommendation of the W3C consortium since October 27, 2009 [16].

FuzzyOWL [1] is an extension of OWL using elements of fuzzy logic. FuzzyOWL allows you to take into account the fuzziness in the features of PrA by introducing structures in order to describe the membership functions in ontology.

The following limitations of the existing software for ontology processing in the OWL / FuzzyOWL format were identified in the process of development of the knowledge base (KB):

- lack of support for the transaction mechanism;
- lack of multi-user mode for working with content of KB;
- low speed of mechanisms for inference [17].

These problems can be solved using graph database management systems (DBMS). Thus, it is necessary to develop a mechanism for mapping the ontology in the OWL / FuzzyOWL format to a graph structure taking into account the different contexts of the OWL.

II. Constructing of Fuzzy KB by Analysis of Domain Contexts

It is necessary to extract the basic entities and relations for the translation of the ontology in OWL / FuzzyOWL format into a graph. These entities and relations accurately interpret the nodes and relations of the graph when using the KB.

The authors decided to include contexts in the ontology model of the KB, in addition to the basic entities and relations. Ontology contexts represent the contents of the KB in the context of space and time.

The use of space contexts allows solving the problem of taking into account the competence level of an expert in a certain subarea of the PrA [18][19] by creating separate contexts of formalized descriptions in constructing a domain ontology. Each context is associated with a value in the range

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from 0 to 1 that determines the expert's degree of confidence (competence) in the given subarea of the PR.

Temporary contexts allow to versioning of content of the ontology of the KB. This makes it possible to trace the dynamics of the development of this formalized description and return to a certain state of the domain ontology.

Formally, the ontology can be represented by the following equation:

$$O = \left\langle T, C^{T_i}, I^{T_i}, P^{T_i}, S^{T_i}, F^{T_i}, R^{T_i} \right\rangle, i = \overline{1, t},$$

where t is a number of the ontology contexts, $T = \{T_1, T_2, \ldots, T_n\}$ is a set of ontology contexts, C^{T_i} is a set of ontology classes within the i-th context, I^{T_i} is a set of ontology objects within the i-th context, P^{T_i} is a set of ontology classes properties within the i-th context, S^{T_i} is a set of ontology objects states within the i-th context, F^{T_i} is a set of the PrA processes fixed in the ontology within the i-th context, R^{T_i} is a set of ontology relations within the i-th context defined as:

$$R^{T_i} = \left\{R_C^{T_i}, R_I^{T_i}, R_P^{T_i}, R_S^{T_i}, R_{F_{IN}}^{T_i}, R_{F_{OUT}}^{T_i}\right\},$$

where $R_C^{T_i}$ is a set of relations defining hierarchy of ontology classes within the i-th context, $R_I^{T_i}$ is a set of relations defining the 'class-object' ontology tie within the i-th context, $R_P^{T_i}$ is a set of relations defining the 'class-class property' ontology tie within the i-th context, $R_S^{T_i}$ is a set of relations defining the 'object-object state' ontology tie within the i-th context, $R_{F_{IN}}^{T_i}$ is a set of relations defining the tie between $F_j^{T_i}$ process entry and other instances of the ontology within the i-th context, $R_{F_{OUT}}^{T_i}$ is a set of relations defining the tie between $F_j^{T_i}$ process exit and other instances of the ontology within the i-th context.

Let us consider the operation of logical rules on the example of an ontology describing turning operations (Fig. 1).

The ontology presented on Fig. 1 includes 'Object' and 'Subject' classes with specific properties. These classes are the parent ones for all other ontology classes, herewith, parent properties are inherited by descendants. The ontology also includes objects 'Machine', 'Component', 'Turner' and 'Smith'; each of them has its own set of statements. The object 'Smith' has the statement 'hasAProfession' with a value 'Turner'.

'Working with' is the SWRL-rule [20] for the logic output of the type 'hasAProfession'(Smith, Turner) → 'workingWith'(Smith, Machine) represented in the form of the domain ontology function. The rule describes the implicit relation between 'workingWith' and objects 'Smith' and 'Machine' (Fig. 1).

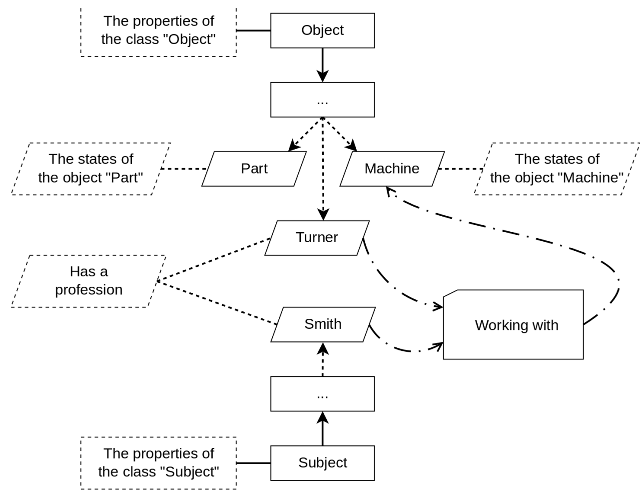

Fig. 1. Ontology «Turning operations».

Thus, many nodes and relations are formed in the knowledge base during the import of the ontology in the OWL / FuzzyOWL-format. The resulting nodes and relationships form a graph. The resulting graph is stored in a graphical DBMS. This approach helps to solve the problems presented in the introduction.

III. Construction of an Expert System Based on a Fuzzy Domain KB

A. Description of the problem

Modern public policy of the Russian Federation is aimed at family support and highly appreciates its role in formation of the identity of the child. Effective activity of parents as first tutors is caused by their level of pedagogical competence. Competence of parents is especially significant in early childhood development. Teachers and psychologists are defined the early childhood as the most sensitive time to formation of the identity of the child.

Currently, many parents are incompetent in early childhood development. Many young parents do not have complete knowledge about early childhood, ways and forms of interaction with the small child [21]. Parents often underestimate possibilities of the kid and a phenomenon of delay of parents concerning the level of development of the child arises. This phenomenon is called a parental blindness to the changed opportunities, requirements and problems of a child development [22]. In other case, parents overestimate possibilities of the child up to three years and use of techniques of early childhood development placing excessively great demands on the kid.

Young parents need to psychological and pedagogical knowledge in the field of early childhood development and education to own pedagogical competence [23].

Pedagogical competence of the parent assumes ability to study the child and to diagnose his development. Diagnostic inspection acts as one of forms of psycho-pedagogical support of early family education. An important role for harmonious development of children is played by the organization of timely psycho-pedagogical diagnostics of the level of development of children of early age [24][25].

Diagnostics allows not only to define the current level of achievements of the child, but also to define a zone of proximal development. Also, diagnostics allows to effectively direct pedagogical process and to provide significant individualization of educational work at early age [26].

The existing diagnostic tools do not include complex psycho-pedagogical analysis of a child development and are concentrated only on separate aspects [27]. The existing diagnostic tools are focused on work of narrow experts of the education sphere. Using of such tools demands some professional knowledge.

Thus, there is a need for the expert system (ES) allowing to diagnose the level of development of the child. Such ES will help to create recommendations for parents having increased a family role in early child diagnostics and correction. One of the major requirements to similar ES is the convenient and clear interface both for parents and for the experts. For work with ES expert should not have skills in the field of knowledge engineering and ontological analysis.

B. Technique of diagnostics of the level of the child development

There is a number of methodical developments of the Russian researchers representing system of early diagnostics and psycho-pedagogical support to children of early age now [27]:

- a technique of early diagnostics of intellectual development by Strebelove E.A. (1994) [28];
- a technique of development and education of children of early age by Golubeva L.G. (2002) [29];
- a technique of diagnostics of mental development of children from the birth up to 3 years by Smirnova E.O. (2003) [30];
- a technique of studying of emotional insufficiency of the child of early age by Bayenskaya E. and Libling M.M. (2001);
- a technique of inspection of children with violations in the sphere of formation of movements by Prihodko O.G. and Moiseeva T.U. (2001) [31];
- a technique of pedagogical inspection of hearing at children of the first year of life by Pelymskaya T.V. and Shmatko N.D. (2001);
- a technique of psycho-pedagogical diagnostics of violations of visual perception at children by Ilchikova I.I., Vernadskaya M.E. and Paramey O.V. (2003);
- a technique of early logopedic diagnostics by Chirkina G.V. and Razenkova Y.A. [32];
- a technique of diagnostics of development of children of early age (from the birth up to three years) by Pechora K.L. and Pantukhina G.V. (1979) [33]etc.

As a technique of diagnostics of the level of development of the child the technique developed by K. L. Pechora and G. V. Pantyukhina was chosen [33]. This technique has the following advantages:

1. Existence of the indicators of the psychological development (PD) of:
    - speech development;
    - touch development;
    - behavior of the child in a game and actions with objects;
    - motive abilities;
    - skills of independence;
    - skills in constructive and inventive activity;
    - social development.
2. Existence of an assessment of level of the PD of children on groups of development approved in long-term practice of work.
3. Existence of an opportunity to track dynamics of an individual child development.

The technique developed by K. L. Pechora and G.V. Pantyukhina assumes emotional business communication between the parents and the child. This technique considers not only the alternative solution of the offered task, but also an orientation of children's thinking, manifestation of the identity of the child. This technique allows to define complexity of a task and "comfortable" for the child in connection with novelty aspects.

The technique of diagnostics of the level of development of the child by K. L. Pechora and G. V. Pantyukhina is contains:

- list of tasks;
- description of material, necessary for performance of tasks (for example, articles of clothing);
- description of a technique of diagnostics;
- description of the expected result;
- list of the tasks for development of certain PD indicators.

Formally, the level of the PD of the child:

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$$PD = \begin{Bmatrix} Speech, Touch, Game, Motive, \\ Independence, Inventive, Social \end{Bmatrix},$$
$$L = \{x : x \in [0, \ldots, 1]\},$$

where $Speech$ is a value of an indicator of speech development; $Touch$ is a value of an indicator of touch development; $Game$ is a value of an indicator of behavior of the child in a game and actions with objects; $Motive$ is a value of an indicator of motive abilities; $Independence$ is a value of an indicator of skills of independence; $Inventive$ is a value of an indicator of skills in constructive and inventive activity; $Social$ is a value of an indicator of social development.

Formally the current level of child development:

$$PD^j = \frac{\sum_{t=1}^{T} R_t^j}{T}, R_t^j \in [0,1],$$

where R_i^j is a result of a task for j-th indicator of the PD of the child in timepoint t; T is a number of timepoints of an assessment of indicators of the PD of the child.

In order to form of the list of the tasks for development of certain PD indicators the following function is used:

$$F : \{PD^j < SPD_p^j\} \rightarrow \{L^j\},$$

where $\{PD^j < SPD_p^j\}$ are indicators of the PD which value is less than reference indicator SPD_p^j for the development period p; $\{L^j\}$ - is a list of the tasks for development of certain PD indicators that picked up on the basis of degree of a deviation of the level of development of j-th indicator of the PD of the child.

Thus, the chosen technique contains all data necessary for the solution of an objective and can be used for building of KB of developed ES.

C. The architecture the ES for diagnostics the level of child development

An expert system for diagnostics the level of child development consists of modules:

content management module for KB;

ontology import/export module (OWL / FuzzyOWL);

screen forms generation module;

user interaction module;

administration module.

The architecture of the ES for diagnostics the level of child development is shown in Figure 2.

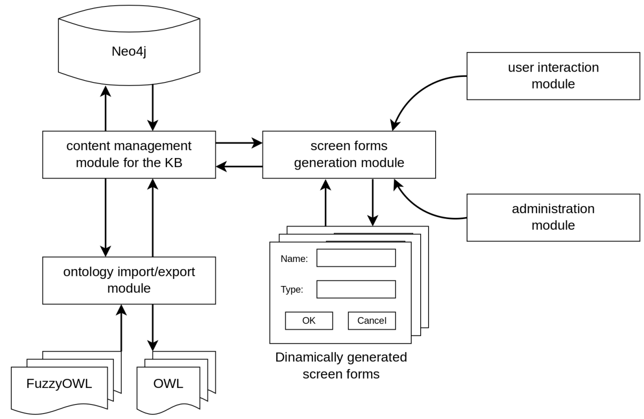

Fig. 2. The architecture of the ES for diagnostics the level of child development.

The content management module for the KB provides the basic methods for working with the entities of the KB. Also, it allows to use logical rules of the ontology to create implicit connections between the nodes of the graph.

Ontology import / export module provides mechanisms for translating OWL / FuzzyOWL elements in the KB entity. The reverse process is also possible.

Screen forms generation module allows to generate an interface based on the structural elements of the ontology of KB dynamically (classes and properties of classes) [12].

User interaction module and administration module use the screen forms generate module and create mechanisms for setting up and using the expert system.

Java programming language and Spring Boot framework were used for developing the expert system. Java language and Spring Boot increase the speed of development.

Modules are performed in the Jetty servlets container. Jetty has modular architecture. Modular architecture allows to use only needed functions and reduces the performance load on the server. Also, Jetty is highly scalable for performing a lot of connections with significant downtime between the queries.

The basis of the ES architecture is the principle of microservices. Microservices is a variant of the service-oriented architecture (SOA) architectural style that structures an application as a collection of loosely coupled services. In a microservices architecture, services should be fine-grained and the protocols should be lightweight. The benefit of decomposing an application into different smaller services are:

it improves modularity and makes the application easier to understand, develop and test;

it parallelizes development by enabling small autonomous teams to develop, deploy and scale their respective services independently;

it allows the architecture of an individual service to emerge through continuous refactoring;

microservices-based architectures enable continuous delivery and deployment.

The REST (Representational State Transfer) [34] mechanism was used for the interaction of ES modules. According to the REST architecture, the remote procedure call is a normal HTTP request (GET, POST, PUT, etc.) and the required data is passed as query parameters.

Neo4j [35] graph database is used as storage of ontologies for managing the KB content. It has the following advantages:

- native format for graph storages;
- one database instance can serve graphs with billions of nodes and relations;
- it can process graphs that do not have enough space in RAM;
- graph-oriented query language – Cypher.

All the above resources, applications, and technologies are free.

IV. CONCLUSION AND FUTURE WORKS

Thus, the application of the ontological approach for the construction of ES based on fuzzy KB will provide teachers and parents with a universal tool for diagnosing the level of child development.

Using the developed ES helps to speed up the process of diagnosing the level of development of the child, increase the competence of parents in the issues of upbringing and development of young children. The developed ES does not require users to have skills in the field of knowledge engineering and ontological analysis.

In future works, the authors plan to develop an algorithm for self-learning the KB by extracting knowledge from semi-structured resources. We also plan to apply the developed expert system in the work of the diagnostic children's medical center.

REFERENCES

[1] F. Bobillo and U. Straccia, “Representing fuzzy ontologies in OWL 2”, Proceedings of the 19th IEEE International Conference on Fuzzy Systems (FUZZ-IEEE 2010), IEEE Press (2010), pp. 2695–2700.

[2] M. Gao and C. Liu, “Extending OWL by fuzzy description logic”, Proceedings of the 17th IEEE International Conference on Tools with Artificial Intelligence (ICTAI 2005), IEEE Computer Society (2005), pp. 562–567.

[3] D. Bianchini, V. DeAntonellis, B. Pernici and P. Plebani, Ontology-based methodology for e-service discovery, Information Systems no. 31 (4), pp. 361-380.

[4] N. Guarino and M.A. Musen, “Ten years of Applied Ontology”, Applied Ontology no. 10 (3-4), pp. 169-170.

[5] G. Guizzardi, N. Guarino and J.P.A. Almeida, “Ontological Considerations About the Representation of Events and Endurants in Business Models”, International Conference on Business Process Management, pp. 20-36.

[6] R.A. Falbo, G.K. Quirino, J.C. Nardi, M.P. Barcellos, G. Guizzardi and N. Guarino, “An ontology pattern language for service modeling”, Proceedings of the 31st Annual ACM Symposium on Applied Computing, pp. 321-326.

[7] A. Hotho, S. Staab and G. Stumme, “Ontologies improve text document clustering Data Mining” Third IEEE International Conference, 2003, pp. 541-544.

[8] T. Gruber, “Ontology. Entry in the Encyclopedia of Database Systems”, Springer-Verlag, 2008.

[9] A. Medche, Ontology learning for the Semantic Web. Engineering and Computer Science, Kluwer International, no. 265, 2002.

[10] T.A. Gavrilova, The Ontological Approach to Knowledge Management in the Development of Corporate Information Systems, Novosti iskusstvennogo intellekta [News of Artificial Intelligence], 2003, no. 2(56), pp. 24-29.

[11] V.N. Vagin, “Development of the method of integration of information systems based on metamodelling and ontology of the subject domain”, Programmnye produkty I sistemy [Software products and systems], 2008, no 1, pp. 22-26.

[12] V.V. Gribova and A.S. Kleshchev, “Managing the design and implementation of the user interface based on ontologies” // Problemy upravleniya [Management issues], 2006, no. 2, pp. 58–62.

[13] Y.A. Zagorulko, “Building scientific knowledge portals based on ontologies”, Vychislitelnye tekhnologii [Computing technologies], 2007, no. 12, pp. 169-177.

[14] A.S. Kleschev, “The role of ontology in programming. Part 1. Analytics”, Informatsionnye tekhnologii [Information Technology], 2008, no. 10, pp. 42-46.

[15] S.V. Smirnov, “Ontological modeling in situational management”, Ontologiia proektirovaniia [Ontology of design], 2012, no. 2 (4), pp. 16-24.

[16] OWL 2 Web Ontology Language – Specifications. Available at: https://www.w3.org/TR/owl2-syntax (Accessed 28.03.2017).

[17] S.D. Makhortov, “About Algebraic Model of a Distributed Production System”, KII-2016, Smolensk, 2016, no. 1, pp. 64–72.

[18] V.B. Tarasov, A.P. Kalutskaya and M.N. Svyatkina, “Granular, fuzzy and linguistic ontologies to provide mutual understanding between cognitive agents”, OSTIS-2012, Minsk, 2012, pp. 267–278.

[19] V.S. Moshkin and N.G. Yarushkina “Methods for constructing fuzzy ontologies of complex subject domains”, OSTIS-2015, Minsk, 2015, pp. 401–406.

[20] SWRL: A Semantic Web Rule Language Combining OWL and RuleML. Available at https://www.w3.org/Submission/SWRL (Accessed 20.03.2017).

[21] Y.Y. Malkova, “Problem of incompetence of parents in education of children of an early age”, Molodoy uchenyy [Young Scientist], no. 1, 2013, pp. 340-342.

[22] O.V. Novikova and V.A. Romanenko, “Pedagogical line item of the parent of the child of an early age: content, dynamics of development”, Vospitaniye i obucheniye detey mladshego vozrasta [Education and training of children of younger age], 2016, no. 5. Available at: http://cyberleninka.ru/article/n/pedagogicheskaya-pozitsiya-roditelya-rebenka-rannego-vozrasta-ee-soderzhanie-dinamika-razvitiya (Accessed 26.03.2017).

[23] V.V. Selina, Development of pedagogical competence of parents of children of early age of preschool educational institution. Available at: http://www.dissercat.com/content/razvitie-pedagogicheskoi-kompetentnosti-roditelei-detei-rannego-vozrasta-v-doshkolnom-obrazo#ixzz4cVQmMliD (Accessed 18.03.2017).

[24] N. Y. Maydankina, “Specifics of formation and updating of potential of the teacher of the preschool educational organization in the modern conditions”, Vektor nauki tol'yattinskogo gosudarstvennogo universiteta [Vector of science of the Tolyatti state university], no. 2-1 (32-1),. 2015. pp. 180-185.

[25] N.Y. Maydankina, L.I. Ziyazetdinova and L.L. Lebed', “Features of support of pedagogical support of early family education in the conditions of preschool educational institution of a general education look”, Sovremennyy detskiy sad [Modern kindergarten], 2013, no. 2, pp. 64-66.

[26] Y.M. Khokhryakova, “Problem of diagnostics of mental development in pedagogics of an early age”, Sibirskiy pedagogcheskiy zhurnal [Siberian pedagogical journal], no. 9, 2010. Available at: http://cyberleninka.ru/article/n/problema-diagnostiki-psihicheskogo-razvitiya-v-pedagogike-rannego-vozrasta (Accessed 28.03.2017).

ISSN (Print): 2204-0595
ISSN (Online): 2203-1731

[27] O.M. Bondarenko, “The review of diagnostic techniques for identification of children of risk group of an early age”, VIII International Student Electronic Scientific Conference "Student Scientific Forum - 2016". Available at: https://www.scienceforum.ru/2016/1623/20224 (Accessed 28.03.2017).

[28] Y.A. Strebeleva, “The early correctional pedagogical help to children with limited opportunities of health”, Defektologiya [Defectology], 2003, no. 3.

[29] L.G. Golubeva, Development and education of children of an early age, Manual. Academy, Moscow, 2002.

[30] Y.O. Smirnova, Diagnostics of mental development of children from the birth up to 3 years, Moscow, 2003.

[31] O.G. Prikhod'ko and T.Y. Moiseyeva, Children with motive violations: correctional work on the first year of life, Moscow, 2003.

[32] G.V. Chirkina, Methods of inspection of the speech of children, Manual for the diagnosis of speech disorders. Moscow, 2003.

[33] K.L. Pechora and G.V. Pantyukhina, Diagnostics of development of children of early age. The developing games and occupations, TTS Sfera, Moscow, 2016.

[34] Representational state transfer. Available at: https://en.wikipedia.org/wiki/Representational_state_transfer (Accessed 9.03.2017).

[35] Neo4j – Official site. Available at: https://neo4j.com/product (Accessed 10.01.2017)

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ISSN (Online): 2203-1731