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Modification of Models Intensive Development Ontologies by Fuzzy Logic

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ABSTRACT

The problem of eliminating the inadequacy that arises during by using develop ontologies is solved by modifying the development model of fuzzy ontologies. We propose a modified model of the development of ontologies in time, as well as a formal model of intensive development, which makes it possible to efficiently solve the problems of analysis and estimation of the state space of ontologies that are developing using fuzzy logic. These models allow us to determine and eliminate the properties of inadequacy by using develop distributed ontology control systems. Based on interpreting by using develop ontologies, the ways of further stages of this research, and the development of methods for presenting fuzzy information in ontologies, are determined.

Key words: Ontology, Intensive Development of Ontologies, Fuzzy Import of Ontologies, Adequacy, Membership Function, Fuzzy Logic

1. INTRODUCTION

The research of the intellectual mechanisms of using develop fuzzy ontologies, the means of eliminating the inadequacy that arises during this development, increasing the reliability of decisions made by these approaches is one of the priority areas in complex information systems [1].

Ontologies occupy a leading place in the tasks of managing information flows. They are constantly developing, supplemented by knowledge, and updated [2]. The most difficult task of updating ontologies is by using eliminating conflicts when they entered knowledge contradicts those that were postulated earlier [3].

Intellectual support for such problems is especially relevant if we take into account the multi-scale systems that traditionally use ontologies [4]–[6].

2. REVIEW OF THE LITERATURE

Modern tools that allow operating with ontologies do not fully solve the aspects of by using occur inadequacy, in particular, inconsistency in the development process, which is a significant drawback [7], [8].

Ontologies in artificial intelligence systems are an important step in the representation and integration of knowledge and data; they provide both high levels of expression and formalization by using describe the subject area [9].

The adequacy of such structures is a property by which the subject area is accurately transmitted in a formal language. Given the predominantly modular nature of ontologies, issues of adequacy and consistency become especially relevant [10]. A significant step in information technology to the widespread use of ontologies was the use of fuzzy information and fuzzy inference [11]–[15]. Introducing linguistic variables into axioms and rules [16] allows us to formalize fuzzy information using a language close to natural [17]. Models that are being developed or changed should include work with both clear and fuzzy ontologies.

Despite many scientific papers [1], [2], [4]–[10], today there is still a problem of research and determining the adequacy of ontologies that are developing. There is a need for comprehensive solutions to complex problems that arise during by using develop ontologies.

3. PROBLEM STATEMENT

Promising is by using modify the development models of fuzzy ontologies, which will allow, based on intelligent approaches, to realize the processes of supporting the development and integration of ontologies of complex systems.

This research modifies the development model of fuzzy ontologies to eliminate the inadequacy that arises during by using develop ontologies.

The object of research is fuzzy ontologies that develop over time.

The subject of the research is the analysis models by using develop fuzzy ontologies of complex systems.

The solution to the problem of decision-making intellectualization during by using develops ontologies involves the use of such methods: hypothetical-deductive, artificial intelligence, logical inference, and the provisions of the theory of fuzzy sets and fuzzy logic.

4. MATERIALS AND METHODS

The main goal of the ontology is to attract standard dictionaries into information systems most users of the system can use that. Centralized ontologies use standardized terms, for large ontologies that are developing, this approach becomes critical [18]. Ontology at each stage of development is less susceptible to memorization; internal navigation becomes difficult for development and support.

Each current development of the ontology, and the principles of its construction, must be provided with clear instructions on how they should be used [19], be reflected in dictionaries and subject areas, and provide information on the potential ambiguity in interpreting terms.

A standardized dictionary is not the only one; there is a set of options. Given the features of ontology problems, it is necessary to maintain their compatibility with many dictionaries. They lead to by using generalize parallel existing ontologies using the means of an intelligent integration system [20].

Improving the quality of information retrieval is achieved through the use of inference mechanisms [11]–[14], [16], [17]. The accuracy and completeness of the search are enhanced by using specified ontologies. We use the semantic load of ontology: properties of equivalence, incompatibility, class restrictions [18]. The high expressiveness of the ontology allows us to draw a deep deductive conclusion, which requires a significant investment of time [8].

By using develop formal knowledge bases involve the use of linguistic variables and the apparatus of fuzzy logic to adequately reflect the domain [9].

There are various approaches to presenting fuzzy ontological information [1], [2], [4]–[10], [18]–[20]. The disadvantage of these approaches is the lack of a formal presentation of a fuzzy axiom or concept, which reduces the possibility of constructing formal models of fuzzy ontologies in general.

The formal model of fuzzy descriptive logic looks

$$(a:c)^I \to [0,1], ((a,b):r)^I \to [0,1],$$

where $a:c$ and $(a,b):r$ – are declarative axioms; I – interpretation.

Existing applied solutions in the field of ontology development do not fully implement the functionality of working with fuzzy ontologies [19].

The disadvantages of by using develop ontology systems and introducing tools based on ontologies are [20]:

– low level of formalization of the ontology development process;
– we provide ontological information only in terms of set space;
– lack of fully functional tools for managing integration and development of ontologies.

During this research, it is necessary to identify and evaluate change ω of ontology Ont when changing its element $Elem$ to some variable ξ

$$\Delta Ont = \omega \big| \Delta Elem = \xi,\ Elem \in Ont\ , \tag{1}$$

or in general terms

$$\begin{gathered} \Delta Ont = \omega \big| \Delta Elem_i = \xi_i,\ Elem_i \in Ont, \\ (\forall Elem_i \big| \xi_i \neq \varnothing) \end{gathered} . \tag{2}$$

Definition ω and a reasonable interpretation of this indicator will greatly simplify and increase work efficiency, reduce the level of the laboriousness of ontology development modifications, and also increase the reliability of decisions made.

To determine change ω (1), (2) it is necessary to build formal models of static Ont and variable $Ont(t)$ of the ontology, and also to determine the patterns observed within these models.

Ontology, as a formal reflection of reality, requires a clear presentation of information, which leads to significant conceptual difficulties in implementing procedures for adequate fuzzy inference and adequate integration blocks of ontological information. There are several tasks for which an effective fuzzy representation of knowledge: a description of complex processes, the creation of dictionaries and thesauruses.

The approaches to the analysis of ontologies [1], [8], [19] have several functional limitations and fundamental shortcomings: the inability to work with fuzzy data, the high complexity of the analysis procedures. Using fuzziness in ontologies [11], [16] does not contain generally accepted methods.

We associate fuzzy mapping in ontology with the task of forming meta-descriptions of ontological information.

The meta-described statement has a couple

$$a_m = \langle a, meta_a \rangle, \quad (3)$$

where $meta_a$ – is the meta-information about a.

Common methods for introducing meta-descriptions (3) are the following approaches [18]:

– reformation;
– introduction of meta-ratio;
– introduction of the goal class.

These approaches have their advantages and disadvantages [18], but an important aspect is that formally we can transform each of the given descriptions into one of the other two.

The meta-element of the statement is the membership function μ_a [14], [19]:

$$\tilde{a} = \langle a, \mu_a \rangle, \quad (4)$$

where $\tilde{a}$ – is a fuzzy statement; a – corresponding clear statement; μ_a – membership function, which determines the degree of confidence in the existence of statement a.

Any ontology Ont that has at least one statement of the form (4) is fuzzy. If the value is $\mu_a = 1$ in (4), then this statement will be clear, there is no need for a fuzzy ontology. If the value is $\mu_a = 0$ in (4), then this statement can be removed from the ontology without affecting its semantics.

5. EXPERIMENTS, RESULTS AND DISCUSSION

We formalize the concept of ontology. Ontology Ont – is a set of semantically related elementary ontologies Ont_e

$$Ont = \{Ont_e\}.$$

Elementary ontology Ont_e is a pair

$$Ont_e = \langle KB, M \rangle, \quad (5)$$

where KB – is a knowledge base containing a finite set of all ontology elements; M – meta-information of ontology.
Imagine the semantic connection of ontologies with the help of their interpretation. An independent element A from element B of ontology Ont is an element for which it is true:

$$independent(A,B) = \\ = true \left| \begin{array}{l} A_1^I = A_2^I, B_1^I = \Delta^I, B_2^I = \varnothing, \\ A_1, B_1 \in Ont_1, \\ A_2, B_2 \in Ont_2, \\ Ont_1 / B_1 = Ont_2 / B_2, \end{array} \right. \quad (6)$$

where A and B – are elements of ontology; Δ^I – the universe; Ont_1 and Ont_2 – ontologies.

Interpretation A remains unchanged at any value of B.

An independent set of elements $U = \{A_i\}$ from many elements $V = \{B_i\}$ of the ontology Ont is called U, for which it is true:

$$independent\ (U,V) = \\ = true \left| \bigcap_i \bigcap_j independent\ (A_i, B_j) = true. \right. \quad (7)$$

The sum of two ontologies is ontology

$$Ont_1 \cup Ont_2 = \\ = Ont \left| \begin{array}{l} Ont = < KB_1 \cup KB_2, M >, \\ Ont_1 = < KB_1, M_1 >, Ont_2 = < KB_2, M_2 >. \end{array} \right. \quad (8)$$

Any set of elements U of ontology Ont, where $U \subset Ont$, can be considered as a separate ontology Ont_U with some M, where $U = KB$.

Given (7) and (8), the semantic independence of ontology looks

$$independent\ (Ont_1, Ont_2) = \\ = true \left| independent\ (KB_1, KB_2) = true. \right. \quad (9)$$

Ontology Ont is defined by the expression

$$\exists Ont_j, independent(Ont_i, Ont_j) =$$
$$= false \mid \forall Ont_i, (Ont_i, Ont_j \in Ont), i \neq j,$$

for

$$Ont' = (Ont / (Ont_n \cup Ont_m)) \cup Ont \mid Ont =$$
$$= Ont_n \cup Ont_m, (Ont_n, Ont_m \in Ont)$$

the statement remains true. Ontology Ont is a multitude of independent ontologies.

Ontology meta-information M has specific ontology characteristics that are not related to domain knowledge: information about the authorship of the ontology, its version, namespace, explicit indications of connectivity with other ontologies, a brief description of the ontology in natural language.

To avoid a significant increase in the dimensions of the models, the meta-information of ontology M is considered as final information.

Consider the features of using exist fuzzy elements in the ontology, for those (6), (7) and (9) take values of $true$ implicitly. A set of statements $\tilde{A}$ can use predicate elements ρ as property values that are identical to some membership functions μ_a . Extending the ontology with predicate elements is one direction by using developing the ontological representation of knowledge [18].

We integrate any distributed ontology into a single whole through the use of import relations

$$import(RI^+, RI^-) = \begin{cases} 1, RI = true, \\ 0, RI = false, \end{cases} \qquad (10)$$

where RI^- – is the imported ontology (basic); RI^+ – is the ontology that imports.

Let a finite set of all RI , defined on an ontology have the form

$$MRI = \{RI_i\}, \qquad (11)$$

where $i = \overline{1, N}$.

The import property is transitive

$$IF \quad import\,(Ont_x, Ont_y) \cap import\,(Ont_y, Ont_z) = 1$$
$$THEN \quad import(Ont_x, Ont_z) = 1, \qquad (12)$$

$$RI_i \neq RI_j, \quad i \neq j, \quad RI_i, RI_j \in MRI, \quad \forall i, j = \overline{1, N}.$$

To simplify further entries for some ontology Ont the set of inputs or relations that import is represented as $\{RI_i\}^+$, the set of output relations as $\{RI_j\}^-$.

Relations got because of the transitivity property (12)

$$RI = true \mid RI \notin MRI ,$$

is an implicit import, which we denote nRI .

We distinguish two main types of development of ontologies: extensive and intensive [18].

Extensive development is any elementary ontology Ont_e for ontology Ont_r [18]. All ontologies in Ont_r , are denoted by Ont_{ext} (extended)

$$Ont_r = \langle Ont, \{Ont_{ext}\} \rangle .$$

The intensive development of ontology Ont' is ontology Ont , which reflects some statements of Ont' [18]

$$Ont \cap Ont' = Ont_\xi, \quad Ont_\xi \neq \varnothing.$$

Extensive development complements and concretizes the subject area of ontology Ont_r , and intensive development scans the existing Ont' and refines (or changes) them by actual needs (or in connection with the identification of errors) based on definitions (5) and (6).

We focus on some existing approaches to the development of ontology on introducing additional meta-information during the development of the ontology and further semantic analysis of these data.

This approach is effective in the formal development of ontologies; it applies to the spontaneous development of ontological structures. Approaches [2], [6], [18], [19] have several important results, but they do not adequately formalize the ontology development process, there is no possibility of quantitative evaluation of versions from integrity, which does not allow solving maximization and minimization of adequacy problems.

It is necessary to modify the generalized approach to the presentation of intensive ontological development, which will subsequently allow creating effective methods for evaluating and processing processes for intelligent decision-making systems in ontological engineering.

Let ontology Ont be represented by a set of related elementary fuzzy ontologies

$$Ont = \langle MO, MRI \rangle, \tag{13}$$

where $MO = \{Ont_i\}$ – is the set of all elementary ontologies included in the ontology; $MRI = \{RI_j\}$ – the finite set of all import relationships RI, specified on the ontology.

Let the ontology elements Ont are subject to discrete changes and be introduced by the syntax of the selected ontology presentation language. The showed ontology changes are an intensive development.

We introduce the tuple D, which describes the stages of development Ont, and a pair serves the elements of the tuple: ontology and the instant of creation of this ontology. Intensive development is an expression

$$D = \{\langle Ont_i, t_i \rangle_i\} \mid t_i < t_{i+1}, \quad i = \overline{0, K}, \tag{14}$$

where K – is the final non-negative version Ont number.

We introduce the functions connecting the ontology and time by using D:

$$Ont_i = f_D(t) \mid \forall t, t \in [t_i, t_{i+1}), \tag{15}$$

where $f_D(t)$ – is the function of the ontology value at time t for development D.

$$t_i = F_D(Ont_i),$$

where $F_D(Ont_i)$ – is the inverse function (14).

We introduce the version relation:

$$IF \quad RD = true, \ THEN \quad Ont_1 \in D, Ont_2 \in D,$$

and vice versa

$$IF \quad Ont_1 \in D, Ont_2 \in D, \ THEN \quad RD = true,$$

where $ratio(Ont_1, Ont_2) = \begin{cases} 1, RD = true \\ 0, RD = false \end{cases}$ – is the version relation function.

Comparable ontologies Ont_1 and Ont_2 are ontologies for which the proximity relation holds

$$aboutness(Ont_1, Ont_2) = true.$$

Sometimes we can use the continuous value of proximity $aboutness\ (Ont_1, Ont_2) \in [0,1]$. Assessing the proximity of two ontologies is a non-trivial task and is the subject of further research in this area.

To calculate this condition, we use a simplified procedure that compares the power of the intersection of two versions and the sum of the power of their differences

$$\begin{aligned} &aboutness\ (Ont_1, Ont_2) = \\ &= (|Ont_1 \cap Ont_2| > |Ont_1 / Ont_2| + |Ont_2 / Ont_1|), \end{aligned} \tag{16}$$

where $|Ont|$ – power of ontology.

We can describe the modified development of the ontology as a tuple comprising five isolated elements:

$$RD \Rightarrow \langle inc\_N, dec\_N, inc\_E, dec\_E, ch\_E \rangle,$$

where inc_N, dec_N – is the set of added and remote nodes with subordinate links; inc_E, dec_E – many added and removed independent links; ch_E – many changed relationships.

For a clear ontology ch_E is always $\varnothing$.

We get a modified formal model of the intensive development of the ontology and several basic relationships. We base the proposed model of intensive development of ontologies on the discreteness of changes in ontological knowledge. It allows generally to present by using develop ontology in time and determine the one-to-one functions of time and structure.

6. CONCLUSION

The model of intensive development of ontologies, which describes ontologies in time, is modified, which allows one to efficiently solve the problems of analysis and assessment of the state space of ontologies that are developing, and determine and eliminate the properties of inadequacy using fuzzy logic.

Based on the above interpretation of by using develop ontologies, methods for presenting fuzzy information in ontologies can be further developed, which will allow one to consider fuzzy ontologies without specific specifications, avoiding the loss of generalization of conclusions and will significantly reduce the requirements for formalizing the initial data and knowledge of ontologies. We modified the import relation of fuzzy ontology, which is an important aspect of using the application of fuzzy ontology.

The results can intellectualize the processes of supporting changes in distributed ontologies by the apparatus of fuzzy sets.

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