Knowledge Representation Using Fuzzy Ontologies: A Survey

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Summary

In recent decades, the growth of communication technology has resulted in an explosion of data-related information. Ontology perception is being used as a growing requirement to integrate data and unique functionalities. Ontologies are not only critical for transforming the traditional web into the semantic web but also for the development of intelligent applications that use semantic enrichment and machine learning to transform data into smart data. To address these unclear facts, several researchers have been focused on expanding ontologies and semantic web technologies. Due to the lack of clear-cut limitations, ontologies would not suffice to deliver uncertain information among domain ideas, conceptual formalism supplied by traditional. To deal with this ambiguity, it is suggested that fuzzy ontologies should be used. It employs Ontology to introduce fuzzy logical policies for ambiguous area concepts such as darkness, heat, thickness, creaminess, and so on in a device-readable and compatible format. This survey efforts to provide a brief and conveniently understandable study of the research directions taken in the domain of ontology to deal with fuzzy information; reconcile various definitions observed in scientific literature, and identify some of the domain's future research-challenging scenarios. This work is hoping that this evaluation can be treasured by fuzzy ontology scholars. This paper concludes by the way of reviewing present research and stating research gaps for buddy researchers.

Keywords:

Ontology, Fuzzy Ontology, Semantic Web, Fuzzy Ontology tools

1. Introduction

With the advancement of communication technology in recent years, information and data have risen swiftly. Because there is an increasing demand for data integration and accompanying functionality, the ontology idea is critical to improving quality. Ontologies should facilitate reusability and interoperability. However, in a big scale environment with a high number of distributed and heterogeneous components, such as the Web, reuse or interoperability is particularly challenging because it is sometimes difficult for diverse parties to create a common understanding and agreement. Ontologies have the same structure regardless of the language in which they are expressed, and this is true for all languages. In general, most ontologies describe persons (instances), classes (concepts), properties (attributes), and links. Currently, there are many proposals for fuzzy extensions to ontology to provide the necessary methods for dealing with ambiguous and imprecise data. By merging fuzzy theory and ontology, the fuzzy ontology was suggested as a solution to problems.

Fuzzy ontology is today regarded as a significant and crucial component for designing applications in a broad variety of real-life circumstances, thanks to its position as a standard "World Wide Web Consortium recommendation (WWWC)" for expressing information on the Semantic Web. It is a formal, explicit expression of a widely held belief in a human- and machine-readable format. It serves as the knowledge backbone for many intelligent and knowledge-based systems [1]. In other areas, however, real-world knowledge is incomplete or confusing. For example, one might use a search engine to look for an extremely quick, compact, low-cost automobile. The classical ontology model, on the other hand, is widely accepted as insufficient for dealing with the imprecise and ambiguous information that characterizes some real-world applications. As a result, many practical implementations of knowledge-based systems, like the Semantic Web, need the extension of ontologies to fulfill their needs.

Berners-Lee (2001) suggested the Semantic Web (SW), which ties all data together with machine-readable semantic knowledge. The semantic web is essentially an extension of the current web that gives information in a manner that computers can understand. By making the semantics of data technically visible, the semantic web aims to solve problems like interoperability, enhanced search algorithms, and data reliability, among others. As a consequence of recent breakthroughs in semantic web research, it is now feasible to switch from keyword-based to semantic web retrieval approaches in traditional information search and retrieval systems.

The next parts deal with fuzzy ontology from a variety of perspectives, including representation (categories, formal definitions, representation languages, and fuzzy ontology tools), reasoning (reasoning techniques), and applications (fuzzy logic) (the most relevant applications about fuzzy ontology). Other essential aspects for fuzzy ontology are then comprehensively addressed, including creation, mapping, integration, query, storage, assessment, extension, and future research prospects. This paper gives an overview

Manuscript received December 5, 2023
Manuscript revised December 20, 2023
https://doi.org/10.22937/IJCSNS.2023.23.12.20

of the current state of the art in fuzzy ontology construction. As a result, the majority of our research will be devoted to a survey of the second group of studies; nevertheless, this survey also provides some related works from other categories.

2. Literature Survey

2.1 Ontologies

According to a recent review on ontology engineering in [2], ontologies have grown widely employed in a range of industries ranging from biomedicine to finance, engineering, legal, and cultural heritage in the previous few years". Ontologies are the core and most essential component of the semantic web, as it is a machine-readable web. In a domain of discourse, an ontology defines conceptions and their associations [3]. Ontologies are required for knowledge-based applications since they serve as formal models and machine-readable representations of the domain. Ontologies aid in the transfer of domain knowledge to other domains, whether relevant or irrelevant. For example, investigates how knowledge sharing might increase employee individual and team performance. Because organizational knowledge is scattered, knowledge-based applications using ontologies must be able to combine knowledge from disparate sources and offer an overview of the knowledge available in the organization [3]. Finding a proper ontology for a domain is one of the more difficult research difficulties in this setting [4]. Organizations have utilized ontologies as a conceptual tool and fundamental component of knowledge-based systems for effective knowledge management in the area of discourse. In the last decade, the industry has shown interest in building semantic technology applications to provide solutions. For instance, in the medical domain, there is the HIV Protein Ontology [5]. Artificial intelligence (AI) exhibits interest in knowledge representation, knowledge management, and semantic relationships as an opportune area of study and a challenge for the academic community [6]. Given the benefits of an ontology-based approach, there are only a few ontology-based solutions that profit from this method [7]. It's worth noting that ontology-based machine-readable systems aid in the development of better decision support systems by enhancing knowledge management. Furthermore, the ontology approach makes it simple to share domain conceptions [3], which give stakeholders more opportunity to solve real-time challenges.

The major goal of an ontology concept was to allow software agents and people to communicate domain information. As a result of the increased interest in ontologies, multiple ontologies have been developed in various fields, each with its purpose, for as Gene Ontology (GO) in the biomedical area. The topic of ontology engineering is primarily concerned with the study of principles, methods, and tools for constructing upper or domain ontologies. A technique gives guidance for the building of ontologies in this setting. Researchers have proposed many approaches to aid and support the building of ontologies. Ontologies help people communicate more effectively to enhance decision-making, knowledge sharing, information storage, and knowledge reuse, among other things. An ontology can be created manually with an ontology editor like Protege, or automatically with appropriate ontology creating algorithms written in a computer language like Java. For certain topics of study, many academics create ontologies manually, as in, or automatically, as in. It is required to follow a series of defined and structured steps while building a domain or upper ontology. Researchers have proposed many approaches to aid and support the building of ontologies. Ontology engineering, on the other hand, requires a well-documented, mature, and widely accepted approach. In this work, a survey has been prepared to compare approaches for generating domain ontologies in various domains developed between 2015 and 2020. A methodology is a collection of well-designed approaches and processes that ensure the quality of an ontology design process's outcomes. This paper discusses several relevant concepts connected to ontology design approaches.

2.2 Fuzzy Ontologies

According to Ortega [8], fuzzy ontology is an ontology that uses fuzzy logic to provide a natural representation of imprecise and ambiguous data while simultaneously enabling reasoning over it. It disagreed with defining a fuzzy ontology by enumerating its fuzzy constituents because it jeopardizes definition scalability and reusability. It claims that new languages will provide new opportunities for fuzzy elements to be added, but that current definitions do not cover them. None of the previous definitions, for example, specified fuzzy taxonomy of relations.

2.3 Fuzzy Ontology Frameworks

Abulaish and Dey [9] suggests a fuzzy ontology generation framework in which a concept descriptor is defined as a fuzzy relation with a fuzzy membership function to describe the degree of a property's value. The following is a description of the fuzzy ontology generating framework. As an extension of the standard framework, this framework proposes to store idea descriptions in a form. Qualifiers are modifiers or hedges that are used to build new fuzzy sets and change the meaning of linguistic variables on a dynamic basis. They are derived via text mining or defined by a domain expert. A fuzzy approach is also described for merging new qualifiers into the set of original qualifiers.

This framework is utilized by Dey and Abuliash [8] to augment an existing crisp ontology with fuzzy property descriptors obtained from rule-based text mining and NLP text mining. Locating ideas, attributes, and relationships from free-form text is required when gathering information to improve an existing ontology. Some rules have been established for this purpose. Adjectives represent attributes, adverbs represent qualifiers, and verbs represent relationships between concepts, according to the principles. However, because there may be many such elements satisfying these constraints in any given text, not all of them are necessarily important, lexical patterns are established to recognize ontological concepts from the text. To mine such structures from annotated text, they use the SPAM method. There are defined patterns such as "determiner, adjective, noun" and "noun, verb, preposition, noun." So, first, they look for components that meet the patterns, and then they look for a suitable match in the ontology. If no match is found, the pattern is saved for future use. Aside from that, the pattern is recognized as a data component. A text information retrieval application uses the proposed fuzzy ontology framework. The overall effect of matching a pair of tuples is influenced by the distance between qualifiers, just as it is influenced by the distance between value pairs.

2.4 Fuzzy Ontology Tools

To incorporate fuzziness into ontology reasoning, a growing number of fuzzy ontologies [17] are being used; however, as Borgwardt et al. [10] recently pointed out, all existing fuzzy description logics have decidability limits, and existing fuzzy ontology tools, parsers, and reasoners are still in their infancy.

Ontologies can be created and used with a variety of software tools. Ontology editors and reasoners are two key groups of ontology tools. The following are some examples of software tools for creating and managing fuzzy ontologies that have been developed. There have also been some tools created for fuzzy ontologies. Some examples are discussed here.

Bobillo and Straccia [11] propose a Fuzzy OWL2 Protégé plug-in that encodes fuzzy ontologies using OWL 2 annotation attributes. They also create a parser for converting OWL2 annotations that express fuzzy information into a language that is supported by some reasoners, such as fuzzyDL and DeLorean.

Calegari and Ciucci [12] build on the KAON Project by adding fuzziness to ontology. A fuzzy inspector is created, which consists of a table that represents a fuzzy object, membership degree, and several updates (Q). This development tool is based on their approach, which allows for query-based updating of fuzzy integers.

A fuzzy plug-in for Protégé 3.3.1 is introduced by Ghorbel and colleagues [8]. The plug-in supports the instantiation of fuzzy concepts and roles, as well as the construction of parameterized membership functions. It also allows for the computation of membership degrees automatically and the querying of fuzzy ontologies using fuzzy criteria.

Slavek [13] is a package that allows you to combine a fuzzy ontology with.NET object-oriented programming (OOP) classes. The implementation presently supports FuzzyOWL2 ontologies that are reasoned with FuzzyDL, but it can be updated to support any fuzzy ontology notation and fuzzy reasoner.

Protégé [14], developed at Stanford University, is one of the most extensively used ontology editors. Protégé has a broad community of academic, government, and business users since it is free, open-source, and easily downloadable. It has been used to build knowledge-based applications in a variety of fields, including medical, biomedicine, education, manufacturing, and eCommerce. It has several advantages, including full support for the latest OWL 2 Web Ontology Language and the World Wide Web Consortium's RDF specifications. It has a plug-in design and a Java-based Application Programming Interface (API) for constructing knowledge-based tools and applications, making it exceedingly flexible. Numerous plug-ins for ontology visualization, project management, software engineering, and other modeling tasks exist due to its extensibility.

To aid in the creation of fuzzy ontologies using the fuzzy ontology representation described in [15], a Protégé plug-in was created. Using this method, the non-fuzzy half of the ontology can be built first using Protégé, and then the fuzzy part can be built using the annotation attributes. The syntax for specifying all of the different fuzzy elements utilizing annotation attributes becomes apparent to the user with the Fuzzy OWL 2 plug-in. The Fuzzy OWL tab can be used to create any of the fuzzy elements previously described in the discussion on the fuzzy OWL language: fuzzy datatypes, fuzzy modified concepts, weighted concepts, weighted sum concepts, fuzzy nominals, fuzzy modifiers, fuzzy modified roles, fuzzy axioms, and fuzzy modified datatypes after installing the plug-in (http://www.straccia.info/software/FuzzyOWL/). The fuzzy logic that will be employed in the ontology can also be specified.

Because each reasoner is based on its own fuzzy DL language, parsers were built to translate the constructed fuzzy ontologies into the languages supported by certain fuzzy DL reasoners [16]. A universal parser is supplied to provide for flexibility in choosing a DL reasoner. It can be customized for any fuzzy DL reasoner. Adapting the general parser to the fuzzy DL reasoners fuzzyDL [16] and DeLorean is demonstrated. The template, general parser, and two particular parsers can all be downloaded from the Fuzzy OWL 2 Protégé plug-in.

3. Conclusion

This work examined the area of ontology, fuzzy ontology, fuzzy methodology tools, and their evolution. Because of the ambiguity inherent in some real-world domains, the requirements of particular applications, and variances in experts' conception of a topic, fuzzy ontologies are required, it was stated. Following that, other fuzzy ontology definitions were presented. Different aspects could become fuzzy as a result of the application's needs, which use fuzzy ontologies. A detailed explanation of fuzzy ontology was also presented. Then, as a theoretical counterpart to fuzzy ontologies, fuzzy description logic was examined and introduced as a good alternative for representing and reasoning fuzzy ontologies. In any case, none of the ways of representation are conventional. Following that, according to the proposed framework, various ways for constructing fuzzy ontologies were discussed and contrasted. The suggested framework compares development approaches based on fuzzy elements, beginning points, preprocessing, results, learning methods, application and evaluation domains, and fuzzy reasoning support. However, no fully automated methods for creating fuzzy ontologies exist yet. The majority of development methodologies are domain-specific. They're useless for guiding the development of fuzzy ontologies in other fields. The majority of them employ statistical approaches for fuzzification, with only a few using rule-based or linguistic methods. They fuzzify items according to the needs of their applications. Some approaches start with a crisp ontology, and the fuzzification process is based on the structure of the underlying crisp ontology. The majority of them lack fuzzy entailment and fuzzy representation of ontologies. Qualitative (approximate) reasoning is one of the most important applications of fuzzy ontologies. A fuzzy ontology is a fantastic notion for a system to be able to reason with quality. There should, however, be a way for mapping quantitative elements to their qualitative counterparts. Finally, various fuzzy ontologies applications and evaluation studies were discussed.

References

[1] Zhang, X., Hu, B., Chen, J. and Moore, P.: *Ontology-based context modeling for emotion recognition in an intelligent web.* World Wide Web 16(4), 497-513 (2013).

[2] Tudorache, T.: *Ontology engineering: Current state, challenges, and future directions*. Semantic Web 11(1), 125-138 (2020).

[3] Sattar, A., Surin, E.S.M., Ahmad, M.N., Ahmad, M. and Mahmood, A.K..: *Comparative analysis of methodologies for domain ontology development: A systematic review.* Int. J. Adv. Comput. Sci. Appl 11(5), 99-108 (2020).

[4] Shvaiko, P. and Euzenat, J. *Ontology matching: state of the art and future challenges.* IEEE Transactions on knowledge and data engineering 25(1), 158-176 (2011).

[5] Zhang, L., Chen, H., Zhang, Y. and Chen, T.: *Fine construction of HIV protein ontology.* 3rd International Conference on Information Systems Engineering (ICISE). IEEE (2018).

[6] Sarker, I.H., Hoque, M.M., Uddin, M. and Alsanoosy, T.:*Mobile data science and intelligent apps: concepts, ai-based modeling and research directions.* Mobile Networks and Applications 26(1), 285-303 (2021).

[7] Fernández, M., Cantador, I., López, V., Vallet, D., Castells, P. and Motta, E.: *Semantically enhanced information retrieval: An ontology-based approach*. Journal of Web Semantics 9(4), 434-452 (2011).

[8] Samani, Z.R. and Shamsfard, M.: The state of the art in developing fuzzy ontologies: A survey." *arXiv preprint arXiv:1805.02290* (2018).

[9] Abulaish, M. and Dey, L.: *A fuzzy ontology generation framework for handling uncertainties and non uniformity in domain knowledge description.* International Conference on Computing: Theory and Applications (ICCTA'07). IEEE (2007).

[10] Borgwardt, S., Distel, F. and Peñaloza, R.: *Decidable Gödel description logics without the finitely-valued model property*. Fourteenth International Conference on the Principles of Knowledge Representation and Reasoning (2014).

[11] Bobillo, F. and Straccia, U.: *Fuzzy ontology representation using OWL 2*. International journal of approximate reasoning 52(7), 1073-1094 (2011).

[12] Devadoss, N. and Ramakrishnan, S.: *Knowledge representation using fuzzy ontologies–a review.* International Journal of Computer Science and Information Technologies 6(5), 4304-4308 (2015).

[13] Straccia, U.: *All about fuzzy description logics and applications*. Reasoning Web International Summer School. Springer (2015).

[14] Abanda, F.H., Kamsu-Foguem, B. and Tah, J.H.M.: BIM–New rules of measurement ontology for construction cost estimation. *Engineering Science*

and Technology, an International Journal 20(2), 443-459 (2017).

[15] Cross, V.V.: *Fuzzy ontologies: The state of the art.* IEEE Conference on Norbert Wiener in the 21st Century (21CW), IEEE (2014).

[16] Huitzil, I., Molina-Solana, M., Gómez-Romero, J. and Bobillo, F.: *Minimalistic fuzzy ontology reasoning: An application to Building Information Modeling.* Applied Soft Computing 103, 107158 (2021).

[17] Szwed, P.: *Application of fuzzy ontological reasoning in an implementation of medical guidelines.* 6th International Conference on Human System Interactions (HSI). IEEE (2013).

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