A Hybrid Approach using Ontology Similarity and Fuzzy Logic for Semantic Question Answering

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Abstract. One of the challenges in information retrieval is providing accurate answers to a user’s question often expressed as uncertainty words. Most answers are based on a Syntactic approach rather than a Semantic analysis of the query. In this paper our objective is to present a hybrid approach for a Semantic question answering retrieval system using Ontology Similarity and Fuzzy logic. We use a Fuzzy Co-clustering algorithm to retrieve collection of documents based on Ontology Similarity. Fuzzy scale uses Fuzzy type-1 for documents and Fuzzy type-2 for words to prioritize answers. The objective of this work is to provide retrieval systems with more accurate answers than non-fuzzy Semantic Ontology approach.

Keywords: Question and Answering, Fuzzy Ontology, Fuzzy type-1, Fuzzy type-2, Semantic Web.

1 Introduction

The Educational Semantic web aims to discover knowledge using educational learning areas such as personal learning, education administration and knowledge construction [12]. Semantic web (web 3.0) is providing data integrity capabilities by not only machine readability but also machine analysis. Education is improving by using Semantic web approaches like large number of Online student sharing data semantically also student portal help student to be connected everywhere to the update of class. Electronic textbook [1] provides open context from source like openstax, ck12.org, crowd sourcing, NCERT etc. Massive open online courses (Moocs) example coursera, udacity, khan, Edx, TED-Ed also small virtual classes are found on Internet easily. The web is naturally Fuzzy in nature, so text document and building Ontogy requires Fuzzy approach. To improve the education Semantic web, the first step is a Semantic question answering systems where uncertain words are questions. To implement such as a system, a Fuzzy Ontology approach can be utilized by use Fuzzy logic (Fuzzy type-1, Fuzzy type-2) [11] levels for text retrieval. A Fuzzy Scale is proposed for two levels, first for membership of document (Fuzzy type-1) and membership of the word (the words having uncertainty (synonyms) as Fuzzy type-2). A Fuzzy Co-clustering algorithm is used to simultaneously cluster documents and words and hence handle the overlapping nature.
of documents in terms of membership functions. To get even more meaningful results Semantic Fuzzy Ontology is proposed as a hybrid approach for question answering. The question answering system is based on Semantic approaches as well as Ontology driven representation of knowledge. The rest of the paper is organized as follows: section 2 gives a background; section 3 presents a methodology including comparisons and use of Fuzzy type-2, and a conclusion in section 4.

2 Background

2.1 Question and Answering system

In information retrieval, the challenge is to find accurate answers to questions asked by the user. Questionnaire Mining helps to give accurate answers by handling complex words for which Fuzzy type-2 and linguistic variables can be considered. Thus a Fuzzy Ontology information retrieval system (FOIRS) [4] can play a vital role in understanding Semantic relationships. FOIRS provide basis to find corelationship between user query terms with the document terms. The user query, analysis can be done in much the same way as syntax analysis and also as Semantic analysis for question answering. If the user wants to search any information which is already present in the database for example, if our digital library stores information about painting created by Ravi on subject Irises, nature, soil etc. and the user queries the database with conjunction between the keywords like "Painting" and "Ravi" and "Irises" then no accurate result will be return as keyword are not enough basis to reach accurate answer. While in Semantic system considers the structure of sentence as set of objects, set of functions and various relationships between them. So if user input query example "Painting” by "Ravi” with subject "Blossom” retrieve accurate result, even the query terms can vary like "Painting” by “Ravi” with subject "Irises” will also give accurate result because Ontology define "Blossom” as subclass-hierarchy of Irises in Knowledge graph representation. The Ontology plays a vital role in understanding such ambiguous user questions and helps retrieve appropriate answers. Ontology is way toward Semantic analysis for the question answering search engines like Google, Yahoo etc. For these purposes, Ontology indexing ensemble with Semantic relation among terms is useful.

The question answering (QA) systems main challenge is to retrieve accurate answers to questions [7] asked by users not only based on keywords, but also on Semantic bases, summarized as:

- Syntax query based retrieval
- FAQ (question templates) based retrieval
- Semantic query based retrieval
- Ontology based retrieval approach
- Transparent query based approach

Word Net and link grammar approaches toward scaling QA [5] for the web can prove helpful tools in recommender systems and feedback analysis.
2.2 Ontology

Ontology plays an important role in development of knowledge based systems to describe Semantic relationship among entities. Ontology basically describes a formal conceptualization of a domain of interest. Fuzzy Ontology [6], can help in understanding Semantic relationships by applying Fuzzy logic to deal with vagueness of data. Fuzzy type-1 can deal with Crisp membership, whereas Fuzzy type-2 deal with Fuzzy membership describe by Table 1. Scientifically Fuzzy type-1 set as model for words is incorrect as it is unable to deal with uncertainty. As Words means different things to different people so they are uncertainty [10] in nature. Uncertainty about words and be further classified into two types:

- Intra uncertainty: This is uncertainty that a person has about the word.
- Inter uncertainty: This is uncertainty that a group of people have about the word.

| Fuzzy type-1 | Fuzzy type-2 |
|--------------|--------------|
| Level 1      | Level 2      |
| Membership Document | Membership of words(synonyms) |
| Uncertainty is in range [0,1] | Uncertainty is measured by an additional dimension |
| Two dimension | Three dimension |
| Notation use A | Notation use tilde A |

The proposed methodology uses Fuzzy concepts like linguistic variable and Fuzzy type-2 for information retrieval. In Fuzzy type-2 Model can deal with the uncertainty of words. Fuzzy type-2 reduces to Fuzzy type-1 in case where there is no uncertainty exit in scenario. Ontologies play important role in Information extraction.

Ontology represents knowledge in a graph conceptual diagram using Semantic approach rather than Syntactic approach where each node show either document or word. Various Ontology match a user query and finally retrieves the Ontology for the query Knowledge based (short - path), corpus based (Co-occurrence), Information content and probability of encountering an instance. Then Ontology matching is used as a solution to the Semantic heterogeneity problem. Applying reasoning from an Ontology to text data play an important role in question answering system.

Ontology Similarity:
An edge count method can be used for calculating similarity [2] between a keyword question and hierarchical ontology tree to obtain Semantic relations. For two similar words, the return value is 1 whereas for two dissimilar words return 0 represented as an equation:

$$S_t(t_1, t_2) = (e^{x_n} - 1)/(e^{x_n} + e^{y_n} - 2)$$

Where d = depth of tree, S= shorted path length, x and y are smoothing factors and $S_t(t_1,t_2)$ = similarity value ranging from 0 to 1.

Protégé OWL plug-in [3] shows a major change in describing information of various Ontology by adding new facilities. OWL Ontology can be categorized as OWL Lite, OWL Full and OWL DL [3]. OWL DL can be considered as the extension of OWL.
Lite. Similarly OWL full is an extension to OWL DL. Semantic web use RDB2onto, DB2OWL and check d2rq etc. to match between Ontology and database. Ontologies do not only represent lexical knowledge, but complex world knowledge about events. Ontologies can be created by Protégé tools, software and after that, use Protégé Java API or translate the Ontology into a rule base using Fuxi [8].

2.3 Data Clustering

In hard clustering data elements are partitioned in such a way that any single data element can belong to only one cluster rather than to many clusters. Fuzzy clustering [9] represents data elements are partitions data in such a way that data can belong to two or more clusters with the degree of belongingness, between overlapping between the cluster can be seen.

3 Methodology Description

The user enters a source string as a question. The first objective of the machine is to Syntactically analyze the text from the source. Only after that the Lexical Analysis can be done for each term in a question and then they are tokenized by removing stop words present in the user’s question. The next step is linguistic preprocessing; POS (part of speech) are tagged in such a way that Syntactic analysis can be done easily as shown in Fig. 1, as flow diagram. In POS, a tree is created to differentiate between each question term and label; each term is labeled as a noun, a verb or adjective. The Structural sequence is identified by POS. Then questions can be interpreted for its Semantic meaning. WordNet tool shows the results for all available synonyms of such word which are nouns and verbs. This tool represents knowledge which is also useful for creating a lexical Ontology for the domain knowledge. A word can be processed Semantically by WordNet tools. The groups of words describing the same intension are called synsets. The edge-count method is used to match for question Similarity with the existing Ontology. Fuzzy Co-cluster is used to present collection of answers and Fuzzy scale (Fuzzy type-1 for document and Fuzzy type-2 for words) in order to score the collection obtained by Fuzzy Co-clustering. The final result is the matrix where x-axis represents "Ontology Similarity" and y-axis represents "keywords".

Our proposed Algorithm is as follows:

a) Input text in search engine (Question).

b) Parse the question for structural analysis.

c) Remove stop words for keyword extraction.

d) Use WordNet tool to get synonyms of a word in the keyword. Generate all possible combinations of synonyms.
Fig. 1. Flow diagram of Semantic question answer

e) Retrieval is based on the Semantic Ontology Similarity (edge-count method) match for question; where question is matched with the answer on the basis of existing Ontologies.

f) Result is obtained from the matrix where the x-axis represents “Ontology similarity” and y-axis represents “keywords”.

g) Use Fuzzy Co-cluster to retrieve answers by using Semantic Ontology Similarity.

h) Retrieve the final answer from matrix by prioritizing answers obtained by Fuzzy Co-clustering using Fuzzy scale.

Fuzzy Co-cluster manages data and features into two or more clusters at the same point of time. Here it can be observed overlapping structure of web documents is represented in the cluster with the degree of belongingness for each web document. Reasons to choose the proposed Fuzzy Co-clustering in our case are:

a) Fuzzy Co-clustering is a technique to manage cluster data (Document) and features (Words) [9] into two or more clusters at the same point of time. Here bi-clustering
(Co-clustering) has the ability to capture overlap between web documents and words mentioned in the documents. The degree of belongingness for each document and word are mentioned in Co-clustering.

b) The Fuzzy Co-clustering has the following advantages over the traditional clustering:

- Dimensionality Reduction as the feature is stored in the overlapping form for various clusters.
- Fuzzy Co-clustering provides efficient results in situations which are vague and uncertain.
- Interpretability of document clusters becomes easy.
- Improvement in accuracy due to local model of clustering.
- Fuzzy membership functions improve representation of overlapping clusters in answers by using Semantic Ontology Similarity.

c) Fuzzy type-2 deals with 3-D (three dimensional data) while FCC_STF [9] algorithm has the ability to deal with problem of curse of dimensionality and outliers.

d) Fuzzy Co-clustering concept is used in algorithm like FCCM, Fuzzy codok and FCC_STF as describe in Table 2. FCC_STF is found to be the best in comparison to FCCM and Fuzzy codok with the new single term fuzzifier approach. FCC_STF is a solution to the curse of dimensionality and outliers.

Table 2: Comparison of Co-clustering Algorithm.

| Categories            | FCCM                        | Fuzzy Codok                  | FCC_STF                        |
|-----------------------|-----------------------------|------------------------------|--------------------------------|
| Algorithm for Co-clustering | Fuzzy Co-clustering for categorical multivariate | Fuzzy Co-clustering of document and keywords | Fuzzy Co-clustering with Single Term Fuzzifier |
| Fuzzifier             | Fuzzy entropy is use as Fuzzifier in FCCM Algorithm | Fuzzy Gini index is use as Fuzzifier in Fuzzy codok Algorithm | Single Term Fuzzifier is use in FCC_STF Algorithm |
| Advantage             | Algorithm for Co-clustering | Ability to deal with the exponential problem | Clipping for negative value and renormalization take place |
| Disadvantage          | Overflow (exponential) problem | Negative membership | - |

To retrieve accurate answers Semantic processing plays an important role. Fuzzy scale (Fig.2) is an approach towards the Semantic analysis of the question at level 1 and level 2.

Level 1 represents the membership of document in a cluster ($\mu = 0.7$). Here Fuzzy type-1 is used for the document as it unable to deal with uncertainty. Whereas Level 2 represents the membership of word in a cluster ($\mu = 0.61 - 0.69$) using Fuzzy type-2. As one word can have different meanings to different users, so uncertainty come into play. Fuzzy type-2 [10] has ability to deal with uncertainty which can be helpful to
deal with the synonyms present in the user question, while Fuzzy type-1 considers no uncertainty.

Calculating Score:

\[
\text{Score} = \frac{(\text{Membership of document (A)} + \text{Membership of Word (A)})}{\text{Number of document (N) = (A+\check{A})}}.
\]

Upper membership function for word (\(\mu = 0.69\)).

Lower membership function for word (\(\mu = 0.61\)).

Fuzzy type-2 is used for computation of the Word as it has the ability to deal with linguistic uncertainty. Whereas Fuzzy type-1 has the crisp membership like for document (\(\mu = 0.7\)). Fuzzy type-2 has a Fuzzy membership for synonymous words (\(\mu = 0.61 - 0.69\)), it can be called as Fuzzy-Fuzzy set. Here the computation of word is applied to find appropriate synonym for each question. An Exact synonym helps in obtaining the meaning of the question. So to retrieve appropriate answer Semantic analysis of each query term along with synonyms is a must.

"sweet" is a vague term which we use in our common life every day in common language. The term sweet depends on perception based assessment. The Same word "sweet" has different meanings. When a user types the term "sweet" in the search engine
Fig. 4. Foundation of uncertainty (FOU)

as question this term is treated as a vague term. But uncertainty arises in associating the word "sweet" particularly to sugar. Here uncertainty can arise because the term "sweet" can be associated to describe behaviors like kind, melodious, musical not only to the sugar. In Fig. 3, various memberships of word "sweet" are described. Let us consider the following statements where the term "sweet" needs to be checked for a similar context with respect to its meaning, for which Fuzzy linguistic rules can be applied. Then according to the context of the word membership of word can be applied. For example:

a) "Sarah is such a sweet little girl. she’s always looking after her brother." - Kindly ($\mu=0.63$).

b) "This tea is too sweet for me to drink, how much sugar is in it?" - sugary ($\mu=0.66$).

Fuzzy type-2 can be visualized by plotting footprints of uncertainty (FOU) in a 2-D domain representation form as shown in Fig. 4. Fuzzy type-2 represents three dimensions data whereas Fuzzy type-1 represents two dimensional data. The uniform color represents the uniformity of possibilities; due to this uniformity Fuzzy type-2 is called Interval type-2 represented by IT2. Till now there is not much progress in IT2 as it’s unable to choose best secondary member functions, but computation of words can be an emerging field to use it.

4 Conclusion and Future Work

We have proposed a hybrid approach for Semantic question answering based on Semantic Fuzzy ontology for retrieval systems. Fuzzy Co-clustering is used to retrieve
the answers by matching user’s question with the existing hierarchical Ontology. Fuzzy scale is use to prioritize the answers retrieved by matrix using Fuzzy Co-clustering. For Fuzzy Co-clustering FCC_STF algorithm is preferred to FCCM and Fuzzy codok. Future work will implement this hybrid approach based on the proposed Semantic Fuzzy Ontology with various applications including e-learning and intelligent web search systems. Users not only get syntactic answers, but also Semantic answers based on the question terms. The proposed question answering system provides a gateway for deep web search along with surface web search.

References

1. R. Agrawal. Computational education: The next frontier for digital libraries? 2013.
2. F. Benamara and P. Saint-Dizier. Advanced relaxation for cooperative question answering. In *New Directions in Question Answering*. Massachusetts: MIT Press, 2004.
3. Fernando Bobillo and Umberto Straccia. Aggregation operators for fuzzy ontologies. *Applied Soft Computing*, 13(9):3816 – 3830, 2013.
4. Stefania Gollova. Fuzzy ontology and information access on the web. *IAENG International Journal of Computer Science*, 34(2), 2007.
5. Qinglin Guo and Ming Zhang. Question answering system based on ontology and semantic web. In *Rough Sets and Knowledge Technology*, pages 652–659. Springer, 2008.
6. AC Kaladevi, A Kangiaiammal, S Padmavathy, and S Theetchenya. Ontology extraction for e-learninga fuzzy based approach. In *Computer Communication and Informatics (ICCCI), 2013 International Conference on*, pages 1–6. IEEE, 2013.
7. Cody Kwok, Oren Etzioni, and Daniel S Weld. Scaling question answering to the web. *ACM Transactions on Information Systems (TOIS)*, 19(3):242–262, 2001.
8. Phillip Lord. The semantic web takes wing: Programming ontologies with tawny-owl. *arXiv preprint arXiv:1303.0213*, 2013.
9. S. Kumar M. Rani and V. K. Yadav. Optimize space search using fcc atf algorithm in fuzzy co-clustering through search engine. *IJARCET*, pages 123–127, 2012.
10. Jerry M Mendel. Fuzzy sets for words: why type-2 fuzzy sets should be used and how they can be used. presented as two-hour tutorial at IEEE FUZZ, Budapest, Hongrie, 2004.
11. Jerry M Mendel. Type-2 fuzzy sets and systems: an overview. *Computational Intelligence Magazine, IEEE*, 2(1):20–29, 2007.
12. Jason Ohler. The semantic web in edcausme Quarterly, 31(4):7–9, 2008.