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A Study on Components, Benchmark Criteria and Techniques used in Ontology-based Question Answering Systems

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Abstract: With the massive shift in advancement of technology from early ages to present world, there is record change in techniques related to data storage to data access. Principally, Search Engines aims to provide information relevant to the user needs from huge archive of data storage units adopting Information Retrieval (IR) and Information Extraction (IE)techniques where the retrieved results display the long list of web links concerned with the user's interest topic and to present the information to the user in human understandable form that can enhance the user experience.

With the introduction of Artificial Intelligence (AI) and Computational Linguistics, the technology era shifted towards Question Answering – the Answer Driven Search. The main aim of QAS is to provide exact answer instead of big pack of words to the user's query automatically in minimal amount of time. Present QASs are built on state-of-art technology attempting to answer user queries from heterogeneous and scattered data sources like semantic web. The preciseness of answering the questions may be enhanced with the integration of ontological enhanced processing. Ontology-based QAS helps better in identification of query context and query words semantics understanding, thus may satisfy the queries in a better way. Presently there are a number of ontology-based QAS evolved in last twenty years and practically comparing all of them in systematic manner is not possible. Hence, some method is required to compare these ontological QAS. Thus, we focused on some benchmarking criteria and techniques used to differentiate and compare these ontology-based QAS.

Keywords: *Question Answering, Question Answering Components, Question Answering Systems, QAS Domain, Natural Language, Ontology*

1. Introduction

With the easy access of available information spread across the web, many users are exploring the web to find the substantial answers to their general questions generating in daily routine. The questions may be related to online grocery delivery service, online shopping for clothes and accessories, internet banking, education, etc. Question Answering systems are built such that they are able to answer very general queries of common man.

Ever-increasing use of smart phones and exponential growth of computers in communication, supported by high-speed free internet and others, motivated the users to get the answers of respective questions in no time. "Digital India" initiative launched in the previous years by the Govt. of India also promote technology use in India. Now the users are more aware of technology, but consequently losing patience to wait for reaching exact answers. Users want to get quick information on everything they indent to know about.

The domain of question posted by various users may range from any domain – open, close or restricted domain. Search engines provide impeccable support to offer answering in almost any domain. A Question Answering System acts similar to search engines but works better for close and restricted domains. Both the question answering system and search engine allows the user to type-in their queries through some interfaces. Only viable difference between the two is the resultant information that is retrieved through some knowledgebase(s). Generally, a search engine provides an optimized list of hyperlinks or ranked list of documents, but a question answering system returns exact or close to exact answers to the users. In addition, the returned answers by a QAS are precise and short in a few words instead of long list of hyperlinks or long paragraphs.

Similar to any engineered system, Ontology-based Question Answering System also have many components committed to perform various inherent tasks to reach the ultimate answer result. User's query is fed to the system, passing through various components in between, reach to the end result. The prime components in any QAS are Input ->

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Question Analysis, Classification -> Answer Generation, Extraction, etc. Many evaluation parameters like precision, recall, F-Measure, Mean Reciprocal Rate (MRR), similarity measures, etc. and tools like Reasonor. Miners, NLP libraries, toolkits, etc. are exploited along with the support of various datasets available or manually constructed datasets. For ontology-based QAS, ontological datasets comprising of question ontology, answer ontology or general ontology are employed.

The remaining sections in this paper are organized as: Section-II contains the literature review about Question Answering Systems (QAS) and other relevant information. Section III comprehends the different raising components in question answering system. Section-IV briefly detail about the existing QAS, the classification strategies & techniques in QAS, ontology based QA systems and comparison between various ontology-based QAS. Section-V outlines the conclusion to overcome the identified gaps the existing QAS. Finally, Section-V notes the references i.e. publications and web references in the list form.

2. Literature Review

Research in Question-Answering (QA) is an ongoing process since decades. Literature review addresses the QA problem since the beginning of 1960s. As always referenced, the two earlier question-answering systems i.e. BASEBALL [5] and LUNAR [5] that are developed in 1971, are the two well-known successful models in their respective restricted domains. Whereas BASEBALL system answers against the recorded data of Baseball game played over one season by American league, LUNAR is capable of answering questions dealing with rock samples taken during Apollo moon missions. SHRDLU [3] is another early experimental research project QA program that is developed in late 60s used to simulate the operation of a robot in a restricted domain of toy world.

The QUALM system [11], a story understanding system by means of information retrieval, intended to describe general QAS motivated by theory of natural language processing similar to verbal communication device between people. AskJeeves [11] is another QA problem in open domain that directs the user to Web pages (similar to search engines) that might contain relevant information about asked question by incorporating advanced NLP and data mining techniques. Another system, with a different approach, is the FAQFinder [11] QA system, is developed for answering factual questions over the web through statistical similarity and semantic similarity. This system is backed by a database of question-answer pairs constructed from existing frequently asked question (FAQ) files over the web. START [11] (SynTactic Analysis Using Reversible Transformations) system, is a dynamic open domain QA system and first web based QA that extracts answers from different sources using NL Annotation technique.

In the 1970s, with the creation of many narrow domain knowledge bases, a number of QA systems are developed to interface with expert systems to produce more repeatable and valid responses to questions within the specified domains. Modern QA systems are extended versions of these expert systems with difference in their internal architecture. Modern QAS implies NL techniques to process questions and the text & knowledge corpus (mostly World Wide Web) from which the answers are extracted.

TREC [5, 9] has enabled research on QA from an IR perspective, thus reducing the task of question answering to finding the paragraph(s) that contains the answer to the question and extracting the answer. The main goal of the QA Track is to retrieve precise answers to questions by searching collection of documents, rather than entire documents.

MedQA [6, 7] and HonQA (Health On the Net) [6, 8], medical domain restricted QA systems, are the systems that are designed to help biologists to access short definitional type answers.

From the preliminary study, it is witnessed that there are many ontologies based question-answering systems developed in the last two decades. [5] Within computer science, ontology is usually defined as a formal explicit description of concepts in the domain of discourse, together with their attributes, roles, restrictions, and other defining features. MOSES [5] uses an ontology-based methodology to respond to queries posted in natural language from fact-based knowledgebase built from semantically structured content of Semantic Web. AQUA [5, 12] is an ontology based closed domain QAS that combines domain-related documents and database knowledge through academic life based ontology. AQUA involves human interaction to find answers from its knowledge base. Another example is JAVELIN [4], an open-domain ontology-based QA system that is extended to focus on restricted domains. JAVELIN is a star architecture where all subtasks such as question analysis, information retrieval, answer extraction and answer computing are observed as nodes that connected to a center node. After user submits a question, the center node generates appropriate scheduling strategy to find answer by the class of question.Another example of restricted domain ontology-based system, as mentioned in [13], represented an Intelligent QAS whose main aim is to build a QAS for students interested in online QA system without any interference of teacher in answering process.

Two popular ontology based restricted QA systems discussed here are PowerAqua [10] and AquaLog [3]. PowerAQUA is a Multi-Ontology based QAS that focus on querying multiple Semantic Web resources by accepting user queries in natural language. AquaLog [3] is ontology based restricted domain portable QAS that takes domain specific ontology, WordNet and NL queries as input and return responses from ontology-compliant semantic knowledge bases.

3. Components in Question Answering Systems

Largely, the component arrangement of any QAS comprises of an input module, several in-between processing modules and an output module. Sketchily, the components in ontological QAS may be listed as below:

(i) Input Component
(ii) Pre-processing Component
(iii) Question Analysis or Question Preprocessing or Linguistic Processing Component
(iv) Question Classification or Question Classifier Component
(v) Question Reformulation or Question Simplification or Question Formulation Component
(vi) In-between component stages like Document Retrieval, Document Procession, Passage Retrieval, Passage Ranking, Paragraph Extraction
(vii) Answer Generation Component or Answer Selection Component
(viii) Answer Extraction Component
(ix) Standard Answer Extraction Component

These components can be briefly explained as under:

Input Component: Input component is an intermediary between the user and the system. The input module or component is used to fed natural language user's query or question to the Question Answering System through graphical user inteface (GUI) along with optional ontology input. Ontological support helps to better understand the user query.

Pre-processing Component: Preprocessing component is an optional component and is not necessarily available in all QASs. XMQAS [18], an Ontolgy-based Medical QAS implemented the preprocessing component for Term-Document Matrix Creation (TDMC) and for pattern generation. TDMC is a mathematical matrix to exemplify the frequency count of medical terms/keywords in available set of medical documents. Pattern generation targets semantic relations to formulate top rated questions from medical question taxanomies.In many QAS, pre-processing component is an comprehensive component of Question Analysis Component. In [29], linguistic pre-processing of question is done to remove irrelevant data from question such as quotation marks, parenthesis, etc.

Question Analysis or Question Preprocessing or Linguistic Processing Module: This is very critical component in any QAS. This component performs multiple tasks including Ontology Pre-processing, Tokenization & morphological analysis, lexicon-syntactic analysis, shallow parsing [23], semantic analysis using Semantic Role Labelling (SRL) [18] pattern matching and calculation of Expected Answer Type (EAT) [18], Stop-word removal & filtration of punctuation symbols, quotation marks, braces, etc. Though question reformulation is a separate component (discussed later in this section), but in some QAS, reformation of question is done using domain ontology & lexico-syntactic patters at earlier stage along with the construction of question's typed-attributed graph using question ontology as mentioned in [20].

Question Classification or Question Classifier Component: Question classification component identifies focus of the question by using shallow parsing for phrase/clause detection [18]. In some QAS, string mapping is also utilised by adopting template-based regular expressions. [14] identifies Question Classification Approaches into Machine Leaning Approach, Knowledge-based Approach & Template-based Approach. Mainly, statistical techniques like SVM, Bayesian Classifiers, Maximum Entropy Models, Headwords & their hypernyms, etc. are used for the purpose of Question Classification.

Question Reformulation or Question Simplification or Question Formulation Component: This component completely depends upon domain knowledge and domain ontology. [20] utilizes lexico-syntactic patterns and concepts of domain ontology for improved query reformulation results. In [24, 25] QAS convert user query/question posted in natural language to intermediate query triple or OntoTriple and then to SPARQL or SQL. In [29], the user query is first converted to RDF Triple and then to SPARQL straight forward.

In-between components: In many document based QAS, several in-between stages are like Document Retrieval, Document Procession, Passage Retrieval, Passage Ranking are executed. In document retrieval stage, top 'N' documents that are relevant to the user query keywords are download or collected from web or from other sources. Then using statistical pattern matching algorithms these documents are processed to extract top 'M' relevant paragraphs. These ranked paragraphs are then fed to the answer generation component.

Answer Generation Component or Answer Selection Component: This component is required to get the potential answers from which the final validated answer may be chosen. Usually, manually-built templates that are independent to domain and ontology are used, alternatively [26] used relational database and previous question cache (PQC) for answer generation. Further, the answer construction component [27] transforms answer into natural language sentences.

Answer Extraction Component: This component is responsible for the selection of answers according to the need of user query. The architecture of QAPD [16], an ontology-based QAS, incorporated answer extraction module to reach to the final answer as intended by user. The backbone of this component is used Inference Schema Mapping (ISM) that is used to map user's NL Query to ontology compliant query. Further, n-grams, Jaccard Measure, Attribute-based inference and some query simplification techniques are applied for combined semantic and syntactic analysis in the overall process of ISM [23] adopted answer ranking method by calculating semantic similarity between user query and the answer frame for final answer generation. In [28], SPARQL language and JENA reasoning is adopted for extraction of answer using ontology.

Standard Answer Extraction Component: This component is responsible to reflect the inherent relations between the knowledge in much better way by using extended ontology comprised of several extensions for properties, synonyms, instances, etc. [28]. The hierarchy of Ontology is represented using father-son relationship to extend the conceptual query.

Popular QAS exploit some or all components as discussed above. Many QAS combines the functionalities of two or more components into one component in order to reduce the countable steps. Many times the component is renamed with a different name but performing the same functions. Some of the popular QAS and their relevant components/modules are listed in Table I:

Table 1. Table showing some QAS Components

QAS	Components/Modules
QUARK-2004	1. Article extraction module 2. Answer type determination module 3. Answer candidate extraction module 4. Answer candidate weight calculation module
DeepQA IBM Watson's system	1. Question Analysis Module 2. Question Classification Module 3. Question Reformulation Module 4. Information Retrieval Module 5. Paragraph Filtering Module 6. Paragraph Ordering Module 7. Answer Identification Module 8. Answer Extraction Module 9. Answer Validation Module
START (SynTactic Analysis Using Reversible Transformations)	1. Question Analysis Module 2. Question Classification Module 3. Question Reformulation Module 4. Information Retrieval Module 5. Paragraph Filtering Module 6. Paragraph Ordering Module 7. Answer Identification Module 8. Answer Extraction Module 9. Answer Validation Module
FALCON-2000	1. Question Classification Module 2. Question Reformulation Module 3. Information Retrieval Module 4. Paragraph Filtering Module 5. Paragraph Ordering Module 6. Answer Identification Module 7. Answer Extraction Module 8. Answer Validation Module
AQUA-2003	1. User interaction (Query Interface, Answer, Answer Validation) Module 2. Question processing module 3. Document processing (Search Query Formulation, Search Engine) Module 4. Answer extraction (Passage Extraction, Answer Selection) module
Raj-2013	This system includes four main components: 1. Question Analysis (analysis, classify & reformulate user's query) 2. Document Retrieval (collect relevant documents) 3. Document Processing (processes the collected documents) 4. Answer Extraction (extraction & generation of concise answer)

CASIA @ V2 (2014)	1. Query input 2. Phrase detection 3. Mapping phrase to semantic item 4. Feature extraction and joint inference 5. SPARQL generation 6. Answering component
XMQAS-2014	1. Pre-processing 2. Question Analysis Phase 3. Document Retrieval Phase 4. Passage Retrieval Phase 5. Answer Extraction Phase
PQONT-2010	1. Power quality database 2. Query handler (convert NL queries to SQL) 3. Query interface (for user interaction with the developed system)
AQUALOG (2007)	1. Query Interface 2. Linguistic Component (converts NL queries to Query-triples) 3. Relation Similarity Service Component - RSS (converts Query-triples to Onto-Triples) 4. Ontological KB Component 5. Answer Processing Interface 6. User Feedback Component
A FRAMEWORK FOR RESTRICTED DOMAIN QUESTION ANSWER ING SYSTEM (2014)	I) Question Processing Module 2) Document Processing Module 3) Paragraph Extraction Module 4) Answer Extraction Module
OntoNLQA-2015	1. Linguistic preprocessing 2. Entity recognition from Processed Question 3. Lexical matching using Ontology and element matching techniques 4. Building of RDF Triples implemented through discovery of semantic association 5. Query construction & response retrieval through semantic path discovery
Xie et al. -2015	1. Knowledge base of Ontology 2. Question analysis module (word segmentation and part-of-speech tagging; Extracting keyword) 3. Answer extraction module 4. The standard answers' extension module
Besbes et al. (2015)	1. Question processing 2. Information retrieval (from the web) 3. Answer extraction
QAPD-2016	1. Ontology construction using domain specific knowledgebase 2. User interface component (to create user-friendly environment for sending user queries and retrieve answer in textual format without knowing the backend language rules) 3. Question processing component (to perform linguistic analysis of question) 4. Answer extraction component (uses Inference Schema Mapping to determine the query pattern in query database & query itself and returns corresponding SQL) 5. Users' query database component (to store various types of questions such as affirmative negative type, yes/no type, imperative query, etc.)

4. Question Answering Systems

Due to all extant issues [1, 3] in search engines, there is a need to come with some dynamic solution of all prevalent limitations in search engines. Question Answering System (QAS) came as a solution. Most significantly, QAS has the deduction capability to synthesize an answer spread in chunks in different parts of knowledgebase that is most lacking feature in search engines.

Question Answering is a computer science discipline and an active research area for allied fields for processing of natural language, retrieval & extraction of information, etc. QAS takes input in natural languages and output relatively short answers. Mainly, QA systems are classified as:

i) Classification based on Domain i.e. open domain and closed domain
ii) Classification based on Approach i.e. linguistic approach, statistical approach and pattern matching approach
iii) Classification based on Technology i.e. web-based QAS, IR and IE-based QAS and rule-based QAS

Apart from these major classifications, QAS can also be classified based on the type of response expected such as QADR [30], a closed or restricted domain QAS, utilizes lexico-conceptual resources like knowledge bases and ontologies to provide anticipated answers and strictly provide no answer instead of providing wrong answering. QAC (Community Question Answering) [30], is developed to respond the consultation related posts submitted over virtual social QA network community such as Quora and Stack Overflow. QASOBO [31], is another Ontology-based QAS where the answers are expected in the form of ontologies itself instead of plain text or structured format, etc.

Towards ontology-based QAS

Natural language understanding is the prerequisite to question answering and most of the world knowledge is depicted in natural language. To achieve significant improvement in the functionality of question answering, many new methods based on natural language processing and computational theory are developed over the years. Earlier research on QAS is done in the field of Artificial Intelligence (AI), Information Retrieval (IR), Natural Language Processing (NLP) and Machine Learning (ML) where the focus is on the knowledge encoded in database. Obviously, such systems are restricted to answer only from the database-encoded information. Then comes the era of semantic search, when ontologies are created to represent lot of new structured data, which drastically promoted the use of ontology-based information to make data more meaningful.

Presently there are a number of ontology-based QAS evolved in last twenty years and practically comparing all of them in systematic manner is not possible. Hence, some method is required to compare these ontological QAS. Thus, we focussed on some benchmarking criteria and techniques used to differentiate and compare these ontology-based QAS. Table II and Table III shows some techniques used in QA Components, QA Approaches and QA Tasks, respectively. Besides the comparison mentioned in Table II and Table III, Question Answering Systems can also be compared on the basis of some in-depth aspects as discussed in [15], such as Searching, Matching Technology (Exact Match, Best Match, etc.), Form of Answers (Short Answers, Mixed Answers, etc.), Types of Questions (Simple, Wh-type, Descriptive, hypothetical, etc.), Relevancy Techniques (Pattern Matching, Syntactic Analysis, Pragmatic Analysis, etc.), Knowledge Source (Database, Syntactic Web, etc.), Models adopted for Retrieval Process and Reliability etc.

Table 2: Main components used in Question Answering Systems

Sr. No.	Component Vs QAS	QAS Domain	Question Processing Component			Document Processing Component			Answer Processing Component			References
			Question Analysis	Question Classification	Question Reformulation/ Simplification	Information Retrieval	Paragraph/Passage Filtering	Paragraph/Passage Ordering	Answer Identification	Answer Extraction	Answer Validation	
1.	**XMQAS (2016)**	Ontology-based QAS (in Medical Domain)	Y	-	-	Y	Y	-	Y	Y	-	[18]
2.	**QAPD**	Ontology-based (in Physical Domain)	Y	Y	Y	Y	-	-	-	Y	Y	[16]
3.	**OntoNLQA (2015)**	Ontology-based QAS (in Biomedical Domain)	Y	-	Y	Y	-	-	-	-	Y	[4], [16], [19]
4.	**Besbes et al. (2015)**	Ontology-driven Visual QA framework	Y	Y	Y	Y	Y	Y	-	Y	Y	[16], [20]
5.	**AQUALOG (2007)**	Ontology based portable QAS (in Restricted Domain)	Y	Y	Y	-	-	-	Y	-	-	[3], [6], [10], [14], [16], [17], [21]

Sr. No.	Component Vs QAS	QAS Domain	Question Processing Component			Document Processing Component			Answer Processing Component			References
			Question Analysis	Question Classification	Question Reformulation/ Simplification	Information Retrieval	Paragraph/Passage Filtering	Paragraph/Passage Ordering	Answer Identification	Answer Extraction	Answer Validation	
6.	**AQUA (2003)**	Ontology-driven experimental QAS	-	Y	Y	Y	Y	-	-	Y	Y	[12], [16], [22]
7.	**Raj (2013)**	Ontology-based domain specific NL QAS – NLQA	Y	Y	Y	Y	-	-	-	Y	-	[16], [23]

Table 3. Common approaches used in referenced Question Answering Systems

Sr. No.	Approach Vs QAS	QAS Domain	Question Classification Approach		Information Retrieval Approach		Answer Extraction Approach		References
			Hierarchical Taxonomy	Rule-based Classifier	Web Corpus	Knowledge base Corpus	Text Patterns	Named Entity	
1.	**XMQAS (2016)**	Ontology-based QAS (in Medical Domain)	-	-	-	-	Y	-	[18]
2.	**QAPD**	Ontology-based (in Physical Domain)	-	-	-	Y	-	-	[16]
3.	**OntoNLQA (2015)**	Ontology-based QAS (in Biomedical domain)	-	-	-	Y	Y	Y	[4], [16], [19]
4.	**Besbes et al. (2015)**	Ontology-driven Visual QA framework	-	-	Y	Y	Y	Y	[16], [20]
5.	**AQUALOG (2007)**	Ontology based portable QAS (in Restricted Domain)	Y	-	Y	-	Y	-	[3], [6], [10], [14], [16], [17], [21]
6.	**AQUA (2003)**	Ontology-driven experimental QAS	-	-	Y	Y	-	-	[12], [16], [22]
7.	**Raj (2013)**	Ontology-based Domain specific NL QAS – NLQA	-	-	Y	-	-	Y	[16], [23]

5. Conclusion

This work presented a survey on Ontology-based Question Answering Systems. The main goal of any QA system is to quick revert to the queries asked by the users in the language normally they use in day-to-day activities. This raises the challenge to exploit searching techniques. Previous studies show that there are still many chances of improvement in reaching exact results, especially by formulating methods for automatic ontology construction and answering the user-specific questions more precisely.

Though many QAS already exists are able to answer based on ontology that is manually constructed and such ontologies give good results, but these are still not very popular due to two main limitations i.e. (i) it is very expensive to build ontologies manually because of the involvement of highly paid experts and domain specialists. (ii) it is very time-consuming and error prone too to manually build the ontologies. Thus, there is great motivation for automatic creation of ontologies for Natural Language based QASs and to improve the results of existing QAS in terms of performance and other comparative parameters.

Conflicts of interest

The authors declare no conflicts of interest.

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