Causality for Question Answering

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Abstract. Question Answering System automatically answers natural language questions asked by user. Promising results have been achieved for factoid-type questions but there is a need to improve non-factoid question answering. This paper has addressed the issue for automatically answering Why-type questions in Question Answering System. The concept of causality is studied and its important role for different modules in developing Why-type Question Answering System. There are various researchers who have used causality as a key component to focus on causes and effects involved in the sentences and ultimately answering Why-type Questions.

Keywords: Causality · cuephrases · semantic relations · synonyms · hypernyms

1 Introduction

Causality is viewed as a semantic relation that exists between different parts of a sentence [1]. It connects two phrases representing as a cause and its effect. It has its significance in various disciplines like Psychology, linguistics, philosophy and even computer science. In computer science, causality plays its major role in understanding the meaning and determines how different parts of a sentence are related to each other. The paper tries to explore the importance of causality in understanding natural language text and thus helping to find candidate answers to a question asked on question answering system.

In English language, semantics deconstruct the words and use sentence structure to determine the meaning of text. Semantics is understood by three dimensions, formal semantics uses logic to find the relation between language and reality, lexical semantics separates words and phrases to understand the meaning of a text, and conceptual semantics finds out the basic meaning of the text before any context and feelings included in it. There are various types of semantic relations between words represented as (1) *synonymy* between words of same sense e.g. unhappy/sad, (2) *antonym* between words of opposite meaning or contradictory to each other e.g. big/small, (3) *hyponymy* having inclusion relationship for example, lion, dog, cat are examples of animal and thus animal is subordinate to its hyponyms 'lion,dog and cat', (4) *homonymy* between words of no related senses e.g. know-now, (5) *meronymy* describing part-whole relation between words e.g.

arm, leg are part of human, (6) *metonymy* which substitute word with its associated words e.g. white House or US government , (7) *polysemy* between words having multiple meanings and (8) converseness between words having reciprocal relations e.g. husband-wife, child-parent. Besides these types of semantic relations, part-whole, part-of, if-then, cause-effect and many more are present among entities related to each other [2]. Causality is determined from the cause-effect relation in a sentence which plays a very crucial role for decision making.

There are different forms of causality contained in a sentence (1) A sentence connects two processes, cause part which under some circumstances, influence effect part, (2) Causal parts determine some action or event occurred in past and its effect is its consequence which generally happens to be in future and (3) The cause and effect parts may or may not be contained in one sentence [3]. A combination of lexical and semantic techniques is employed to identify causality involved in a sentence and thus understanding its meaning. In the domain of question answering, concept of causality is explored by researchers for answering why-type questions which is motivated by the fact contained in Aristotle's philosophy [4]. It has been stated that the word 'cause' refers to 'explanation' and since answers to why-question need explanation/reasoning for entities asked, it is determined as 'answer to a why-question'.

The paper is divided into various sections. Section 2 puts light on the importance of causality with its motivation. Section 3 discusses different dimensions of causality and its role in different fields. Section 4 introduces different type of causality involved in a sentence. Section 5 describes various approaches used to identify causal relations in a sentence with future directions. Section 6 addresses different issues and challenges involved in identifying causality. Section 7 at last finally concludes the work with future research directions.

2   Motivation for using semantic relations in QAS

The Question Answering System (QAS) [5] returns an answer to a question asked by user. The primary requirement of QAS is to understand the need of the user from the question asked by him/her. The research started by identifying adverbial clauses [6] in a relevant document that depicts events occurring in different parts of a sentence. The clauses are classified by containing various semantic relations e.g. place, manner, cause/reason, purpose, result, condition, contrast, similarity etc. [7] The appropriate answer candidates to a question are assumed to containing such semantic relations. Different semantic relations contained in answer candidates depend on their question types. For example, answers to why-question are expected to contain semantic relations 'cause/reason' and 'purpose', how questions are expected to contain semantic relation 'manner', where type questions contain semantic relation 'place' and comparative questions are expected to contain relations like 'substitution and contrast' and so on. Thus, semantic relations play significant role in extracting appropriate answer candidates to a question.
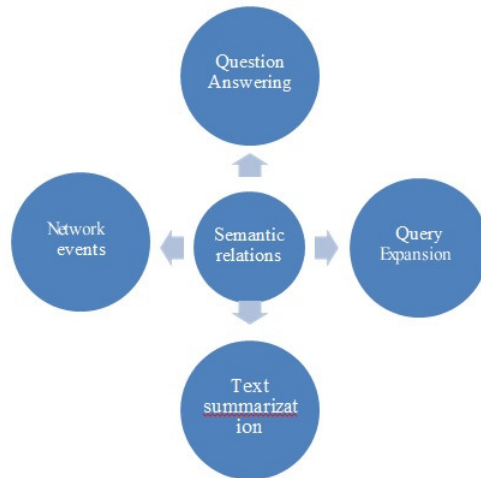
3 Applications of semantic relations

Fig. 1. Fields requiring extensive use of semantic relations

Question Answering System: QAS is an application of Information Retrieval and Natural Language Processing that returns one appropriate answer to a question depending on the user and context of time at which the question is being asked. The process requires identifying semantic relations in document which match the relations contained in the user's question. Depending on the type of question, appropriate semantic relation is identified from the documents which are expected to containing an answer to a question.

Query Expansion: Semantic relations play a major role to extract related terms that are associated with existing query terms to use it for query expansion. This is required whenever there is a lexical mismatch between query and answer documents, and the need is to improve query by appending related terms to it. The query expansion process is either carried out automatically or explicitly by user suggesting the terms to be appended [8].

Text Summarization: Text summarization [9] is a process of removing redundant information and including valuable information. It is performed by

considering the relations between terms or concepts involved in the text documents. The part of the text which comprises terms from user query as well as cue phrases which determine semantic relations between them are considered while summarizing text documents.

Network Events: Semantic networks for the text are constructed which depict the semantic relationships contained between the events involved in a sentence. Semantic relations are used to deduce meaning from the text by finding semantic roles of the entities involved in different events [10].

4   Classification of Causal Relations

The table below 1 discusses several parameters used by researchers to classify causal relations. They are used in various different scenarios for example, as cue phrases which act as connectives, adverbs, questions etc. [11]

Table 1: Different parameters for classifying causal relations

S.No.	Criteria	Labels	Explanation with example
1.	Type of terms	Ambiguous	Terms not reflecting causation everytime (e.g. since)
		Non-Ambiguous	Terms always reflect causation (e.g. because)
2.	Patterns involved in text	Explicit	Patterns explicitly present in sentence
		Implicit	Explicit patterns are not present but still express causation relation
3.	Connectives (used in explicit causal patterns)	Adverbial connectives	Used to link words by referring forward and backward in a sentence (e.g. for this reason,with the result that)
		Prepositional connectives	Prepositions are used to link causal and effect part of a sentence e.g. as a result of, because of, due to etc.
		Subordination connectives	Conjunctions are used to address immediate effect e.g. so, since, because etc.
4.	Causation verbs (used in explicit causal patterns)	Linking verbs	e.g. lead to, force, generate, cause etc.
		Resultative causatives	e.g. kill, melt, break etc. where it results into some other condition
		Instrumental causatives	e.g. poison, hang, clean etc. where instrument is used to perform action
5.	Causative adverbs (used in explicit causal patterns)	Conjunctive adverbs of cause or reason	e.g. because, as, since, that, due to, hence and many more
		Adverbs referring to effects	e.g. painful, consequently

6.	Implicit verbs (used in implicit causality)	causality to agent	e.g. Rahul confessed for not calling Shakshi
		causality to patient	e.g. Rahul admired Shakshi because he like her
7.	Causal Relationships	one cause	One cause having multiple effects
		one effect	Multiple causes resulting one common effect
		chain of causes and effect	A cause prompts an effect, which further prompts another different effect with repeating process
		causal homeostatis	Cycle of cause and effect relationships where final effect has initial cause as its effect
8.	causation questions	Explicit questions	Comprise explicit keywords that determine type of relation in it e.g. cause, effect, consequence etc.
		Semi-explicit questions	Includes ambiguous keywords causing difficulty to determine semantic relations e.g. generate, trigger etc.
		Implicit questions	No explicit keywords present but cause and effects are contained in a sentence e.g. kill,sing etc.

5 Using Causality to address modules of Question Answering

This section discusses the usage of causal relations in different modules of Questions. Researchers have utilized causal semantic relations to address the development of Why-type Question Answering System.

5.1 Corpus Preparation

Jong Hoon Oh et. al. in 2018 [13] has identified causal relations in text to automate the retrieval of Question and Answer pairs for the training data. The process is carried out to improve the answer re-ranking process. The authors extracted sentences containing cue phrases from the text document and identified cause and effect parts from the sentence. For example, consider the sentence (The sun rises in east) $_{effect}$ because (the earth rotates around its axis toward the east) $_{cause}$. The sentence helps to form question and its answer. It has been stated that cause part is regarded as an expected answer to a question which can be automatically extracted from the effect part. Thus, the cause part 'the earth rotates around its axis toward the east' serves as an answer to the question formulated from the effect part 'Why sun rises in east?'

5.2 Answer Retrieval

J. Fukumoto in 2007 hand-crafted various extraction and non-extraction patterns for each type of non-factoid questions, whether it is why-type, definitional or how-type questions [14]. Causal semantic relations are identified from the document using Rhetorical Structure theory. Answer candidates are extracted from these retrieved passages containing causal relations in it. If a sentence in document matches extraction patterns, it is considered as an appropriate answer candidate and those containing non-extraction patterns are not considered as appropriate candidate for answers.

In 2013, Jong Hoon Oh et. al. identified intra and inter-sentential causal relations for answering Why-type questions [15]. Intra-sentential causal relations contain cue phrases like 'because', 'since', 'causes' etc. and inter-sentential are expected to comprise phrases like 'This causes' and 'As a result' etc. These associations are found using bag-of-word approaches.

5.3 Answer Re-Ranking

Higashinaka and Isozaki in 2008 addressed the issue of assigning appropriate weights to the hand-crafted patterns [16]. The authors ranked answer candidates on the basis of three features contained in them which are (1) causal expressions extracted from FrameNet [17] and PropBank [18], (2) content similarity which share common words in question and candidate answers. Common terms are not enough to find content similarity rather it is weighted by finding

semantic relatedness using semantic relations such as synonyms, hypernyms and hyponyms [19]. (3) causal relations comprising pairs of cause and effect in answer and question respectively and such semantic relations between two concepts are found using EDR dictionary [20].

Jong Hoon Oh et. al. in 2013 trained answer re-ranker on the basis of three features viz. morphosyntactic, semantic word classes and sentiment polarity [21]. Causal relations are accessed through term-matching in which effect part comprises more than one content word as contained in question, partial-tree matching in which effect part comprises more than one partial tree as contained in question and excitation- polarity matching in which effect part and question share one common noun of same polarity.

6 Challenges and Issues involved in identifying causality

6.1 Understanding Ambiguous cue phrases:

There are certain phrases which always express causation, and some rarely express causation depending on the context of their appearance in a sentence. It is difficult to understand the nature of sentence which requires semantic interpretations to understand the implications of such cue phrases encountered in a sentence.

6.2 Identifying implicit causality

Implicit causations are complex and difficult to address. There are some phrases which are often used consecutively and address cause and effect but doesn't contain any connectives between them e.g. 'cold tremble' is a phrase which doesn't contain any explicit cue phrase but there is causal relationship between them where cold is the cause and tremble is its effect. Inference procedures based on semantic knowledge with some background knowledge and common sense reasoning is required to identify such causation within a sentence [22].

6.3 Automatic extraction of cause and their effect

It has been viewed that causes and effect may or may not be contained in one sentence. Also there are some cases where there is a chain of causes and their effects which creates difficult to determine immediate effect of the causal event involved in a sentence. The procedure requires some background knowledge to identify causes and effects present in a sentence.

6.4 Identifying event causality in a sentence

It is very difficult to identify the events and determine causality relations between two events mentioned in a sentence. Discourse relations help to judge how events are related to each other semantically playing significant role in developing question Answering Systems.

7 Conclusions and Future Directions

The paper discusses a concept of causality with its significance in question answering system. A classification of causal relations and the approaches used to discern them in a sentence are described. There are some challenges and issues discussed which are needed to get resolved so as to further improve the performance of question answering module. In the future work, other than causal relations, other semantic relations like 'purpose' and 'motivation' can be explored to improve the accuracy of Question Answering System.

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