International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Anaphora Resolution using ThemeSets

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Abstract: Anaphora resolution is a procedure of replacing pronouns with its referring nouns which may be available in the same sentence or in different sentences within the same document. Even multiple approaches are available for anaphora resolution; there may be some space for semantic approaches which provides solution better than syntactic or corpus based approaches. In syntactic approaches, all noun phrases from the previous or current sentences are checked for getting constrains agreement with the anaphor and score value is calculated for a pair of Noun-Pronoun based on these constrains. The pair getting the highest positive score is treated as the result. In some cases the sentence structure is not changed, hence the score corresponding to the feature values and syntactic structures are same. Here the actual replacement of pronoun with noun depends on the meaning of the sentence especially the meaning of the verb. To resolve such situations, here we are proposing a method which is a combination of syntactic and semantic approaches based on ThemeSets or thematic sets. Using ThemeSets we are exploiting the role of verbal lexemes associated with the noun or pronoun for the resolution of anaphora. Anaphora resolution in semantic way has great importance in the modern era of artificial intelligence which enhance multi-dimensional research in the area of natural language processing in a better way.

Index Terms: Anaphora Resolution, ThemeSets, Verbal lexemes, Nominal Anaphora, Feature Constraints.

I. INTRODUCTION

Natural language processing is one of the major fields of information exploration which needs a deep collaboration of humans and computers. Anaphora resolution is one among the challenging research areas, in which a number of algorithms were proposed but lack of an efficient semantic proposal for a complete solution. Anaphora resolution or pronoun resolution is a procedure which replaces pronouns with its referring noun phrase and is inevitable for other natural language applications such as machine translation, coreference resolution, text summarization, question answering etc.[1][2] The noun phrase may be definite, indefinite, demonstrative or reflexive. Simply anaphora resolution is the marking of antecedent and referent which may be available in the same sentence or in different sentences within the same document. For example: "Ramu is studying in third standard and he is the class leader". In this sentenced 'he' stands for the noun 'Ramu'. The referring word 'he' is an anaphor and the preceding word 'Ramu' is called an antecedent. As mentioned above the process or procedure of finding the antecedent of an anaphora is called Anaphora Resolution.

Manuscript published on 30 August 2019.
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Anaphora resolution is mainly of two types: 1) Intra sentenential 2)Intersentential. [3]Intrasentential stands for the situation where the pronouns and corresponding noun phrases are available in the same sentence, but for the case of intersentential both are in different sentences. Through human intervention it is much easy for finding the anaphor for a specifi c referent, but for an automatic text processor it is difficult due to lack of semantic knowledge. Also the process may goes to complex as the number of antecedent increases. In such situations we have to consider different agreement constraints such as gender, number etc.

Even if we consider different agreement constrains there may be some situations where we can find the correct antecedent only with the help of verbal lexemes. Let us consider below sentences: sentence 1- "Rama tried to kill Ravana, but he failed". Sentence 2-"Rama tried to kill Ravana, but he escaped". The above mentioned sentence has one anaphor, i.e. 'he'. For sentence 1, 'he' refers Rama and for sentence 2 it refers Ravana. Here the antecedent-anaphor combination is decided by the verbal lexemes 'failed' and 'escaped'. For humans it is easy to predict the antecedent accurately but for a computer it may not.

In the present day of Artificial Intelligence, it is very important to properly address Anaphora resolution because it will greatly assist the various ongoing researches in the different phases natural language processing. It is therefore essential that the Pronoun Resolution be carried out completely and accurately. Pronoun resolution is currently being carried out in many different ways in different languages. But it is not practical to adopt a generalized approach of resolution for every language, as it depends on factors such as the syntax, semantics, and practicality of that particular language.

II. BACKGROUND

There are many types of anaphors in many languages but they show similarity in their basic nature. These can be categorized into the following general categories according to the form of anaphor.[4]

a. Nominal Anaphora: It's a frequently occurring type of anaphora, and occurs when an anaphor has non-prominal noun phrase as its antecedent.

b. Pronominal Anaphora: It is a most commonly seen anaphora, which occurs due to the presence of pronouns such as personal (he, him, she, her, it, they, them), reflexive (himself, herself, itself, themselves), possessive (his, her, hers, its, their, theirs), relative (who, whom, which, whose) etc.

c. Lexical Noun phrase Anaphora: It occurs in sentences, where the reference is based on syntax, and to definite noun phrases.

d. Zero Anaphora: Zero pronominal anaphora occurs when the anaphoric pronoun is omitted but is nevertheless understood

In almost all the verses, we can find one or more kinds of anaphora listed above are visible. Various methods are being used for the resolution of such anaphors. Much of these are based on some trivial syntactic or semantic constraints. Although not all constraints are applicable to all approaches, many of them are used in one way or another. Advanced methods such as statistical, machine learning etc use these constraints in the initial phases. The approaches using these constraints are comparatively simple but are very useful and are applicable in every language. The constraints used for this purpose are universally acceptable and some of them are listed below.

Gender constraint: It's regarding the gender lexemes he, she or him, her etc. i.e., it consider whether it is a male, female or non-living entity such as 'it'. [5]The gender agreement of the anaphor and corresponding antecedent may help much in the process of resolution. On the process of resolution we can eliminate number of antecedents based on the gender constraints. This is one of the important constraints which also help to evaluate the correctness of resolved anaphors. For example, in the sentence "Rama (1) helped sita(2 and she (3) is happy", on application of this constraint, (1) is eliminated due to gender disagreement with (3), and we can predict the pronoun she denotes the male person 'Rama'. But is has some limitations, we cannot confirm whether it is a male or female from the name itself. Also it is not easy to predict the correct one if their exists multiple antecedents which satisfies the gender agreement.

Number constraint: Here we are considering the singularity or plurality of the anaphor and the antecedents. [6][7]If the anaphor is a singular one then we can eliminate the plural antecedents from the evaluation process. It may not predict the correct antecedent, but helps greatly in the entire anaphora resolution process. This approach is followed in various advanced machine learning systems. For example, in the sentence "Teacher (1) gave sweets to students (2). On receiving it they (3) were happy". Here the reference (3) refers to (2) and we can predict it on the basis of number agreement.

Selectional constraints: In all languages, some words are closely associated with some other words.[8] For example some verbal lexemes are closely associated with living things, so they cannot be used with non-living ones. Due to the specificity of these words, the Anaphora solution becomes easy to an extent. This leads to the introduction of world knowledge in the entire resolution process. This can be explained in the below example. The sentence "I bought a cuckoo bird(1) from the pet shop and put in a cage(2) and it(3) sung.", Here it is very difficult for a computer to interpret. Here, (3) can refer to (2) or (1). The reference (2) should be filtered out here using this selectional constraint.

Person agreement: In linguistics, grammatical person denotes the set of personal pronouns in a language, and it has a classification as first person, second person and third person. [9]Simply first person denotes the speaker, second person denotes the audience and third person refers everybody else. These difference in pronouns helps in the process of anaphora resolution if we use it intellectually. Some approaches have already exploited these features.

Grammatical role: [10]In linguistics, a sentence is a composition of subject, verb and an optional object. In this approach, we are giving priority for the antecedents which come in the subject portion than that occurs in the object portion. It's not always true, but seems very likely to be true. This approach is mentioned by Kennedy and Boguraev. For example, in the sentence "Rama (1) likes to travel with his brother Laxmana(2). Last month he (3) went to a jungle", Here (3) refers to (1) and not to (2) as we described above.

Positional priority: [11]The positions of the reference and referee have great importance in the process of anaphora resolution. That is, when we finding the correct antecedent for a specific anaphora, the nearest antecedent has higher priority than the distant one. This approach is exploited by Carbonell and Brown, 1988.

Frequency: [12] Frequency of occurrence of noun phrases has great importance in the process of anaphora resolution. In some approaches it is assumed that the frequently occurring antecedent has a great chance of being the correct antecedent. Antecedents that are repeatedly occurring in the context are given a higher priority than the rest.

All of the above constraints are commonly used in syntactical approaches for the resolution of anaphora. We can see the usage of many more constraints in many different ways in various approaches or in languages. The performance of these constraints may vary depending on the approach in which it is used. In the modern approaches of artificial intelligence, we can see some more constraints also.

III. EXISTING APPROACHES – A BRIEF NOTE

To To this end, many different approaches have been proposed to solve the problem of anaphora. Difficulties arise when there are multiple choices for a specific anaphor. Here we are discussing some approaches which provide an acceptable percentage of correct output. The attempt for a better method of resolving anaphora had begun long ago. The first one was suggested by Hobbs in 1978 [13].

He has presented two approaches to the problem of solving anaphora. The first is an imperative algorithm that works by searching for the proper gender and numeral nouns in a particular order of surface parsing trees of text. The second approach shows how to handle anaphora resolution in a comprehensive system for semantic analysis of English texts. The algorithm doesn't work properly in all cases, but get a better performance among syntactic approaches. He also proposed the usage of syntactic constraints such as gender, number etc. Hobbs algorithm is still treated as an important algorithm, even after various syntactical approaches are proposed.

In 1994 Lappin and Herbert proposed an algorithm RAP (Resolution of Anaphora Procedure) for the resolution of anaphora both intrasentential and intersentential [14]. It depends on the dimensions of the solution derived from the syntactic structure and the simple dynamical pattern of attention to select a noun prefix from the list of candidates. It does not use semantic conditions or real-world knowledge to evaluate candidate antecedents. It provides a slight improvement in the performance.

The approaches discussed above are syntactic or rule based. These are not the only approach in rule based strategy, various approaches in different angles are proposed, but these approaches can be considered as basic forms. All others in rule based approaches are built on these foundation stones.

Another way of anaphora resolution is the corpus based approach in which the available corpus is used for the resolution process. Knowledge-independent Approach [15], Machine Learning Approach [16] etc are also using the provision of corpus in their methods. The method proposed by Michael Paul in 2002 is an example of corpus based approach by combining a machine learning method and statistical information [17]. First, a decision tree trained on an annotated corpus determines the coreference relation of a given anaphor and antecedent candidates and is utilized as a filter in order to reduce the number of potential candidates. In the second step, preference selection is achieved by taking into account the frequency information of coreferential and non-referential pairs tagged in the training corpus as well as distance features within the current discourse.

Discourse based Approaches, and knowledge poor approaches are also provides better results, but a semantic consideration is not fully implemented. LRC Algorithm [18], BFP Algorithm [19], COGNAIC [20] etc are some examples of such methods. The result generated through manual intervention is still better than by a computer. This is because of language specialties, and the limitations of incorporating semantic knowledge in computer algorithms. Here we are proposing a semantic approach for the resolution of anaphora. Here we are considering the verbs or meaning of verbs for finding the actual one from the candidate set.

IV. PROPOSED ALGORITHM

Our pronoun resolution technique mainly inspired by the rule based and the corpus-based approaches (Mitkov, 2002) and is expanded by incorporating semantic calculations also. A number of approaches are available for the resolution of anaphora in a document. But majority are running on the basis of syntax and corpus information and a semantic approach is needed for a complete and accurate resolution of pronouns. In syntactic approaches, all noun phrases from the previous or current sentences are checked for getting constrains agreement with the anaphor and score value is calculated for a pair of Noun-Pronoun based on these constrains. The pair getting the highest positive score is treated as the result.

In some cases the sentence structure is not changed, hence the score corresponding to the feature values and syntactic structures are same. But the actual replacement of pronoun with noun depends on the meaning of the sentence especially the meaning of the verb. Following is a case of such situation.

Sentence 1:Rama(1) tried to kill Ravana(2), but he(3) failed.

Sentence 2:Rama(1) tried to kill Ravana(2), but he(3) escaped.

Here two sentences, which are same in syntax and structure but the only difference is a change in verbs. Based on the change in verbs, the antecedent corresponds to the anaphor is also changed. In sentence 1 the reference (3) refers to (1), but in sentence 2 the reference (3) refers to (2).

The above sentences are structurally and syntactically same and the general constraints like gender, number, person, position etc are also same. Hence the score calculated for the noun-pronoun pair is same for both the sentences, but the result is not same in two sentences because of the change in the meaning of the verbs. Humans can easily identify the change in antecedents based on the change in the meaning of verbs, but a computer cannot. Hence we require a semantic approach for anaphora resolution by considering the meaning of the verbs also.

For taking verbs into consideration, we are proposing an alternative version of thematicset, which a collection of words which are thematically connected. The basis of grouping this time is not only linguistic but also extra-linguistic: the words are associated, because the things they name occur together and are closely connected in reality. It has been found that these words constitute quite definitely articulated spheres held together by differences, oppositions and distinctive values. For an example it is convenient to turn to the adjectives. These are known to be subdivided into qualitative and relative lexico-grammatical groups. Among the first, adjectives that characterize a substance for shape, colour, physical or mental qualities, speed, size, etc. are distinguished. Here we also include the action verbs and its resultant action verb based on some extractive relations. E.g.; think-understand, kill-escape, look-saw etc. Here we have slightly changed the appearance of ThemeSets for our purpose. For the purpose of resolution we are introducing some relations for connecting different lexemes in this ThemeSet, and are essential for considering verbs in the resolution process but are not limited. Some of the relations are follows:

Retrieval Number: J96010881019/19©BEIESP
DOI: 10.35940/ijitee.J9601.0881019
Journal Website: www.ijitee.org

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1. Synonymy: If one lexeme is a synonym of another lexeme, then we can connect these lexemes with the relation synonymy.
2. Result: If one lexeme is a resultant action of another lexeme semantically, then we can connect these two lexemes by using the relation result.
3. Reason: if one activity or state is a reason for another activity, then we can connect the corresponding lexemes by the relation reason.

In this approach if two verbal lexemes are included in same ThemeSets, then those sentences have a large bonding in the process of pronoun resolution. For reducing the complex procedure, we are creating the ThemeSets from corpus information, by collecting antecedent verbal lexemes to the group with bonding reduces when we proceed to farther.

A. Proposed Algorithm

Our methodology can be explained by the following algorithm:

i) Preprocessing of the text: Here we are breaking the text into sentences and common words with no semantics and which do not aggregate relevant information to the task (e.g., “the”, “a”) are eliminated.

ii) POS tagging: Here we are putting part-of-speech tag as an annotation on each word or symbol using a suitable POS Tagger.

iii) Data extraction: Extract relevant information from the text for the resolution process. Collect all nouns and pronouns with its features such as frequency, position, gender etc also its syntactic structure for generating scores with respect to the application of various rules and syntactic analysis.

iv) Score calculation: Individual score is calculated for each N-P(noun-pronoun) pairs based on various constraints and syntactic analysis. The noun with the highest accumulated score is proposed as antecedent. The score calculation can be expressed as below:

$$S(N\text{-}P)=\sum(Pt , Pg, Pn, Ps, Pd,Pf) \qquad (1)$$

Where Pt -> Score value on pronoun type
Pg -> Score value on pronoun gender
Pn -> Score value on number constraint
Ps -> Score value on selectinal consistency
Pd -> Score value on position
Pf -> Score value on frequency

v) N-P score updation using the bond dependency value from the ThemeSet.

After getting a score in the syntactic analysis in (iv) we are proceeding to the semantic approach by considering the ThemeSets. From the ThemeSet we are getting a bond dependency value for the verbal lexemes corresponding to the noun and pronoun. The bond dependency value denotes how deeply the verbs are connected in the ThemeSet using the defined relations. It is calculated from the corpus which is used as a baseline data for the creation of ThemeSet. In thematicset, verbal or adjective lexemes are arranged as per their bond dependency value with the given lexeme. It is as below:

$$TS(Wi)=\{W_1\text{-}R_1\text{-}[S_1], W_2\text{-}R_2\text{-}[S_2], \ldots, W_n\text{-}R_n\text{-}[S_n]\} \quad (2)$$

Where TS denotes the thematic set, W denotes the verbal lexemes, R denotes the connecting relation or quality adjective, S denotes the bond dependency value. Bond dependency value for a specific relation is calculated by using the probability of occurrence of lexemes in the corpus with the relational values. The general calculation is as below:

$$P(W_1|Wi,R)=P(W_1) . P(W_1/Wi) . P(W_1/Wi,R) \qquad (3)$$

where $P(W_1|Wi,R)$ is the probability of occurrence of lexeme W_1 with respect to a thematic set Wi and its relational constraints R.

By considering the bond dependency value and relation getting from the ThemeSet, we are updating the equation for calculating N-P score as given below:

$$S(N\text{-}P)= (\sum(Pt , Pg, Pn, Ps, Pd,Pf)) * T(S_{N\text{-}P},R) \qquad (4)$$

Where T is the score value of the verbal lexeme associated with the pronoun got from the Thematicset of the verbal lexeme associated with the noun with the relation R.

We are explaining its application by a case study. Consider the below two sentences.

Sentence 1:Rama(1) tried(2) to kill(3) Ravana(4), but he(5) failed(6).

Sentence 2:Rama(1) tried(2) to kill(3) Ravana(4), but he(5) escaped(7).

After syntactic analysis and score calculation, we got a same value for both the sentences. But on human calculation, it is predictable that in sentence1 (5) refers to (1) and in sentence2 (5) refers to (4). Here result can easy be calculated by following the semantic approach using ThemeSets. Here three verbal lexemes are present in sentence1, i.e. (2) corresponds to (1), (3) corresponds to (4) and (6) corresponds to (5). In sentence 2 all are same except (7) corresponds to (5). The ThemeSet generated from the corpus gives the information that (6) is connected with (2) using the relation ‘Reason’ and are in the same ThemeSet and (7) is connected with (3) and are also in same sets. This information provide a high score value to their corresponding N-P pairs in both Sentences and declared the result as ‘he’ refers to ‘Rama’ in Sentence 1 and ‘Ravana’ in sentence 2.

In this proposal we have exploited only three relations, but are able to construct number of relations, by considering the meaning and occurrence of lexemes inside a sentence which may be much useful for the process of pronoun resolution. But here we are limiting the relations since it is sufficient for our proposed approach.

V. RESULT AND DISCUSSION

Finally, the obtained results are compared with existing techniques. We have give a standard document with 254 occurrence of pronouns are given and we are performing the resolution process using different approaches. The implementation for this anaphora resolution approach is performed in the python platform. In this the tokenization of pre-processing is performed in ‘NLTK’ tool.

The two most commonly used parameters for evaluating results obtained in Anaphora Resolution are namely precision and recall. They are the measure of accuracy and completeness respectively. The false positive (FP) denotes the pairs which are incorrectly marked as coreferent and the false negative (FN) represent the pairs which should have been marked as coreferent but have not been.

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DOI: 10.35940/ijitee.J9601.0881019
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TP denotes the pair of N-P which are correctly resolved. F-measure usually is the combination of precision and recall scores. The equations for calculating precision, recall and F-Score are as mentioned below:

$$\text{Precision} = \frac{TP}{TP+FP} \quad (5)$$

$$\text{Recall} = \frac{TP}{TP+FN} \quad (6)$$

$$F-measure = \frac{2*precision*\text{Re}call}{precision+\text{Re}call} \quad (7)$$

This comparison indicates that this proposed method using ThemeSets provide better result than other existing methods. We are comparing our method with the traditional approaches - The Hobb's algorithm and Lappin's algorithm. The obtained parameter values show a better performance of proposed methodology than the traditional algorithms. The parameter values are as given below:

Table- I: Comparison of Quality Measuring Parameters

Algorithm	TP	FP	FN
Hobbs	186	40	44
Lappin	198	32	36
Using Themeset	226	19	23

And corresponding precision, recall and F-measure is given in the below table.

Table- II: Comparison of Evaluation Parameters

Algorithm	Precision	Recall	F-Score
Hobbs	82%	80%	81%
Lappin	86%	84%	85%
Using Themeset	92%	90%	91%

A graph showing the comparative performance of proposed methodology with the traditional algorithms is shown in Fig.1

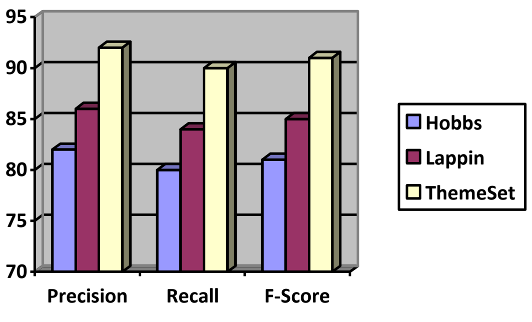

Fig. 1. Graph showing the Performance Comparison

From the graph we can find that our proposed algorithm has improved 6% in accuracy and completeness compared to that of Lappin's algorithm and has 10% of improvement that of Hobb's algorithm.

VI. CONCLUSION

Anaphora resolution has a great importance in the era of modern research in natural language processing. Even multiple approaches are available for anaphora resolution; there is a space for semantic approaches which provides solution better than syntactic or corpus based approaches. The proposed algorithm using ThemeSet is one that uses the simplicity of syntactic approaches with the intelligence of semantic approaches. The results can further be improved by generating more relations in the ThemeSets that leads to an accurate prediction better than this.

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