CAREER POINT UNIVERSITY HAMIRPUR

CPUH-Research Journal: **2016***, 1(2),* 01-07
ISSN (Online): 2455-6076
http://www.cpuh.in/academics/academic_journals.php

Anaphora Resolution for Indian Languages: The State of the Art

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ABSTRACT: Anaphora Resolution is a process of finding antecedent of corresponding referent. It affects the accuracy of all Natural Language Processing (NLP) applications. The paper describes the research done in the development of anaphora resolution techniques in Indian Languages in the last one and half decades. Over the years, researchers have been trying to address this problem. Though, the work is going on for Indian Languages but English and European languages are far ahead. Here, the detailed analysis of various papers and Master dissertations was carried out.

Keywords: Natural language processing [NLP]; Anaphora Resolution [AR]; Machine Translation [MT] and Text Summarization.

INTRODUCTION: The growing technologies in every field have made the whole world a global village where in the only barrier is language. Natural Language Processing (NLP) provides an interface to knowledge bases and natural language translation. The work in this area will increase the quality of research to enrich language resources and will enhance translation accuracy which in turn will help the mankind in better communication and understanding.

"The etymology of the term "anaphora" goes back to Ancient Greek with "anaphora" (αναφορα) being a compound word consisting of the separate words ανα − back, upstream, back in an upward direction and φορα - the act of carrying and denoted the act of carrying back upstream." (Ruslan Mitkov)

Example 1: "**And do you now** put on your best attire? / **And do you now** cull out a holiday? / **And do you now** strew flowers in his way / that comes in triumph over Pompey's blood? Be gone!" – Julius Caesar

Example 2: If **child** does not strive on raw **milk**, boil **it**.
In the Example 2 machine translation "it" may refer to "child". Which will reverse the meaning of sentence? The "it" is anaphora and the "milk" is antecedent. For correct translation and other application of NLP, "it" must refer to the "milk".

BASIC TERMINOLOGY: Types of Anaphors according to the form of the Anaphor:

Nominal anaphora: Nominal anaphora arises when a referring expression (pronoun, definite noun phrase or proper name), has a non-pronominal noun phrase as its antecedent.

Pronominal anaphora: Pronominal anaphora is the most widespread type of anaphora. Example 3: John had to go to a meeting so he decided to have a shave.
Lexical noun phrase anaphora: Lexical noun phrase anaphora is realized syntactically as definite noun phrases, also called definite descriptions, and proper names.

Zero anaphora: Zero anaphors are 'invisible' anaphors. Zero pronominal anaphora occurs when the anaphoric pronoun is omitted but ∅ is nevertheless understood.
Example 3: Ram went to market and ∅ bought a camera.

LITERATURE OF ANAPHORA RESOLUTION: Prasad *et al*.[1] proposed A Corpus Study of Zero Pronouns in Hindi based on "Centering Theory"[2]. Given the Hindi-specific centering constraints presented in [1], it was argued that the discourse constraint to license the felicitous use of Hindi, zero pronouns should be formulated as a combination of preferences for sequences of transitions and a "zero pronoun rule", adapted from Rule 1 of Centering Theory which comprised the list of forward-looking centers in Centering terms and are ranked according to their salience. The anaphoric relationships in the local discourse segment [3] are dependent on the list ranking, in that the more highly ranked entities in an utterance are more likely to be talked about in the following utterance. Investigation of the factors that determine the list ranking which have not yet been completely

specified has therefore, constituted an important aspect of the research for centering theory in particular, and for discourse anaphora in general.

A notable work has been done for the Hindi by different researchers [1-6], [13-18], [20], [22-23], [30], [34-39], [42-45], [47], [53].Prasad *et al.* [4] described the study of discourse connectives in a small corpus of Hindi texts in an effort towards developing an annotated corpus of discourse relations in Hindi, adopting the lexically rounded approach of the Penn Discourse Treebank. They had identified a wide range of connectives, analyzed their types and distributions, and discussed some of the issues involved in the annotation. They focused on explicit connectives in this paper, future work will investigate the annotation of implicit connectives, the semantic classification of connectives, and the attribution of connectives and their arguments. Prasad *et al.*[5] proposed a novel approach that represents arguments as the sentences containing them, and classifies connectives in terms of their expected collocation with their arguments in sentences and paragraphs. The algorithm on the data showed an absolute 3%improvement, showing that the proposed approach and method holds promise. However, the error analysis showed room for improvement, since most errors were due to failure of the algorithm.

Sobha L.*et al.*[6], [49]proposed a system VASISTH for resolving anaphora, ellipsis and gaps in two Indian languages namely, Malayalam and Hindi. Computational grammars of both the languages for this specific purpose were developed. Only a part of the system was presented here. Although, at this stage this system could handle only two languages, they had reasons to believe that it could be used without major modification for anaphora resolution in all Indo-Aryan, Indo-Dravidian and Indic family of languages, in general all morphologically rich languages. A system which could resolve pronominals in Tamil using probabilistic method was presented Sobha L. *et al* [7]. Also, Sobha L. *et al.*[8] used named entity and ontology for anaphora resolution, algorithm for anaphor resolution in Sanskrit[9].

Sobha L[10] introduced pronominal resolution in south Dravidian languages [51].Further, anaphora resolution in Malayalam language was presented[11].The analysis was dependent on the salience weight of the candidate noun phrases (NP) for the antecedent-hood of the pronominal from the list of possible candidate NPs. The salience weight ofNP was obtained from the salience factors, which were determined by the probability of a NP to be the antecedent on the basis of the grammatical features. The system gave 86.32% precision and 80.9% recall. High accuracy only for small data set was the limitation of this paper. Sobha *et al.*[12],[49] presented a generic anaphora engine for Indian languages, which are mostly resource -poor languages and also analyzed the similarities and variations between pronouns and their agreement with antecedents in Indian languages. They tested the system with Indo-Aryan and Dravidian languages namely Bengali, Hindi and Tamil. Linguistic pre-processing modules have been used in this anaphora resolution system. In this task, the authors have performed the basic task of sentence splitting and tokenization. They had selected six features for Machine Learning to train the CRF module, anaphora resolution as a technique of semantic analysis of text documents written in Hindi language was shown[13]. The approach used here was based on machine constrains for the grammatical attribute of different words. The accuracy of anaphora resolution was nearly 96% for simple sentences and for compound and complex sentences the accuracy was 80 percentages.

A modified Hobbs algorithm for Hindi language was presented[14], which took into account the free word-order and grammatical role in pronoun resolution in Hindi. The author exploited the binding among the different constituents and case markers in sentences to resolve prenominal anaphora .For example, ergative case marker has binding with possessive reflexive pronouns. However, the scarcity of NLP resources restrict the algorithm to be tested on larger data set. They also highlighted the importance of anaphora resolution for machine translation application by evaluating the existing Machine translation systems: AnglaHindi by IIT Kanpur, Matra2 by CDAC Mumbai and Google translation system. Theapplications of machine learning algorithms and probabilistic neural network models on the demonstrative pronouns in Hindi were studied.

Pronominal anaphoras can be classified in two categories namely direct anaphoras and indirect anaphoras. Direct anaphorasare explicitly described in the sentences whereas indirect anaphoras are implicitly described. It is difficult to resolve indirect anaphora than direct anaphora therefore, it has to be categorized.

Figure 1. below shows the number of papers published every year for Indian languages. As it can be seen, a fairly high number of papers have been published in 2015 which infers that the work in the field of anaphora resolution is increasing rapidly.

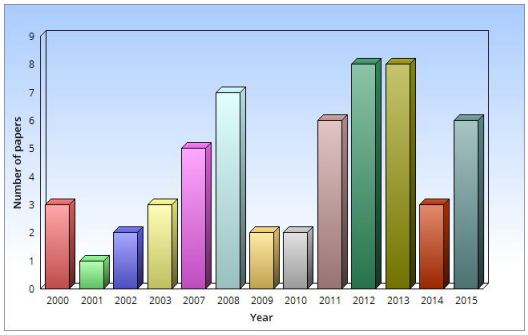

Figure 1. Number of papers per year for Indian Languages

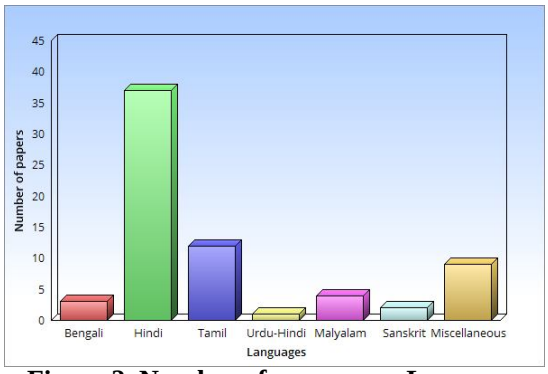

Figure 2. Number of papers per Language

The Figure 2. above counts the number of papers presented for every Indian language. It can be seen that the number of papers in Hindi exceeds by far amount than any other language.

Ambati B. R. *et al*. [15] depicted experiments which lead to state-of-the-art dependency parser for Hindi. Bhatt R*et al.*[16] surveyed the various ways of expressing modality in Urdu/Hindi and showed that Urdu/Hindi modals provide interesting insights on current discussions of the semantics of modality. They then investigated whether the Actuality Entailment that has been long documented in the context of modality also holds in Urdu/Hindi. Triveni Lal *et al*. [17] reviewed the work done in the field of anaphora resolution in Hindi and covered different issues and challenges in developing computational models for Hindi. The paper covered issues related to syntactic/semantic structure of Hindi and influence of cases on pronouns, mainly personal pronoun. Dakwale P. *et al*.[18] presented a hybrid approach to resolve Entity-pronoun references in Hindi. In this approach, dependency structures were used by a rule-based module to resolve simple anaphoric references, while a decision tree classifier was used to resolve more ambiguous instances with the help of grammatical and semantic features. The rule based system achieved a substantial accuracy of 60% which implied that the dependency relations can help achieve an acceptable resolution performance for Hindi, and the use of decision tree classifier demonstrated a substantial improvement of 10% over the rule based system‘s accuracy. Sikdar *et al*.[19] displayed the first attempt on anaphora resolution for a resource poor language, namely Bengali and addressed the issue of adapting a state-of-the-art system BART, which was originally developed for English. The system produced the recall, precision and F-measure values of 56.00%, 46.50% and 50.80%, respectively. Lakhmani P*et al*. [20] presented a report on anaphora resolution for Hindi language. Single and multi-objective optimization for feature selection in anaphora resolution were observed[21].

Davison A.[22] considered a construction in Hindi-Urdu which consisted the preposition “BINAA” followed by an oblique verbal participle. Singh Smita *et al*.[23] presented a computational model for anaphora resolution in Hindi that was based on Gazetteer method. Gazetteer method is a creation of lists and then applies operations to classify elements present in the list. Here, the experiments conducted on short Hindi stories, news articles and biography content from Wikipedia, its results& future directions to improve accuracy were described. In Tamil, conditional random fields based pronominal resolution was presented[24]. Akilandeswari A.*et al*.[25]presented resolution for pronouns in Tamil using CRF, in proceedings of workshop on machine translation and parsing in Indian languages. SobhaL *et al*.used tree- CRF for anaphora resolution in Hindi text[26], [52]. Murthi *et al*. worked on pronominal resolution in Tamil using machine learning approach[27].Sundar Ram V. *et al*presented anaphora-antecedent annotation in Indian language using PALINKA[28]. Chandra Mohan *et al*. [29]built a Rule Based System for anaphora Resolution in Telugu language. The system designed was mostly based on syntactic information with only certain semantic and morphological features. The evaluation of the system was done with a limited set of data and these accuracies 58.19%, 57.3%, 80.5% and 48.14% were obtained for personal pronouns, demonstrative pronouns, interrogative pronouns and reflexive pronouns respectively. The base system (without gender agreement) gave an average of 48% accuracy on different pronouns. Singh P. *et al*. [30] investigated the type of antecedent for Hindi and discussed the five values of this feature of antecedent. They analyzed165 news items of Ranchi Express from EMILEE corpus of plain text.

DISCUSSION: Anaphora resolution techniques can be classified into four categories. First is syntactic based technique (Hobbs algorithm [54]) also called rule based approach which was implemented by Dutta *et al*.[14] requires a number of a natural language resources e.g. part of speech tagger and parser. Non availability of these resources for Hindi language acts as a major hindrance in the implementation of the algorithm on larger data set. Second is knowledge poor approach which does not rely on linguistic and domain knowledge. Using this approach the success rate recorded was up to 70%[18]. Corpus based study is the third one which exhibits the features of the genre to resolve anaphora resolution. Initially, this approach used by Botley *et al*.[31] for English[32]which was later adopted by Sinha [33] in the master dissertation. Dutta *et al*.[34] also carried work on this approach .Fourth is discourse based approach which is modeled through a sequence of utterances. Here, world knowledge and inferencing are also employed in order to resolve anaphora.

S No.	Languages	Authors
1.	Tamil	Shobha L. 2007, A. Akhilandeswari and Shobha L 2013, P. Padmamala2015, Akhilandeswari A. *et al.* 2015.
2.	Hindi	Prasad 2002, Prasad and Strude 2000, Gupta and Chatterjee 2000,Prasad 2003, Dayal 2003, Agarwal *et al.* 2007, Dutta K.*et al*.,2008, Prasad et al. 2008, Dutta *et al.* 2011, Ambati 2011, Dayal 2011, Dutta *et al.* 2012,Lalita 2012,Dakwale 2013, Lakhmani and Singh 2013, Soni*etal.* 2013, Singh *et al.* 2014,Lakhmani*et al.* 2014, Komla Mehla 2015, Singh P. and Dutta 2015, Ahir*et al.* 2015, Singh , Mahato and Thomas 2015
3.	Bengali	Sikdar*et al.*2013, Sikdar 2014
4.	Urdu-Hindi	Mohan *et al.* 2014, Alice Davison 2013
5.	Indo-Aryan	Bhatt *et al.* 2011
6.	Sanskrit	Pralayankar P. *et al.* 2008, Lalithadevi*et al.* 2008
7.	Indian languages	R.M.K. Sinha 2002, Lalitha Devi 2003,Sundar Ram *et al.* 2012, D. Chandra M. *et al.* 2012,Lalitha Devi *et al.* 2014

Table 1: Status of research done in Indian languages

CONCLUSION: It is observed from the literature survey that most of the techniques of anaphora resolution are inspired from other languages such as English and European languages and hence, are adopted for Indian languages. Anaphora resolution techniques can be divided into four categories after concluding from the section of literature of anaphora resolution.

Rule Based Approach: Small set of rules are created to identify the antecedent of NPs of interest. System does not require training.

Corpus Based Approach: Uses selection patterns, statistics or co-occurrence patterns observed in the corpus. Training (Machine Learning) is required.

Knowledge Poor Approach: Approaches that uses domain and linguistic knowledge (which is difficult both, to represent and to process) require considerable human inputs. Therefore, the idea of knowledge poor approach came into existence. Knowledge poor approach does not require linguistic (and domain) knowledge therefore, is less labor intensive and less time consuming. This approach is further motivated by the emergence of cheaper and reliable corpus based NLP tools such as Part Of Speech taggers and shallow parsers, corpora and other NLP resources (e.g., ontology).Knowledge Poor Approach is difficult to implement when there is lack of annotated corpora.

Discourse Based Approach: Corpus based (history based) approach cannot handle references(anaphors)in general, but it may resolve some type of references(anaphors) as it does not take into account the effect of discourse structure on anaphora resolution. Discourse based resolution approach is an attempt to exploit discourse structure, specially the relationship between references and discourse theme, to resolve definite references.

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