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Anaphora Resolution in Hindi: Issues and Directions

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Abstract

Natural language processing is way of understanding the human languages by machine which involves the field of computer science and artificial intelligence. The basic aim of NLP is to develop such software that will analyze, understand and generate human languages. It has many challenges anaphora is one of them. Anaphora is considered as the problem of referring pronoun phrase to noun phrase within the sentence or between the sentences. Anaphora resolution is required in various NLP applications. Lot of work has been done in English but less work has been done in Hindi. Anaphora Resolution in Hindi is a complex task because Hindi is independent word order language. Pronouns in Hindi show a great deal of dubiety. This paper presents the various approaches to resolve various issues of anaphora resolution in Hindi. The paper also presents research gaps and direction for future researchers.

Keywords: 5-6 words, Drawn from title, Word representing the work

1. Introduction

Natural Language Processing (**NLP**) is referred with the intercommunication between computers and human languages. It is linked with the field of human and computer intercommunication. It has many challenges anaphora is one of them. Anaphora is considered as the problem of referring pronoun phrase to noun phrase within the sentence or between the sentences. Anaphora resolution is required in various NLP applications of natural language processing such as Automatic summarization, Co reference resolution, Machine translation, Named Entity Recognition (NER), Discourse analysis, Parsing, Part-of-speech tagging etc.

E.g. : ***Sachin asked Rahul to borrow him the money.***

- The referring word (him) is called an anaphor.
- The preceding form (Sachin) is called an antecedent.
- The document in which the anaphor fall is called its discourse.
- The procedure of directing the antecedent of an anaphora is called Anaphora resolution.

Anaphora resolution can be categorized into Inter sentential and Intra sentential [1]:-

- **Intrasentential** is the expression where the antecedent and its anaphor fall in the same sentence.
- **Intersentential** is the expression where antecedents and its anaphor fall in different sentences .

It can also be classified as [2]:-

- **Entity** anaphora defines those pronominal references which refer to a real Entity such as Person, place and other common nouns.
- **Event** anaphora refers to those pronominal references which refer to Events.

Now challenge in anaphora resolution is

Challenge: *Who does each pronoun refer to?*

E.g.:

S1: The books are given to the students because they were required.

S2: The books were given to the students because they were useful.

S3: The books were given to the students because they were there.

Now the question is that in the example they refer to books or student. Because of the contradictory explanation of "*they*" in each sentence, the entire definition of the sentence changes [3].

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In S1 – '*They*' refer to '*students*', S2- '*They*' refer to '*books*' and in S3 –'*They*' refer to '*students*'. A human can easily understand this but a machine can't.

Anaphora occurs very repeatedly in text and spoken sentences. The main aim of natural language processing applications is that they must resolve anaphors but there is no existing theory or methodology which resolves all anaphora. Almost all NLP applications such as automatic summarization system, question answering model, natural language generation system, information extraction system, , machine translation system etc., require complete identification and complete plan to resolve an anaphora.

Anaphora resolution is not an easy process. The machine should have good understanding of the interaction between the syntax, semantics and pragmatics of a language. It requires not only the understanding but also the skill of nearly all language domains as shown in [Figure 1].

Lot of work has been done in English but less work has been done in this aspect in other languages. This paper presents a detailed review of the research done till date in the area of anaphora resolution in Hindi. The main contributions of this paper are:-

1. It figures out the list of various resolved and unresolved issues of anaphora resolution in Hindi.
2. It also provides the list of different approaches that are used to resolve the anaphora.
3. It identifies the research gaps of existing approaches and also provides a road map of the existing shape of the current research in anaphora resolution.

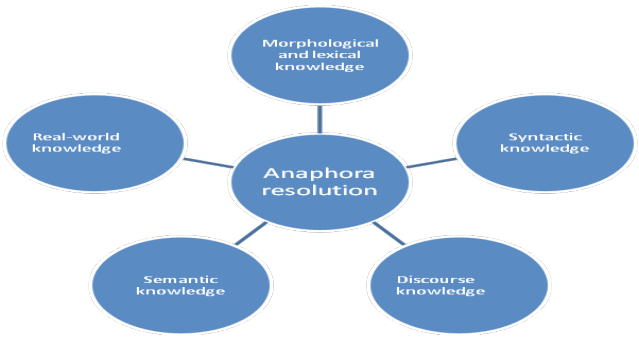

Figure 1. Ashima

The paper is assembled in following way: section 2 portrays the background. Section 3 portrays related work. Section 4 portrays research gaps .Section 5 portrays conclusion. Section 6 portrays references respectively.

2. Background

Hindi language is an independent from the word order and it has no proper structure like English. So Pronoun in Hindi shows a great deal of uncertainty. To well understand the complexity of anaphora resolution one has to be clear about se classification of anaphora and pronouns in Hindi mentions in section 2.1. Different approaches used in anaphora resolution presents in session 2.2. Issues of anaphora resolution and the basic process of anaphora resolution present in session 2.3 and 2.4.

2.1 Classification of Anaphora and Pronouns in Hindi

There are different types pronouns like Possessive pronoun that can take place of noun phrase to show ownership and which has first, second and third person pronouns, Demonstrative pronoun that point to specific things, Reflexive pronouns that mention to particular subject of the sentence, Place pronoun that refer to location or places and Relative pronouns that introduce dependent clauses in sentences [4]. The summary of comparison of pronominal anaphora for first, second and third person paradigm in Hindi are given below in [Table 1]:-

2.2 Different Approaches Used In Anaphora Resolution

Researchers have used various approaches to identify the various pronouns as shown in table 1 .Various models which are used are rule based, corpus based and applying AI and machine learning techniques [5]. The researchers have also combined these approaches to give better results in some cases. Those are called Hybrid approaches. These approaches can be broadly categorized into four types. They are shown under:

2.2.1 Rule Based Approaches

Rule based approaches combine knowledge sources and various factors that remove the items which are not required up to a set of the feasible items is obtained. The constraints work as a filter to remove the unwanted candidates within a set of defined rules. Thereafter, preference- based factors are applied.

Various Examples of algorithms under the Rule based approach:

Tree search algorithm [6]

Table 1. Different types of pronoun in Hindi

S.r. no	Pronoun	Singular	Plural
1	**Possessive pronoun (Svatvātmāka sarvanāma)** A possessive pronoun is a pronoun that can take the place of a noun phrase to show ownership		
	First Person (उत्तम पुरुष)	मैं	-
		मझको, मुझे	-
		मेरा (m) , मेर (f)	मेरे (pl)
		-	हम
		-	हमको
		हमारा (m) ,हमार (f)	हमारे (pl)
	Second Person (मध्यम पुरुष):	तुम , आप (r)	-
		तुमको , आपको (r)	-
		तु)हारा(m) , तु)हार	तु)हारे (pl)
		(f) आपका (m) , आपकी (f)	आपके (pl)
	Third Person (अन्य पुरुष)	वह	वे(r)
		यह	ये (r)
		उसको, उनको(r)	उसको, उनको(r)
		इसको, इनको(r)	इसको, इनको(r)
		उसका (m) , उसकी(f)	उसके (pl)
			वे
			उनको
		उनका (m) , उसकी (f)	, उनके (pl)
2	**Demonstrative Pronoun (*Nishchyavaachak Sarvanaam*) :** Pronouns that point to specific things	यह	
		यह	
		वह	
		वह	
			ये
			वे

3	**Reflexive pronouns (Nijavaachak Sarvanaam):** Pronouns that refer back to the subject of the sentence or clause. They either end in –self	आप (or अपने आप), खुद, and स्वयं/स्वयम	खुद
4	**Relative pronouns (*Sambandhvaachak Sarvanaam*):** Pronouns that introduce dependent clauses in sentences	जब ... तब/तो , जहाँ वहां , जैसे वैसे , जैसा वैसा, जतिना उतना, जो वह	जब ... तब/तो , जहाँ वहां , जैसे वैसे , जैसा वैसा, जतिना उतना, जो वह
5	**Place pronouns** (जगह सवर्नाम) : Pronouns that refer to location	वहां , यहां	-

Shallow processing approach [7]
Multi-strategy approach [8]
Syntax based approach [9]
Combination of linguistic and statistical methods [10]

2.2.2 Corpus Based Approaches

Corpus approaches are those which use the available corpus (a collection of written texts). These corpuses have been created specifically for the discourse task.

Various Examples of algorithms under the Corpus based approach:

Knowledge-independent approach [6]
Statistical / Corpus processing approach [11]
Machine Learning Approach [12]

2.2.3 Knowledge Poor Approaches

Knowledge poor approaches are economical, fast and reliable. They are acceptable for huge category of languages because they do not depend on the semantic and syntax. They enroll many Artificial intelligence techniques for e.g. neural network system, semantic framework etc and do not depend on the domain and linguistic knowledge. They can be run without the parsing.

Various Examples of algorithms under the knowledge poor approach:

Kennedy and Bogurae[13 14]
Robust knowledge poor approach [9 15]
COGNAIC [16]
ROSANA [17 18]

2.2.4 Discourse Based Approaches

Discourse is modeled through a sequence of sentences. A single item is focused at the any given point in the text and it has to be unlike from all others items that have been raised. In order to resolve anaphora, the world knowledge and conclusion are also employed.

Various Examples of algorithms under the discourse based approach:

Centering theory [19]
BFP algorithm [20]
S-List algorithm [19]
LRC algorithm [21]

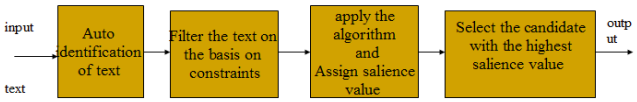

Figure 2. The basic process of anaphora resolution.

3 Related Work

In anaphora resolution a lot of the work is done in other European Languages and English but less amount of work is done in Hindi language. The researchers focused on various issues of anaphora resolution Hindi and used various existing or hybrid approaches to resolve these issues.

In[24] presented a translation system of English to Hindi Machine-Aided named as AnglaHindi. Anglabharti was a pseudo-interlingual rule-based translation methodology. It also used example-base and statistics to get more accurate translation for frequently encountered noun and verb phrasals. It used semantics to resolve most of the intra-sentence anaphora/ pronoun references. It had problem in making a choice of correct reflexive pronouns .The system generated approximately 90% acceptable translation in case of simple, compound and complex sentences up to a length of 20 words .

In[3] presented methods to handle anaphora and used ellipsis and implemented a model by using a prototype of natural language interface (NLI) to databases for Hindi – Matra2. It resolved the issues of Reflexive Pronoun, Possessive Pronoun, and Demonstrative Pronoun where

AnglaHindi had problem in making a choice of correct reflexive pronouns. Matra2 was also compare with the Google translator which had also problem in making a choice of correct reflexive, possessive, demonstrative pronoun. It did not differentiate pronouns on gender .

In[25] presented in paper the report on anaphora resolution for Hindi language. The primary focused on the solution of pronominal anaphora. It also covered the issues related to syntactic and semantic structure of Hindi. It performed a experiment on different kinds of data sets and gave result of approx 71% but only on number agreement and animistic knowledge but Gender agreement don't show any accuracy .

In[22] presented the pronominal anaphora resolution for Hindi Language and a computational model for anaphora resolution in Hindi that was based on Gazetteer method which involved many salient factors for resolving anaphora. But the proposed model resolved anaphora by using two factors that is Animistic and Recency. The experiment conducted on different data set - data set 1 - children story – gave accuracy of 65%, data set 2 - news article - gave accuracy of 63%, data set 3 - biography from wikipidea- gave accuracy of 83% .

In[23] presented how Anaphora Resolution was useful in performing computation linguistic task in different Natural languages as well in the Indian languages and told about the how the Anaphora Resolution was conducive in handling unknown words in Named Entity Recognition. Transliteration approach was used to solve name entity recognition in various languages.

E.g.:

आशमिा /*PER* बैडमटिन खेल रही है

रामू/*PER* जम्मू/*CITY* में रहता है

Above, Named Entities in Hindi were transliterated into English as: Ashima, Ramu, and Jammu. And it had given approx 96% of result but it did not focus on other issues .

In[4] presented the application of Hobbs algorithm for pronominal resolution in Hindi and solved reflexive and possessive pronouns. Modified the Hobb"s algorithm into hobb's naïve algorithm for hindi and do not solve the gender agreement, number agreement, NER etc .

In[26] presented an algorithm which is in line with S-List (Prasad and Strube, 2000) to resolve the Hindi third person pronouns and showed that there was a refinement of the S-List algorithm in the performance by taking two lists one was present and second was past instead of one. It also explored, how complex sentences could be broken into utterances as motivated by Kameyama (Kameyama, 1997). The algorithm also introduced another algorithm for resolving the first and the second person pronouns and it had given 61.11%, 77.45% of result on different data sets. But author did not focus on other issues .

In[27] presented a system for Indian languages called a generic anaphora engine, which were poor recourses languages. It had analyzed the likeness and unlikeness between the pronouns and their agreement with antecedents. The machine learning approach used the features which could handle major Indian languages. It took shallow parsed text as input and marked Generic Engine and used CRFs, a linear graphical machine learning algorithm to train the system. It had solved the gender problem in past.

In[28] drafted approach to resolve Entity-pronoun references in Hindi called hybrid approach and used dependency structures as a source of syntactic information. In this approach, the dependency structure were used with a rule-based caliber for resolving the simple anaphoric references and a decision tree classifier was used to solved the more puzzling sentences, using grammatical and semantic features. The results show that used of dependency structures that gives syntactic knowledge is used to resolve some specific types of references. Semantic information such as animacy and Named Entity categories further helped to improve the resolution accuracy .It also resolved the Reflexive, Locative, Relative and Personal pronouns. And it had given 70% of accuracy but did not solve the gender agreement and other problem [28].

In[1] presented the Gazetteer method for pronominal anaphora resolution for Hindi Language. It had developed a model that used Recency factor which was acted as the baseline and Animistic knowledge which forms the criteria of classification of different pronouns and nouns for performing the pronominal anaphora resolution task for Hindi Language and gave approx 60 to 70% of result but did not solve other issues .

In[29] presented the classification of indirect anaphora in Hindi corpus by using machine learning approach. This was depending on the knowledge of semantic structure provided by the collocation of various patterns and following pronouns were also drilled out. It had given 12.44% result on indirect anaphora in whole data but did not other issues.

The relate work is précised in tabular form in [Table 2]:-

Table 2. Summery of Related Work

Sr. no	Issues	Paper name	Work done	Limitation
1	Pronoun resolution (first, second and third person), Number agreement, Animistic	Anaphora Resolution in Hindi Language [25]	1)Resolved the issue of pronominal anaphora on the bases of number agreement and animistic knowledge ,added gender agreement 2)It produced result of approx 71%.	1)Gender agreement didn't show any accuracy. 2)Did not solve NER problem. 3)Other pronouns like reflexive, relative etc were not solved.
2	Pronoun resolution(first, second and third person) , recency and animistic	Anaphora resolution in Hindi Using Gazetter Method [22]	1)Solved the pronominal anaphora resolution using gazetteer method . 2)The proposed model resolved anaphora by using two factors that is Animistic and Recency. 3)It produced result of aprrox 83%.	1)Gender agreement didn't show any accuracy. 2)Did not resolve other pronouns like reflexive, relative etc 3) Number agreement , intrasentential and intersentential, NER problem wer not resolved.
3	Pronoun resolution(first , second and third person, reflexive pronoun), Gender agreement	Resolving Pronominal Anaphora in Hindi Using Hobbs' Algorithm [4]	1)Solved the pronominal anaphora using hobb's algo. 2)Focused on reflexive and possessive pronouns, 3)Solved the gender agreement in past	1)Gender agreement didn't show any result in present. 2)Did not resolve number agreement , intrasentential and intersentential, NER, regency problem.
4	Pronoun resolution(first , second and third person) intrasentential sentences and Number agreement	Pronoun Resolution For Hindi [27]	1)Modified algorithm which was in line with S-List resolving the Hindi third person pronouns in intra sentential It produced 61.11%,77.45% of result on different data sets.	1)It only focused on first ,second and third pronoun not on other pronouns like reflexive, relative etc 2)Did not solve pronouns in intersentential sentences, recency . 3) Gender agreement was not solved.
5	Pronoun resolution(first , second and third person), recency and animistic	Gazetteer Method for Resolving Pronominal Anaphora in Hindi Language [1]	1) Solved the pronominal anaphora by using gazetteer method and used animistic knowledge and recency factor and 3)It produced result of 60 -70%.	1) Did not focus other factors like number, gender agreement. 2)Intrasentential and intersentential, NER, recency problem was not solved.
6	Ambiguities and Unknown words in Named Entity Recognition	Handling Ambiguties And unknown Words In Named Entity Recognition Using [23]	1)It resolved the issue of name entity recognition. 2)Handle the ambiguities using 3)Transliteration approach. 4)It produced result of 90%.	1)Did not focus on other factors like gender agreement, number agreement. 2)Did not resolve other pronouns like reflexive, relative etc.
7	Reflexive, Possessive, Demonstrative, Place, Relative, Indirect pronounces resolution .	Anaphora Resolution in Hindi: Issues and Challenges [3]	1)Matra2 is compared with the, Anglahindi, Google translator which had also problem in making a choice of correct reflexive, possessive, demonstrative pronoun. It solved the issues.	1) It did not differentiate pronouns on gender. 2) NER problem was not resolved. 3) Did not resolve number agreement, recency.
8	Gender Agreement.	A Generic Anaphora Resolution Engine for Indian Languages [28]	1) Developed the generic algorithm for Indian languages by using the machine learning approach for the sameness and variations between the various pronouns and their agreement with their antecedents	1) Did not focus on number agreement, NER, recency. 2) Had used very minimal resources
9	Reflexive, Possessive, Demonstrative, Place, Relative, Indirect pronounces resolution ,Name entity Reorganization, recency and animistic	A Hybrid Approach for Anaphora Resolution in Hindi [27]	1) Resolved Entity-pronoun references in Hindi by using dependency structures with rule-based module 2) Worked on Reflexive, Locative, Relative and Personal pronouns, animacy , name entity recognition	1) Did not focus on other 2) salient factors only focused resolving only entity pronouns

10	Reflexive, Possessive, Place, Relative, Indirect ,Demonstrative pronounces resolution	Machine Learning Approach for the Classification of Demonstrative Pronouns for Indirect Anaphora in Hindi News Items [2]	1) Presented classification of indirect anaphora in Hindi corpus by using machine learning approach 2)It produced result on 12.44% of indirect pronouns .	1) Only focused on indirect anaphora. 2) Did not solve other issues.
11	Handel IntrasententiaI and Intersentential sentences	Angla Hindi: An English to Hindi Machine-Aided Translation System [24]	1) Developed AnglaHindi System. 2) It used semantics knowledge to resolve most of the intrasentence pronoun references. 3) It produced result of 91% on simple, compound,complex sentences up to 20 words.	1) It had problem in making a choice of correct reflexive pronouns . 2) Did not focus on other issues.

4. Research Gaps

It can be observed from the table 2 that the area of Anaphora Resolution is still lacks of resolving various issues. The research gaps of existing approaches are listed below:

1) Very less amount of work has been done on Gender Agreement.

2) Researchers should develop better algorithm to handle pronouns in intrasentential, intersentential, entity and event sentences.

3) Standardization of single text processing tool for anaphora resolution is required by limiting the utilization of corpus.

4) There is need to develop a better algorithm which can work on all issues at the same time and it is also required researchers to develop approaches for Indian languages which resolve anaphora resolution.

5) Researchers used only one metric that is F value to measure the performance. But there are many other methods for calculating the functioning of anaphora resolution are , ware BLANC, MUC, B3, CEAF and these metric exhibits significantly different behaviors from each other and globally accepted .

5. Conclusion

Finally, we have analyzed the benefaction of various researchers and which are able to work out various research gap for the future researchers. The paper describes the definition, type and challenge of Anaphora resolution, various approaches like Rule based, Corpus based, Knowledge poor, Discourse and Hybrid. The paper presents various aspects of anaphora resolution like Recency factor, Animistic knowledge, Gender, Number agreement, NER, Pronoun resolution etc. It can be seen that the problem of anaphora resolution is challenging but not uncontrollable. From last few years anaphor resolution has gain a large attention; a large amount of work has demonstrated which showed good results. None of them are able to cover all issues of anaphora resolution. We can wish to have better results with a time and anaphora resolution approaches for Indian languages.

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