

# Anaphora Resolution in Hindi: Issues and Challenges

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## ABSTRACT

Anaphora occurs very frequently in written texts and spoken dialogues. Almost all NLP applications such as machine translation, information extraction, automatic summarization, question answering system, natural language generation, etc., require successful identification and resolution of anaphora. Though the significant amount of work has been done in English and other European languages, the computational work, in reference to Hindi, is lagging far behind. In this paper, we present a review of work done in the field of anaphora resolution in Hindi. We also cover different issues and challenges in developing computational models for Hindi. The paper covers issues related to syntactic/semantic structure of Hindi and influence of cases on pronouns, mainly personal pronoun. The work is mainly dedicated to pronominal anaphora. As the pronouns in Hindi do not differentiate gender, it is the verb and case markers that signify different genders. Influence of case markers in deciding the antecedent is explored. Pronoun resolution in context of EHMT (English-Hindi Machine Translation) systems is demonstrated to substantiate the need of anaphora resolution for NLP application.

## General Terms

Natural Language Processing

## Keywords

Anaphora, Anaphora Resolution, Case markers, Natural Language Processing, Pronominal Anaphora

## 1. INTRODUCTION

Anaphora is a referencing expression that refers to some entity which previously introduced into the discourse. The process of binding (mapping) the referring expression to the correct antecedent, in the given discourse, is called anaphora resolution. According to Halliday and Hassan [18], anaphora is “the cohesion (presupposition) which points back to some previous item.” Hirst [5], more formally, defines anaphora as “a device for making an abbreviated reference (containing fewer bits of disambiguating information, rather than being lexically or phonetically shorter) to some entity (or entities) in the expectation that the receiver of the discourse will be able to disabbreviate the reference and, thereby, determine the identity of the entity.” Here, reference is an anaphora and the entity to whom it refers, is an antecedent.

Among the various types (pronominal anaphora, nouns anaphora, nouns phrase anaphora and zero anaphora, as in [5])

of anaphora, pronominal is most common type of anaphora. Anaphora resolution is a challenging task in natural language processing because it need not only knowledge but expertise of almost all language processing domains (morphological and lexical knowledge, syntactic knowledge, semantic knowledge, discourse knowledge, real-world knowledge, etc.). Sometimes pragmatic knowledge is very important in anaphora resolution. This can be understood by following example:

1. S1: The Mangos were given to the children because they were hungry.  
S2: The Mangos were given to the children because they were ripe.  
S3: The Mangos were given to the children because they were there.

Who does each *they* refer to in the example 1? Because of the different interpretation of “they” in each sentence, the wholesome meaning of the sentence changes.

This paper is divided into two main parts. A literature survey of existing anaphora resolution approaches is presented in first part of the paper. Corresponding result on the basis of comparative study is presented. The second part of the paper concentrates on issues and challenges in anaphora resolution in Hindi.

## 2. RELATED WORK IN ANAPHORA RESOLUTION

Most of the earlier work done in the field of anaphora resolution is for English and other European languages. Hirst [5], have done extensive work to propose a computational solution to anaphora and co-reference resolution in English, as in [5]. Hobbs algorithm, as in [4], [22]; is an effective algorithm for anaphora resolution. It uses syntactic information rather than semantic information. The Hobbs algorithm, [9], depends only on a syntactic parser plus a morphological gender and number checker. For this reason, it is often used as a baseline, when evaluating new pronominal anaphora resolution algorithms. Mitkov’s [21] work is very comprehensive in the field of anaphora resolution. JavaRAP [26] and Mitkov’s Anaphora Resolution System [21] are among some good anaphora resolution systems.

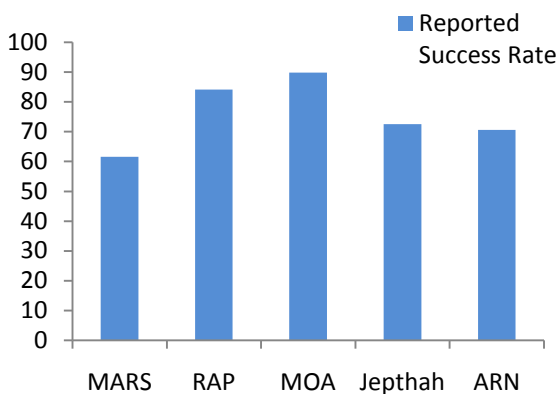
Earlier, knowledge-based anaphora resolution approach relied on manually developed knowledge by linguists. This type of anaphora resolution is solved by hearer’s set of beliefs (knowledge) that is used to represent syntax, semantic and

discourse algorithm. These resolution approaches require inputs which are pre-processed manually and normally assumed to be perfect and if required has been check or modified by the experts. The difficulty to adapt the knowledge base system for other language and existence of pre-processing tools motivate the researchers to their focus into knowledge poor approaches (heuristic based systems).

Knowledge Poor (KP) systems provide simplicity and robustness design and are comparable in performance with knowledge based systems. Some examples of KP approach are Mitkov’s Original Approach (MOA) [22], RAP [26] and ARN [6]. Brief comparison of these systems is given in Table 1(as in [19]-[20]).

**Table 1. Comparison of existing systems**

Models/Element	MARS	RAP	MOA	Jepthah	ARN
Data Sets	Technical Manual	Computer Manual	Technical Manual	Manual Dialogues, G. B. Shaw Play	Oslo andBREDT corpus
Prerequisite	Pre-processing task conducted automatically using FDG parser	The data manually check and corrected Pleonastic it manually remove	The data manually check and corrected Pleonastic it manually remove	manually tagged corpora, then be tuned using Genetic Algorithms	manually tagged corpora, then be tuned using Genetic Algorithms
Purpose	Third personal pronouns and lexical anaphora (reflexives and reciprocals)	Third personal pronouns and lexical anaphora (reflexives and reciprocals)	Third personal pronouns and lexical anaphora (reflexives and reciprocals)	pronouns, reflexives and deictic anaphora	Third personal Pronoun exclude “it”
Language	English	English	English	English	Norwegian
Reported success rate	61.55	84.10	89.70	72.50	70.50



**Fig 1: Comparison of success rate of different Anaphora Resolution Systems**

### 3. ANAPHORA RESOLUTION IN HINDI

In Hindi and other Indian languages anaphora resolution studied are presented by Bharti et al. [1]. Authors designed methods to handle anaphora and ellipsis and implemented in a prototype natural language interface (NLI) to databases for Hindi. Parse structure of sentence has been formed by Panini parser developed at IIT Kanpur. Sobha and Patnaik[17] gave a rule based approach for the resolution of anaphora in Hindi and Malayalam as well. Anaphora resolution using rule based approach, corpus based studies, and using centering theory are presented in [24]-[25]. Prasad’s thesis work is based on the principle that the grammatical function is important for discourse salience in Hindi Language, as in [24].

Dutta et al. [11] presented modified Hobbs algorithm for Hindi. The algorithm takes into account the free word-order and grammatical role in pronoun resolution in Hindi. Authors

concluded that in Hindi, the role of subject and object are significant for reflexive and possessive pronouns. Dutta et al. [12] 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. Authors also highlighted the importance of application of pronominal divergence in machine translation and concluded that “pronominal divergence can help in identifying anaphoric and non-anaphoric occurrences of pronoun”. Authors further highlight that machine translation is affected by improper anaphora resolution. They point out the issues in different translation systems. Where, Google translation, is unable to resolve the ambiguity between nominative and ergative forms of subject pronouns; MaTra2, on other hand, fails to specify correct forms of pronouns occurring in the object position. AnglaHindi has problem in making a choice of correct reflexive pronouns. The work of [13], [14] studied the application of machine learning algorithms and probabilistic neural network models on the demonstrative pronouns in Hindi. The work conducted so far, in [13], [14];demonstrate that classification of demonstrative pronouns as direct and indirect anaphora is essential for successful anaphora resolution. The work is conducted on the Emille Corpus (<http://www.emille.lancs.ac.uk/>).The studies conducted so far, as in [12], demonstrate that, for a successful NLP application the resolution of anaphora is essential.

Recently, NLP tool contest on Anaphora Resolution in Indian Languages was organized in an annually conducted International Conference,ICON 2011 (9th International Conference on Natural Language Processing ) held at Anna University,

Chennai(<http://ltrc.iit.ac.in/icon2011/contests.html>). The task included identification of antecedents for an anaphor from POS (Part Of Speech), NP (Noun Phrase) Chunked and NE (Named Entity) tagged corpus. Participants were provided

with the training, development and test data. Efficiency of the system was measured using Precision and Recall.

### 3.1 Anaphora Resolution and its Importance in Machine Translation

Anaphora resolution is crucial in many NLP applications such as machine translation, information extraction, automatic summarization, question answering system, natural language generation. Natural languages across the world are quite diverse in their structure. One language does not follow the syntax and semantics of other. For instance, it might happen that one language differentiate in gender of pronouns (like English, he, she, etc.), whereas other does not (like Hindi, voh, ve, etc.). Therefore, in order to translate/ generate correct sentence from source language to some target language, resolution of anaphoric expressions is crucially important. Solving the anaphora and extracting the antecedent are key issues for correct translation into the target language. If anaphors are not resolved properly, it may change the meaning of entire discourse. Example 2 illustrates what happen if anaphora not handled properly ([http://www.bhaskar.com/article/NAT-anna-defends-his-comment-on-pawar-slap-saying-he-is-not-gandhi-2619674.html?RHS=badi\\_khabare=](http://www.bhaskar.com/article/NAT-anna-defends-his-comment-on-pawar-slap-saying-he-is-not-gandhi-2619674.html?RHS=badi_khabare=)).

- अन्नानेब्लॉगमेंआगेकहा,  
मेरीतुलनामहात्मागांधीसेकरनाठीकनहींहै,  
गांधीजीकेपासबैठनेकीभीमेरीपात्रतानहींहै।

Google translation of same in English-

Annasaidinthe blog, is not fair tocompare mewithMahatmaGandhi, **Gandhiis noteligible to sit close tome.**

The real sense of the sentence is “I am not even eligible to sit close to Gandhi ji”. But the sentence is changed in translation just to reverse the meaning. This type of translation cannot be accepted. This happens because references are not properly resolved in English translation. Some other examples are shown in Table 2-4 (sentences as translated by different English-Hindi MT systems, for different pronouns).

#### 3.1.1 Possessive Pronouns

**Table 2. Examples of possessive pronouns**

ENGLISH (SOURCE SENTENCE)	GOOGLE TRANSLATION	MATRA2 TRANSLATION
I saw her book on your table.	मैंअपनीमेजपरउसेपुस्तकदेखा.	मैंनेतुम्हारामेजपरउसकाकिताबदेखी
The house is theirs and its paint is flaking.	घरऔरउनकीअपनीपेंट flaking है.	घरठेरिसहैऔरउसकारंगपरतकररहाहै
My dog is better than their dog.	मेराकुत्ताअपनेकुत्तेसेबेहतरहै.	मेराकुत्ताउनकाकुत्तासेअच्छाहै

In the fourth sentence (Table 2), mine should be resolved as “mera” (of my), but MATRA2 (<http://www.cdacmumbai.in/matra/>) unable to resolve it.

#### 3.1.2 Reflexive Pronouns

Reflexive pronouns ends as “...self” or “...selves” and rename subjects of action verbs. They function as various types of objects. For example ‘myself’, ‘yourself’, ‘himself’, ‘herself’, ‘itself’ are singular and ‘ourselves’, ‘yourselves’, ‘themselves’ are plural reflexive pronouns. As in the Table 3, reflexive pronouns are not properly handled by both the translation systems.

**Table 3. Examples of reflexive pronouns**

ENGLISH (SOURCE SENTENCE)	GOOGLE TRANSLATION	MATRA2 TRANSLATION
She bought herself a new purse for her new job.	वहखुदउसेनईनौकरीकेलिएएकनयाबटुआखरीदाहै.	उन्होनेखुदउसकानयाकामकेलियेएकनयाबटुआखरीदा
They managed themselves very well as members of the conference panel.	वेखुदसम्मेलनपैनलकेसदस्योंकेरूपमेंबहुतअच्छीतरहसेप्रबंधित.	वेखुदकीसदस्यकेरूपमेंसम्मेलनपैनलकाबहुतअच्छीतरहकीदेखबालकिये
He loved himself too much, and never thought about anyone else.	उसनेअपनेआपकोबहुत ज्यादाप्यारकरताथा, औरकिसीऔरकेबारेमेंकभीनहींसोचा.	उन्होनेकोईअन्यकेबारेमेंसन्दकियाखुदबःउतबहुत

### 3.1.3 Demonstrative Pronoun

Table 4. Examples of demonstrative pronouns

ENGLISH (SOURCE SENTENCE)	GOOGLE TRANSLATION	MATRA2 TRANSLATION
I like this better than that.	मैं इसतरहसेहैकिबेहतर.	मैं यह उनसे अच्छा पसन्द करती हूँ ।
This is great.	यह महान है.	यह बड़ा है ।
These look tasty.	ये स्वादिष्ट देखो.	ये स्वादिष्ट देखता है ।

I really like that.	मैं सच है कि पसंद है.	मैं यथार्थ मेवह पसन्द करता है ।
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In the first sentence (Table 4) ‘this’ and ‘that’ are demonstrative pronouns used to represent closeness of object from speaker but Google translator (<http://translate.google.co.in/?hl=en&tab=TT>) does not able to resolve ‘that’ pronouns. It takes ‘that’ as subordinating conjunction not as demonstrative pronoun. On the other hand MaTra2 is able to resolve somehow better than Google in this sentence. Similarly in the last sentence, “I really like that”, “that” is resolved as subordinating conjunction rather than demonstrative. Whereas MaTra2 resolve as expected.

Table 5. Several translation systems with good reported results

Element	SUPAR	AGIR	SYSTRANLinks
Data Sets	CRATER corpus	SemCorpus, MTI corpus	Unrestricted text
Prerequisite	Texts from CRATER corpus automatically tagged by the Spanish version of the Xerox tagger.	Partial parsing technique has been applied then interlingua representation of entire text has been obtained	
Purpose	Resolves several kinds of anaphora pronominal references, surface-count anaphora, one-anaphora, definite noun phrases and VP-anaphora	Translation of inter sentential anaphora, detection of co-reference chains, translation of Spanish zero pronouns into English.	Commercial product for translation between English and Spanish
Language	Spanish	Spanish, English	Spanish
Reported success rate	76.25	80.4 Spanish, 84.8 English	56.9

We have studied some key systems which deal with several kind of anaphora with good results and presented them in Table 5 [2], [8]. Though, these systems are not for Hindi, but can be quite helpful in developing the concept for anaphora resolution in Hindi.

## 4. ISSUES IN ANAPHORA RESOLUTION IN HINDI

Large amount of information is available in Hindi on www (on electronic document form). But this information is encoded in different fonts. That is, there is difficulty in encoding the document in some standard form. Unicode might be a solution to this problem of standardization. But there is another problem that all the sites does not use Unicode based tools. The second problem with Unicode based font is that Unicode based tools may not support Hindi. This lack of standardization limits the use of these documents in developing corpus. Therefore, neither a single corpus nor a language processing tool is developed and freely available for research. The tools available are either not up to the mark or limited to some specific domain only.

Anaphora resolution can improve the performance of many NLP applications like question answering system, short

answer examination system, information extraction system, etc. consider the example 3-5.

3. आम बच्चों को दे दिए गए क्यो कि वे भूखे थे.  
The Mangos were given to the children because they were hungry.
4. आम बच्चों को दे दिए गए क्यो कि वे पके थे.  
The Mangos were given to the children because they were ripe.
5. आम बच्चों को दे दिए गए क्यो कि वे वहां थे.  
The Mangos were given to the children because they were there.

Consider the application of question answering, if the question asked कौन भूखे थे (who were hungry)? The answer will only be given if pronoun वे (they) is correctly resolved with the antecedent. The possible antecedents for “they” are “the mangos” and “children”. In all the sentences in example 3-5, each “they” refers to different antecedent. Whereas in the example 3 they refers to the “children”, in example 4, refers to the “mangos” and again in the last sentence they refers to the “children”.

#### 4.1 Cases and their Influence in Pronoun Resolution

As the Hindi does not differentiate pronouns on gender, its verb that differentiate masculine from feminine gender. Therefore knowledge of verb is also essential correct pronoun resolution. Despite knowledge about verb, there is one more important element which influences anaphora resolution in Machine Translation. In Hindi, cases plays very important role in correct translation of some source text in some foreign language to target text in Hindi. Therefore study of cases and their influence on pronoun resolution is also important.

In Hindi the pronouns are inflected depending on the number and case. In Hindi, pronouns may be classified into six categories, namely personal (purush vachak) pronoun, demonstrative (nischay vachak) pronoun, indefinite (anischay vachak) pronoun, relative (sambandh vachak) pronoun, interrogative (prashna vachak) pronoun and reflexive (nij vachak) pronoun. Among these the most important is the personal pronoun category. We present only about them here. The Table 6 shows various personal pronouns according to first, second and third person.

**Table 6. Personal pronouns with different cases**

Cases/Person		1st	2nd (intimate)	2nd (honorific)	3rd (proximal)	3rd (distal)	
Direct	Singular	मैंMain (I)	तूTu(You)	आपAap(You)	यहYeh(This/It/He/She)	वहVeh(That/He/She)	
	Plural	हमHum(We)	तुमTum(You)	आपAap(You)	येYe(These/They)	वेVe(Those/They)	
Dative	Singular	मुझे/मुझकोMujhe/Mujhko	तुम्हें/तुमकोTumhen/Tumko	आपकोAapko	इसे/इसकोIse/Isko	उसे/उनकोUse/Unko	
	Plural	हमें/हमकोHumen/Humko	तुम्हें/तुमकोTumhen/Tumko	आपकोAapko	इन्हें/इनकोInhen/Inko	उन्हें/उनकोUnhen/Unko	
Genitive / possessive	Singular	masculine	मेराMera(my/mine)	तेराTera(thine/yours)	आपकाAapka(your/yours)	इसकाIska(of this/Its/his)	उसकाUska(his)
		feminine	मेरीMeri(my/mine)	तेरीTeri(thine/yours)	आपकीAapki(your/yours)	इसकीIski(of this/Its/her)	उसकीUski(her)
	Plural	masculine	हमारीHumaree(our/ours)	तुम्हाराTumhara(your/yours)	आपकाAapka(your/yours)	इनकाInka(their)	उनकाUnka (their)
		feminine		तुम्हारी(your/yours)	आपकी(your/yours)	इनकी (theirs)	उनकी (their)
Ablative	Singular	मुझसेMujhse	तुझसे/तुमसेTujhse/Tumse	आपसेAapse	इससेIsse	उससेUsse	
	Plural	हमसेHumse	तुमसेTumse	आपसेAapse	इनसेInse	उनसेUnse	
Locative	Singular	मुझपरMujhpar	तुझपरTumpar	आपपरAappar	इसपरIspar	उसपरUspar	
	Plural	हमपरHumpar	तुमपरTumpar	आपपरAappar	इनपरInpar	उनपरUnpar	
Ergative	Singular	मैंनेMaine	तुनेTune	आपनेAapne	इसनेIsne	उसनेUsne	
	Plural	हमनेHumne	तुमनेTumne	आपनेAapne	इन्होंनेInhone	उन्होंनेUnhone	

The Table 6 shows how personal pronoun changes as the cases changes from direct to dative, genitive and other forms. There are always separate forms of intimate and honorific second person pronoun in the same case. But the honorific second person pronoun remains the same for both singular and plural. Generally, dative case shows the noun/pronoun to whom, something is given. For example, in “Ram gave

Shyam a book”. The thing given to Shyam is “book” which is tangible object it may also be intangible like “advice”. The dative, generally, marks the indirect object of a verb. Generally, ablative pronoun/nouns represent a motion away from something. Ablative pronouns in Hindi sentences can be roughly corresponds to some work done by

somebody/something. The next section covers another issue in anaphora resolution i.e., pleonastic “it”.

## 4.2 Pleonastic ‘it’

Though pleonastic ‘it’ has great importance in English language, more often it is quite irrelevant to translate in Hindi. But its appearance has pronoun create big difficulty. This can be clearer from Example 6, a sentence in English language-

6. It is bright sun shine today.

It has corresponding translation in Hindi as “*aaj tej dhoop hai*”. Though the corresponding translation of “it” in Hindi be “*yeh*” or “*veh*”, in the given example it have no mapping. Therefore it quite irrelevant to translate this type of “it” in Hindi target text form English source text. Frequent occurrences of this type of “it” can cause problem in machine translation. Therefore, for a good translation, it is quite necessary to point out the situations where “it” is treated as pronoun (the translation of “it” as “*yeh*” or “*veh*”), and the situations where “it” have to be dropped (pleonastic “it”) [12].

## 5. CONCLUSION

Anaphora resolution is very important in almost all NLP applications. As in Hindi, there is not a significant amount of work has been done this paper presents the issues and challenges in anaphora resolution in Hindi. Comparison table shows the reported success rate of different methods for anaphora resolution (especially in machine translation). Forms of pronouns has been changed according to cases, discussed and presented in Table 6. Pleonastic “it” also influences the resolution processes. We, in this paper, only discuss the different issues in the anaphora resolution (especially pronominal anaphora) in Hindi. In future we will try to develop a model for anaphora resolution in Hindi.

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