

Peer-to-Peer Network for Co-reference Resolution

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ABSTRACT

Co-reference resolution has been a perennial issue in linguistics and language processing discipline. Over the past more than fifty years, researchers have developed a variety of strategies to solve this problem. The problem is still being researched today and trying to address the challenges of the problem in various languages. We have discussed a Peer-to-Peer (P2P) network-based strategy for developing a co-reference resolution system in this research. This method substitutes global information for local information in the text and hence improves the accuracy. The Assamese data set is created with the necessary tagging to test the system, and the results are pretty encouraging.

Keywords: Anaphora Resolution, Assamese Language, Co-reference Resolution, Natural Language Processing, Peer-to-Peer Network, Rule Base.

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INTRODUCTION

Co-reference resolution is a fundamental task in Natural Language Processing (NLP) that is crucial in language and comprehension. It involves identifying and connecting expressions in a text that refer to the same entity, bridging the gap between pronouns, noun phrases, and other mentions to facilitate coherent discourse understanding. Although co-reference resolution has been extensively studied in major languages, resource-scarce languages like Assamese have received limited attention in the NLP community. Assamese is an Indo-Aryan language spoken by millions of people in the Indian state of Assam and neighboring regions. Despite its significance as one of the major languages in the Indian subcontinent, the lack of annotated data and dedicated research efforts have hindered the development of advanced NLP applications in Assamese. Co-reference resolution, in particular, remains an understudied area, leaving a significant gap in the language's NLP capabilities. To address this gap and harness the potential of co-reference resolution in the Assamese language, we propose a novel approach i.e. peer-to-peer network-based approach.

This paper presented a Peer-to-Peer network-based approach for co-reference resolution for the Assamese language. From the algorithmic point of view, the method is new and has some advantages compared to the other rule-based systems. A

dataset in Assamese has been curated with essential tagging to evaluate the system, yielding results that outperform the current state-of-the-art.

Peer-to-Peer Network

In a peer-to-peer network (Figure 1), nodes are connected directly without the use of intermediary nodes (like a server). Here, all nodes or devices are regarded as belonging to the same level or equivalent. P2P networks are different from client-server networks (Figure 2), in which numerous nodes are connected to a single server, which controls the network. Peer-to-peer networks often consist of nodes that are physically close to one another and use comparable networking protocols.

Based on the architectural and networking point of view P2P network is advantageous over the client-server model. Some of these are cost, reliability, implementation, scalability, administration, server requirements, resource sharing, etc. There are also some disadvantages too, like, performance, decentralization, remote access, security, virus attacks, backup recovery, illegal content, etc.

Related Work

A thorough analysis of this field is carried out by Mitkov still 1998.^[1] The primary focus of these works is on anaphora resolution using significant algorithms and syntactic constraints. Anaphora resolution applications in several NLP tasks are also studied.

Ng^[2] provided a quick summary of the study on co-reference resolution. The mention-pair, mention-ranking, and, entity-mention, models are the main topics of this research.



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Based on the literature that is now available, studies on co-reference have been carried out for the past fifty years. This domain seems to be developing consistently and gradually. First came rules-based systems,^[3,4] then various machine learning-based methods,^[5,6] and finally, the ever-evolving deep learning approaches.^[7,8] Listed here is a summary of some of the noteworthy contributions.

Work in languages similar to English

Based on syntactical information, Hobbs proposed one of the first algorithms. It follows the syntax tree according to a predetermined sequence, with the result that the pronoun is most likely the antecedent of the noun phrase. He tested using texts on archaeology and found that his accuracy was 88%. Mitkov describes an integrated model that incorporates classical language traits and a few heuristics.^[9,10] The salience metrics were combined with the syntactic features by Lappin and his fellow researcher. Grammatical function and precedence were added by Boguraev *et al.*^[11] to the Lappin *et al.* approach. With limited linguistic resources and expertise, such as noun phrase recognition, part-of-speech tags, basic semantic type, etc., Baldwin^[12] developed Cog-NIAC, a pronoun resolution system. Lee *et al.*^[13] first suggest the end-to-end neural co-reference resolution model, which is subsequently found in a simplified and modified version.^[14] Gandhi *et al.*^[15] recently demonstrated how neural coreference models can be fine-tuned to achieve higher performance when adapted to other domains. On the CoNLL 2012 shared^[16] task data, they obtained an 80.2 F1 score. According to Zeldes *et al.*, the Xrenner^[17] is a rule-based co-reference resolution system. They have attempted to investigate relatively uncommon co-reference categories such as compound modifiers, cataphora, etc. using the dependency syntax as input.

Haghighi *et al.*^[18] provide a generative model that is trained unsupervised while taking into account the required factors using modular encapsulation.

Related Work similar to Indic Languages

Co-reference resolution in Indian languages is not well covered in the literature. Anaphora resolution is one example of a specialized Co-reference that requires some work. Many researchers have tried in Telugu, Bengali, Malayalam, Hindi, and other languages. There have been significant contributions to this topic in the Indian language from Sobha *et al.* (2000, 2014). She addressed a variety of challenges in different languages, created a resolution system,^[19] and attempted to incorporate a generic model.^[20] Senapati *et al.* developed a rule-based system for Bengali using an off-the-self system.^[21] They also presented a new methodology for pronoun emitting.^[22] Sikdar *et al.*^[23] implemented the cutting-edge system BART.

A lexical, syntactic, and semantic framework for a textual entailment recognition system has been published by P. Pakray *et al.*^[24] The entire system has been examined using the assessment

metrics provided as part of the TAC RTE 2011 track. On the other hand, S Chatterji *et al.*^[25] address a data-driven technique for resolving anaphora in Bengali, Hindi, and Tamil, three Indian languages. There are two steps to this activity: marking links and markables. To find a mark, a conditional Random Field is employed. It can be used to ascertain the connections between markables, a decision tree-based algorithm. F-value is used to evaluate and show the results for both steps. To address the issue of anaphora resolution in resource-poor languages such as Indian languages, Utpal Sikdar *et al.*^[26-28] adopted a state-of-the-art anaphora resolution system, a joint model of feature selection and ensemble learning, and the first attempt at anaphora resolution for a resource-poor language, namely Bengali.

The first attempt at Assamese language co-reference resolution was made by Das *et al.*^[29] Their effort produced a significant amount of labelled data that will be highly helpful for future research in that sector. Their research shows how grammatical agreements and norms have changed over time, as well as a number of issues in the area of Assamese co-reference resolution. Das *et al.*^[30] also created a semi-automated method for generating tagged data collection for Assamese co-reference resolution. Together with their co-reference connections, they resolve co-references using this resource or tagged data collection. The data set can be used by both rule-based and learning-based techniques because it includes the POS tag, the NER tag, and chunking information.

P2P Network for Co-reference Resolution

The majority of systems for resolving co-references attempt to resolve the co-reference relation locally or in the sentence label. When a co-reference is encountered in a sentence, it tries to resolve its backward direction in the same sentence or earlier sentences. Contrary to that approach here, all the co-reference and mentions are considered separate entities in the entire text. Each entity (co-reference and mentions) is along with all its syntax and semantic attributes. Then the entities are partitioned based on their semantic information. Here the semantic information implies the prominent categories of entities like a person, location, etc. The other entities are tried to connect with other nodes and form a network or links. In this way, nodes are linked or connected and gradually network grows and hence resolves the co-reference relations. This method is illustrated with the following sample text.

His nickname was Lalu. He had a formal name but I don't remember it. After school, we were admitted to college but Lalu said, he would do business. He took ten rupees from his mother and started a contractor business. Early when we were in Bengali school, he was everyone's helper... There is the worship of the god Kali in Monohor Chatterjee's home. ... Lalu's father ordered him to go.

First, identify all the mentions from this text, and hence mentions are highlighted.

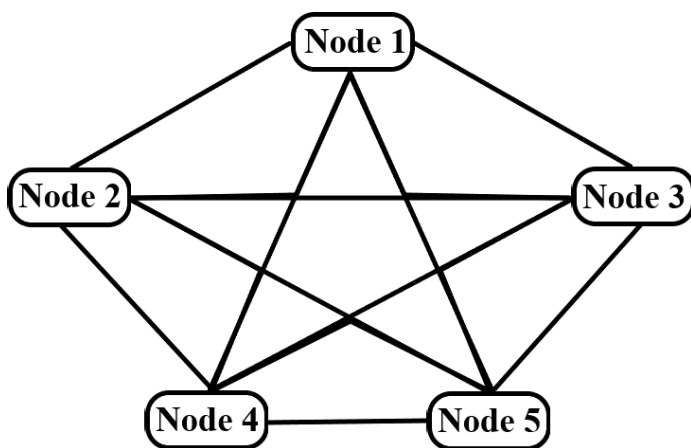


Figure 1: P2P Architecture.

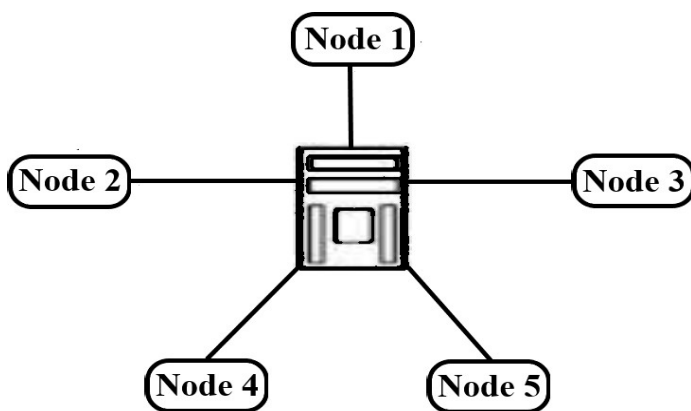


Figure 2: Client-Server Architecture.

His nickname was **Lalu**. He had a formal name but I don't remember it. After school, we were admitted to college but **Lalu** said, he will do business. He took ten rupees from his mother and started a contractor business. Early when we were in **Bengali school**, he was everyone's helper... There is the worship of the god **kali** in the **Monohor Chatterjee's** home. ... **Lalu's father** ordered him to go. ...

Initially, all the mentions are considered in a single cluster (Figure 3) and next categorized semantically in Figure 4. Finally partitioned them based on their semantic category (Figure 5). Note that pronouns or co-references are not included in the partitions and need to be resolved.

Resolution Strategies

The resolution strategy is a rule-based approach based on some grammatical and lexical agreements in a peer-to-peer network framework. Here all the mentions are presented along with their grammatical and lexical information. The grammatical information includes their semantic categories i.e. whether it is person, location, institution, etc. (the criterion of partitioned), animate, inanimate, etc. On the other hand, grammatical information includes number, person, gender, honorific

information, etc. It includes lexical information like sentence number (where it belongs), token number (token number in the sentence), etc.

Next, it resolves the alias name entities. In a text, a name may be present with various alias names. For example, the name **Lalu** is an alias for **Lelo**, this is used in a subsequent section. Similarly, **Dr. Srimanta Karmakar** may be considered as **Dr. Karmakar** or **Prof. Karmakar**, etc. This is done by analyzing the naming variation, name qualifiers (Mr., Dr., Prof., etc.), and surname or sometimes using the abbreviated name.

In a particular partition, all the entities are aliases to each other and are considered a peer-to-peer network. When an external entity wants to refer to any one entity, which is equivalent to that a node wants to join a peer-to-peer network, any node of the network is allowed the new node in the network. Here we have introduced the concept of a virtual node, that will act as an entry point of a network. That means when a new entity wants to refer any node, it will send a request to the virtual node and that node will allow or reject based on the grammatical and other agreements.

Virtual node formation: For each partition, all the entities are aliases and hence create a virtual node containing all the grammatical and lexical information. The virtual node formation mechanism is depicted in Figure 6. It illustrates that there are two nodes (n_1 and n_2) along with their grammatical and lexical information (attributes).

The new node (Virtual node, Figure 7) is considered the representative of nodes (n_1 and n_2), with the attribute (Virtual node) = $\text{attribute}(n_1) \cup \text{attribute}(n_2)$.

When any external entities try to join in a partition or when an external entity tries to co-refer with any entities of a partition then it communicates with this virtual node and the virtual node will decide based on the rules and agreements.

Preparation of Dataset

Though the proposed approach is generic, it is tested on the Assamese data set. As described in the resolution strategies it is clear that it needed all the mentioned information and all other grammatical information. So far in Assamese no such sophisticated tools to get such information, hence such tagging is done manually by the linguistic expert.

With the Indic language, there is an insufficient data set available for co-reference resolution. As far as we are aware, Assamese co-reference resolution is not supported by any ready-made materials. We began developing resources in the Assamese language as a result of this circumstance.

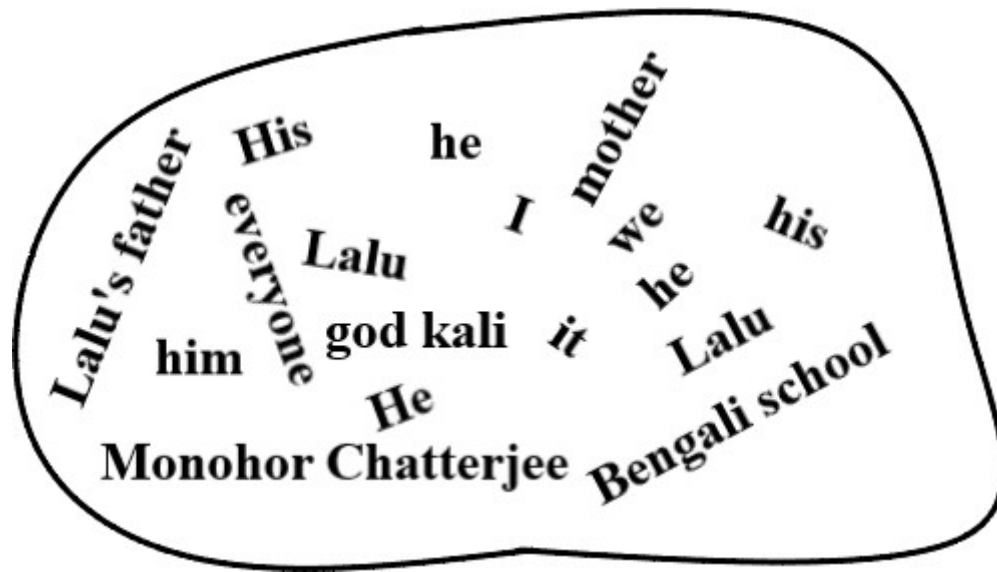


Figure 3: Initial Cluster with all Mentions.



Figure 4: Categorised them Semantically.

Challenges in Data Preparation

It encountered several difficulties when preparing the co-reference data. These are some of the primary challenges that need to be addressed.

Text selection

Different texts from various domains, such as news items and stories, are chosen in our examples. Texts from a varied topic and a significant number of co-reference relations are the two factors we have taken into consideration when selecting texts. The 10 different domains are- Biopic text¹, sports², news text³, tourism text⁴, Assamese novel text⁵, short stories⁶, study material text⁷, etc.

Tag selection

Certain information is required for various co-reference resolution techniques, particularly for the rule-based approach. The number of tags required, including Past-of-speech, named entity, parsing, gender, and number information, varied based on the algorithm. We have taken into consideration the tagging strategy for ICON 2011 Anaphora Resolution^[31] in our scheme. Consequently, chunking, named entities, and past-of-speech markers were employed.

Format of the Dataset

We created the Assamese tag data set using the annotated data, which was supplied by ICON in 2011. The annotated data is supplied with chunking metadata, POS and NER labeling, and a column format. They offered annotated data for five Indian

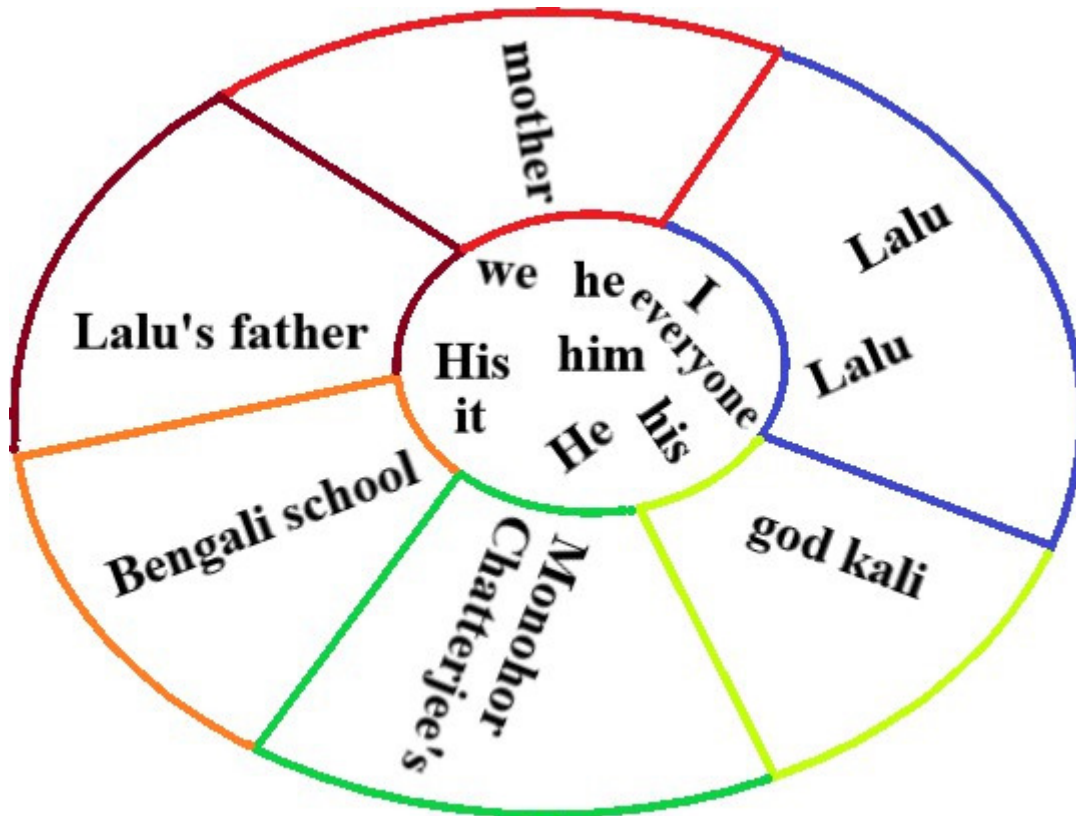


Figure 5: Partitioned them based on Semantic Category.

languages, including Bangla. Given that Bangla and Assamese are comparable, we considered this data structure when creating our tag data collection. There are eight columns with eight different sorts of information. The CoNLL column format tagging technique is the one in use. Figure 8 provides the sample data, while Table 1 provides a tabular description of the detailed data format.

Volume of the Dataset

The data set includes ten different stories from various domains. The linguistic specialist chooses the texts manually. These are from tourism, short stories, news articles, sports, novels, science fiction, biopics, poems, study materials, and social media writings. For this particular experiment of peer-to-peer network relations, we combined the stories into one large corpus. The dataset consists of around 600 lines and 4,000 tokens with co-reference entity relationships.

¹<https://assamintro.com/mamoni-raison-goswami-biography-in-assamese>. (last accessed 14-04-2024)

²<https://as.wikipedia.org/sports> (last accessed 13-04-2024)

³<https://dainikjanambhumi.co.in> (last accessed 14-04-2024)

⁴<https://as.wikipedia.org/wiki/tourism> (last accessed 12-04-2024)

⁵<https://www.newjobsinassam.com/gk/download-best-assamese-books-pdf> (last accessed 14-04-2024)

⁶<https://www.jonakaxom.in/2019/08/assamese-short-story.html> (last accessed 13-04-2024)

⁷<https://dte.assam.gov.in/portlets/study-materials> (last accessed: 14-04-2024)

THE RULE BASED APPROACH

The resolution strategy is a rule-based approach based on some grammatical and lexical agreements in a peer-to-peer network framework as mentioned earlier.

Rule 1

Names can occur in discourse in a variety of ways that are regarded as co-referring

It is standard to refer to someone by their last name or another qualifier in subsequent conversations after first mentioning their name.

Example in Assamese

ড. হিমন্ত বিশ্ব শৰ্মা হৈছে অসমৰ এগৰাকী ৰাজনীতিবিদ তথা অসমৰ বৰ্তমানৰ মুখ্যমন্ত্ৰী।
ড. শৰ্মাই ২০২১ চনত অসমৰ মুখ্যমন্ত্ৰীৰূপে নিৰ্বাচিত হয়।

Here ড. হিমন্ত বিশ্ব শৰ্মা and ড. শৰ্মা refers to the same person. There could be alternative ways for this like বিশ্ব শৰ্মা, মুখ্যমন্ত্ৰী শৰ্মা, etc. and it occurs across multiple languages. The notion that names can refer to individuals in a variety of ways is emphasized in the second category. For instance, the name of a river ব্ৰহ্মপুত্ৰ appears as লুইত, বাবা, নৈ, লোহিত in the Brahmaputra narrative [similarly, Soumar may appear as Sam, Samar, etc.]. These forms will have the same honorific quality if

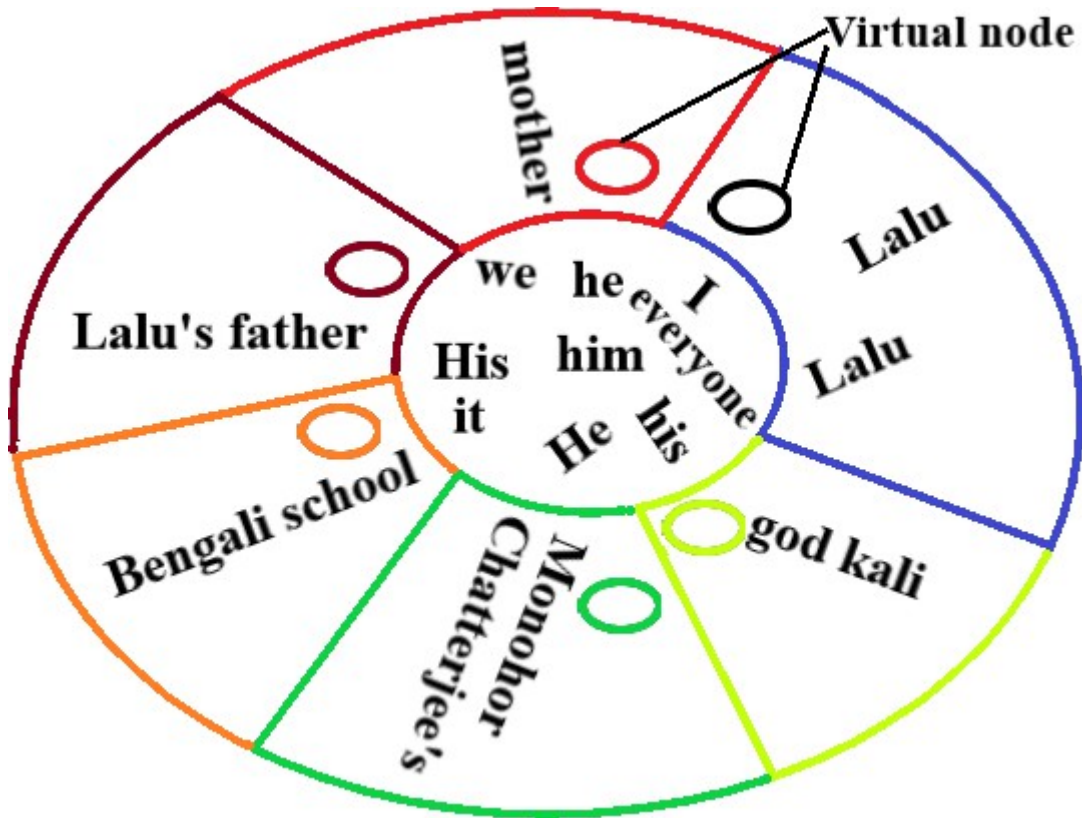


Figure 6: Virtual Node in each Partition/Network.

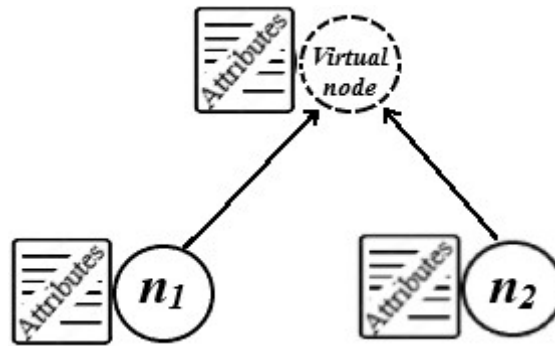


Figure 7: Formation of Virtual Node.

we can determine that they are identical. This data contributes to the resolution of co-reference.

Rule 2

The honorable person is co-referred by the honorific anaphora

The resolution of co-references in both the Assamese and English languages is significantly influenced by honorificity.

Certain qualifiers are used with names in Assamese to indicate an honourable person, for example, ড., প্ৰফেছাৰ, মহাশয়, দেৱ, শ্ৰীমন্ত, শ্ৰীশ্ৰী etc. In this circumstance, we consider that person to be an honorable person for a possible resolution.

Example

শ্ৰীমন্ত শংকৰদেৱ একাধাৰে এগৰাকী ধৰ্ম প্ৰচাৰক, সমাজ সংগঠক, গায়ক, নৰ্তক, অভিনেতা, কবি, চিত্ৰকৰ আছিল।
অসমীয়া তথা ভাৰতীয় সাংস্কৃতিক জীৱনলৈ তেওঁ যি অবদান আগবঢ়াই গ'ল, তাৰ বাবে তেওঁক মহাপুৰুষ আৰু অৱতাৰী পুৰুষ আখ্যা দিয়া হয়।

An honorable person is always indicated by a pronoun that signifies honor. The pronoun does not co-refer since the honorific agreement is violated. An honorable person is always referred to with honorific co-reference. Senapati *et al.* employed certain guidelines in their study on pronominal anaphora resolution in the Bengali language. They described it as a rule base with a collection of heuristic rules established by the rule base. The honorific agreement norm is one of them.

#begin document	story1.text	part 000						
story1.text	0	0	মহীকান্ত	NNP	B-NP	B-PERSON	O	[1]
story1.text	0	1	চৌধীন	JJ			O	
story1.text	0	2	মানুহ	NN	B-NP		O	
story1.text	0	3	।	SYM			O	
story1.text	0	0	চৌধীন	JJ			O	
story1.text	0	1	হবলৈ	VBX			O	
story1.text	0	2	তাৰ	PP			O	[1]
story1.text	0	3	সম্বল	NN			O	
story1.text	0	4	আছে	VBF			O	
story1.text	0	5	বহুত	JJD			O	
story1.text	0	6	।	SYM			O	
.....	
#end document								

Figure 8: A Snapshot of Sample Data.

Table 1: Description of Data Format.

Column	Type	Abbreviation
1	Document Id	Contains the filename
2	Part number	File are divided into part numbered
3	Word number	Word index in the sentence
4	Word	Word itseld
5	POS	POS of the word
6	Chunking	Chunking information using IOB format
7	NE tags	Name Entity Information is given
8	Reference	Co-reference information

Rule 3

Two co-referring pronouns in a phrase have to be person-compatible and adhere to the honorific agreement

Person compatible in this context refers to the requirement that both must be first or second person.

Example in the Assamese Language: মই তোমাৰ মা

Here, the pronouns **মই** and **তোমাৰ** are in the first and second person, respectively, and do not refer to each other together. This requirement must be adhered to, nevertheless, to see the pronouns as co-referring when they are in the third person. Pronouns cannot be used in co-referring unless they are consistent with the subject.

Rule 4

Pronouns in autobiographical texts only apply to the writer, who is the first person singular number

For example,

মোৰ নাম লক্ষীনাথ বেজবৰুৱা। মই ১৪ অক্টোবৰ ১৮৬৪ চনত আইতপুৰিত জন্ম গ্ৰহণ কৰো। মোৰ আত্ম জীৱনীৰ নাম “মোৰ জীৱন সোঁৱৰণ”।

Here all the first-person pronouns **মই**, **মোৰ** etc. are referring to **লক্ষীনাথ বেজবৰুৱা**.

Rule 5

In a sentence, pronoun pairs that occur together are co-referring to each other

The pronoun pairs, যোঁতীয়া-তেতিয়া, যি - তি, যাৰ - তাৰ, যেনে - তেনে, আ'ত ত'ত, যলৈ - তলৈ, etc. appear in the same sentence and are co-referring.

For example, যোঁতীয়া – তেতিয়া তেনেকুৱা কথা নকৰা।

Rule 6

For a community or organization, the plural pronouns are permissible

For an organization or community, the plural pronouns **সিহঁত**, **তেখেতসকল**, etc., are acceptable.

For example, **অসমৰ বৈষ্ণৱ সমাজৰ** নীতি নিয়ম অনুসৰি তেখেতসকলে মুৰ্তি পূজা নকৰে।

Here, **তেখেতসকল** is referring to **বৈষ্ণৱ সমাজ**।

Coverage of the rules: It is needed to check the coverage of the rules. For example, if in the text “not only” appears, we can assume that there will be a “but also” following in the text. So, we have to check how many times correctly it has appeared in the text. coverage of the rules is important to find out the accuracy of a large amount of data.

Table 2: Comparison Table.

Dataset		Metric	
Score before applying the Rules:	MUC	R	13.76
		P	33.98
		F1	19.58
Score after applying the Rules:	MUC	R	65.32
		P	77.21
		F1	71.26

Error Analysis

In comparison to the other efforts, the outcome displayed in the comparison Table 2 is somewhat decent. The MUC Score of a recent work done on co-reference resolution in the Assamese language is 50.93. This strategy, with a MUC score of 71.26, is moving us in the direction of improvement (Table 2). In an attempt to identify the vulnerabilities in our system, an error analysis is performed. Despite the analysis's lack of detailed investigation, the following conclusion was drawn. (i) All forms of co-reference, including Nouns, were taken into consideration by the system. For example, pronoun-pronoun and noun-pronoun. (ii) All forms of relations, such as anaphora, cataphora, exophora, etc., are included. (iii) It merely took into account a few fundamental grammatical restrictions, such as a person, gender, or number. Nevertheless, it is observed that additional knowledge, such as context, discourse, and real-world knowledge, is also necessary. In conclusion, the rules taken into consideration are manually constructed rules that encompass a small portion of the data set. Expanding the scope of the data collection requires additional general rules.

Advantage of Peer-to-Peer Network

The approach employed here exhibits uniqueness across several facets. It can be summarized as follows: (i) Incorporate the peer-to-peer network concept into co-reference resolution. (ii) Allow a mention to move freely for resolution, not limited to backward movement, enabling it to approach any network to join. (iii) Ensure the absence of conflict scenarios i.e. inherently the system allows only one co-reference link to join in a network at a time (iv) use limited resources.

FUTURE SCOPE AND CONCLUSION

A point-by-point list of the findings of this study is followed by (i) As much as we are aware, this is the pioneering attempt at a peer-to-peer network approach in co-reference resolution in the Assamese language, (ii) a sizable amount of tagged data sets that will support the communities' study in that area were contributed, (iii) discusses the various problems in this area in Assamese languages, (iv) applies a novel approach to solve the co-reference resolution in the Assamese language. The context information and real-world knowledge can be used to enhance the system.

This paper presents a pioneering approach to co-reference resolution in the Assamese language, utilizing a peer-to-peer network strategy. This novel method not only improves accuracy by incorporating global information but also addresses specific challenges unique to the Assamese language. The contribution of a substantial amount of tagged datasets for Assamese enriches the resources available for research in this area. Furthermore, the paper provides valuable insights into the co-reference resolution problems in Assamese and offers a novel solution, which could significantly benefit the language processing community.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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