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Modeling of Link Grammar Parser for Parsing of Kumauni Complex Sentences

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ABSTRACT

The Kumauni language, a regional dialect of India spoken in the Himalayan region of Kumaun, remains relatively understudied. This study aims to address this gap by developing a parsing tool specifically for Kumauni language research. The tool is designed to analyze and validate grammatical structures in complex Kumauni sentences. To achieve this, a collection of existing complex sentences in Kumauni was used to extract grammatical rules, which were then incorporated into a Link Grammar Parser model. This model enables the parsing of new complex sentences in Kumauni, offering researchers a valuable tool for linguistic analysis.

INTRODUCTION

Parsing, also referred to as clause analysis, is a traditional grammatical exercise that involves breaking a text into its constituent parts of speech while explaining their form, function, and syntactic relationships. This process relies heavily on the study of a language's conjugations and declensions, which can be particularly complex in highly inflected languages. For example, parsing the phrase "man bites dog" entails identifying "man" as the singular noun serving as the subject, "bites" as the third-person singular present tense form of the verb "to bite," and "dog" as the singular noun functioning as the object. Sentence diagrams are sometimes employed to visually represent the relationships between elements in a sentence.

In certain machine translation and natural language processing systems, written texts in human languages are analyzed through computer programs that parse them. However, parsing human sentences is challenging due to the inherent ambiguity in language structures. Human language is designed to convey meaning (semantics) across an almost infinite range of possibilities, though only a subset may be relevant in a given context. For instance, the sentences "Man bites dog" and "Dog bites man" are unambiguous in English, but in another language, they might appear as "Man dog bites," with the context determining the intended meaning, if the distinction is even important. Developing formal rules to capture such informal behavior is difficult, even though some underlying rules are clearly followed.

Building on computational Panini grammar, as proposed by Bharati *et al.* (1995) and Patil *et al.* (2013), Karaka links have been introduced to define relationships between nominal words and the verbs in a sentence, as summarized in Table 1. Parsing was once a core aspect

of grammar instruction in English-speaking countries and was considered essential for understanding written language, but it is no longer widely taught.

Abukhader *et al.* (2024) had studied the need for tailored instructional methods to support Arabic learners of Chinese by recognizing structural differences and designing effective teaching materials and strategies, thereby promoting a deeper understanding of measure words.

Working on Philippine language, Rivera (2023) analyzed the presence of both new and old words in the lexicon used by some editorial writers, and concluded that the language is also evolving as it adapts new words in its set of vocabularies.

In natural language processing, parsing algorithms cannot depend on grammars with "neat" properties, as is typical with programming languages. Some grammar formalisms are computationally challenging to parse. Therefore, even when a grammar is not context-free, a context-free approximation is often used as an initial step. Algorithms that employ context-free grammars, such as variations of the CYK algorithm, frequently use heuristics to eliminate unlikely analyses and save processing time.

Seungmi Lee (1997) introduced a re-estimation algorithm and a best-first parsing (BFP) algorithm for probabilistic dependency grammars (PDGs). The re-estimation algorithm adapts the inside-outside algorithm for PDGs. Poon *et al.* (2006) developed the first unsupervised method for learning a semantic parser using Markov logic. Earley's algorithm (1970), suitable for all context-free grammars (CFGs), operates with a worst-case performance of $O(N_1)$ but achieves $O(N_2)$ for unambiguous grammars. It is based on dynamic programming and is commonly applied in computational linguistics.

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Vaishali *et al.* (2014) explored links between complex sentence clauses and modeled these structures using the Link Grammar Framework for parsing. Pandey *et al.* (2010) adapted Earley's algorithm specifically for parsing Kumauni sentences.

Different parsing algorithms generally place various restrictions on the grammar of the language to be parsed

- Top- down
- Bottom - up
- Recursive descent
- LL
- LR
- LALR
- SLR
- CYK
- GLR
- Simple precedence parser

Link Grammar

The Link Grammar Parser is a syntactic parser of English, based on link grammar, an original theory of English syntax. Given a sentence, the system assigns to it a syntactic structure, which consists of a set of labeled links connecting pairs of words. The parser also produces a "constituent" representation of a sentence (showing noun phrases, verb phrases, etc.). The link grammar is a grammatical system to classify natural languages by designating links between sequences of words. Instead of using part-of-speech tags based on rules to parse sentences, it uses links to create a syntactic structure for a language. There are three conditions that each sequence of words (or a sentence) must satisfy in order to be considered in the language of a link grammar:

- Planarity: The links do not cross (when drawn above the words).
- Connectivity: The links suffice to connect all the words of the sequence together.
- Exclusion: Links must satisfy the linking requirements of each word in the sentence. Linking requirements are defined in the dictionary of the grammar.

The Link Grammar framework provides a more generalized approach to tagging compared to the Penn Treebank tags. The core element of Link Grammar is its use of links or connectors, which must be compatible for words to connect. Each word's linking requirements are specified in a dictionary. For example, a simple dictionary for words like "a," "the," "cat," "snake," "Mary," "ran," and "chased" can illustrate how these linking requirements work. These requirements are represented graphically above each word. Link Grammar operates as a formal grammatical system based on the principle that, if arcs are drawn to connect related words, the arcs will not cross. Sleator *et al.* (1991) developed a parsing system to account for numerous aspects of English grammar, using approximately 700 definitions that include words and their linking requirements. Lafferty *et al.* (1995) proposed an algorithm for parsing sentences according to this grammar. A sentence is accepted by the system if three conditions are

met: (1) all linking requirements of the words are satisfied (connectivity property), (2) no links between words cross (planarity property), and (3) there is at most one link between any two words (exclusion property).

Goyal *et al.* (2006) analyzed Hindi complex sentence structures to ensure planarity in Link Grammar-based parsing. Their proposed scheme not only provides the parse structure for Hindi complex sentences but also verifies planarity conditions.

As part of the Indo-Aryan dialect continuum, Kumauni shares grammatical features with other Indo-Aryan languages such as Nepali, Hindi, Rajasthani, Kashmiri, and Gujarati. It also shares much of its grammar with other Central Pahari languages. The unique grammatical characteristics of Kumauni and other Central Pahari languages stem from the influence of the now-extinct Khasa language, spoken by the region's earliest inhabitants. In Kumauni, for instance, the substantive verb is derived from the root *ach*.

Kumauni belongs to the Central subgroup of the Pahari languages and has a rich literary tradition, although its dialects are not formally classified as a "language" (Bhasa). Sharma (1985), a prominent linguist, was the first to undertake a linguistic study of Kumauni. To advance this work, we have focused on information processing for Kumauni, particularly in verifying the grammar of input sentences.

The parsing process relies on two key components: a parser, which is procedural, and a grammar, which is declarative. While the parser remains constant, the grammar changes depending on the language being parsed. Thus, by modifying the grammar, the same system can parse different languages. For this study, we used the Link Grammar Parser to analyze Kumauni complex sentences based on a grammar specifically defined for the Kumauni language, derived from a set of pre-existing complex sentences.

Kaaraks in Kumauni Dialect

Kaarak are the words which are commonly used before a noun, noun phrase, pronoun or verb. Also, connects with the noun, pronouns and phrases to other words in a sentence in order to make the sentence comprehensible for readers.

Example: Ram ne dande se ghode ko pita (राम ने डंडे से घोड़े को पीटा): "Ram bitted the horse with stick" - Here 'Ne' 'Se' and 'Ko' are kaarak.

Like as Hindi language, Kumauni has also eight Kaaraks;

- 1) Karta kaarak (कर्ता कारक) - Nominative Case
- 2) Karma kaarak (कर्म कारक) - Instrument Case
- 3) Karan kaarak (करण कारक) - Ablative Case
- 4) Sampradan kaarak (संप्रदान कारक) - Possessive Case
- 5) Apadan Kaarak (अपादान कारक) - Objective Case
- 6) Sabandh kaarak (संबंध कारक) - Dative Case
- 7) Adhikaran kaarak (अधिकरण कारक) - Locative Case
- 8) Sambodhan kaarak (संबोधन कारक) - Vocative Case

It can be more understood from the table below:

A complex sentence in the Kumauni dialect, as in other

Table 1: Table of Kaaraks in Kumauni

Kaarak	Sign	Meaning	Functionality
Karta	ले (le)	Who does work	Verb to Subject
Karma	को (ko)	The work done/ to be done	Verb to Object
Karan	बटी (bati)	By which karta does work	Verb to instrument of the activity
Sampradan	क, लजिी (k, ligi)	The work done for which	Verb to word which gives donation meaning
Apadan	(habe) से {अलग होना} (se)	The break	Verb to word which gives separation meaning
Sambandh	की, के, रा, री, रे (ki, ke, ra, ri, re)	Relation with other terms	signifies any relation or any connection which may exist between two persons or things
Adhikaran	में, बे, (me, be, par)	Base of Karm (verb)	Verb to time and place of the activity
Sambodhan	हे!, अरे! ऊजा! (he! Are!, Uja!)	a sudden cry or remark expressing surprise	The Vocative is the case when a person or persons are directly addressed

languages, consists of one main clause (independent clause) and one or more subordinate clauses (dependent clauses). Subordinate clauses are connected to the main clause using conjunctions, relative pronouns, or other subordinators. The structure of complex sentences in Kumauni follows certain grammatical patterns that are influenced by its Indo-Aryan roots, shared with Hindi and other Central Pahari languages.

Structure of Complex Sentences in Kumauni

1. Main Clause: Contains the primary idea or action of the sentence.

2. Subordinate Clause: Provides additional information, such as reason, time, condition, purpose, or manner, and depends on the main clause for meaning.

Examples of Complex Sentences in Kumauni

Reason Clause (Karan Vaakya)

Example: Woh ghar na gyo kyunki baarish ho rahi thi. (He did not go home because it was raining.)

- Main Clause: Woh ghar na gyo (He did not go home)
- Subordinate Clause: kyunki baarish ho rahi thi (because it was raining)

Conditional Clause (Shart Vaakya)

Example: Jo tum kaam karoge, to main madad karun. (If you work, I will help.)

- Main Clause: Main madad karun (I will help)
- Subordinate Clause: Jo tum kaam karoge (If you work)

Time Clause (Samay Vaakya)

Example: Jab woh aya, tab hum khana kha rahe the. (When he arrived, we were eating.)

- Main Clause: Hum khana kha rahe the (We were eating)
- Subordinate Clause: Jab woh aya (When he arrived)

Relative Clause (Sambandhak Vaakya)

Example: Woh ladka jo padhai kar raha hai, mera bhai hai.

(The boy who is studying is my brother.)

- Main Clause: Woh ladka mera bhai hai (The boy is my brother)
- Subordinate Clause: jo padhai kar raha hai (who is studying)

Purpose Clause (Uddeyshya Vaakya)

Example: Woh bazaar gaya taaki dawai le sake. (He went to the market so that he could buy medicine.)

- Main Clause: Woh bazaar gaya (He went to the market)
- Subordinate Clause: taaki dawai le sake (so that he could buy medicine)

Grammatical Features of Kumauni Complex Sentences Postpositions and Conjunctions

Subordinate clauses are introduced using postpositions like kyunki (because), jo (who/that), jab (when), agar (if), and taaki (so that), similar to Hindi but with slight dialectal differences.

Verb Placement

The main verb often appears at the end of the clause, maintaining the SOV (Subject-Object-Verb) structure typical of Indo-Aryan languages.

Kaarak Roles in Subordinate Clauses

The roles of subject, object, and other Kaaraks in subordinate clauses align closely with their counterparts in the main clause, but their linking to the main clause depends on context and subordinator choice.

Planarity in Link Grammar

The subordinate clause is connected to the main clause without overlapping links, ensuring grammatical planarity, which is essential for parsing.

A complement clause is a clause introduced by a complementizer like that or whether. A complement

clause is attached to a preceding noun, adjective or verb. In the sentence ‘The news that she was selected surprised us all’, ‘that she was selected’ is a noun complement clause attached to the noun news.

Kumauni complement system is complex. The Principal Complementizer is “ke” (के) and “jaik” (जैक). “ke” (के) precedes the complement clause and in main clause words. There subsist many variations of complement structure.

For Example: मलि सुनो के राजू घर ऐगो। Mil suno ke Raju ghar aigo./ I heard that Ram came home.

Correlative structures in Kumauni involve paired words or phrases that work together to show a relationship between two parts of a sentence. These structures are used to express comparisons, conditions, alternatives, reasons, or emphases. Correlative conjunctions often appear in both the main and subordinate clauses of a sentence, linking them in a meaningful way.

Common Correlative Pairs in Kumauni

The correlative pairs in Kumauni are similar to those in Hindi and other Indo-Aryan languages but adapted to Kumauni’s dialectal peculiarities. In each clause carries its own relative marker J and correlative marker T.

Here are some examples:

Jo...to (If...then)

Purpose: To express conditional relationships.

Example: Jo tu padala, to safal hwe jala. (If you study, then you will succeed.)

- Jo introduces the condition: Jo tu padla (If you study).
- To introduces the result: to safal hwe jala (then you will succeed).

Jatko...utiko (As much...so much)

Purpose: To indicate proportional relationships.

Example: Tum jatko mehnat karala, utiko fal milala. (The more you work, the more you will be rewarded.)

- Jatko indicates the amount of effort: Tum jatko mehnat karla (As much as you work).
- Utiko indicates the result: utiko fal milala (so much reward you will get).

Na...na (Neither...nor)

Purpose: To show the absence of two or more alternatives.

Example: Na oo padhun, na kaam karun. (He neither studies nor works.)

- Na...na connects two negatives: Na oo padun (He does not study) and na kaam karun (nor does he work).

Je...yi (Whether...or)

Purpose: To present alternatives or choices.

Example: Je tum waan jaya, ya ni jaa, kaam poor hon chain. (Whether you go there or not, the work must be done.)

- Je introduces the first option: Je tum waan jaya (Whether you go there).
- Ni introduces the second option: ya ni jaya (or not go).

Jaan...waan (Where...there)

Purpose: To indicate spatial relationships.

Example: Jaan tum rah chaa, waan bahutt shanti chu. (Where you live, there is a lot of peace.)

- Jaan introduces the location: Jaan tum rah chaa (Where you live).
- Waan indicates the result or reference: waan bahutt shanti chu (there is a lot of peace).

Jab...tab (When...then)

Purpose: To express temporal relationships.

Example: Jab dyo lagol, tab tum ghar rula. (When it will rain, then you will be at home.)

- Jab introduces the time of the action: Jab dyo lagol (When it will rain).
- Tab introduces the concurrent or subsequent action: tab tum ghar rula (then you will be at home).

Ya...ya (Either...or)

Purpose: To offer a choice between two options.

Example: Ya tu el ber padhai karcha, ya fail hun liji liye tayar rya. (Either study now, or be prepared to fail.)

- Ya...ya presents two alternatives: Ya tu abhi padhai karcha (Either study now) and ya fail hun liji liye tayar rya (or be prepared to fail).

Bal...par (Although...yet)

Purpose: To express concession.

Example: Bal dyo lag rochi, par oo kaam karan lar rochi. (Although it was raining, yet he kept working.)

- Bal introduces the concession: bal dyo lag rochi (Although it was raining).
- Par introduces the contrasting action: par oo kaam karan lar rochi (yet he kept working).

Ji ... U(Who...he/she)

Example: Ji chhoral inaam jiti U Rameshak chyal chu (Who won the prize, he is the son of Ramnesh)

- Ji introduces the concession: Ji chhoral inaam jiti (who won the prize).
- U introduces the contrasting action: U rameshak cyal chu (He is the son of Ramesh).

Being part of the Indo-Aryan dialect continuum Kumauni shares its grammar with other Indo-Aryan languages especially Nepali, Hindi, Rajasthani, Kashmiri and Gujarati. It shares much of its grammar with the other languages of the Central Pahari like Garhwali and Jaunsari. The peculiarities of grammar in Kumauni and other Central Pahari languages exist due to the influence of the now extinct language of the Khasas, the first inhabitants of the region. In Kumauni the verb substantive is formed from the root ach, as in both Rajasthani and Kashmiri. In Rajasthani its present tense, being derived from the Sanskrit present rccchami, I go, does not change for gender. But in Pahari and Kashmiri it must be derived from the rare Sanskrit particle *rcchitas, gone, for in these languages it is a participial tense and does change according to the gender of the subject.

Thus, in the singular we have: - Here we have a relic of the old Khasa language, which, as has been said, seems to have been related to Kashmiri. Other relics of Khasa, again agreeing with north-western India, are the tendency to shorten long vowels, the practice of epenthesis, or the modification of a vowel by the one which follows in the next syllable, and the frequent occurrence of disaspiration. Thus, Khas siknu, Kumauni sikhno, but Hindi sikhna, to learn; Kumauni yeso, plural yasa, of this kind.

Modeling of Kumauni Complex Sentences for LG Parsing

Usually Kumauni complex sentence can be represented

in various forms. Therefore, we may have more than one parsing structure of the complex sentences. Our approach is to develop such linking scheme for Kumauni complex sentences which is consistent for all type of structures. In this respect the major confronts dealing with complex sentences is crossing of the links. That is planarity rule. We can observe that, in general planarity cannot be maintained for Kumauni complex sentences. For example, following complex sentence disobey the planarity rule if system constructs links in its customary style.

Sentence: Ji chhoral inaam jiti U Rameshak chyal chu (जी छोरल इनाम जीती उ रमेशक च्यल छू) / The boy who won the prize is the son of Ramesh.

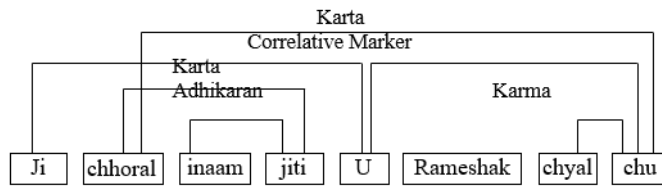


Figure 1: Crossing of the Links

The crossing of the links occurs because of the correlative structure. In above example since choral (छोरल: Son) is subject of the verb phrase “is the son of Ramesh” (रमेशक च्यल छू: is the son of Ramesh), Karta karaka is also required in it and so crosses the correlative marker “U” (उ). To overcome such conditions of crossing of links in complex sentences one can parse the sentence two levels:

1. In first level, give the clausal links

2. In second level, give the internal clausal links.

By the splitting the parse structure in two levels the upper-level deals with relative-correlative marker and chunks of clauses and lower-level deals with the words within the clause.

In this study we propose new links having valid and functional linkage between the words of complex sentences.

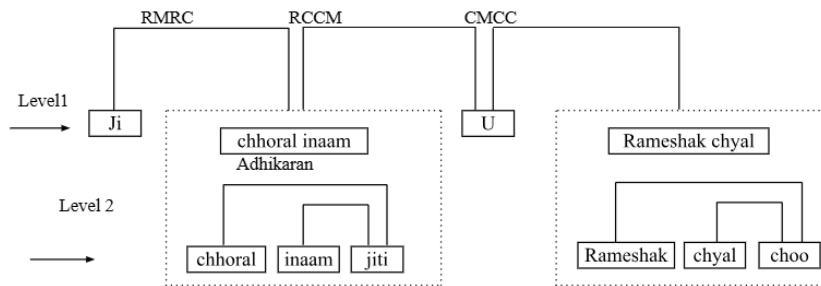


Figure 2: Two Level Linkage Parsing

Sentence: Ji chhoral inaam jiti U Rameshak chyal chu (जी छोरल इनाम जीती उ रमेशक च्यल छू) / The boy who won the prize is the son of Ramesh.

Correlative Marker used in figure 2 is divided into two links RMRC and CMC. The links anticipated as shown

in above figure 3 are RMRC which connects relative marker to relative clause, link CMC connects relative clause to correlative marker and link CMCC connects the correlative marker to correlative clause.

Table 2: Proposed Links for Complex Sentence Structures

Sr. No.	Function		Link Name
	From	To	
1	Header	Main Clause	HM
2	Header	Complementizer	HCo
3	Main Clause	Complementizer	MCo

4	Complementizer	Complement Clause	CoCC
5	Complement Clause	Header	CCH
6	Subject	Header	SH
7	Complement Clause	Jaik Liji (“जैक लजी”)	CCJL
8	Object	Complement Clause	OCC
9	Subject	Main Clause	SMC
10	Relative Marker	Relative Clause	RMRC
11	Relative Marker	Correlative Marker	RMCrM
12	Relative Clause	Correlative Marker	RCCrM
13	Correlative Marker	Relative Marker	CrMRM
14	Correlative Marker	Correlative Clause	CrMCrC
15	Correlative Clause	Relative Marker	CrCRM
16	Correlative Clause	Subject	CrCS
17	Relative Clause	Correlative Clause	RCCrC
18	Header	Subject	HS
19	Subject	Relative Clause	SRC
20	Adverbial Clause	Main Course	ACM
21	Main Clause	Conjunctive Particle	MCP
22	Conjunctive Particle	Adverbial Clause	CPAC

Modeled complex structure and proposed links in Kumauni LG parsing

The algorithm of proposed model can be demonstrated as:

- Step 1. Input sentence
- Step 2. Pre process
- Step 3. Apply parsing algorithm
- If success
- go to step 5.
- else
- Step 4. Link dictionary with step 2
- Go to step 2
- Step 5. Post processing

Step 6. Parsed output
Stop

We propose several models according to the type of complex sentences existing for Kumauni dialects.

Model (1)

In this model link proposed to connect complement type complex structure are HM which connects Header ‘hi’ to Main Clause, MCCo connect Main Clause to Complementizer ‘ki’, CCoC connects Complementizer (Co) to Complement Clause (CC).

For example: Tau baat bari Khatarnaak chu ki baaghal

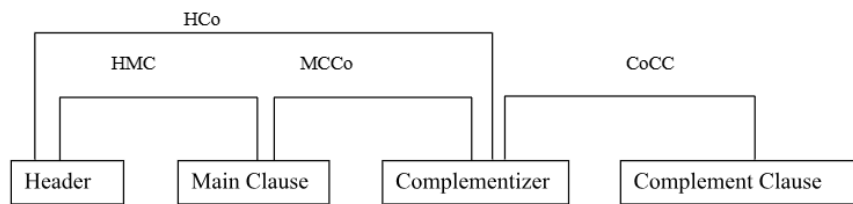


Figure 3: Model 1 for complex sentence structure

Sureshak baakar kha haili (तौ बात बड़ी खतरनाक छू के बाघल सुरेशक बाकर खा हैली): It is very dangerous that tigers has eaten Suresh’s goat.

Model (2)

This second model is developed for the condition if complementizer (Co) is absent. It is the variation of Complement Clause (CC). In such structures link CCH

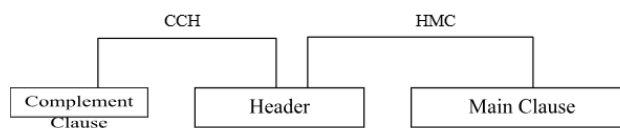


Figure 4: Model 2 for complex sentence structure

is used to join Complement Clause (CC) to Header (H).
 For example: Baaghal Sureshak baakar kha haili Tau baat bari Khatarnaak chu (बाघल सुरेशक बाकर खा हैलीतौ बात बड़ी खतरनाक छू); Tiger has eaten Suresh's goat, it is very dangerous.

Model (3)
 This model is used for another variation of Complement Clause (CC), in this model header is absent and it is still grammatical. Link MCCo is used to join Main Clause

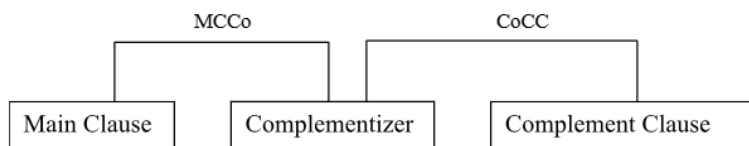


Figure 5: Model 3 for complex sentence structure

(MC) to Complementizer (Co).
 For example: Mee Jannu ki tum kis dagar pyaar karo (मी जानू की तुम कके दगढ़ प्यार करो); I know that you love someone.

Model (4)
 If subject of Main Clause is separated from the Main Clause and position before complement clause without header. Link SH is proposed to connect subject with

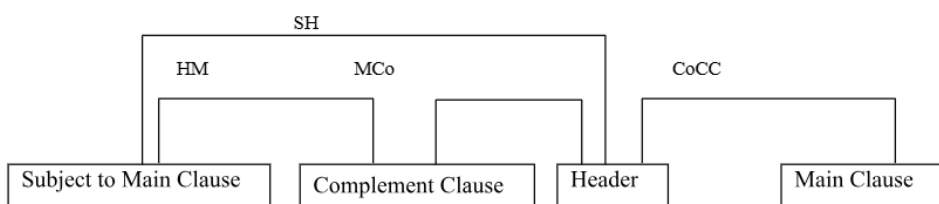


Figure 6: Model 4 for complex sentence structure

Header of Main Clause
 For Example: Mee tum kake pyaar karo tas samajh chu (मी तुम कके प्यार करो तस समझ छू); I think you love someone.

Model (5)
 In this model we have taken those sentences which contain other variations like deletion of relative marker

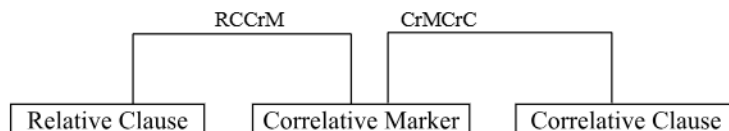


Figure 7: Model 5 for complex sentence structure

that we can demonstrate in the following structure:
 For Example: Jo dhok dino u chhor barh shath chhu (जो धोख दनि उ छोर बढ़ शठ छू); who cheats that boy is very cunning.

Model (6)
 This model has another variation of complex sentence
 For example: Jo chhor barh shath chhu u chhor dhok dino (छोर जो बढ़ शठ छू उ छोर धोक दनि); The boy who is

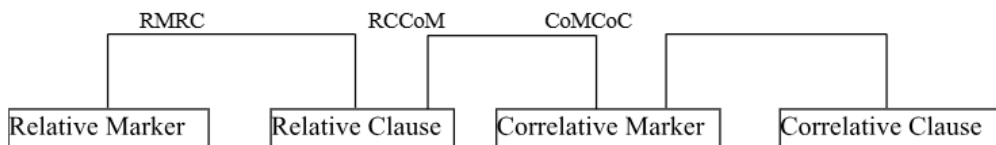


Figure 8: Model 6 for complex sentence structure

cunning that boy cheats.

RESULTS AND DISCUSSION

Result From the proposed models we can observe that in Correlative clause structures the following four types of patterns exist.

1. Free Relatives- These structures are headless relatives.
2. Gap Relatives- In these types of structures there is deletion of relative marker and common to both clauses.

3. Full Correlatives – In these sentences relative and correlative markers as well as clauses exists.

4. Multiple headed relatives- In these structures several Noun phrases are simultaneously relativized.

In this study we have modeled complex sentences in the form of possible valid linkage and proposed various links to connect the clauses in appropriate way. Our system identifies 16 such complex sentence structures.

CONCLUSION

This paper explained how link grammar parser can be used for parsing of Kumauni complex sentence. After intensive study of Kumauni complex sentences some links are proposed to develop connection between the clauses. Here we have proposed 22 new links for Complex Sentence Structures. To solve the issue of crossing of the links, two level links are also projected. This model can be used for other Indian languages to parse complex sentences.

Future Work

In this work, we have considered a limited number of Kumauni complex sentences for modeling of link grammar parser. We have also considered only twenty two links of complex sentence structures. In future work(s) related to the field of study covered in this paper, an effort can be made to reflect on many more Kumauni complex sentences and more complex sentence structures, for developing a more effective model of Link grammar parser.

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