Heuristic Computational Matrix Method for Marathi Grammar Checker

Nivedita S. Bhirud, R.P.Bhavsar, B.V.Pawar

Abstract: Spelling, morphology, syntax and semantics are the important areas of Natural Language (NL) sentence analysis. Syntax checking of a sentence is broadly referred to as a ‘grammar checking’, however it also involves morphological analysis hence technically it is a multidimensional problem. Syntax of a natural language defines permissible sentence structures and constraints on constituents such as their order and unification constraints. It is a purely theoretical aspect and considered as computationally trivial rule enforcement problem. Rule formulation needs expert labour work and is costly and time consuming affair. Modern data driven language engineering approach advocates use of minimal knowledge base (linguistic information) and relies on knowledge extraction from tagged data. It is difficult to find such tagged data for non-English natural languages like Marathi (Indian Language). Considering these facts for grammar checking problem, we have come up with intuitional heuristic method for Marathi grammar checking which uses basic syntactic cues and minimal lexical information. We have modeled this heuristic method scientifically using basic matrix comparison operation. Our approach relies on syntactic cues like word ending, verb ending. We have tested our method on handcrafted Marathi sentences catering different Marathi sentence structures (one hundred and fifty three). The performance is measured using precision and recall metrics. The system has yielded 83% precision and 93% recall on sample data. This approach can be exploited for well structured text documents typically in the closed domains like legal, official, educational etc.

Keywords: Computational Linguistics, Heuristic Function, Marathi Language Grammar, Natural Language Processing, Rule based approach, Statistical approach

I. INTRODUCTION

Information retrieval, summarization, grammar checker, spell checkers, QA system, machine translation, text-speech, and speech-text conversion, etc. are some prominent applications stated under NLP domain. Grammar checking is the most used application and has become attracting research area for researchers. The objective of a grammar checker tool been observed that it require intensive lexical resources. Bhirud and et.al. [8] analyzed grammar checkers of foreign and Indian languages w.r.t. approaches, methodologies as well as features such as grammar errors, weakness and evaluation and found that there is scope to develop grammar checker for the Marathi language.

The proposed work focuses on the development of Marathi grammar checker. Marathi is a morphologically rich language and hence requires intensive lexical resources to develop Marathi grammar checker application. Along with objective of proposed system i.e. suggesting and correcting grammatical errors in Marathi sentences, one of the challenging objectives of proposed system is to reduce requirement of intensive lexical resources that can be achieved by proposed heuristic computational matrix method. Computational matrix method makes use of postpositions primarily to check syntactic and shallow semantic correctness of a sentence.

The rest of the paper is organized as follows: Section II brief at related work. Section III explains core concepts used in proposed system. Section IV and V outline proposed computational heuristic method. Section VI discusses result analysis. The summary and conclusion are listed in section VII.

II. RELATED WORK

This section explains the general algorithm and approaches for developing grammar checker application and its analysis.

A grammar checker takes input in form of a sentence and input sentence has to undergo some preprocessing stages such as sentence tokenization, morphological analysis, and parts of speech tagging [1]. Grammar checking of a preprocessed sentence involves syntactic parsing using chosen methods. Broadly rule-based, data-driven, and hybrid grammar checker methods are used for developing grammar checkers of worldwide languages. In a rule-based method, the text is checked against hand-crafted rules and it is a most common method [9]. Data-driven method has two sub methods, namely, corpus-based and probabilistic/statistical method [14]. The input text is checked against corpus, which is supposed to be a complete document of a language representing all language features under corpus-based method. In probabilistic/statistical checking method, an annotated corpus is used. If correctly occurring sequence observed then it is declared as the correct sentence and uncommon sequence lead to an error [2]. Hybrid method combine both rule-based and data-driven methods [12].

After the study of various grammar checkers for world-wide languages, Bhirud et.al.[8] analyzed some finding based on performance evaluation of grammar checkers developed using the above mentioned approaches. It has been observed that studied grammar checkers gives prominent results, however, requirement of expertise and extensive labor for rule management and availability of relevant good corpus are disadvantages of rule based and data driven method respectively [18]. Finally, reducing the requirement of such extensive lexical resources
can lead to give more promising results.

III. BACKGROUND

The foundation of the proposed method is based upon karaka relation which h describes the theory behind sentence analysis. This section describes the karaka relation followed by data structures used in the system.

A. Karaka Relation

The proposed approach is inspired by Computational Paninian Grammar framework [3]. Many NLP tools of modern Indian languages have been developed using this framework and most suitable for free word order languages. Paninian framework is also known as ‘karaka theory’ and due to its features; it is more suitable to Marathi.

A sentence is composed of words to which parts of speech is assigned. In Marathi, there are 8 types of parts of speech [5] viz. noun (ना), pronoun (पुत्तू, नाता), adjective (विशेषण), verb (क्रियापद), adverb (क्रियाविशेषण), conjunction (उपसाधनी अंक), postposition (अद्वितीय अंक) and interjection (कवलाप्रयोगी अंक), play vital role in valid sentence construction at core level.

Words have semantic relations with each other in a sentence, and such semantic relations are called as ‘karaka’ relation. These karaka relations can be identified from syntactic cues provided by postposition markers and these postposition markers are ‘vibhakti pratayaya’ (विभक्ति प्रत्यय). In Marathi, generally vibhakti pratyayas are attached to nouns or pronouns [7] whereas postpositions attached to verbs are called as TAM (Tense, Aspect, Mood) label [4]. Vibhakti pratayaya have one to many relations with karaka i.e., one vibhakti pratayaya can imply more than one karaka which provide syntactic-semantic information.

In Marathi, there are 6 karaka relations namely: karta(कर्ता), karma(कर्म), karan(करण), sampradan(सम्प्रदान), apadan(अपदान), adhikaran(अधिकरण). Table I shows a couple of examples of mapping between vibhakti pratayaya and karaka relations (relation w.r.t. verbs).

Illustration: In the sentence, ‘रामने भांडूंने वाचल्याने’, word रामने has ‘नें’ vibhakti marker, and according to table I, word रामने is assigned with karta, karan and adhikaran karaka relations w.r.t. verb. However, ‘कारा’ karaka relation is more appropriate w.r.t. verb वाचल्या. Whereas in the sentence, ‘राम वाचल्याने फड कापले’, word राम has ‘करण’ karaka relation w.r.t. verb कापले. Though same vibhakti marker ‘नें’ is attached to a different word in both sentences, a relation of that word with verb i.e. semantic role changes.

IV. PROPOSED APPROACH

This section will describe the proposed method to check grammaticality of Marathi sentences, where minimal lexical resources are required. Initially, details of dataset explaining types of sentences considered for testing of the system is given followed by explanation of pre-processing steps such as sentence extraction, tokenization, morphological analysis, and parts of speech tagging. Further, word group formation and its validation are explained. Along with the validation of words within a group, there is a need to check the validation of inter-group words, which is explained in section 4.D. Proposed computational matrix method which checks grammaticality at the sentence level is described with the illustration of the system.

A. Dataset

Simple handcrafted sentences of Marathi are considered as the dataset. We have used handcrafted simple sentences to cover all structures of Marathi sentences which make sentence grammatically fit. A simple sentence consists of a single clause, where only a single subject and predicate is involved.

Simple sentences are broadly categorized into copular, declarative and modal sentences. In copular sentences, copular verbs are involved in sentence construction, declarative sentence states a fact and modal auxiliary verbs are used in modal sentences. "मुलगा हुच्छ आहे, आणि काम करू शकतो" are an example of copular and modal sentences respectively.

Declarative sentences further can be categorized into:

Transitive: transitive verbs are involved such as खाण, पीण, घुसण

Intransitive: intransitive verbs are involved such as लॉप, पडण, नाचण

Ditransitive: ditransitive verbs are involved such as इक, निचण, सांगण

Casual: transformation from intransitive to transitive e.g. हसबले

Impersonal: involves verb that do not require a subject e.g. उजाडले, संजावले, घाळले

Dative: involves verb which show physical or psychological notion such as आवड, चिस, पट
Passive: verb agrees with an object rather a subject.

For experimental purpose, we have considered sentences as given in table II. While considering these sentences, we also considered different categories of verbs stated in table III. Verb inflects for grammatical feature such as gender, number and person of subject or direct object or sometimes verb remain in their unmarked form. While inflection, the verb ending plays vital role as inflectional form depends on verb ending whether consonant ending or vowel ending.

**Table II: Dataset**

| Types                        | Verb Count | Sentence Count |
|------------------------------|------------|----------------|
| Copular Sentence             | 2          | 30             |
| Declarative Sentence         |            |                |
| Intransitive                 | 15         | 50             |
| Transitive                   | 15         | 60             |
| Ditransitive                 | 12         | 60             |
| Casuative                    | 12         | 70             |
| Impersonal                   | 15         | 70             |
| Dative                       | 15         | 50             |
| Passive                      | 20         | 60             |
| Modal Sentence               | 15         | 50             |
| Total                        | 119        | 500            |

**Table III. Verb Category**

| Category                  | No. of verbs |
|----------------------------|--------------|
| Consonant ending | अ-कारान्त     | 100          |
| अ-कारान्त                   | 04           |
| इ-कारान्त                   | 04           |
| ऋ-कारान्त                   | 01           |
| ए-कारान्त                   | 08           |
| ओ-कारान्त                   | 02           |
| Vowel ending               |              |

**B. Pre-processing**

Input is in the form of a document. The first step under pre-processing is sentence extraction using the appropriate symbol (full stop) [6]. An extracted sentence is further tokenized and then tokens are morphologically analysed. The objective of morphological analysis is the detection of vibhakti prayaya and TAM label. Root words are identified after removal of postpositions and checked against root verb database or closed set and vibhakti markers are checked against an open set. Parts of speech can be assigned to word using a result of morphological analysis. Tagged words then send to next step of word grouping.

**C. Word-Grouping**

In Marathi sentence, a basic unit word may belong to a noun group [16] or verb group. Each word in a group is related to each other by grammatical rules. Each group has a head which has grammatical relation with the head of other groups. E.g. (मुल्याचा भाषाचा बाळका) (कोरी वेळी) (तिती होती), in this sentence group is indicated by brackets and head of a group is shown by underlined word. (तिती होती) is verb group and each noun group head is agreed with a verb group head by agreement rules. The rule set required for word grouping validation is inspired from [18] and [19].

**D. Mapping**

After preparation and checking the validity of noun group and verb group, provision of the optionality of karakas for root verb and assignment of semantic roles to noun head is done using karaka-verb mapping and karaka transformation rules respectively. Vibhakti markers and TAM labels are important elements of mapping.

- **Verb-Karaka Mapping**

Verb-Karaka mapping specifies karaka permitted for verb root. Mandatory presence of karaka is indicated by ‘1’, optional presence of karaka is indicated by ‘0’ and not permitted karaka is indicated by ‘*’. Table IV represent verb-karaka mapping where root verb झोप is transitive (karma is not permitted and hence indicated by ‘*’). Verbs classes are formed on the basis of TAM label and verb classification and these classes are assigned to root verbs. Root verb and verb class have one to many relationship.

- **Karaka Transformation Rules**

Once an appropriate verb-karaka mapping is completed, the next task is the application of karaka transformation rules using verb class and karaka-vibhakti transformation rule along with inter-group (noun group-verb group) validation checking.

**Table IV. Verb-Karaka mapping**

| Root verb | Kart a | Karm a | Karan | Samprada n | Apadan | Adhikar an |
|-----------|--------|--------|-------|------------|--------|------------|
| झोप      | 1      | 1      | 0     | 0          | 0      | 0          |
| श्री      | 1      | *      | 0     | *          | 0      | 0          |

Transformation rules give mapping for TAM label of verb class. It specifies vibhakti markers permitted for applicable karaka relation. Example: Consider verb class of TAM label ‘श्री’. Vibhakti markers applicable for karaka relation of class ‘श्री’ are as in table V.

Noun group and verb group validation checked using grammatical features Gender, Number, Person (GNP) of noun group head with Tense Aspect and Mood (TAM) label of verb group head (syntactic cue).

**V. COMPUTATIONAL MATRIX METHOD**

Grammatical checking at a sentence level can be completed using proposed a heuristic method, a computational matrix method.

Proposed matrix has words/noun group head as rows and their karaka relation as columns. It checks syntactic as well as shallow semantic correctness of sentence. Let $N = n_1; i = 1, 2, \ldots, n$, where ‘n’ is noun groups’ head and $K = k_1, k_2, k_3, k_4, k_5, k_6$ where ‘ $k$ ’ represents karaka relation explained in section III.A.
Heuristic Computational Matrix Method for Marathi Grammar Checker

Let \( \{C_{ij}\}_{N \times K} \) – resulting computational matrix where \( C_{ij} \) is the value from verb-karaka mapping.

1. Scan all rows of \( \{C_{ij}\}_{N \times K} \) if single ‘1’ or ‘0’ found assign respective karaka to noun head. \( /to\) allocate single karaka to word/head of group
2. Scan all columns of \( \{C_{ij}\}_{N \times K} \) if single ‘1’ or ‘0’ found assign respective karaka to noun head. \( /to\) allocate single karaka to word/head of group
3. If single ‘1’ or ‘0’ not found after scanning all rows and columns, scan rows again till all karaka assignment to all \( n_i \)
   a. If a row has ‘1’ and ‘0’, assign karaka with value ‘1’ to \( n_i \) //priority set to ‘1’
   b. Else if a row has ‘1’ and ‘1’, assign initial karaka to \( n_i \) //priority set to initial karaka
   c. Else if a row has ‘0’ and ‘0’, assign initial karaka to \( n_i \) //priority set to initial karaka
4. If karaka not assigned to all \( n_i \), suggest an error.
   Else if declare sentence as “Grammatically correct”.

### Illustration:
Consider Marathi sentence, “चंदू शाळेत रामचा डबा खातो”.

### Table V: Transformation rules for a class with TAM label नोट

| Vibhakti Marker | Karaka Relation |
|-----------------|-----------------|
| नसेर, आ | कार्टा, कर्मान हन | कार्टा, अपादन |
| वेद | अविकरण |

Using the proposed system, steps to check grammaticality of the sentence are as follows:

Tokenization: (चंदू) (शाळेत) (रामचा) (डबा) (खातो)

Morphological Analysis: (चंदू) (शाळेत) (रामचा) (डबा) (खातो)

Parts of Speech Tagging: (चंदू Noun) (शाळेत Noun) (रामचा Adjective) (डबा Noun) (खातो Verb)

Word Grouping: (चंदू) (शाळेत) (रामचा) (डबा) (खातो).

In word group, (रामचा डबा), डबा will play the role of a group head.

Verb-Karaka Mapping: Root verb ‘खातो’ is obtained after pre-processing steps. To get optionality of karaka relation of root verb ‘खातो’ refer Table IV. From TAM label ‘तो’ of verb ‘खातो’, the respective class is assigned and permitted vibhakti markers are fetched. Table V gives vibhakti markers for a class with TAM label ‘तो’ and we get following karaka relations for each word and group head, and karaka relations are assigned as follows:

| Word/Group Head | Karaka Relation |
|-----------------|-----------------|
| चंदू | कार्टा, कर्मान |
| शाळेत | Adhikaran |
| डबा | कार्टा, कर्मान |

Computational Matrix method: Initially, computational matrix formed as follows.

| कला | कर्म | अधिकरण |
|------|------|----------|
| चंदू | 1    | 1        |
| शाळेत | -    | 0        |
| डबा | 1    | 1        |

By applying algorithm depicted in section V, resultant computational matrix formed as:

| कला | कर्म | अधिकरण |
|------|------|----------|
| चंदू | 1    | -        |
| शाळेत | -    | 0        |
| डबा | -    | 1        |

We get karaka relation to each word/ group head and can conclude that the sentence is grammatically correct.

### VI. RESULT ANALYSIS

Dataset considered for the proposed method is discussed in section IV.A. So far, we have tested the proposed method for simple Marathi sentences. As per the description in section IV.A, total 500 simple sentences are taken into consideration which is formed using 119 types of verbs of different categorization (table III) consisting 400 grammatically correct sentences and 100 grammatically incorrect sentences verified by a linguist. A document consisting of 500 simple sentences fed to the system as an input. The accuracy of the system needs to be measured using metrics such as ‘Precision’ and ‘Recall’. For our proposed approach, both can be calculated using the following formulae.

\[
\text{Precision} = \frac{\text{True Positive}}{\text{True Positive} + \text{False Positive}}
\]

\[
\text{Recall} = \frac{\text{True Positive}}{\text{True Positive} + \text{False Negative}}
\]

Where,

**True Positive** = proposed method detect actual grammatically correct sentences as a correct

**False Positive** = proposed method detect actual grammatically incorrect sentences as an incorrect

**False Negative** = proposed method detect actual grammatically correct sentences as an incorrect
Document tested on the proposed system and results were analysed. We have tested results for all types of sentences mentioned in table II and results are depicted in table VI. The overall system then evaluated using evaluation metrics precision and recall, mentioned in table VII.

Results for the proposed approach are promising. We investigated outcome of proposed method and found prominent reasons for short falling. These reasons are as a) number of karaka and noun head mismatch, b) agreement failure within a group and c) agreement failure between groups. Error analysis is shown in fig. 1.

Overlapping of vibhakti markers with noun last word, overlapping of rules, and rule mismatch are found to be some minor reasons.

Table VI. Result Analysis of various types of Simple sentences

| Sentence Type | Data set | Precision in % | Recall in % |
|---------------|----------|----------------|------------|
| Copular       | 30       | 85             | 95         |
| Transitive    | 50       | 86             | 93         |
| Intransitive  | 60       | 81             | 91         |
| Ditransitive  | 60       | 79             | 97         |
| Causative     | 70       | 79             | 89         |
| Impersonal    | 70       | 87             | 89         |
| Dative        | 50       | 81             | 91         |
| Passive       | 60       | 83             | 96         |
| Modal         | 50       | 85             | 95         |

Table VII. Overall Result Analysis

| Sentence Type | Data set | Precision | Recall |
|---------------|----------|-----------|--------|
| Simple sentences | 500  | 83%       | 93%    |

![Error Analysis Diagram](image)

Fig. 1 Error Analysis

VII. CONCLUSION

Proposed computational matrix method uses minimal linguistic heuristic method for checking syntactical and shallow semantical correctness of Marathi simple sentences which make use of postpositions of words prominently rather applying the general algorithm of grammar checker which require heavy lexical resources. Proposed system tested on real-world handcrafted Marathi sentences and it has been observed that system detect the error at a various level ranging from word level to sentence level. Proposed method covers checking of Marathi sentence structures which is base of grammaticality of a sentence. A heuristic method is a key processing step under system suggests syntactical as well as shallow semantic errors in a sentence with the help of matrix comparison type operations. The performance is evaluated based on precision and recall metrics, giving precision 83% and recall 77% for simple sentences respectively. Typically using proposed method, documents of closed domain such as legal, educational, official, medical etc. can be checked grammatically using minimal lexical resources. Due to its lightweight nature can be easily ported to handheld device platforms. In the conclusion, proposed method is capable of checking grammaticality of simple Marathi sentences, using minimal lexical information with coverage of most of grammatical errors.

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