Verbal Inflection in Hindi: A Distributed Morphology Approach*

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Abstract. In this paper, we provide a complete description of Hindi verbal inflection within the framework of Distributed morphology. We discuss the categories that are visible on the verb itself and on associated auxiliaries. We show how both analysis and generation are possible using this model. We also discuss the implementation of such linguistically motivated analysis in a morphological analyzer for Hindi, one of the several NLP tools that we have developed for Hindi, and discuss the outcomes of such an implementation.

Keywords: Hindi, Distributed Morphology, verbal inflection, morphological analyzer

1 Introduction

In this paper, we present an analysis of Hindi verbal inflection in the framework of Distributed Morphology (DM) (Halle and Marantz 1993 1994, Harley and Noyer 2003). The analysis presented in this paper demonstrates how DM may be used to provide a systematic and economical account of verbal inflection in Hindi. This DM analysis also lends itself straightforwardly to implementation in a Hindi Morphological Analyzer. We begin by detailing the different inflectional categories of Hindi verbs and the morphemes that realize them. Using the tools of DM we demonstrate how Hindi verbal forms can be both generated and analysed. The Hindi Morphological Analyzer that implements this analysis, produces the root, the suffixes and the morpheme analyses for any given verbal form. We would like to show that a linguistically motivated analysis provides a completely natural and successful way of implementing NLP tools.

2 Inflectional Categories of Hindi Verbs

There has been much debate about the number of tenses, aspects, moods and modal auxiliaries that may be expressed by a single verb in Hindi. Many grammarians and morphologists including Kellogg (1875), Vajpeyi (1958), Guru K P (1920), Kachru (1966), Olphen (1975), Shapiro (2000) have discussed the inflectional categories of Hindi verbs but these studies are either pedagogical or structural in approach. Singh and Agnihotri (1997) give a word-based description of Hindi verb morphology discounting the concepts of stem, roots or affixes and using word-formation strategies to express lexical relatedness between word forms. Across all approaches, there is much agreement on the kinds of inflectional categories that are seen on Hindi verbs. These categories and their exponents are given in Table 1.

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Table 1: Inflectional categories and their markers for Hindi verbs

Verbal Form	Grammatical Category		Exponents
Finite	Tense	Present	ho
		Past	th-
		Future	-g-
	Aspect	Habitual	-t-
		Progressive	rəh
		Perfective	-(y)ā, -(y)ī, -(y)ĩ, -(y)e
		Completive	cuk
	Mood	Imperative	null, -o, -iye, -jiye, -nā
		Subjunctive (root)	-ũ, -o, -(y)e, -(y)ẽ
		Subjunctive (auxiliary)	ho
		Presumptive	ho-g-
		Root conditional	-t-
		Condition (auxiliary)	ho-t-
	Gender-Number	Masculine-singular	-(y)ā
		Masculine-plural	-(y)e
		Feminine-singular	-(y)ī
		Feminine-plural	-(y)ĩ
	Person-Number	1st p-singular	-ũ
		1st p-plural	-(y)ẽ
		2nd p-singular	-(y)e -o (semi-honorific)
		2nd p-plural	-o (semi-hon) -(y)ẽ (honorific)
		3rd p-singular	-(y)e
		3rd p-plural	-(y)ẽ
	Voice	Passive	Perfective + auxiliary ‘jā’
Non-Finite	Infinitive		-n-
	Past Participle		-(y)ā, -(y)ī,-(y)ĩ,-(y)e
	Present Participle		-t-

The inflection on Hindi verbs may appear as suffixes or as auxiliaries as shown in the examples in 1-4. In 1 and 2, the habitual and perfective aspects are marked on the verbs using suffixes. In 3, the progressive aspect is marked by the auxiliary *‘rəh’*. Present and past tense are marked by the auxiliary form of the verb *to be* in 1, 2 and 3. The future tense is marked directly on the verbal root (if the tense auxiliary is absent, as shown in 4).

1) vəh khā-**tā** hai
he eat-participle-sg-m be-3s-present
He eats

2) us-ne khā-**yā** hai
he-ERG eat-en-sg-m be-3s-present
He has eaten

3) vəh khā **rəh**-ā **hai/thā**
he eat progressive-sg-m be-3s-present/be-3s-past-m
He is/was eating

4) vəh khāe-**g**-ā
he eat-fut-3sm
He will eat

Morphemes of all languages are subject to constraints while they combine to form words or word groups or phrases. These constraints can be syntactic, phonological or semantic. For example, the Hindi future morpheme *-g-* cannot be attached to a verb stem unless the *person-number* morpheme is already present. Further, the verbal stem must be closed using a *gender-number* marker if the future morpheme *-g-* is present. These constraints reject forms such as *khāgā (eat-Future), sogī (sleep-Future)* or *soũg (sleep-1p, sg-Future)* while permitting *khāyegā (eat-3p,masc-Future-3p,sg), soũgī (will sleep-1p,fem-Future-3p,sg)*. Morpheme arrangement rules enable us to identify valid word forms and rule out invalid ones. The order in which the primary Hindi verbal elements arrange themselves is Verb-Aspect-Tense/Mood. The order for all inflectional categories for Hindi verbs (or the template of the verbal group) is given below.

5) Template for verbal inflection
Main Verb > infinitive > passive marker > person-number > Modal > Aspect > Tense/Mood > gender-number

In Table 2, we provide a complete list of the various verb forms (all aspects, moods, tenses, etc.) for the 3rd person, singular for different kinds of verbal roots as a sample of the kinds of inflections that are found in Hindi.

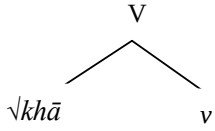
Table 2: Inflections marked on Hindi verbal roots

Root ending → / Aspect/Mood/Tense ↓	**ā** *khā* 'eat'	**ī** *pī* 'drink'	**e** *de* 'give'	**ū** *chū* 'touch'	**o** *so* 'sleep'	**C** *b^{h}āg* 'run'
Perfective Aspect	khāyā	piyā	diyā	chuā	soyā	b^{h}āgā
Habitual Aspect	khātā	pītā	detā	chūtā	sotā	b^{h}āgtā
Infinitive	khānā	pīnā	denā	chūnā	sonā	b^{h}āgnā
Subjunctive	khāye	piye	de	chuye	soye	b^{h}āge
Conditional	khātā	pītā	detā	chūtā	sotā	b^{h}āgtā
Future	khāyegā	piyegā	degā	chuegā	soyegā	b^{h}āgegā
Imperative/intimate	khā	pī	de	chū	so	b^{h}āg
Imperative (semi-hon)	khāo	piyo	do	chūo	soo	b^{h}āgo
Imperative (hon)	khāiye	pījīye	dījīye	chuiye	soiye	b^{h}āgiye

3 Hindi Verbal inflection in Distributed Morphology

The Distributed Morphology framework states that terminal nodes are organized into hierarchical structures at the level of SS by syntactic operations. These nodes contain a complex of semantic and syntactic features but lack any phonological content. After syntax, the nodes may undergo changes as a result of various morphosyntactic operations (such as *merger, fusion, fission, impoverishment*, etc.) at the level of MS (morphological structure). Phonological content is supplied at PF through vocabulary insertion to these modified terminals. This yields the phonetic form of the utterance (and the surface structure of a word/phrase) through sequential derivation (Halle and Marantz 1994). There are two kinds of terminal nodes available at syntactic structure. The first kind of terminal node is typically filled by root entries. Root entries contain phonological and semantic features but no grammatical category features. They acquire a category only after insertion into the syntactic structure. For example, the root terminal combines with the category head as shown in 6 below to produce a V that represents the verb *khā* 'eat'.

6)



The second kind of terminal node has grammatical features but no phonological form. The phonological form is supplied through the process of Vocabulary Insertion. Some features, however, may never be expressed phonologically and are thus *phonologically null*. For example, the verbal form in the imperative mood to indicate intimacy (between the speaker and the addressee) in Hindi is not marked using any specific suffix. Thus, [+imperative, +intimate] is realised as the bare root verb in Hindi, as in */jā/* 'Go!', */ā/* 'Come!', etc. Conversely, a single grammatical feature may have multiple phonological realizations. In this case, competition among the possible phonetic exponents dictates the final selection based on their feature specifications. For example, the 'plural, direct' form of the nouns in Hindi is marked through the suffixes *-ẽ*, *-yã̃*, *-e* or the *null* morpheme and the selection is driven by the gender and the phonological ending of the noun root. The selection of one of these suffixes is based on the features that best match those present at the terminal node. The framework of Distributed Morphology (DM) relies on *late insertion*, *underspecification* and *isomorphism between structures at all levels in the grammar of a language*. As was mentioned earlier, the terminal nodes in the structure that syntax provides to the level of MS are manipulated using certain morphological operations before vocabulary insertion. These operations work under strict adjacency principles and can *split*, *fuse* or *merge* terminal nodes. These operations account for the mismatches between syntactic structure and the morphological structure of word forms. In English, the verbal form in the past tense is generated by assuming a syntactic structure in which T(ense) and the V(erb) appear as separate nodes. T(ense) first lowers (known as Tense lowering) in the tree and then merges with the main verb (V). Merger may or may not lead to fusion of the adjacent morphemes. For example, in English past tense, T(ense) and V(erb) nodes fuse to give rise to a single terminal node. If the two adjacent morphemes fuse into a single terminal node, they are represented using a single exponent. And, if the two nodes do not fuse, different exponents are inserted at each of the two merged nodes.

In Hindi, verbs are cumulatively marked for gender and number (*e.g.*, *bhāg-ĩ* (ran-feminine-pl)) or person and number (*bhāg-ũ* (run-1st person-singular)) as the nodes for the two features fuse before vocabulary insertion. These fused nodes then merge with that of verbal head and make slots available for two vocabulary items. Hindi offers a case where unlike English, the verbal head raises to tense or aspect or mood in order to adjoin to the higher syntactic head(s). We give the example of the verb *'khāyā'* (ate) where a single exponent *-yā* represents aspect and agreement (gender-number). Figure 1 provides a diagrammatic representation of merger and fusion in Hindi verbs. Note that Hindi is right-headed and syntactic heads appear stacked one above the other.

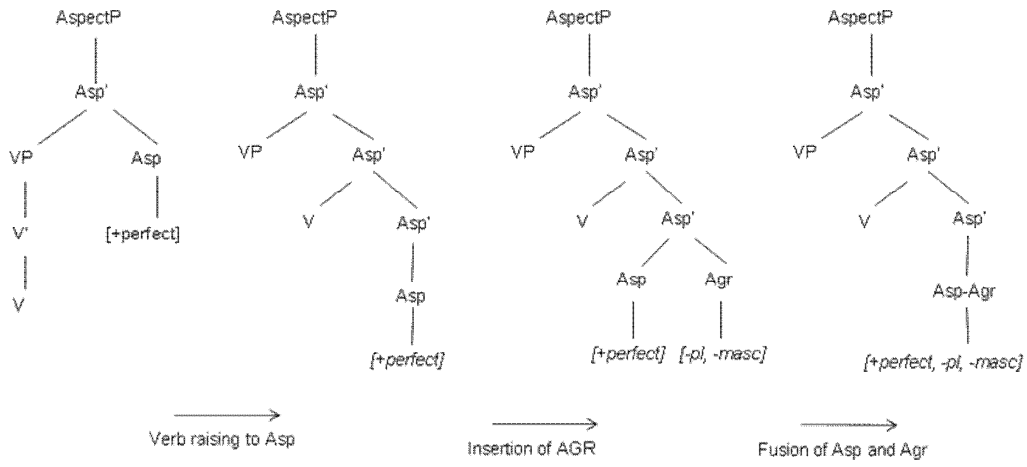


Figure 1: Merger and fusion in Hindi verbs

Vocabulary items (affixes) also carry information about the contexts of their phonological realization (Halle and Marantz 1993). In addition, their form or shape may either be contextually determined by neighbouring morphemes or trigger changes in those morphemes. These typically yield phonologically conditioned allomorphs, stem alternations or deletion or modification of particular features of the morphemes (impoverishment). In the following, we discuss each of these processes in Hindi verbal morphology.

An allomorph is a contextually determined variant of a given morpheme. The phonological shape of a particular morpheme (verb root here) may affect the choice of other morphemes (a suffix, for example) that may be inserted in adjacent nodes. Roots that are inserted prior to affixal entries may have different phonological shapes. The interaction of the root and the suffix may trigger changes in the shape of a suffix or the root itself. In Hindi, the verbal roots that end in consonants or in the vowel */ũ/* select suffix *-ā* in the features [+perfect, +masc, -pl]. But, for the verbal roots ending in the vowels */ā/, /ĩ/, /e/* or */o/*, the glide */y/* is inserted between the suffix and the final vowel of the verbal stem. The suffix *-yā* is thus an allomorph of the suffix *-ā*. Stem alternation is seen when a stem undergoes phonological modification that is triggered by the presence of an adjacent suffixal morpheme**.** The shortening or the lengthening of root final vowels, sandhi or suppletion (either partial or complete), constitute typical changes as shown in 7. The readjustment rules in DM are designed to account for these changes post-syntactically.

7)

Root	**Root-Suffix**	**Final Form**	**Phonological Change**
pī (drink)	*pī-yā*	*piyā*	*Vowel shortening*
chū (touch)	*chū-ā*	*chuā*	*Vowel shortening*
le (take)	*le-yā*	*liyā*	*e → i*
jā (go)	*jā-yā*	*gəyā*	*Complete suppletion*
kər (do)	*kər-ā*	*kiyā*	*Partial suppletion*

Certain verbal features may be deleted or modified in the presence of other features and this is known as impoverishment in DM. Impoverishment allows insertion of default or underspecified entries at a node as entries specified for the deleted feature are taken out of the competition. In Hindi, verbs are marked cumulatively for the perfective aspect and the gender-number feature. The fused gender-number feature appears at a number of places where perfective is absent but not vice-versa. This can be represented using the rule given in 8 below that says that the feature [+perfect] is deleted in the presence of the gender-number features at a node. This results in the insertion of entries that are specified only for gender and number features. Another impoverishment rule is given in 9 which blocks the insertion of */ho/* for the subjunctive and inserts the person-number morpheme instead.

8) *[+perfect] → null / [gender-number]*
9) *[+subjunctive] → ø / [person-number]*

3.1 Vocabulary Insertion

The insertion of verbal affixes and auxiliaries can be understood in terms of vocabulary items (both root and affixal) given below in Table 3. The symbols *Vī, Ve, Vā, Vũ* denote different vowel endings of verbal roots. The vocabulary items compete for insertion at the terminal nodes, and are chosen based on their feature specification. The auxiliary insertion entries in Table 3 insert auxiliaries while all other entries insert suffixes at the terminal nodes. The first six suffixal rules mark Hindi verbs for the imperative mood and the sixth rule is the default rule for the imperative mood. The suffixal rules are arranged in the order of their proximity to the verbal stem. The suffixes that appear closest to the stem are placed first in the list followed by those that appear after them (more distally). For example, the person-number marking rules must be applied before the application of the rule that inserts the future morpheme. Similarly, the future morpheme *-g-* must be inserted before any *gender-number* morpheme is inserted. The

future morpheme insertion rule entails a necessary condition that should be fulfilled first − that a person-number marker must be inserted before the future morpheme is inserted. The conditional mood, the infinitive, and the habitual aspect are all followed by the insertion of the gender-number morpheme.

3.2 Readjustment Rules

Hindi verb roots may end in a consonant (*b^{h}āg* 'run', *cəl* 'walk') or in a vowel such as */ā/ (khā* 'eat'*, jā* 'go'*), /ī/ (pī* 'drink'*, sī* 'sew'*), /e/ (de* 'give'*, le* 'take'*), /ū/ (c^{h}ū* 'touch'*),* or */o/ (so* 'sleep'*, ro* 'weep'*).* The V-V sequences are resolved by glide insertion (a), vowel shortening (b and c), vowel modification (d), or vowel nasalization (e). The readjustment rules given in 10(a-e) pertain to these changes that are made to the inflecting verb.

10) Rules**:**

a)	Root final Vā or Vī or Ve or Vo → Glide insertion / [+perfect]	(pīyā-piyā)
b)	Root final ī [Vī] → i / gender-number	(pīyā-piyā)
c)	Root final ū [Vū] → u / gender-number	(chūā-chuā)
d)	Root final e [Ve] → i / gender-number	(deyā-diyā)
e)	Root final e [Ve] → nasal / person-number	(de-dẽ)

Table 3: Rules to account for verbal inflection in Hindi

Auxiliary Insertion Rules	Suffix Insertion Rules
[+passive, -past] ↔ jā	*[+imperative, +neutral] ↔ nā*
[+subjunctive] ↔ /ho/	*[+imperative, -intimate, +polite] ↔ /-jiye/ /Vī or Ve*
[+ability] or [+probability] ↔ sək	*[+imperative, -intimate, +polite] ↔ /-iye/*
[+ability] ↔ pā	*[+imperative, -intimate, -polite] ↔ -o*
[+obligation] ↔ /pəR/ / vInfinitive	*[+imperative] ↔ null*
[+necessity] ↔ cāhiye / vInfinitive	*[2p] ↔ -o*
[+permissive] ↔ de / vInfinitive	*[1p, -pl] ↔ -ũ*
[-perfect, -habitual] ↔ rəh	*[-masc] ↔ -ī*
[+completive] ↔ cuk	*[+pl] ↔ -ẽ*
[-past] ↔ /ho/	*[-pl] ↔ -e*
	Future ↔ -g- (person, ±pl)
	Conditional ↔ -t-
	[-perfect, +habitual] ↔ -t-
	Infinitive ↔ -n-
	[+perfect, +pl, -masc] ↔ -ĩ
	[+pl, +masc] ↔ -e
	[-pl, +masc] ↔ -ā

3.3 Rules for Irregular Roots

The phonological changes that occur as a result of the association of the verb stem and a suffix can be explained using the rules given above. However, there are cases when stems undergo some modifications that cannot be explained phonologically as in suppletive or irregular forms. The irregular behaviour of certain verb stems in Hindi is accounted for as shown below.

11) Rules:

i. *jā → /g-/ / [+perfect]*
ii. *kər → /ki-/ / [+perfect, +masc]*
iii. *kər → /k-/ / [-masc]*
iv. *ho → /h/ / [-past,1p, -pl]*
v. *ho → /hai/ / [-pl]*
vi. *ho → /hãĩ/ / [+pl]*
vii. *(ho) subjunctive → /hõ/ / [+pl]*

The analysis presented is a comprehensive one and is expected to describe and generate all and only the grammatically acceptable forms of the Hindi verbs. The analysis economises on the descriptive classes that are generated and relates roots and affixes in an unambiguous and complete way. We expect that any new root that enters the language can also be treated straightforwardly with this account which attempts to capture native speakers' intuitions about the formation of verbal forms. We implement this analysis in a morphological analyzer to demonstrate its accuracy and competences and to develop an NLP tool that is independently required for the language.

4 Implementation of Hindi Morphological Analyzer

The DM-based Morphological analyser uses a set of ordered contextual rules to isolate and extract the suffixes from a given word form. For implementation purposes, the vocabulary entries developed for nouns, adjectives, quantifiers, ordinals and verbs (discussed in the previous section) were converted into *if-then* rules and arranged in order of specificity of inflectional and contextual features. These rules being bidirectional can both synthesize and analyse word forms. Although, we have not implemented a synthesizer or a word generator, we would like to point out that the implementation does not require a new set of rules. The internal processes of the DM-based morphological analyser are shown in Figure 2. The rules are applied from right to left iteratively until no suffixes remain and only the base root (that is identified from the root lexicon) is left. Readjustment rules apply wherever applicable to produce the correct root which is then matched with the incorporated root-list to determine a match or matches. The three distinct steps that are used in the analyzer are as follows:

12) Morphological Analyzer
a) Stemming
b) Root formation and lexicon look up
c) Morphological analysis

The system produces a detailed morpheme analysis for each word and provides the root, the grammatical category, the inflectional class and the feature values associated with the word. The system also produces a detailed morphological analysis for each morpheme that constitutes the word form. The sample output format of the system is given in 13.

13) Input Token: X/Y/Z
Possible Root 1: class: category: suffix: morphemes (morpheme1, morpheme 2, ...): Morpheme analysis (morpheme 1, morpheme 2, …)
Possible Root 2: category: suffix: morphemes (morpheme1, morpheme 2, ...): Morpheme analysis (morpheme 1, morpheme 2, …)

The morpheme analysis of each suffix is produced in a seven field with values for the features *gender, number, person, case, tense, aspect*, and *mood* with the applicable values completed as appropriate to the grammatical category. Therefore, for verbs, the values for the case feature are not applicable while the other six fields will include the values that are present. If an input word form could yield multiple roots through multiple analyses (within or across grammatical categories), all such analyses are offered by the analyser. Since, a morphological analyser deals only with words, all analyses offered are retained for the use of higher processing tasks such as POS Tagging or Word Grouping. The analysis for verbs that we presented has been used to develop a DM based Morphological Analyzer for Hindi. An Analyzer extracts suffixes from a word form and outputs its possible morphemes and their analyses. We used a lexicon with approximately 1500 verbal roots. In Figure 2 we show how stemming and morphological analysis is done for the input word *pāegā* (पाएगा) 'will get' (masculine, singular). The vocabulary rules that are applied in the analysis of a word such as *pāegā* are:

14) *[-pl, +masc] ↔ /ā/*
[+Future] ↔ /-g-/
[-pl] ↔ /-e/ / V
[+ability] ↔ pā

The verb root */pā/* can be a main verb or a modal auxiliary. The system outputs both options. In 15 we provide the details of both possibilities. Features with no exponents are marked 'x':

15) *Token: pāegā, Total Outputs: 2*

Output 1:

[Root 1: pā, Category: verb main, Suffix: egā]

[Gender: +masc, Number: -pl, Person: 2p, Tense: +future, Aspect: x, Mood: x]
[Gender: +masc, Number: -pl, Person: 3p, Tense: +future, Aspect: x, Mood: x]

Output 2:

[Root 2: pā, Category: verb_auxiliary, Suffix: egā]

[Gender: +masc, Number: -pl, Person: 2p, Tense: +future, Aspect: x, Mood: +ability]
[Gender: +masc, Number: -pl, Person: 3p, Tense: +future, Aspect: x, Mood: +ability]

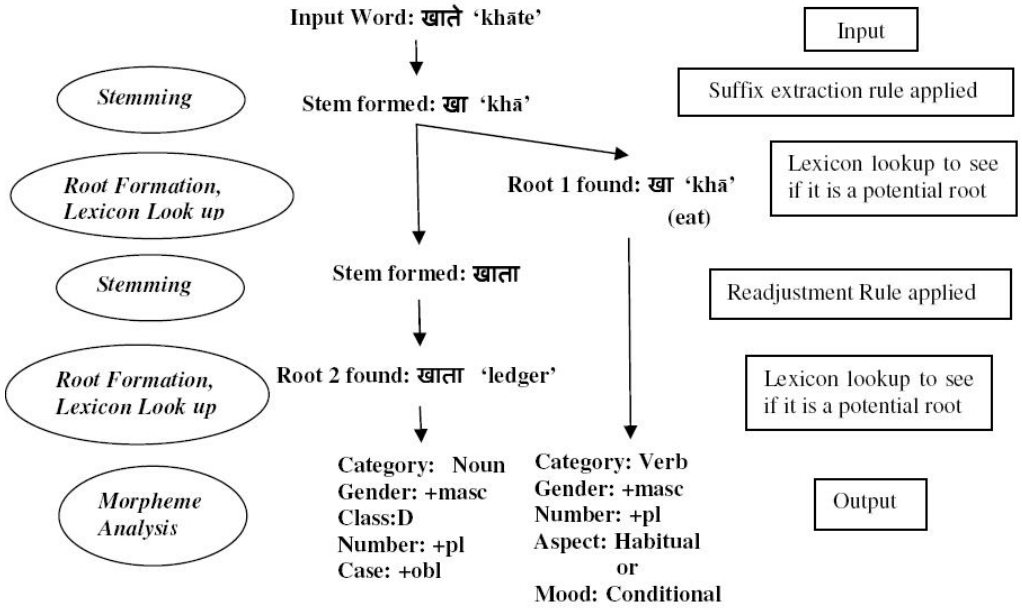


Figure 2: Processes of the DM-based Hindi Morphological Analyser

5 Evaluation, Results and Future Work

We tested the analyser on 13160 Hindi verb forms and manually verified the outputs of the system. The performance of the system on Hindi verbs is very good. The results are given in Table 4. The system fails to identify only 116 forms. The system was able to correctly analyse most of the regular and irregular forms when the root verb is found in the lexicon.

Table 4: Results of the DM-based MA on Hindi verbs

Total number of words	13160
Total number of verbs correctly analysed	13044
Total number of unidentified verbs	116

The main reasons for the errors encountered are (a) incorrect spelling, (b) hyphenated word forms, (c) missing roots and (d) extra/incorrect characters in the word form. We provide the details of the unidentified words with examples in Table 5.

Table 5: Error report of DM-based MA on Hindi verbs

Error Type	Example 1	Example 2	Example 3	Example 4
Root missing in lexicon	मंगा 'məŋā' (order)	धंस 'dhəns' (sink)	भव 'bhəv' (happen)	धड़धड़ा 'dhəDdhəDā' (make noise)
Hyphenated words	आने-जाने 'āne-jāne' (coming-going)	चलते-चलते 'cəlte-cəlte' (walking-reduplication)	रो-धोकर 'ro-dhokər' 'crying etc.'	खाने-पीने 'khāne-pīne' (eating-drinking)
Incorrect/ variant spelling	रक्खा 'rəkhā' (kept)	उड़ाय 'uDāe' (flew-pl)	जायँगे 'jāẽge' (go-fut-pl)	पावें 'pāvẽ' (get-subjunctive)
Words with extra characters	देखने- 'dekhane'	बैठे- 'bæThe-'	है... 'hai…'	लगे- 'lẽge-'

6 Conclusions

In this paper, we have presented a comprehensive analysis of Hindi verb inflection and its implementation in a DM-based Morphological Analyser. The system was able to completely and correctly analyze both regular and irregular verb forms. The system failures were driven primarily by external factors. The output of the system is quite detailed as it produces morpheme analyses for both root and suffixes for a word form. This analysis can easily be done in the reverse to generate verbal forms as well.

The linguistic analysis that was presented in the earlier part of the paper is economical in descriptive terms. Traditional paradigm analyses proliferate paradigms based on features such as gender or number or verb class. Distributed Morphology allows for morphology to work in tandem with syntax (so a parser based on this system can easily incorporate the analyzer) and at the same time allows for the quirks of morphology to be dealt with in specific ways (fusion, fission etc.) NLP tools that are developed on well-argued linguistic analyses are arguably intuitively more appealing, but also, as we have just shown, capable of providing good results.

We have also extended the current analysis to Verb Group Identification (main verb and its auxiliaries). This module selects one analysis out of potentially possible multiple analyses for a word using its contextual information. Strict morphotactical constraints are used to identify verb groups in a sentence and to rule out invalid groups. The DM-based analyser is currently being used in the CRF based POS Tagger and Word Group Identifier for Hindi and deals with all categories of words. It is also being plugged into the Hindi Wordnet and in the Word Sense Disambiguation (WSD) engine to stem the input words and to use their morphological information for sense disambiguation. We hope that this will present a strong case for NLP tools based on well-reasoned and well-argued linguistic analyses.

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