

# Amazighe Verbal Inflectional Morphology: A New Approach for Analysis and Generation

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**Abstract.** Amazighe inflectional morphology poses special challenges to Natural Language Processing (NLP) systems. Its rich morphology and the highly complex word formation process of roots and patterns make NLP tools for Amazighe very challenging. In this paper we present an approach for inflectional morphological analysis and generation for Amazighe verbs. The main motivation for this work is to obtain a linguistically motivated tool based on the concept of patterns and allows, from a verbal entries, to predict the inflectional forms. In this context, the present paper sheds light on three axes. The first axis deals with the levels of the new approach development. The second axis demonstrates the implementation, using finite state transducers, of the extracted rules. The fourth axis discusses experimental evaluations conducted to assess the performance of the analyzer. Our analyzer exploits the efficiency and flexibility offered by finite state machines in modeling while using the NooJ Finite State tools.

**Keywords:** Amazighe Language, Natural Language Processing, Finite state methods, NooJ, Inflectional Morphology, Verbal Morphology.

## 1 Introduction

One of the core enabling technologies required in NLP applications is a morphological analyzer. Morphological component is an important language resource for any language technology. It presents a fundamental input to higher levels of linguistic analysis such as syntactic parsing.

Most of the newly investigated languages in NLP are resource-scarce. Amazighe is one of the endangered languages of West Africa. However, the creation of a new governmental institution, namely IRCAM<sup>1</sup> (Royal Institute for Amazighe Culture), has made it possible for the Amazighe language and culture to reclaim their rightful place in many domains and to get its official status. These changes have strengthened the possi-

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<sup>1</sup> Institution responsible for the preservation of heritage and the promotion of the Moroccan Amazighe culture and its development (see <http://www.ircam.ma/>).

bility of promoting the Amazighe language and enabling it to be introduced in the public domain including administration, media and also in the educational<sup>2</sup> system in collaboration with ministries.

Nevertheless, this language, and like most of the languages which have only recently started being investigated for the NLP, still suffers from the scarcity of language processing tools and resources.

Therefore, a set of scientific and linguistic research are undertaken to remedy to the current situation. These researches are divided on two categories: (1) computational resources which include the optical character recognition (OCR) (Amrouch et al., 2010;) , Amazighe corpora (Boulaknadel and Ataa Allah, 2011, Outahajala et al., 2014), and (2) NLP tools which have been limited and carried out on light stemmer (Ataa Allah and Boulaknadel, 2010a), search engine (Ataa Allah and Boulaknadel, 2010b), concordancer (Boulaknadel and Ataa Allah, 2010c), verb Conjugator (Ataa Allah and Boulaknadel, 2014) and morphological analyzer (Nejme et al., 2012a; Nejme et al., 2012b; Nejme et al., 2012c; Nejme et al., 2013a; Nejme et al., 2013b; Nejme et al., 2013c).

Given that the morphological analyzer is regarded as the first in a series of text processing components, this paper presents the continuation of our previous efforts which are designed for the purpose of developing morphological analyzer of Amazighe nouns and particles (Nejme et al., 2013a; Nejme et al., 2013b; Nejme et al., 2013c; Nejme et al., 2012a; Nejme et al., 2012b; Nejme et al., 2012c).

“Amazighe Verbal Inflectional Morphology: a New Approach for Analysis and Generation” is a part of the whole analyzer for Amazighe. It investigates the processing of the verbal morphology using finite state technology within the linguistic developmental environment NooJ. This technology is computationally very efficient for natural language processing.

The remainder of this paper is organized as follows: in Section 2 we provide some features of Moroccan Amazighe language. In Section 3, we present our inflectional system of Amazighe verbs. In Section 4 we give the evaluation results of our experiments while in the last Section we draw some conclusions and highlight our plans for future work.

## **2 The Amazighe Language**

### **2.1 Historical background**

The Amazighe language also known as Berber or Tamazight (ⵜⴰⴷⴰⵎⴰⴷⵉⵜ [tamaziyt]), is belongs to the African branch of the Afro-Asiatic language family, also referred to Hamito-Semitic in the literature (Greenberg, 1966; Ouakrim, 1995). Geographically speaking, it covers the Northern part of Africa which extends from the Red Sea to the Canary Isles and from Niger in the Sahara to the Mediterranean Sea.

In linguistic terms, the language is characterized by the proliferation of dialects due to historical, geographical and sociolinguistic factors. In Morocco, one may distinguish three major dialects: Tarifit in the North, Tamazight in Central Morocco and South-

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<sup>2</sup> It has become common practice to find Amazighe taught in various Moroccan schools as a subject.

East, and Tachelhite in the South-West and the High Atlas. Since the ancient time, it is the mother tongue of approximately half of the population. However for many decades, it was, until 1994, only oral exclusively reserved for family and informal domains (Boukouss, 1995). While by the creation of the Royal Institute of Amazighe Culture (IRCAM) in 2001 and the constitution update of July 2011, the status of Amazighe has progressively changed.

The Amazighe language has its own script called Tifinaghe that was adapted by the Royal Institute of the Amazighe Culture (IRCAM) in 2003, to provide an adequate and usable standard alphabetic system called Tifinaghe-IRCAM. This system contains:

- 27 consonants including: the labials (ⵍ, ⵍⵍ, ⵍⵍⵍ), dentals (ⵏ, ⵏⵏ, ⵏⵏⵏ, ⵏⵏⵏⵏ, ⵏⵏⵏⵏⵏ, ⵏⵏⵏⵏⵏⵏ), the alveolars (ⵚ, ⵚⵚ, ⵚⵚⵚ), the palatals (ⵛ, ⵛⵛ), the velar (ⵍ, ⵍⵍ), the labiovelars (ⵍⵚ, ⵍⵚⵚ), the uvulars (ⵍ, ⵍⵍ, ⵍⵍⵍ), the pharyngeals (ⵍ, ⵍⵍ) and the laryngeal (ⵍ);
- 2 semi-consonants: ⵏ and ⵏ;
- 4 vowels: three full vowels ⵏ, ⵏ, ⵏ and neutral vowel (or schwa) ⵏ which has a rather special status in Amazighe phonology.

Today, the current situation of the Amazighe language is at a pivotal point. It holds official status beside Arabic. Its morphology as lexical standardization process is still underway. At present, it represents the model taught in most schools and used on media and official papers.

## 2.2 Amazighe Morphology: A Brief Overview

Amazighe morphology is well-known for being rich and complex in terms of its high inflections and derivations involving infixation, prefixation and suffixation (Boukhris et al., 2008). Amazighe morphology has a multi-tiered structure and applies non-concatenative morphotactics. Words in Amazighe are originally formed through the amalgamation of roots and patterns, as shown in Table 1. A root is a sequence of one or many consonants and the pattern is a template of vowels (V) with slots into which the consonants (C) of the root are inserted. This process of insertion is called interdigitation. The resulting lemmas then pass through a series of affixations (to express morpho-syntactic features) and/or clitic attachments (as personal marker: ⵏⵏⵏⵏⵏ [tinid] “you say” → the 2nd singular personal marker in the indicative mood ⵏ--ⵏ [t--d] affixed to the verb ⵏⵏⵏ [ini] “she said”) until they finally appear as surface forms.

Table 1. Example of words made following a pattern.

Root	ⵍⵍ [gl]					
Category	N	N	N	V	V	V
Pattern	uCC	aCCu	aCC'C'a	aCC	CCCaCC	CCCaCaC
Radical	ⵍⵍⵍ	ⵍⵍⵍⵍ	ⵍⵍⵍⵍⵍ	ⵍⵍⵍ	ⵍⵍⵍⵍⵍⵍ	ⵍⵍⵍⵍⵍⵍⵍ
	[ugl - tooth]	[aglu-gizzard]	[aglla-flank]	[agl - suspend]	[ttwagl - be suspended]	[ttyagal- be suspended]

The Amazighe morphology covers three main lexical categories, which are noun, verb, and particles<sup>3</sup> (Boukhris et al., 2008). The focus of this work is practically on verbal morphology.

### Amazighe Verbal Morphology

Practically speaking, verbs are the base of the Amazighe morphology because (1) it represents a wide morphological class which is remarkably rich and (2) as others can be derived from them. It is classified according to the number of consonants of their lexical root: there are Monoliteral verbs, Biliteral, Triliteral ones etc. The verb occurs in two forms: basic and derived one. The basic form (radical) is formed through an amalgamation of a root and a pattern (Root: □□ [gl], Pattern: aCC, Radical: □□□ [agl] “suspend”). While, the derived one is obtained by the combination of a basic verb with one of the following derivational morphemes: □/□□ [s/ss] indicates the factitive form, □□ [tt] marks the passive form and □/□□ [m/mm] designates the reciprocal.

The verb, whether basic or derived, inflects in four aspects namely: aorist, perfective, negative perfective and imperfective, that is marked with vocalic alternations, prefixation or consonant gemination/degimination. Moreover, it displays three moods (indicative, imperative and participial), where in each mood the same personal markers are used (cf. Table 3). The indicative and the participial moods are based on the four aspects, while the imperative mood has two forms simple and intensive that are based respectively on the aorist and the imperfective aspects (Boukhris et al., 2008).

In general, the verbal form of an Amazighe verb can be inflected as shown in Table 2 and described using the template of Figure 1.

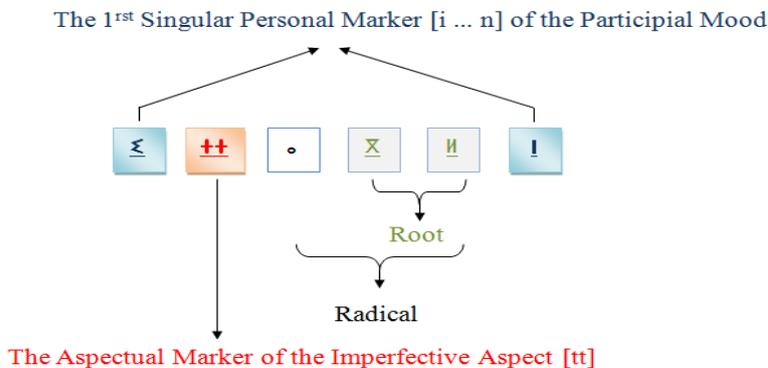


Fig. 1. Example of template describing an Amazighe verbal form for the first singular person.

<sup>3</sup> That includes all other morpho-syntactic categories other than noun and verb.

**Table 2.** The inflectional forms of the verb □□□ [agl] “suspend” in the three moods for the 2nd person masculine plural.

Moods	Aspects					
	Aorist	Imperfective	Perfective	Negative Perfective	Simple	Intensive
<b>Indicative</b>	□□□□ [agly]	□□□□□□ [ttagly]	□□□□ [ugly]	□□□□□ [ugily]	-	-
<b>Participial</b>	□□□□ □ [ya- gln]	□□□□□□□ [ittagln]	□□□□□ [yugln]	□□□□□□ [yugiln]	-	-
<b>Imperative</b>	-	-	-	-	□□□ [agl]	□□□□□ [ttagl]

**Table 3.** Personal markers for the indicative, imperative and participial moods.

	Indicative mood		Imperative mood		Participial mood		
	Masc.	Fem.	Masc.	Fem.	Masc./ Fem.		
Singular	1 <sup>st</sup> pers.	...□	...□	2 <sup>nd</sup> pers.	...∅	...∅	□...□
	2 <sup>nd</sup> pers.	□...□	□...□				
	3 <sup>rd</sup> pers.	□...	□...				
Plural	1 <sup>st</sup> pers.	□...	□...	2 <sup>nd</sup> pers.	...□□/□/ □	...□□□/□ □	...□□□
	2 <sup>nd</sup> pers.	□...□	□...□ □				
	3 <sup>rd</sup> pers.	...□	...□□				

In the following, we will concentrate on the aspects of verbal inflections – i.e. how inflectional aspects are expressed and generated-.

### 3 Inflectional Morphology of Amazighe Verbs: Conjugation rules

This section aims to review the formation processes of the verbal aspect: aorist, perfective, negative perfective and imperfective.

#### 3.1 Related Work

Amazighe verbal morphology is already shown in several previous studies. The first exploration refers to the works which tend to concentrate on particular dialects as Ait

Attab dialect (Jazzi, 1991), Imdlawn Tashlhit (Dell and Elmedlaoui, 1985; Dell and Elmedlaoui, 1989) and Ait Ayache one (Ernest, 1971) and which support that the morphological rules that govern the formation of different verb forms take as a basis the lexical entry of the verb that has two types of information: CV template and melodies. However, these studies are insufficient because they deal with a region within a geographical border.

The second one is relies on study of the various conjugation structures inferred of the three major Moroccan Amazighe dialects (El gholb, 2009; Laabdelaoui et al., 2012). El gholb (El gholb, 2009), given the extent of the Amazighe language on a huge geography, has chosen some representative dialects of the three major ones on sporadic basis in order to give an overview of all relevant changes. Based on this result, he has presented a draft in which he adopts the classification by verbal type: monoliteral, bilateral, trilateral, etc. but limited only to the conjugation of simple and underived verb of monoliteral and bilateral types with the structures: /ccv/, /c<sup>2</sup>c<sup>2</sup>v<sup>4</sup>/, /vcc/, /vc<sup>2</sup>c<sup>2</sup>/, /vcv/, /cvc/, /vc/. Laabdelaoui et al (Laabdelaoui et al., 2012) adopt the class based approach. The verbs are arranged into 31 classes along the aorist/perfective, and the aorist/imperfective conjugation oppositions. In the first 30 classes, independently of the morph phonological alternations, all verbs belonging to a specific class are modeled by the same morphotactic rules to get either the perfective or the imperfective forms, whereas the last class contains a set of 10 verbs that behave differently. Based on these classification criteria, the Amazigh verb and its derived forms do not necessarily belong to the same class, since they may not use the same morphotactic rules to be conjugated.

Class based approach provides a straightforward way of describing a large number of verbs in a compact and generalized way but fails to predict the class for a new verbs (other than those owned by our list and also for the derived forms resulted) or how it forms are morphologically generated. Also, and given the nature of Amazighe morphology, it accounts many classes (31 classes) and, deal with regional varieties, may present different conjugation classes for the same verb.

### **3.2 Our Approach**

Our Approach investigates the mechanism responsible for predicting the conjugation of Amazighe verbs in each aspect. Furthermore, we proposed that the inflection of verbal aspects is based on the pattern. In this context, we have undertaken to develop a set of rules to generalize the inflection model of each pattern.

In line with our goal, and with the aim of the representativeness of the three Moroccan varieties (Tarifit, Tamazight, Tashelhit), we have adopted, as basis of our work, a set of 3676 attested and standardized word lemmas from (Laabdelaoui et al., 2012). This cross-dialectal perspective has several advantages, the main one being that it contributes to a clearer description of the system and allows highlighting the characteristics commonly shared by the different dialects, in order to present the variations that occur.

Starting from this basic list, and in order to simplify the presentation and account for different verbal bases, we choose a classification according to the verbal types (monoliterals, biliterals, etc.), containing a vowel or not and containing geminate radical or not. Then, we extract the rules for each pattern of each type.

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<sup>4</sup> We use the “C” in the pattern presentation when a consonant is reduplicated.

The following diagram (cf. Figure 2) demonstrates the overall architecture of our approach.

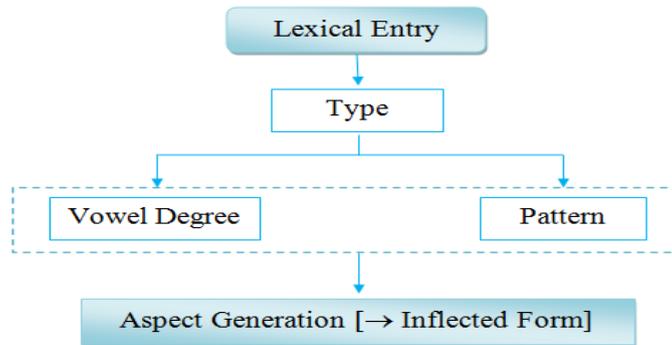


Fig. 2. Verbal inflection architecture.

Our approach is based on hierarchical structures:

- The first phase is to determine, from each entry, the verbal type,
- The second one is to determine the vowel degree (zero vowels or full ones) with the pattern (CV),
- The third one, and based on these two latest, we determine the changes that need to be assign to generate the inflected forms for each aspect.

In order to better illustrate our proposition, we consider as an example the lexical entry  $\square\square\square$  [agl] “suspend”, which correspond to the biliteral type with the pattern “aCC” (full vowels). For this template, the inflected forms are generated as follows:

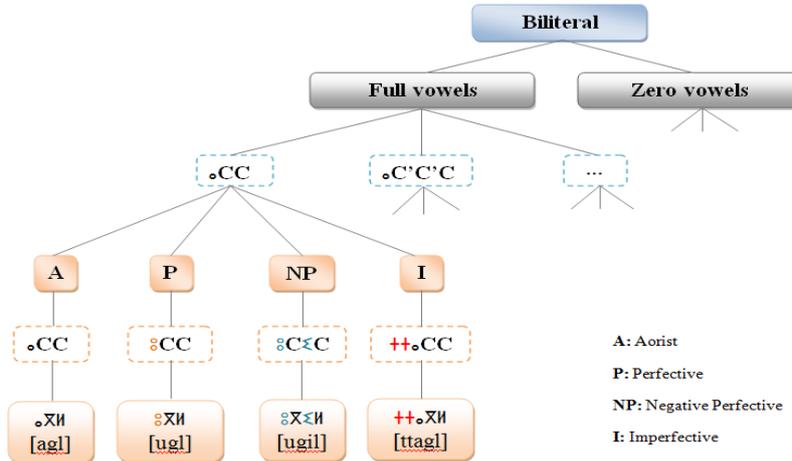


Fig. 3. Inflected forms of the lexical entry  $\square\square\square$  [agl]

Based on this classification, a set of paradigms were carefully developed to cover six verbal types and also to present the verbs inflectional exceptions which require a partic-

ular study. As a result, we have raised a set of 553 general rules: 329 for regular verbs and 224 for exceptional ones. The following table (cf. Table 4) describes these rules in more details.

Table 4. Description of our rules.

Types	Pattern							
	Zero vowels				Full vowels			
	Regulars		Exceptions		Regulars		Exceptions	
	Number of entries	Number of rules						
<b>Monoliterals</b>	5	2	2	2	59	16	9	9
<b>Biliterals</b>	117	5	22	10	570	73	72	44
<b>Triliterals</b>	766	6	64	15	555	88	150	73
<b>Quadriliterals</b>	285	5	63	16	680	90	100	42
<b>Quinquiliterals</b>	21	3	13	5	119	35	10	8
<b>Six literals</b>	1	1	-	-	7	5	-	-
<b>Total</b>	1195	22	164	48	1990	307	341	176

## 4 The Processing of Verbal Morphology: Implementation and Evaluation

Our main agenda is to develop a highly flexible verbal Amazighe morphological analyzer consisting of two major parts:

- (1) Construction of our verb Amazighe lexicon “VAmLex” which stands for “Verbal Amazighe lexicon”,
- (2) And the formalization of the inflectional morphology raised by our approach.

To achieve this goal, we use finite state machines within the developmental environment NooJ (Silberztein, 2005; Silberztein, 2006). The use of finite-state tools was extremely attractive, it used to generate and analyze several thousands of words per second. This linguistic platform will be described inside this paper as the tool used for formalization and morphological analysis of Amazighe verbs.

### 4.1 NooJ: Linguistic Development Framework

NooJ<sup>5</sup>, released in 2002 by Max Silberztein (Silberztein, 2005; Silberztein, 2006), is a freeware language-engineering development environment, runs on different operating systems such as Windows, Linux and Mac OSX, and provides a set of tools and methodologies for formalizing and developing a set of Natural Language Processing (NLP) applications. It presents a package of finite state tools that integrates a broad spectrum of computational technology from finite state automata to augmented/recursive transition networks. This package allows constructing, testing and maintaining large-coverage lexical resources, as well as electronic dictionaries, formal, morphological and syntactic grammars, which can be applied to treat texts and large corpora in order to locate morphological, lexicological and syntactic patterns, remove ambiguities, and tag simple and

<sup>5</sup> See <http://www.nooj4nlp.net/> for information of NooJ.

compound words. For each of these levels, NooJ provides linguists with one or more formal framework specifically designed to facilitate the description of each phenomenon, as well as parsing, development and debugging tools designed to be as computationally efficient as possible, from Finite-State to Turing machines.

One of the important and useful features of NooJ, regarding morphologically rich languages like Amazighe, is its simple description of morphological and syntactic phenomena, efficient morphological processing, its robustness, and also its ability to analyze texts of several million words in real time. According to all these reasons, we have chosen NooJ as our development platform for building local and morphological grammars that should function as verb morphological analyzer. This component would allow us to process and take advantage of this readily available data.

## 4.2 Verb Lexicon and Rules Formalization

Given that the linguistic resources required by the morphological analyzer include a lexicon and inflection rules for all paradigms, we started by building a verbal morphological Amazighe lexicon.

### Verbal lexicon

Lexical entries were developed from Amazighe Conjugation Manual [ⵜⴰⵎⴰⵣⵉⵖⴰ ⵜⴰⵎⴰⵣⵉⵖⴰⵏⵜ ⵜⴰⵎⴰⵣⵉⵖⴰⵏⵜ - adlis n usfti n tmazirt] (Laabdelaoui et al., 2012) and also from the new grammar of Amazighe (Boukhris, 2008). Our main lexicon contains, actually, 3676 entries (3166 regular<sup>6</sup> verbs and 510 irregular<sup>7</sup> ones) represented as a second person, singular, masculine and imperative mood.

Each lexical entry presents the following details: the lemmas, lexical category, type, semantic feature and the translation in French and Arabic languages. Furthermore, each one is linked to its inflection rule invoked by the property “+FLX=” for the inflectional information.

### Rules Formalization

The purpose of this section is the verbal formalization. This study presents the implementation of inflectional rules allowing generating from each entry its inflected forms.

#### *Inflectional Rules*

Relied on the rules presented in the Amazighe Conjugation Manual (Laabdelaoui et al., 2012) and following our approach we have formalized the verbal inflectional rules. Therefore, we have created, through hand-encoded graphs integrated in the linguistic development platform NooJ, a set of hand-encoded inflectional paradigms covering the exceptional cases. The inflectional descriptions include the mood (indicative, imperative or participial), the gender (masculine or feminine), the number (singular, plural), the aspect (aorist, imperfective, positive perfect and negative one) and the person (first, second or third). By these descriptions we refer to the set of all possible transformations

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<sup>6</sup> Verbs with aorist formally identical to the perfective.

<sup>7</sup> Verbs with aorist formally different to the perfective.

which allow us to obtain, from a lexical entry, all inflected forms. On average, there are 82 inflected forms per verb entry and 357805 fully inflected forms in the total.

To give an overview of all these rules, we take as an example the verb  $\square\square\square$  [agl] “suspend”.

$\square\square\square, V+Simple+Bilitère+Irreg+Tr+FLX=aC'C'_{aff}+FR=suspendre+accrocher+être$   
 $suspendu+AR=عَلَّقَ + تَعَلَّقَ$

Inflectional grammar is looking for the paradigm named “aC'C'\_{aff}” in order to generate all forms of a headword. Among the 82 inflectional transformations which are described in the inflectional paradigm “aC'C'\_{aff}”, here is one:

$\square<L2>\square<LW>\square<S>\square/Acc\_Négatif+2+m+s$

This NooJ paradigm, written in NooJ graphic editors, consists of a number of pairs describing all the possible forms. The first part of this pair describes a change on the word (e.g. <LW>/ - position the cursor (|) at the beginning of the form, <L2>/ - go left with 2 character and <S>/- delete next character) while the second part describes features that the newly made word is given (e.g. / Acc\_Négatif+2+m+s- verb is added description that is in negative perfective form (Acc\_Négatif), second person (2), masculine (m) and singular (s)). The meaning of the transformation is: (1) to alternate the first vowel  $\square$  [a]  $\rightarrow$   $\square$  [u], (2) insert the vowel  $\square$  [i] before the last consonant and (3) finally, add the personal markers of the negative imperfective aspect which correspond to the second masculine person. These operations, applied in succession, generate the form:  $\square\square\square\square\square$  (tugild- it has not suspended).

### 4.3 Experiment and evaluation

The performance evaluation of a morphological analyzer has to be observed in terms of its impact on the performance of the applications that use it. Hence, the main goal of this experiment is to prove the flexibility of our approach and to prove that it can satisfy the morphological analysis of the most verbs from the patterns. To do this, at the end of the development phase, we have carried out the evaluation of our inflectional rules against a list of 701 distinct verbs. The list entries, manually constructed, were not used as part of the development of our rules in order to get some feedback and to improve the modeling of inflectional morphology of Amazighe verbs.

After the application of the inflectional rules to the verbs list, we have undertaken a manual analysis of the output to evaluate the performance of our rules. The results for full analysis can be seen in the following table (cf. Table 5).

**Table5.** Amazighe verbal analyzer evaluation.

Results	Verbs correctly analyzed		Verbs incorrectly analyzed	
	Number	%	Number	%
<b>Inflectional rules</b>	591	84,30%	110	15,69%

The above results indicate that our verbal system in its current development has so far registered success. Out of the lists respectively of 701 distinct verbs, 84,30% were found to be correctly inflected.

By taking a closer look at the verbs which were not correctly analyzed we could come up with the following conclusions the incorrect analyses are mostly due to: (1) 30% of verbs which patterns are not included in those already treated and (2) to 70% of incorrect inflections. A high rate of this part represents the difference in the Imperfective form (with correct perfective and negative perfective). This difference is due to verbs of some regional varieties of the Amazighe language. But the inflections remain correct for the standard side.

## 5 Conclusion and future works

We presented a high accuracy morphological analyzer for Amazighe verbs that exploits the regularity in the inflectional paradigms while employing the NooJ Finite State tools for modeling the language in an elegant way. The research results presented above describe the first efforts aimed to investigate the mechanism responsible for predicting the conjugation of Amazighe verbs based on patterns.

The accuracy figures as high in evaluation of our method seem to be appropriate and encouraging. These results allow us to review, correct and complete all our resources in order to improve it.

In order to emphasize more on the usefulness of our approach towards morphological analysis of Amazighe verbs, we plan to add new verbal lemmas and specific tags in order to enlarge the lexicon and to handle the regional varieties. Furthermore, the incorrect forms and the new patterns will be re-examined for further consideration into the morphological system.

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