



## An Algorithm to Analyze Arabic Verbs Morphologically

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### ABSTRACT

Morphological analysis describes a word in isolation from the context, which is an important stage when trying to automatically understand and interpret the text. Many studies have provided morphological analyzers of Arabic verbs. However, although accurate, they do not deal with all cases of Arabic verbs. This research introduces an algorithm to analyze Arabic verbs morphologically based on regular expressions then on Morphological Database. The advantages of this algorithm are that it deals with verbs in their morphological cases, extracting their possible structures and some of their morphological data. This algorithm yielded highly accurate results after being tested on a sample of vocabulary and text. Furthermore, the extracted data is completely error-free.

### KEYWORDS

language processing, match, pattern, regular expression, root, word structure

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## 1. Introduction

Natural language processing is a science that combines linguistics and computer science. Linguistics provides a description of the linguistic material, while computer science automates this description and produces programs and tools such as machine translation and text proofreading.

This paper considers how to process the Arabic language automatically. It answers the question of how the roots of Arabic verbs can be extracted and how their patterns, possible tenses, and parts can be automatically recognized.

Previous studies have presented tools and algorithms to process Arabic verbs automatically (see Section 2). However, the mistake rate in their outputs was inconsistent, and none of them were error-free. Furthermore, some tools only dealt with certain cases of the verb, such as triple verbs.

The difficulty of processing Arabic verbs is due to two features of the verb structure. The first one is diversity; the verb structure is consisted of triple roots, such as "درس", or quadruple roots, such as "حرج". A morphological phenomenon called "derivation" also creates a new verb structure by adding certain characters to the root, such as deriving the verb "قاتل" from "قتل". This phenomenon leads to multiple verb structures. Therefore, to know the letters of the root, we must first know what letters have been added to the root.

The second one is the changes in verb structure; sometimes, changes occur for morphological reasons, and as a result, the verb changes its form. The change may affect the original verbs or their derivatives, as shown in Table 1.

Table 1: Examples of verb structure change

Type Change	Verb	Original Verb	Pattern
Draw "Hamza"	قرأ	قرأ	فعل
Replace vowel	يقول	يغال	يفعل
Remove	عد	عاد	فل
Replace + diphthong	أزهر	أزهر	افتعل
Remove + diphthong	كنّا	كنّا	فلنا
Remove "Hamza"	يرى	يرأى	يفل

The verb pattern also follows the verb structure, so if the root letters are unknown, the verb pattern will not be known.

The paper follows the following order: Section 2 presents the relevant works, Section 3 explains the working of the proposed algorithm, Section 4 presents the testing of the proposed algorithm and its results, and Section 5 reports the results and looks to future work in this area.

## 2. Related Works

Many previous studies have presented proposals describing how to analyze Arabic verbs automatically, but they have mostly focused on extracting roots and patterns. Reference is made to several such studies that have seen positive results, evaluating their method and limitations.

- Yousfi (2010) presented a morphological analysis of Arabic verbs using surface patterns linked to a database of surface patterns. Limitations of this study: Many errors occur in words not associated with surface patterns.
- Abuata *et al.* (2011) presented an algorithm to extract the roots of Arabic words. This algorithm removes valid affixes in an input word according to a set of rules. It then generates possible roots for the word and checks them in the root dictionary. Finally, it generates patterns for the word by using a root from each of the possible roots and checks them against a set of valid Arabic patterns. Limitations of this study: Mistakes that occur due to:
  - Spelling such as "وبارك" → "ارك"
  - Over-stemming "ليبلى" → "بل"
  - Other issues "ووقاهم" → "فا"
- Yaseen and Hmeidi (2014) proposed an algorithm called the word substring stemming algorithm (www-based), which is used to extract the roots of Arabic words and their patterns. The algorithm extracts the substring from the word to check it against the root file and generates patterns that allow the input word to check for patterns by using the root's (التصريف) file. Limitations of this study: It does not deal with words that do not contain all letters of the root, such as "مدّ". Additionally, it does not deal with one-letter words such as "ع".
- Al-Kabi *et al.* (2015) presented an algorithm to extract the roots of Arabic words; however, it only works on triliteral roots. This method depends on matching the stemmed word, with all the patterns having the same word number as the stemmed word. Then, it removes the same letters except the main letters to return to the root. Limitations of this study: It extracts the roots of Arabic words, but only works on triliteral roots. Incorrect roots are produced either by over- or under-stemming. It also cannot deal with words that are less than

four letters, and It cannot process short words where vowels are removed.

- Thalji *et al.*, (2018) presented an algorithm to extract the Arabic roots according to set rules. They classified Arabic letters into two main groups: consonant letters that belong to the root and non-consonant letters that sometimes belong to the root and sometimes do not.

Limitations of this study: The algorithm cannot find the root of words containing three consonant letters where some of them do not belong to the root. It also cannot deal with replacing a consonant with a vowel, because this rarely happens.

- Azman (2019) presented a tool that extracted the roots of Arabic verbs, called "RootIT". This tool requires the use of bottom-up and top-of-bottom analysis together.

Limitations of this study: The tool cannot deal with verbs that have a pronoun attached by a suffix, such as "يستسقوهم". Also, it does not replace roots that have changed form during the morphology process, such as: "يرعى" → "يرعى". Hamza should be changed to "أ".

- Othman *et al.*, (2020) presented an algorithm made up of two levels of analysis: Sentence-level analysis, which uses an Arabic context-free grammar parser to identify the sentence and its parts, and lexical-level analysis, which extracts the verb root. The regular expression engine matches the input word with all its prefixes, derivatives, and suffixes to extract the root from the derivative. The hash function then generates an index for each root and Hash table to check whether the inserted derivative is a verb.

Limitations of this study: The algorithm deals only with trilateral roots. It does not deal with verbs that contain vowel letters. It does not deal with trilateral verbs that contain double letters, and it does not deal with "افتعل" when the "ت" is replaced with "د" or "ظ" or "ط".

- Khafajeh *et al.*, (2021) proposed an algorithm to extract roots from Arabic words based on a modified successor variety algorithm. They developed the body of the proposed text in such a way that it contains multiple morphological forms for the word to be rooted.

Limitations of this study: There is a deficiency in how this algorithm deals with vowels.

### 3. Proposed Algorithm

The algorithm uses regular expressions and Morphological Database to analyze verbs. The regular expressions are built on the structure of Arabic verb roots and their morphological changes and derivations. Morphological Database contains morphological data for the verb structure, as shown in Figure 2.

Figure 6 shows the flowchart for the proposed algorithm, which consists of the following steps:

#### Step 1:

The regular expression matches the input word; it consists of [prefixes = { $Pr_1, \dots, Pr_n$ } + substring verb + suffixes = { $S_1, \dots, S_n$ }]. Prefixes and suffixes are letters that touch the verb and are not a part of the root. A substring verb starts and ends with the letter of root, it contains the root letters and sometimes an infix (a derived letter). An abstract verb consists of a substring verb – infix; it contains only root letters. Step 1 aims to identify the structure of the word and retain its parts; Figure 1 shows an example.

Figure 1: Identification of the structure of the verb "يتساقون"

يتساقون					
ون	يق	ل	س	ت	ي
$S_1$	Root letter	infix	Root letter	$Pr_5$	$Pr_4$
Suffixes	Substring verb			Prefixes	

#### Step 2:

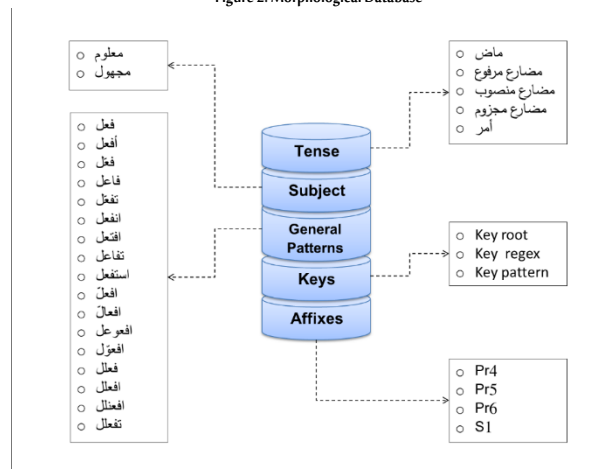
The algorithm checks the structure of the abstract verb using a set of regular expressions containing all the abstract verb structures; each verb has a unique key, which is kept when the match is successful.

Here, the letter type and its shape are important for matching purposes, as the regular expressions do not include "[ء-ي]" but rather "[ب-هـ]".

#### Step 3:

The algorithm calls possible morphological data from Morphological Database; the calling is based on the key that was retained in Step 2 and a set of rules, such as a rule regarding tense. For example, if the prefix contains "ل", the algorithm just chooses the appropriate tense {"مضارع مجزوم", "مضارع منصوب"}.

Figure 2: Morphological Database



#### Step 4:

The algorithm modifies the abstract verb to generate the root; for example, by deleting a letter that appears more than once, consecutively. The list of root structures contains 59 structures, covering all root forms; however, the algorithm only uses the root structures that match the root key. Figure 3 shows the root structures for Keys 1, 2, and 3.

Figure 3: List of root structures

Key	→	root structure
1	→	R
2	→	$R[0]+R[1]"ى"$
3	→	$R[0]+"/"+R[1]$
...	→	.....

#### Step 5:

The algorithm generates an abstract verb pattern. It gives an initial value to this abstract verb pattern according to the root length; if the root length is two or three, then the initial value is "فعل"; if it is four, then the initial value is "فعلل". The algorithm then compares the lengths of the abstract verb and root; if their lengths are equal, the final value is the initial value. If the abstract verb is smaller than the root, the algorithm matches them, and if it does not find one of the letters, the algorithm retains the index of the missing letter and removes a letter from the initial value based on this index. Figure 4 shows how the abstract verb pattern of the verb "ارم" can be generated.



to extract the verb roots and their patterns and provide error-free morphological data. It also outperformed other algorithms' verb analysis, because it solved the problems faced by other algorithms, such as how to deal with verb vowels and instances where the verb contains a repeated character.

In the future, a digital dictionary will be created that contains the roots of Arabic verbs and their derivational patterns according to a numerical indicator. The dictionary will then be linked with the proposed algorithm to remove the possibility of errors in the algorithm's output.

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