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A Realization of Optimality Theory to Arabic Hollow Verb

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***Abstract*—Arabic hollow verb has two kind stems of perfective. Those faced three main factors, (1) root and morphological template, (2) phonological aspect, and (3) imperfective form. The previous study had multilevel analysis using concatenative strategy, to account for conjugation of Arabic hollow verb. The other existing studies just investigated one factor, that was phonological harmony; or standard morphological analysis. So, they just got single approach to formulate morphological processes of Arabic hollow verb. In this paper, we demonstrate a unified interplay approach to outline a learning algorithm which utilize the optimality theory to ascertain the optimal output of two kind stem of Arabic perfective hollow verb, exclusively using blocking and extended exponence. Within this approach, the existence of weak consonants (w and y) in hollow verb can be expressed as realization constraints in accordance to Arabic morphology system, that is associated to the pattern of perfective-imperfective change, and also consider grammatical categories (person, number, and gender). The findings of this study is not only useful for theoretical linguists to understand an alternative way of modeling and processing the inflection of Arabic words, but also for computer practitioners who want to develop an algorithm for natural language processing tasks of Arabic hollow verb conjugations.**

***Keywords*—Arabic hollow verb; consonant; constraints; optimality theory; stem**

I. INTRODUCTION

The stem of perfective hollow verb in Arabic is realized by two characteristic allomorphs, which depend on the person, number, and gender. The following are data of hollow verb with /w or y/ in middle radical.

(1) زَار ← زَوَر **/zawar-a → zaar-a/ 'visited'**
يَزُوْر /ya-zuur-u/ 'he visits'

zaar-**a**	'he visited'	{3,sg, msc}
zaar-uu	'they visited	{3, pl, msc}
zaar-at	'she visited'	{3, sg, fm}
zur-na	'they visited	{3, pl, fm}
zur-ta	'you visited'	{2,sg, msc}
zur-tu	'I visited'	{1, sg, fm/msc}
zur-naa	'we visited'	{1, dl/pl, fm/msc}

(2) نَام ← نَوِمَ **/nawim-a → naam-a/ 'slept'**
يَنَامُ /yanaam-u/ **'he sleeps'**

naam-a	'he slept'	{3,sg, msc}
naam-uu	'they slept'	{3, pl, msc}
naam-at	'she slept'	{3, sg, fm}
nim-na	'they slept'	{3, pl, fm}
nim-ta	'you slept'	{2,sg, msc})
nim-tu	'I slept'	{1, sg, msc/fm}
nimnaa	'we slept'	{1, dl/pl, fm/msc}

(3) سَيَر - سارَ **/sayar-a saar-a/ 'walked'**
يَسِيْرُ /ya-siir-u/ 'he walks

saar-a	'he walked'	{3, sg, msc}
saar-uu	'they walked'	{3, pl, msc}
saar-at	'she walked'	{3, sg, fm}
sir-na	'they walked'	{3, pl, fm}
sir-ta	'you walked'	{2, sg, msc}
sir-tu	'I walked'	{1, sg, msc/fm}
sir-naa	'we walked'	{1, dl/pl, msc/fm}

(4) هَابَ ← هَيِبَ /hayiba → haab-a/ 'feared'
/yahaab-u/ 'he fears'

Haab-a	'he feared'	{3, sg, msc}
Haab-uu	'they feared'	{3, pl, msc}
Haab-at	'she feared'	{3, sg, fm}
Hib-na	'they feared'	{3, pl, fm}
Hib-ta	'you feared'	{2, sg, msc}
Hib-tu	'I feared'	{1, sg, msc/fm}
Hib-naa	'we feared'	{1, dl/pl, msc/fm}

The most problem of that conjugations is how to encode those four phenomenas of Arabic inflection?

Phonological harmony was the famous notion of traditional linguist of Arabic to break down the unique forms of "weak" verb [1,2]. The large number of phonological rules which utilize "if-then formulation" must be considered in this treatment. We figured out the various inconsistent rules. So, we found much exception for every single case of the word form. Another paradigm to answer that question was based on morphological analysis [3,4]. It did not consider the phonological elements which are always involved in the morphological process. So did Cavally-Sforza, Soudi, and Mitamura [5]. They presented morphological transformation

using MORPHE system to treat Arabic as a concatenative language, even though Arabic is a non-concatenative language. In this paper, we try to offer an integrated interplay approach that combine phonological, morphological, and syntactical aspects, for generating the inflective forms of Arabic hollow verb. To answer that problem, we elaborate four questions. Those are:

(a) how to account for the cases in (1) which stem zaar- blocks the occurrence of zawar-; while zur- blocks appearance of zaar-, given both zaar- and zur- represent the same pattern for the perfective stem and contain "w" in original verb?

(b) likewise also for (3), that is saar- blocks the presence of sayar-, meanwhile sir- blocks the occurrence of saar-, given both saar- and sir- represent the same pattern for the perfective stem and contain "y"?

(c) how to capture the change of stem naam- in the context of {3, msc} to become nim- in {2}, while the mid radical is "w", whereas "w" in Arabic is close to vowel "u", and the imperfective stem of a such verb is y-anaam-u not y-aniim-u?

(d) how to describe the change of stem haab- for {3, msc} to become hib- for {2}, while the imperfective stem of that verb is y-ahaab-u not y-ahiib-u?

We propose the optimality theory (OT) approach to account for the unified three interplay factors which significantly influence the morphological process of the Arabic perfective hollow verb stem; **they are root and pattern, phonological constraint, and imperfective stem**. The existence approach to those problems are either standard analysis of theoretical morphology [3,4], or phonological rules [1,2,6], or only address the morphological transformation [5].

The Optimality Theory (OT) will universally capture and analyze the complex problem of these cases, particularly Arabic is non-concatenative language, since it is based on the contraints which each language has. As non-concatenative language, Arabic has an exclusive way to form the word. It uses various patterns which are derivated from one root; while in the same time those patterns rely on affixation, and the affixation process is not sequential, as in non-flective languages.

OT does not work at multilevel analysis to solve the uncovered problem, as Mc Carty did in the autosegmental phonology; or phonological rules (arabian linguist said it ***i'lal***) from Hasan [1] and Al Afghoni [2]. The optimality theory approachs it using unified strategy which cover all contraints, either phonologics, morphologics, or syntactics elements. So, we simultaneuosly identify all constraints at phonology, morphology, and syntactics level. Then, we get the optimal one that violate the least constraint.

II. Arabic Hollow verb

A. *Mid Radical of Triliteral Consonantal*

Morphologically, Arabic is based on root and pattern framework for generating word [7]. As a non-concatenative language, root depicts a semantic abstraction featuring all senses of its derivative word. Too, pattern has an exclusive role to generate the inflective or derivative lexemes.

Arabic has two kinds of verb, based on the number of consonant that construct it. Those are quadriliteral verb and triliteral verb. There are 15 triliteral patterns, of which at least 9 are in common use, and 4 much rare quadriliteral patterns. Triliteral verb consists of two types, strong verb and weak verb. When the one of triliteral consonant of verb consitutes و and ي, we call it weak verb; conversely, if all triliteral consonant lack of و and ي, we call it strong verb. Below is the classification of Arabic verb based on the presence of و and ي.

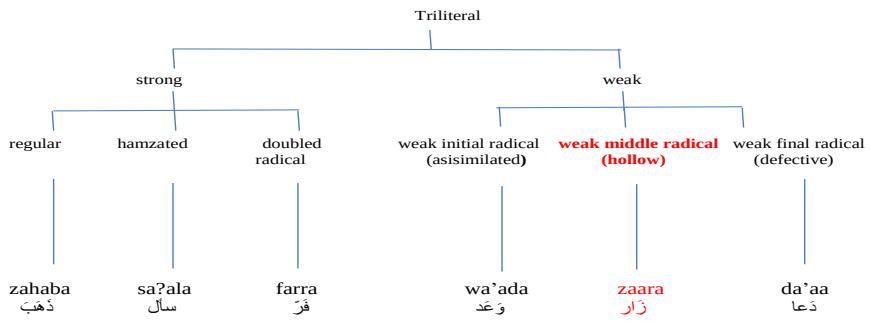

Fig. 1. The classification of Arabic verb based on the presence of و and ي.

B. *W in Mid Radical*

There are two types of verb in this category; which follow a-u pattern, and i-a pattern, as mentioned before at (1) and (2). a-u pattern means vowel in the middle syllable of perfective is a, while vowel in the middle syllable of imperfective is u (C1awaC3-a → ya-C1wuC2-u). i-a pattern means vowel in the middle syllable of perfective is i, while vowel in the middle syllable of imperfective is a (C1awiC3-a→ya-C1waC3-u). Both of them have the unique stem with special characteristics in the context of {3, msc} and {2}. It calls unique, since the stem does not show the triconsonantal root as ussual in arabic conjugation. The weak letter "w" in the second consonant or in the middle of radical never emerge in the most word of Arabic perfective. This situation requires particular treatment for generating inflectional verb in its conjugation, especially when forming verb in the environment of {3, msc} and {2}.

Verb with a-u pattern has two kind stems of perfective, those are **C1aaC3-** (e.g. zaar-a, qaal-a) for {3, msc}and

C1uC3- for {2} (e.g. zur-ta, qul-ta), while verb with i-a pattern has two kinds too. These are C1aaC3- for {3, msc} (e.g. naam-a, zaal-a) and C1iC3- for {2} (e.g. nim-ta, zil-ta).

zaar-a contains w in deep structure, and we know it from its imperfective yazuur-u. naam-a conceives w too, but we know it not from its imperfective, since the stem of its imperfective is yanaa-mu, not yanuum-u. Masdar which alert us to know that the mid radical of that verb is w. Al Afghoni said that when the vowel of w in the second syllable of perfective verb is i, it requires this i to be the stem of perfective verb in the context of {2} [2]. So, those are nim-ta and zil-ta, not nam-ta or zal-ta, following the stem of {3, msc} or not num-ta or zul-ta, since the mid radical is w, and it closes to the vowel u.

C. Y in Mid Radical

There is no different between w hollow verb and y hollow verb, only that w closes to the vowel u and y closes to vowel i. y hollow verb has two types pattern too, those are a-i pattern and i-a pattern with the same characteristics to w in mid radical. a-i pattern is symbol of mid radical perfective and imperfective, respectively. For example, saar-a → y-asiir-u, maal-a → y-amiil-u for {3, msc}. So is the i-a pattern that indicates the same criteria. Nevertheles, the stem of it's imperfective does not contain the vowel i in the surface form. It is haab-a → y-ahaab-u, not y-ahiib-u, while in the same time it conceives y in mid radical verb.

w and y do not appears in most perfective hollow verb. Typically, they will show their existemce in the imperfective stem or masdar. The stem of imperfective become the reference for the stem of perfective, particularly for {2}. For this case, the optimal output of Arabic conjugation does not refer to imperfective stem (for example y-ahaab-u), instead to the vowel of second original consonant in the perfective, that is i. Below are the examples.

naam-a has original consonants **n**a**w**i**m**-a (perfective)
y-anaam-u has original pattern y-a**nw**a**m**-u (imperfective)
nim-ta {2, sg, msc}

haab-a has original consonants **h**a**y**i**b**-a (perfective)
y-ahaab-u has original pattern y-a**hyab**-u (imperfective)
hib-ta {2, sg, msc}

The vowel i in nim-ta and hib-ta took from the second vowel of perfective, not from the stem of imperfective as usual in the most Arabic hollow verb conjugations.

III. Blocking and Extended morphological system with Optimality Theory

Following the blocking and extended morphological system [8-10], the problems which constitute inflectional system of Arabic perfective hollow verb can be explained using OT approach. OT provides a unified account of both blocking and extended exponence, with reference to three main factors, related to root and template pattern, phonological changes, and imperfective stem.

Blocking refers to a phenomenon in which a rule *bleeds* the application of another rule that expresses a similar or the same morphological value set to that expressed by the bleeding rule [11,12]). Meanwhile, extended morphological system refers to a phenomenon in which morphological feature value is realized by more than one exponence in the same pattern [13,9-10].

Within realization model of optimality theory, the optimal output of Arabic perfective hollow verb stem is able to be explained with fine-grain analysis. All constraints which derive from three main factors, relating to root and pattern, phonological harmony, and imperfective stem make the surface structure is optimal output.

Based on the explanation above, we find the contraints in relating to root and pattern, phonological rules, and the imperfective stem. **Firstly**, even though Arabic morphology refers to root and pattern, many forms do not depict the consonantal root and the regular pattern. The triliteral consonantal has three consonants, and they are always available in all derivative or inflective words. But, in this case, it does not apply. The surface structure of Arabic perfective hollow verb violates the root and the pattern

Perhaps, this phenomena is general and universal while all languages have it. But Arabic has an exclusive treatment to solve the triliteral consonantal which consist of weak letter, w and y. **Secondly**, as a consequence of number 1, there are several rules to raise the letters w and y. Those are (1) w and y are in the second sylable of verbal root; (2) they will emerge only in imperfective stem and masdar, in the context of a-u pattern and a-i pattern; (3) their existences are replaced by alif or lengthening the first vowel of verbal root in the perfective stem; (4) those letters can not become sylable which has nucleus. They are just able to be coda; and the most important think is that Arabic does not have complex coda.

Thirdly, the imperfective stem is referent to form the perfective stem in the context of {2}. Nevertheles, in i-a pattern of hollow verb, that rule can not be applied. Arabic has another rule for i-a pattern to conjugate the verb in the environtment of {2}. That is because of that Arabic never has C1aC3- pattern for hollow verb in the context of {2}. It relates to the two weak letters w and y which close to the vowel u and i, respectively.

We formalize the hierarchy of constraints depend on explanation above.

A1. C1vC2vC3-a >> a-u pattern >>*C1vWvC3-a >> w → alif (lengthening the first vowel)

A2. C1vC2vC3-t >> *C1vWvC3-a >> w/y → alif (lengthening the first vowel) >> Ipf stem vowel → Pf stem vowel (a-u and a-i pattern >> *cluster coda

B1. C1vC2vC3-a >> a-i pattern >> *C1vYvC3-a >> y → alif (lengthening the first vowel)

B2. C1vC2vC3-t >> *C1vWvC3-a >> y → alif (lengthening the first vowel) >> second vowel of verbal root → Pf stem vowel (i-a pattern) >> *cluster coda

Based on root and pattern, we can reveal several candidates which match both of them, for example for zaar-an and zur-ta as depicted in Table A1 and A2

The occurrence of zaar-a blocks the hidden one, that is zawar-a which is the deep structure. The stem zur-ta is

extended of zaar- a, since it indicates the same pattern of perfective stem. At strong verb, Arabic conjugation shows the same perfective stem although it meets the first, second, and third person suffixes, in the environment of singular, dual, and plural, feminines and masculines.

It is the fact that weak verb, exclusively the hollow verb, has a particular behaviour in its conjugation. The most influenced thinks is the existence of w and y in the middle radical verb. Moreover, the three interplay factors as mentioned before, play the great role to spell out the optimal output of perfective hollow verb stem.

A. W Hollow Verb

The input in this kind of verb is triliteral root consonantal, which consist of C1vWvC3-. The phonological rules of Arabic prohibit emerging w in perfective stem. Then it was replaced by alif as a symbol to lengthen the first vowel a. In addition, coda complex also has never been allowed in Arabic, particularly for *–uwC3- and *-iyC3-.

The sylable structure in Arabic always CV, CVC, or CVCC with certain conditions. Coda complex can apply in Arabic when the vowel is not close to w and y, e.g zawj, lawn dayn, rayb. Moreover, the *strong letters* always stronger than the weak letters (w and y); so, the two letters may not emerge as full consonant, instead of lengthening the vowel. The change flow of this verb is

Deep structure	Surface Structure
a. zawar-a	zaar-a {3, sg, msc} zur-t {2}

we compare to the strong verb below.

b. katab-a	katab-a {3, sg, msc} katab-t {2}

TABLE I. A1

a. zaar-a {pf, 3}	w → alif to lengthen vowel {v1:C3-}	*C1vWvC 3-a	a-u pattern	Pattern for {pf,3} /C1vC2vC3-a/
☞ zaar-a				*
zawar-a	*	*		
zawir-a	*	*	*	
zawur-a	*	*	*	

Table 1 A1 describes the optimal output for perfective stem of zaar- in the context of {3}. We have four potential candidates, which match the possible principles of Arabic, those are zaar-, zawar-, zawir-, and zawur-. In the same time, we found four items of constraint, relating to three factors (root and pattern, phonological rules, imperfective stem). The optimal output of this case is zaar-a, since it just violates the lowest constraint, that is pattern for {pf,3} /C1vC2vC3-a/. Meanwhile, the existence of a such form blocks other forms, three candidates. zaar- itself is extended form from the verbal root zawar-.

TABLE II. A2

a. zaar- {pf, 2}	*C1vWvC 3-t	If stem vowel → Pf stem vowel	*cluster of coda	w → lengthening vowel u {-v1:-}	Pattern for {pf,2} /C1vC2vC3-t/
☞ zur-t-				*	*
zuur-t			*		*
zaar-t		*	*		*
zawar-t	*	*		*	

Table 2 A2 shows that the best form for zaar- in the context of {2} is zur-. It is allomorph stem of zawar-, exclusively in the environment of {1, 2}. As allomorph, it represents the same pattern of perfective stem of hollow verb, although at distict context. zur- becomes the optimal one, as it violates two lower constraints which demonstrate the possibilities to be violated.

B. Y Hollow Verb

y hollow verb is triliteral consonantal which the middle consonant is y. as the weak verb, w and y hollow verb have the same characteristics, only the type of letter that make both of them different, particularly, for the vowel that located before them as nucleus in the sylable, -uw- and –iy-

Table 3 B1 shows that the optimal output for saar- in the context of {3, msc} is saar-a, since it just violates the lowest rank of constraint, that is perfective pattern C1aC2aC-a. The optimal output saar-a, in this case, blocked the original consonant which constitute that verb, sayar-a.

Table 4 B2 reveals several potential candidates to be the surface output, related to the phonological rules. But, the optimal output refers to sir-ta, since it violates only two lower constraints. sir-t is extended form of saar-, and in the same time it blocks the appearance of saar- with the special environment. sir-t become the best one, since it does not violate the phonological rules of y in the middle root consonantal, which is close to vowel i.

Below are the contrast of strong verb and weak verb, particularly y hollow verb in the conjugation

Deep structure	Surface Structure
a. sayar-a	saar-a {3, sg, msc} sir-t {2}
b. katab-a	katab-a {3, sg, msc} katab-t {2}

From that contrast, we can conclude that Arabic has regular pattern for perfective conjugation, that is C1aC2vC3-. That rule is violated in the context hollow verb. No matter for violance of this rule, because hollow verb has other special rules which not allowed to be violated, as mentioned for constraints in table 3.

TABLE III. B1

a. saar-a {pf, 3}	y → alif to lengthen vowel {v1:C3-}	*C1vYvC3 -a	a-i pattern	Pattern for {pf,3} /C1vC2v C3-a/
☞ saar-a				*
sayar-a	*	*		
sayir-a	*	*	*	
sayur-a	*	*	*	

TABLE IV. B2

a. saar- {pf, 2}	*C1vYv C3-t	Ipf stem vowel → Pf stem vowel	*clus ter of coda	y → lengtheni ng vowel i {-v1:-}	Pattern for {pf,2} /C1vC2v C3-t/
☞ sir-t-				*	*
siir-t			*		*
saar-t		*	*		*
sayar-t	*	*		*	

Table 5 C1 accounts for i-a pattern of w and y hollow verb.

We elaborate two examples.

	Deep S	surface pf	surface Ipf
a.	nawim-a	naam-a {3,msc} nim-t {2}	ya-naam-u
b.	hayib-a	haab-a {3,msc} hib-t {2}	ya-haab-u

The constraints of these two cases are not different from A2 and B2. However, we should add one more constraint, that is second vowel of triliteral consonantal verb, -i-, either at w hollow verb or y hollow verb which must be the vowel in the stem of perfective in the context of {2}. It possess the highest rank constraint, since it is not allowed to be violated. Based on this character, C1iC3- become the optimal one. Two other candidates do not match this rule, so they violate the highest ranks. It leads them no to be the choosen one in the optimal output.

TABLE V. C1

b. C1aaC 3-{pf, 2}	C1vW/YiC 3- (pf root) → C1iC3- {2}	The second vowel of pf → Pf stem vowel	*clus ter of coda	y/w → alif to lengthen the vowel {-v1:-}	Pattern for {pf,2} /C1vC2vC 3-t/
☞ C1iC3-t-				*	*
C1aC3-t	*	*		*	*
C1uC3-t	*	*		*	*
C1aaC3-t			*		

IV. Conclusion

The Arabic hollow verb has two perfective stems, those are C1v:C3- (for example: zaar- and saar-) and C1u/iC3- (for example: zur- dan sir-) based on person, gender, and number. This paper investigated the Arabic phonological, morphological, and syntactical rules which contribute to analysis of **inflectional process**, in particular at conjugation of Arabic hollow verb, using OT approach.

The analysis found 6 rules which become the violable contraints to generate the optimal form of three phenomenas (Table A, B, C); those are (1) original pattern of regular triliteral verb (strong verb), that consist of C1vC2vC3- for {3} and C1vC2vC3-t for {2,1}; (2) The middle radicals of hollow verb (w and y) are not allowed to emerge in the perfective stem, (3) alif is instead of them in the environment of {3}; (4) the stem of imperfective become the stem of perfective with the context of {2, 1}; (5) Arabic has no coda cluster, and (6) the second vowel of perfective {3} become the stem vowel of {2} perfective, in the i-a pattern (Table C).

The lowest ranks of constraints hierarchy are number (1) and (2) which allow to be violated, while the highest one is prohibition to arise the weak consonant (w and y) in the perfective form, which must not be violated. The Table above explained generating of various forms of three phenomenas in Arabic hollow verb. The picture of the hand pointing is the optimal one which violate the lower and lowest rank of constraints.

This paper accounted for morphological process of Arabic hollow verb, notably the inflectional morphology. But, there remains the questions of how to formalize the derivational morphology of Arabic hollow verb, which has a lot of various form and pattern.

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