

# Pivot-based Multilingual Dictionary Model For Under-Resourced Languages

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## Abstract

Electronic multilingual dictionary is a linguistic resource highly sought after by most natural language processing applications. The construction of such dictionary is a difficult task for under-resourced languages, which generally lack even bilingual dictionaries. This is the case of Moroccan Amazigh language. In this paper, we describe our approach of building automatically a multilingual dictionary for this language via the pivot Universal Networking Language (UNL). The dictionary is based on universal concepts, called universal words in the UNL jargon. The idea consists on merging many bilingual dictionaries for constructing a multilingual dictionary that looks like a matrix, allowing the map between a given word from a language, corresponding to an universal word, to another word from another language corresponding to the same universal word. The advantage of this approach is to build a multilingual dictionary between  $n$  languages, even if no bilingual dictionaries exist between them. Presently, the multilingual dictionary is being implemented for the five most used languages in Morocco: Arabic and Amazigh, which are the first and official languages; French, which is used as the second language; Spanish that is used particularly by the population residing in the northern region of the country; and English that is becoming more and more popular in Morocco's education, business, and science sectors.

**Keywords:** Amazigh language, Universal Networking Language, Universal Word, Inflectional paradigms.

## INTRODUCTION

Amazigh language or Tamazight, more frequently known as Berber, belongs to the Afro-Asiatic language (Hamito-Semitic) family. It is the autochthon language of North Africa [1]-[2]. Currently, it is one of the official languages of Morocco along with Arabic. Nevertheless, it has been marginalized for many years until the creation of the Royal Institute of Amazigh Culture (IRCAM), in 2003. Since this date, Amazigh has been introduced in the Moroccan educational system and public administrations. In order to ensure its survival and its position in the information society, the computerization of Amazigh is

primordial. To achieve this end, a number of strategies have been undertaken, as the encoding of Amazigh characters in the Unicode standard [3]; the development of some tools, such as a search engine [4], a concordancer [5], transliterators [6]-[7]-[8], and a conjugator [9]. This list of undertaken works is not exhaustive, there are many other contributions as on the Amazigh Technology OCR [10]-[11], and on Amazigh speech recognition [12]. In this paper, we present our contribution to this language, which constitutes the first attempt of building an electronic multilingual dictionary. To achieve this goal, we have created the bilingual UNL-Amazigh dictionary, and formalized the inflectional paradigms for verbs, nouns and adjectives. However, like most non-European languages, Amazigh still suffers from the lack of automatic language processing resources. Thus, we have faced the challenge to develop from scratch inflectional paradigm for some lexical categories, namely noun and adjectives.

The roadmap for the rest of the paper will proceed as follows: Section 2 gives an overview of the UNL language. Section 3 presents the structure of a Natural Language (NL) dictionary in the UNL specifications. Section 4 describes the Amazigh inflectional paradigms found as a result of the morphological analysis. Section 5 details the lexical mapping stage, between Amazigh words and Universal Words (UWs), also it discusses the most challenges faced during this stage. Section 6 reports the design and the implementation of the multilingual dictionary application. Finally, Section 7 concludes and presents potential future research directions.

## OVERVIEW OF THE UNL LANGUAGE

The Universal Networking Language (UNL) is a computing language developed by the Institute of Advanced Studies of the United Nations University, in Tokyo, Japan, in 1996.

Since 2001, the development and the management of UNL became in charge of the UNL Digital Language (UNDL) foundation that is a nonprofit organization based in Geneva, Switzerland [13]-[14].

The UNL expresses the meaning conveyed by a Natural Language (NL) sentence as a hypergraph consisting of nodes

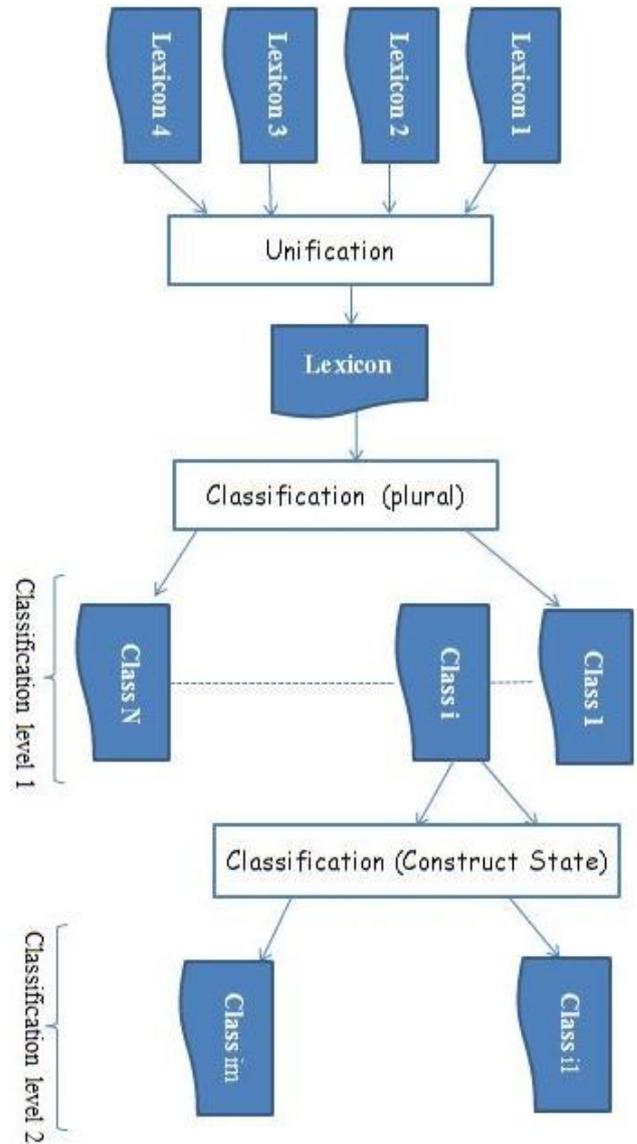


- Amazigh nouns vary in gender (female/male), number (singular/plural) and state (free/construct).
- Amazigh verbs can be either simple (radical) or derived. The simple verb is composed of a root and a pattern. The root is a sequence of one or many consonants, while the pattern is a template of vowels (V) and consonants (C) [17]. Whereas, the derived form is based on the concatenation of a simple verb and one of the following prefixed morphemes: ‘ⵓ’ [s] / ‘ⵓⵓ’ [ss], ‘ⵜⵜ’ [tt], or ‘ⵎ’ [m]/ ‘ⵎⵎ’ [mm] to give respectively the factitive (causative) form, the passive form, and the reciprocal form. Whether the verb is simple or derived, it inflects in three moods: indicative (IND), imperative (IMP) and participial (PTP). In each mood, the same person markers are used in four aspects: aorist (AOR), perfective (PFV), negative perfective (NEG&PFV) and imperfective (NPFV) that are marked with vocalic alternations, prefixation or consonant gemination/ degimination.
- Two types of Amazigh adjectives are distinguished:
  - Type 1: The adjectives that are in the same time nouns as ⵏⵓⵔⵓⵙⵓⵏ [abkkuch] ‘mute’. They inflect in gender (Masculine/ Feminine), number (Singular / Plural) and state (Free / Construct).
  - Type 2: The adjectives that are only adjectives as ⵏⵓⵎⵓⵏⵓⵏ [amaduf] ‘delicious’. They inflect only in gender (Masculine/Feminine), and number (Singular/Plural).

**Formalization of nominal and adjectival inflectional paradigms**

The construction of the inflectional paradigms of the nominal and adjectival categories has presented, for us, a real challenge, due to the lack of references addressing the classification of Amazigh words vis-a-vis to their inflections and to the presence of several unpredictable plural and construct state forms. Our approach, to formalize the inflectional paradigms, consisted in collecting the Amazigh lemmas, grouping them into classes in such a way each class includes lemmas having the same behavior to construct the plural form, feminine and the construct state forms. To this end, we have based our research on a deep analysis of Amazigh word forms from four lexicons [18]-[19]-[20]-[21] to gather, in a first level, lemmas having the same plural forms, in the same class; then, in a second level, we created subclasses for each class to include lemmas having the same inflectional schema<sup>2</sup>. Proceeding in this way, we were able to identify 100 nominal classes and 19 adjectival classes [22]. The evaluation of the coverage of these proposed classes is presented in (see Section 4.3).

<sup>2</sup> Inflectional schema is a template used to create inflectional paradigms. It describes the different forms that a word may assume in a given language



**Figure: 3** Amazigh inflectional classes building approach for nouns and adjectives

Our methodology of classification did not proceed to pattern’s concept, because there are, in the Amazigh language, nouns having the same pattern but they take different plural marks, and there are ones which have different patterns however they share the same plural marks. As shown in Table 2, even if the noun ⵏⵓⵔⵓⵙⵓⵏ [abagus] ‘belt’ and ⵏⵓⵎⵓⵏⵓⵏ [abatul] ‘flat ground’ share the same scheme ⵏⵓⵎⵓⵏⵓⵏ [aCaCuC], they take different plural marks. While, the plural forms of the word ⵏⵓⵎⵓⵏⵓⵏ [adlis] ‘book’, having the pattern ⵏⵓⵎⵓⵏⵓⵏ [aCCiC], and the word ⵏⵓⵔⵓⵙⵓⵏ [abagus], having the pattern ⵏⵓⵎⵓⵏⵓⵏ [aCaCuC] which is different from that of ⵏⵓⵎⵓⵏⵓⵏ, are formed in the same manner .

**Table 2.** Examples of plural forms

Noun	Pattern	Plural form
ⵔⵉⵎⵓⵔ [abagus]	ⵔⵉⵎⵓⵔⵏ	ⵔⵉⵎⵓⵔⵏ [ibagusn]
ⵔⵉⵎⵓⵔⵏ [abatul]	ⵔⵉⵎⵓⵔⵏ	ⵔⵉⵎⵓⵔⵏ [ibutal]
ⵔⵉⵎⵓⵔⵏ [adlis]	ⵔⵉⵎⵓⵔⵏ	ⵔⵉⵎⵓⵔⵏ [idlisn]

After formalizing the potential inflectional nominal and adjectival classes of the Amazigh, we have developed the appropriate inflectional rules for each class to generate all the inflected forms.

**Formalization of verbal inflectional paradigms**

The construction of the inflectional paradigms of the verbal category is based on the classification proposed by [17]. This classification consisted on dividing verbs into thirty conjugation classes, according to the morphotactic rules forming the perfective and imperfective aspects. However, our classification approach aims to bring out, from each class among the thirty ones, new sub-classes that take into consideration the morpho-phonotactic rules forming the negative perfective and imperfective aspects. Thus, each sub-class will include only verbs having the same inflectional rules to generate all conjugated forms.

To generate the inflected forms out of the lemma. We have led to express, first, morphotactic rules to get aspectual stem, followed by morphotactic rules related to the personal markers' level. At this level, the morphotactic rules are determined by mood (indicative (IND), imperative (IMP), participial (PTP)), gender (masculine (MCL), feminine (FEM)), number (singular, plural), and person (first, second, third). Then expressing morphophonological alternations. All these inflection rules are combined to generate the desired inflections in a linear manner, one after the others. Table 4 below outlines an extract of the inflectional paradigm created for the class 17-1.

**Table 4.** Inflectional rules for generating the imperfective forms (NPFV) in the indicative mood (IND)

Classes	Inflectional rules	Inflected words
Class 17-1 "ⵔⵉⵎⵓⵔ" [bdd] 'To get	1PS&NPFV&IND:="++"<0,0>"ⵔ", "ⵔ"<0,0>"ⵔ";	++ⵔⵉⵎⵓⵔⵏ [ttbddagh]
	2PS&NPFV&IND:="++"<0,0>"ⵔ", "ⵔ"<0,0>"ⵔ", "++": "ⵔⵉⵎⵓⵔ";	ⵔⵉⵎⵓⵔⵏⵏ [ttbddad]
	3PS&MCL&NPFV&IND :="++"<0,0>"ⵔ", "ⵔ"<0,0>"ⵔ";	ⵔⵉⵎⵓⵔⵏ [ittbdda]

up'	3PS&FEM&NPFV&IND:="++"<0,0>"ⵔ", "ⵔ"<0,0>"ⵔ";	ⵔⵉⵎⵓⵔⵏⵏ [ttbdda]
	1PP&NPFV&IND:="++"<0,0>"ⵔ", "ⵔ"<0,0>"ⵔ";	ⵔⵉⵎⵓⵔⵏ [nttbdad]
	2PP&MCL&NPFV&IND :="++"<0,0>"ⵔ", "ⵔ"<0,0>"ⵔ", "++": "ⵔⵉⵎⵓⵔ";	ⵔⵉⵎⵓⵔⵏⵏ [ttbddam]
	2PP&FEM&NPFV&IND :="++"<0,0>"ⵔ", "ⵔ"<0,0>"ⵔ", "++": "ⵔⵉⵎⵓⵔ";	ⵔⵉⵎⵓⵔⵏⵏ [ttbddamt]
	3PP&MCL&NPFV&IND :="++"<0,0>"ⵔ", "ⵔ"<0,0>"ⵔ";	++ⵔⵉⵎⵓⵔⵏ [ttbddan]
	3PP&FEM&NPFV&IND :="++"<0,0>"ⵔ", "ⵔ"<0,0>"ⵔ";	++ⵔⵉⵎⵓⵔⵏⵏ [ttbddant]

Legend:

- "X"<0: prefixation of the letter X at the beginning of the lemma
- 0>"X": suffixation of the letter X at the end of the lemma
- "X": "Y": Replacement of the string X by Y
- 1PS: first person of singular; 2PS: second person of singular; 3PS: third person of singular; 1PP: first person of plural; 2PP: second person of plural; 3PP: third person of plural

According to the UNL Specifications, we have achieved to implement 67 inflectional classes for the verbal category. The evaluation of the coverage of these proposed classes is presented in (see Section 4.3). In Amazigh, a verb may belong to more than one class following the meaning that is carried by this verb, and also following the Amazigh regional varieties.

**Evaluation of the formalized inflectional classes**

After describing our methodology, in Section 4.1 and Section 4.2, to formalize inflectional classes for Amazigh nouns, adjectives and verbs, in this section, we would like to evaluate the coverage of these classes. Known that our study, that has been undertaken based on 8728 lemmas that were extracted from five dictionaries [17]-[18]-[19]-[20]-[21], was led to construct the dictionary "D1". We have looked for new lemmas that do not belong to "D1", and tried to apply on them the formalized paradigms. Thus, we have extracted new nouns, adjectives and verbs from a recent and large dictionary of 14 693 lemmas "D2" [23]. Table 3 shows the coverage rate of our classes for each grammatical category.

**Table 3.** Coverage evaluation of the formalized morphological classes

	Nouns	Verbs	Adjectives (type 2)
Lemmas belonging to “D2” and not to “D1”	4 803	1 645	618
Uncovered lemmas	201	160	9
<b>Coverage (%)</b>	<b>96%</b>	<b>91%</b>	<b>99%</b>

As illustrated in Table 3, the results obtained for the noun category are satisfying. The rate of covered lemmas of this category has achieved 96%. The analysis of the 4% remaining uncovered has shown that these lemmas are even loanwords or irregular nouns having unpredictable plural forms such as the noun ⵏⵓⵢⵉ [iwi] ‘my son’, that has the plural ⵜⵓⵏⵓⵢⵉ [tarwa] and the word ⵜⵓⵏⵓⵢⵉ [ssuq] ‘market’, which is borrowed from Arabic and has the following unpredictable plural form ⵏⵓⵏⵓⵢⵉ [laswaq] ‘markets’. For the verb category, the rate of covered lemmas is 91%. The 9%, which remains unrecovered, are irregular verbs or those used, generally, in one aspect, for example the verb ⵜⵓⵏⵓⵢⵉ [skuhhu] “cough” is always used in the imperfective aspect. For adjectives, as shown in Table 3, are well covered, the 1% which remains uncovered are irregular adjectives taking unpredictable plural marks such as ⵏⵓⵏⵓⵢⵉ [inibi] ‘violet’, that has the following plural form ⵏⵓⵏⵓⵢⵉ [inaban].

We expect to improve the coverage rate found, namely for the case of verbs, by formalizing new inflectional classes, to take into account the morphological variation of uncovered “D2” entries.

### MAPPING AMAZIGH LEMMAS WITH THE ADEQUATE UWS

Each entry is associated manually to the identifier of the UW that is the concept carrying the meaning of the Amazigh entry. UWs are divided into four major classes: verbal concept, nominal concept, adjectival and adverbial concepts [24].

#### General steps of lexical mapping stage

We performed the lexical mapping between Amazigh headwords and their equivalent UWs by following these steps:

- Identification of the word sense (concept) of the headword.

- Matching the word sense of the natural language with the appropriate UW.

Creation of new UWs for concepts that could not be matched exactly. We talk about extra UWs, when there is no word that can be suited to convey the intended meaning as in the case of culture-dependent concepts. In this situation, foreign words transliterated in English may be used to label the headword of a UW.

#### Challenges of mapping stage

In the attempt of mapping Amazigh words with the UWs, many challenges have appeared. The UWs are classified into different parts of speech according to the English language, however, their Amazigh counterparts does not always belong to the same part of speech. For example, the word ⵏⵓⵢⵉ [bu], which is classified as a determinant, corresponds to the English word ‘owner’ which is classified as a noun. Therefore, we could not find any UW to correspond to the word ⵏⵓⵢⵉ [bu]. Another issue faced is missing of adequate UWs. In fact, some Amazigh words do not have their equivalents in UNL to express their exact meanings. For example the Amazigh word ⵏⵓⵏⵓⵢⵉ [amzrzr], which means the white horse, the word ⵏⵓⵏⵓⵢⵉ [ahidous], which is the name of an Amazigh dance, etc. In this case, where there is no word that can be suited to convey the intended meaning, we created new UWs for these concepts.

Once the inflection paradigms are created and the mapping of Amazigh lemmas are done, the analysis dictionary that brings all Amazigh inflected forms could be generated thanks to the automata theory. Currently, we achieved to feed our UNL-Amazigh dictionary by 8728 lemmas.

### IMPLEMENTATION OF THE AMAZIGH MULTILINGUAL DICTIONARY

In this section, we report our methodology of building multilingual bidirectional dictionary for n languages before presenting the implementation for the case of five languages: Amazigh, Arabic, English, French, and Spanish

#### Design: the methodology proposed

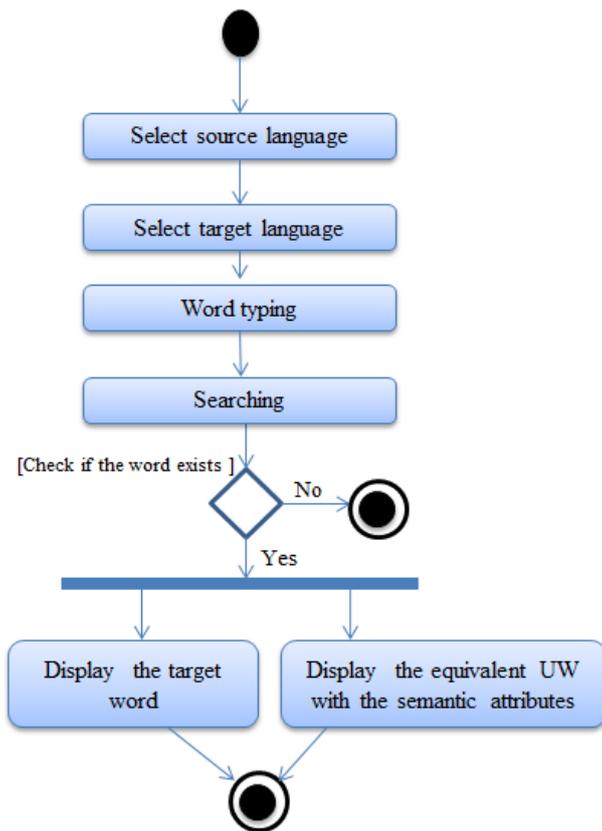
Our methodology for developing a multilingual dictionary for n languages consists on merging n bilingual dictionaries: L<sub>1</sub>-UNL dictionary, L<sub>2</sub>-UNL dictionary, and L<sub>n</sub>-UNL dictionary by creating a matrix a<sub>ij</sub> where i is the number of UWs (rows) and j is the number of languages (columns). As depicted in Table 5, it is associated to each UW, morpho-syntactic features and eventually semantic features.

**Table 5.** Proposed multilingual dictionary structure

UWs	UW description	Amazigh	Arabic	English	French	Spanish
crippled(aoj>thing); ; LEX=J	“disabled in the feet or legs (crippled, halt, halting, lame, gimp, game).”  <ul style="list-style-type: none"> <li>The lexical category (LEX) is adjective (J)</li> </ul>	ⵏⵉⵣⵓⵏ [ahizun], ⵏⵓⵊⵔⵓⵏ [arjda], ⵏⵓⵎⵓⵎⵓⵏ [amuchal], ⵏⵉⵃⵉⵔ [ahidar]	أعرج [aaraj], أكسح [akssah]	lame	Mutilé	Cojo Lisiado
child(icl>person); LEX=N, ABN=CC T, ALY=ALI, ANI=ANM, CAR=CTB, SEM=HUM	“an immature childish person (child, baby).”  <ul style="list-style-type: none"> <li>The lexical category (LEX) is noun (N).</li> <li>The abstractness (ABN) is concrete (CCT).</li> <li>The alienability (ALY) is alienable (ALI).</li> <li>The animacy (ANI) is animate (ANM)</li> <li>The cardinality (CAR) is countable (CTB)</li> <li>The semantic class (SEM) is person (HUM)</li> </ul>	ⵉⵊⵊⵊⵊ [ijiji], ⵏⵉⵃⵉⵔⵓⵏ [ahziz], ⵏⵉⵎⵓⵎⵓⵏ [ahram], ⵏⵉⵎⵓⵎⵓⵏ [ahrmouch]	طفل [tifl]	child	enfant	niño

**Implementation**

The proposed multilingual bidirectional dictionary application is called AMuD (Amazigh Multilingual Dictionary). It has a very simple and intuitive interface. The activity diagram of AMuD is shown in Figure 5.



**Figure 4:** Activity diagram of the AMuD application

The development of AMuD dictionary is based on six dictionaries:

- the UNL-Amazigh dictionary, which we have elaborated, in the previous sections, its size is about of 8728 entries;
- the UNL-French dictionary, which we have participated in its feeding with the UNDL Foundation with 4050 entries. Its size is about of 140 000 entries;
- the UNL dictionary, provided by the UNDL Foundation, its size is about of 107 548 entries;
- the UNL-English dictionary, provided by the UNDL Foundation, its size is about of 130 000 entries;
- the UNL-Arabic dictionary, provided by the UNDL Foundation, its size is about of 144 449 entries;

- the UNL-Spanish dictionary, provided by the UNDL Foundation, its size is about of 73 653 entries;

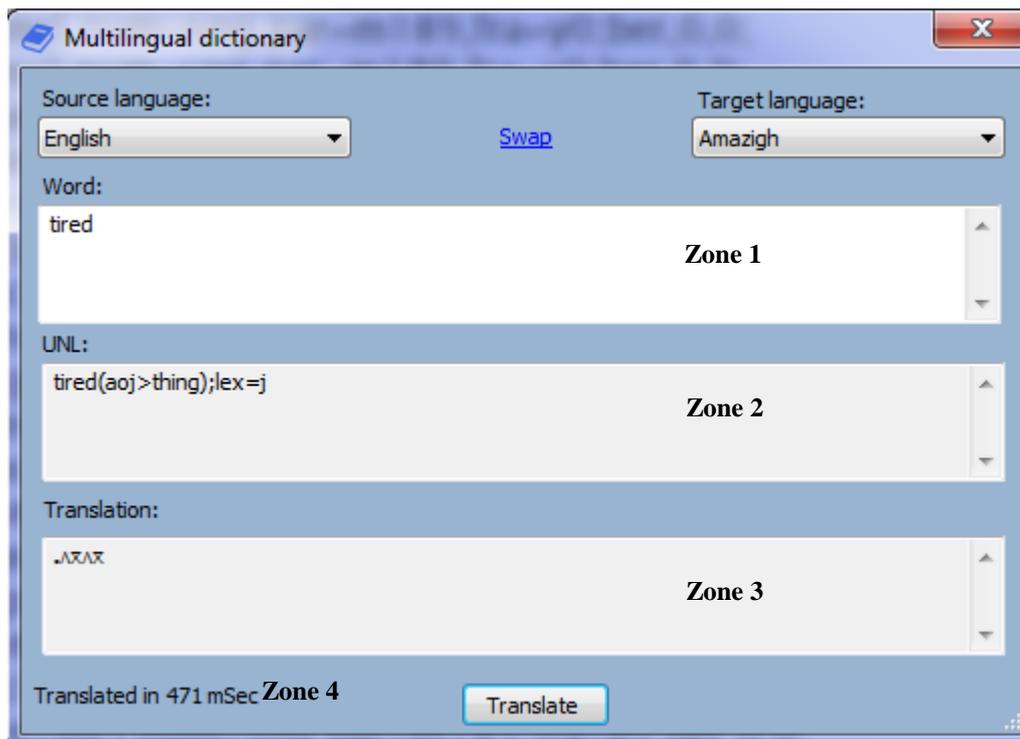
AMUD consists of two combo boxes to choose the source language and the target one from the list {Amazigh, Arabic, English, French, and Spanish}, four zones, and a translation button (Figure 5).

Figure 5 is a screenshot that shows an example of translation from English language to Amazigh Language. Each zone, in the figure, is dedicated to specific information:

- **Zone 1:** After having chosen the source and the target languages, the user typed the English word ‘tired’ to translate it into Amazigh. The user can search the words either in lowercase, uppercase, or mix both lowercase and uppercase.
- **Zone 2:** The system displayed the UW, corresponding to the English word typed, that is *tired* (aoj>thing). The UW is accompanied with its lexical category (Lex=J)
- **Zone 3:** The system displays the Amazigh translation ⵓⴰⴽⴰⴳ [adgdg] of the English word ‘tired’.
- **Zone 4:** The delay time of the system to look-up for a word. We added this information just to give an idea, to readers, on the performance of the look-up operation.

Regarding tools and the environment of development used in developing AMuD application, we have chosen to work

with the database engine SQLite because it is an embedded, open-source, and highly compact, given the big size of our dictionaries. Concerning the Graphical User Interface (GUI), we used C# language with Visual Studio.



**Figure 5:** Screenshot of AMuD application

## CONCLUSION

In this paper, we have proposed a methodology for building a multilingual dictionary for under-resourced languages, which generally lacks even bilingual dictionaries. We have, in particular, worked on Amazigh language as a case of study.

We have dealt with five languages that are Amazigh, Arabic, English, French, and Spanish. However, we can easily integrate new languages into the dictionary AMuD. In fact, there are more than 17 languages having their dictionaries available following the UNL specifications as Russian, Armenian, Panjabi, Hindi, etc. So, we could very well translate words from all these languages to Amazigh and vice versa. In addition to adding more languages, we will also consider to enrich and feed the Amazigh-UNL dictionary with new entries.

## REFERENCES

- [1] Kirsty, R., 2006, "Meroitic – an Afroasiatic language?", *SOAS Working Papers in Linguistics*, 14, pp.169-206.
- [2] Hachid M., 2000 "Les premiers berbères", *Entre Méditerranée*, Tassili et Nili. Aix-en-Provence-Alger : Edisud-Ina-Yas,
- [3] Zenkouar, L., 2004, "L'écriture amazighe tifinaghe et unicode", *Etudes et Documents Berbères*, MSH Paris Nord, 22, pp. 175-173
- [4] Ataa Allah, F., and Boulaknadel, S., 2010, "Amazigh Search Engine: Tifinaghe Character Based Approach". In *Proceeding of International Conference on Information and Knowledge Engineering*, pp. 255
- [5] Ataa Allah, F. and Boulaknadel, S., 2010, "Online Amazigh Concordancer". In *Proceedings of International Symposium on Image Video Communications and Mobile Networks*. Rabat, Maroc, pp. 1-4
- [6] Ataa Allah, F. and Boulaknadel, S., 2011, "Convertisseur pour la langue amazighe : script arabe - latin – tifinaghe". 2<sup>nd</sup> *Symposium International sur le Traitement Automatique de la Culture Amazighe*, SITACAM, Agadir, Morocco, pp. 15-23
- [7] Ataa Allah, F. and Frain, J., 2013, "Amazigh Converter based on WordprocessingML". In *Proceedings of the 6<sup>th</sup> Language & Technology Conference*, LTC, Poznan, Poland.
- [8] Yakoubi, N., Frain, J., Ataa Allah, F., 2016, "Convertisseur numérique : Tifinaghe - Braille". 7<sup>th</sup> *international conference TICAM*, Rabat, Morocco.
- [9] Ataa Allah, F., and Boulaknadel S., 2014. "Amazigh verb conjugator". In *Proceeding of the 9th International Conference on Language Resources and Evaluation*, Reykjavik, Iceland, pp.1051–1055

- [10] Aharrane, N., El Moutaouakil K., Satori, K., 2015, "Recognition of handwritten Amazigh characters based on zoning methods and MLP", WSEAS Transactions on Computers, 14, pp.178-185
- [11] El Gajoui, K., Ataa Allah, F., Oumsis, M., 2015, "Diacritical Language OCR Based on Neural Network: Case of Amazigh Language", Procedia Computer Science, 73, pp. 298–305
- [12] Satori, H. and Elhaoussi, F., 2014, "Investigation Amazigh speech recognition using CMU tools", International Journal of Speech Technology- Springer Journals. 17 (3), pp. 235.
- [13] Uchida, H., Meiying, Z., Tarcisio, D. S., 1999, "The UNL, a gift for a millennium", Institute of Advanced Studies, the United Nations University.
- [14] Teixeira Martins, R., Maria das Graças V., 2005, "On the aboutness of UNL", Universal Network Language: Advances in Theory and Applications. Instituto Politécnico Nacional Centro de Investigación en Computación, Mexico, pp. 51–63.
- [15] Martins, R., and Vahan A., 2009, "Generative and enumerative lexicons in the UNL framework", In Proceeding of the Seventh International Conference on Computer Science and Information Technologies, Yerevan, Armenia, pp. 756
- [16] Boukhris, F., Boumalk, A., El Moujahid, E., Souifi, H., 2008, "La nouvelle grammaire de l'amazighe", IRCAM, Rabat, Morocco.
- [17] Laabdelaoui, R., Boumalk, A., Iazzi, M., Souifi, H., Ansar K., 2012, "Manuel de conjugaison de l'Amazighe". IRCAM, Rabat, Morocco.
- [18] Agnaou, F., Bouzandag, A., El Baghdadi, M., El Gholb, H., Khalafi, A., Ouqua, K. Sghir, M., 2011, "Lexique scolaire", IRCAM, Rabat, Morocco.
- [19] Ameer, M., Bouhjar, A., Boumalk, A., Naït-Zerrad, K., 2009, "Amawal n tjrrumt - Vocabulaire grammatical" IRCAM, Rabat, Morocco.
- [20] Ameer, M., Bouhjar, A., Boumalk, A., El Azrak, N., Laabdelaoui, R., 2009, "Vocabulaire des médias (Français-Amazighe-Anglais-Arabe)", IRCAM, Rabat, Morocco.
- [21] El Azrak, N., 2009, "معجم اللغة الأمازيغية", IRCAM, Rabat, Morocco.
- [22] Taghbalout, I., Ataa Allah, F., El Marraki, M., 2015, "Amazigh representation in the UNL framework: Resource implementation", Procedia Computer Science, 73, pp. 234–241.
- [23] Ameer, M., Ansar, K., Boumalek, A., El Azrak, N., Laabdelaoui, R., Souifi, H., 2017, "Dictionnaire générale de la langue amazighe". IRCAM, Rabat, Morocco
- [24] Uchida, H., Zhu, M., 2001, "The Universal Networking Language beyond machine translation", UNDL Foundation.