

## Self Syntactico-Semantic Enrichment of LMF Normalized Dictionaries

**Elleuch Imen**  
 MIRACL Laboratory  
 B.P. 1088  
 3018 Sfax, Tunisia  
 imen.elleuch  
 @fsegs.rnu.tn

**Gargouri Bilel**  
 MIRACL Laboratory  
 B.P. 1088  
 3018 Sfax, Tunisia  
 bilel.gargouri  
 @fsegs.rnu.tn

**Ben Hamadou Abdelmajid**  
 MIRACL Laboratory  
 B.P. 242  
 3021 Sakiet-Ezzit Sfax, Tunisia  
 abdelmajid.benhamadou  
 @isimsf.rnu.tn

### Abstract

The main challenge of this paper is the syntactico-semantic enrichment of LMF normalized dictionaries. To meet this challenge, we propose an approach based on the content of these dictionaries, namely the “Context” fields and the syntactic and semantic knowledge. The proposed approach is composed of three phases. The first one deals with the data set concerning the syntactic arguments of the “Context” fields. The second consists in connect semantic arguments to the syntactic ones. The last phase links syntactic and semantic arguments. In order to evaluate the proposed approach, we have applied it to an available Arabic normalized dictionary. The results are encouraging with respect to the measurement evaluation.

### 1 Introduction

Natural Language Processing (NLP) tasks require reliable linguistic resources such as lexicons. The latter represent lexical resources that should define for each lemma a highly valuable knowledge such as morphological features, syntactic behaviors and semantic knowledge like meanings, contexts, semantic classes and thematic roles. The availability of such knowledge favors the efficiency of NLP tools. For example, (Briscoe and Carroll, 2002) estimate that about half of the errors of parsers are based on the insufficient amount of knowledge concerning the syntactic argument structure in the used lexicons; on the other hand, (Carroll and Fang, 2004) show that the use of syntactic lexicons by a syntactic parser improves

its performance. Furthermore, the lexicon is the core component for machine translation and information extraction (Surdeanu et al., 2011). Unfortunately, we find that the lexicons that combine syntactic and semantic knowledge (i.e., representing semantic predicates) are shallow for some languages and unavailable for many others. Among the first lexicons dealing with the syntactico-semantic knowledge, we note the framework of (Gross, 1975), which was a revelation in this field. However, the enrichment of the proposed structure and even that of the lexicons proposed thereafter was such a hard task that it could not be accomplished due to the varied and abundant knowledge to be represented and requiring a high linguistic expertise. Thus, this enrichment task is an expensive and time-consuming process. Some other researchers like (Medelyan et al., 2013) have proposed to enrich such lexicons automatically using statistical methods. Nevertheless, the obtained content of such lexicons lacks reliability compared to the expert enrichment work.

We feel that the enrichment issue of syntactico-semantic lexicons cannot be dealt with independently of their models. In this context, the International Organization of Standardization (ISO) has published the LMF-ISO 24613 (Lexical Markup Framework) standard (Francopoulo and George, 2008). LMF provides a unified model for constructing lexical resources covering all linguistic levels and dealing with the majority of languages. It offers a finely-structured model including the syntactico-semantic part. Many compliant lexicons to the LMF standard have been developed such as Wordnet-LMF (Henrich and Hinrichs, 2010), LG-LMF (Laporte and Matthieu-

Constant, 2013) and the El-Madar Arabic dictionary (Khemakhem et al., 2013).

Considering the richness and the fine structure of LMF lexicons, we propose in this paper an automatic approach for enriching LMF lexicons with syntactico-semantic links. This approach uses the available syntactic and semantic knowledge (already enriched) and operates the “Context” fields that explain each meaning with reference sentences. The proposed approach was experimented on an available Arabic dictionary named El-Madar (Khemakhem et al., 2013). This dictionary offered us a good framework for experimentation because it covers, among others, syntactic, semantic and syntactico-semantic levels. The content of this dictionary has been enriched regarding syntactic behaviors (Elleuch et al., 2015). Also, it contains the semantic classes of each meaning of a given lexical entry (Elleuch et al., 2014).

The remainder of this paper is devoted primarily to the presentation of some related works. Secondly, the proposed approach to enrich LMF normalized dictionaries with syntactico-semantic links is detailed. Then, the experimentation carried out on an available Arabic normalized dictionary is described and the obtained results are commented upon. Finally, some future works and perspectives are announced in the conclusion.

## 2 Related Works

Several lexical resources combining syntactic and semantic knowledge for numerous languages have been developed. In this section, we provide an overview of such lexical resources for the French, English and Arabic languages.

Regarding the French language, we quote the Lexicon-Grammar ((Gross, 1975), (Tolone, 2011)) that includes empirical knowledge that is quite extensive and detailed on the syntax and the semantics of verbs, nouns, adjectives and adverbs represented as tables. Each table represents a class which includes lexical items sharing some syntactic and semantic properties. This resource suffers from some gaps. Indeed, common properties of verbs are not encoded in the same tables but only described in the literature. In addition, this resource cannot be directly used in NLP applications due to its complex structure. Another lexicon for the French language is the

Lefff (Lexicon of French inflected forms) (Sagot, 2010), which is widely-used and freely available. This lexicon is based on the Alexina (Architecture pour les LEXiques INformatiques et leur Acquisition) model. Thanks to this framework, Lefff can be directly used in NLP applications. However, this lexicon needs to be improved regarding its precision and its coverage.

Concerning the English language, we can mention VerbNet (Kipper et al., 2008), which is a lexical resource organizing verbs into classes based on the Levin (1993) verbal classification. Each class is described by thematic roles, semantic restrictions on the arguments, and frames consisting of a syntactic description and semantic predicates. This resource doesn't use any standard for its implementation. Moreover, certain verb uses are not covered by frames; besides, syntactic restrictions are not well-defined and difficult to operate. FrameNet (Baker et al., 2010) is another resource for English. It is based on semantic frames and confirmed by attestations in the corpus. It aims to document the syntactic and semantic combinatorial for each lexical entry through a manual annotation of examples selected from the corpus. Nonetheless, the main limitation of this resource is its poor coverage. Indeed, the lexical units are described only with a lexicographic definition, without any example sentences.

As regards the Arabic language, we note the Arabic VerbNet (Mousser, 2010), which is a lexicon for Arabic verbs using the same process as that of the English VerbNet. This Arabic version of VerbNet does not represent the native characteristics and features of Arabic verbs because it is a simple translation of the classes used in the English VerbNet with some adaptations. Another resource for Arabic is the Lexicon semantic verb classes (Snider et al., 2006), which is a lexicon classifying Arabic verbs into semantic classes. The semantic class puts in the same group verbs having similar syntactic behavior and sharing the same semantic elements of meaning, with reference to Levin's verb classes (Levin, 1993). For the arguments of verbs, only the Subject-animacy feature is used to describe the semantic construction of active verbs. This study is based on an unsupervised clustering technique to construct semantic classes of verbs exploiting the Arabic Treebank and the Arabic Gigaword resources. The major insufficient point of this

lexicon is its primordial dependence on the most frequent verbs in the Arabic Treebank. All the approaches presented in the above-mentioned related works suggest some interesting ideas, but each one of them represents some gaps related to their structure and content.

### 3 General Presentation of the Proposed Approach

The Context field is widely available, semantically well-guided, controlled and syntactically described. It includes reference sentences explaining the use of a meaning and containing the dealt with lexical entry. Thus, the analysis of such sentences provides enough knowledge on the syntactic and semantic arguments related to a given meaning.

The proposed approach is composed of three phases as shown in Figure 1 in below. The first phase, “Identifying syntactic arguments of Contexts”, aims to find out the syntactic arguments for each Context. As for the second phase, “Identifying semantic arguments of Contexts”, it consists in the identification of semantic classes for each syntactic argument from the LMF normalized dictionary. The third phase, “Establishing syntactico-semantic links”, associates syntactic and semantic arguments in order to obtain syntactico-semantic links. In the following sections, we will detail these three phases.

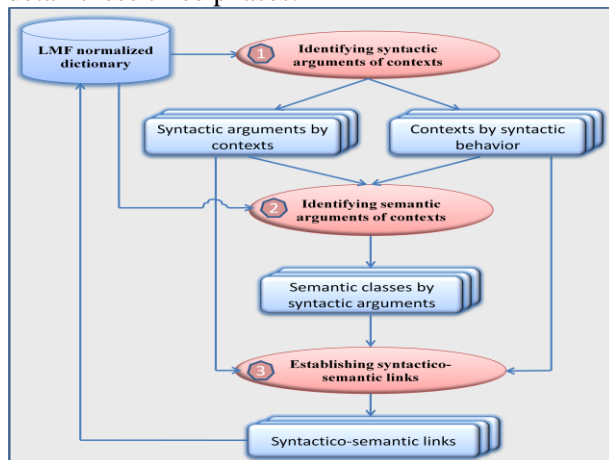


Figure 1: Proposed approach

### 4 Identifying the syntactic arguments of Contexts

According to the LMF representation, each lexical entry is linked to the concerned Syntactic

Behaviors (SBs) and, in a fine representation, each meaning of an entry is linked to the syntactic behaviors that match with it.

As mentioned in Figure2, the purpose of this phase is to search all the SB instances attached to a processed lexical entry from the LMF normalized dictionary and to determine the related SBs for each meaning or Context. We point out that the contexts are associated to meanings. The Contexts will be segmented in order to identify their syntactic arguments (SAs).

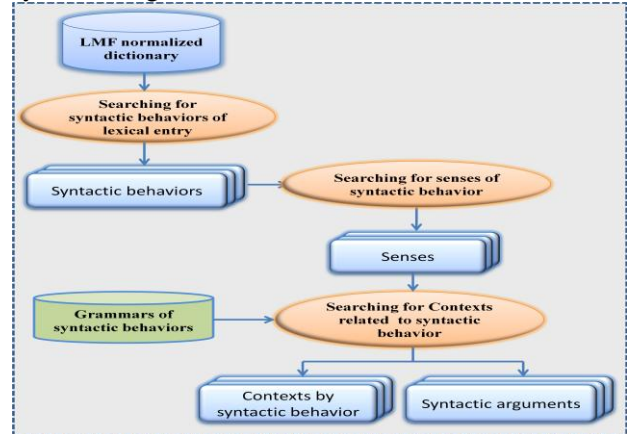


Figure 2: The “Identifying SA of Contexts” phase

#### 4.1 Searching for the SBs of a Lexical Entry

It consists in finding out the SBs of a given lexical entry. For example, Figure 3, given below, represents the verb “eat”, which has three SBs. The first SB describes the “SVC” (Subject (S) followed by a Verb (V) followed by a Complement (C)) syntactic construction. The second SB represents the ”SVupC” syntactic construction ((S) followed by (V) followed by the “up” preposition followed by a (C)). The third SB characterizes the intransitive syntactic construction “SV” ((S) followed by a (V)). This step searches for those three SBs.

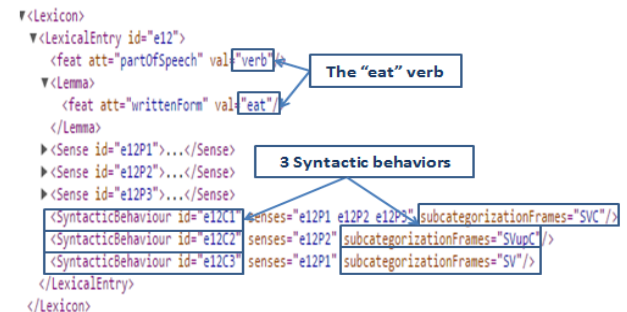


Figure 3: Application of the “Search for the SBs of the verb ‘eat’”

### 4.2 Searching for Senses of SBs

As mentioned previously, an SB can be attached in the LMF dictionary to the Sense class. Indeed, an SB can have zero to many attached senses. The aim of this step is to search for each meaning of a lexical related SB.

The application of the “Search for senses of SBs” to the verb “eat”, as shown in Figure 4, can reveal that senses “e12P1”, “e12P2”, and “e12P3” respect the “VSC” SB. Sense “e12P2” can use the “VSupC” SB. Also, Sense “e12P1” can use the “SV” SB.

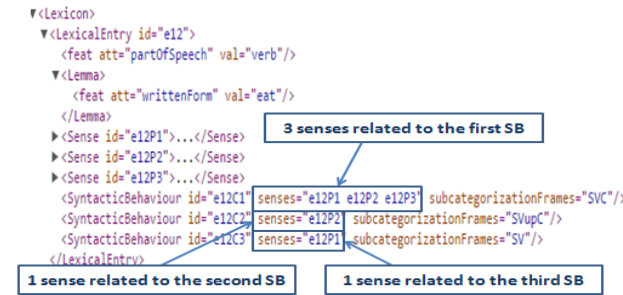


Figure 4: Application of the “Search for the senses of the SBs of the verb ‘eat’”

### 4.3 Searching for Contexts Related to SBs

We point out here that in the LMF dictionary, the MRD extension contains the Context class that represents a text string which provides an authentic context for the use of the Lemma. This context is related to a sense of a given lexical entry. It represents an example of use by a simple sentence. Thus, a meaning of a lexical entry in the LMF dictionary can be attached to different SBs and it is described by Contexts of text strings. This step aims to associate Contexts to SBs. This search is performed by the application of the Grammars of syntactic behaviors -constructed in our previous work (Elleuch et al., 2013)- to these Contexts. Thus, the application of the Grammars of syntactic behaviors on a sentence can out puts the corresponding syntactic behavior and all SAs composing the SB. At this stage, for each SB we know the related meanings. This step aims to detail the related contexts for each meaning attached to an SB.

Figure 5 illustrates the search for contexts of SBs with a concrete example. In this figure, the “SVC” SB is related to senses “e12P1”, “e12P2” and “e12P3”. The application of the Grammar of the “SVC” SB to the contexts of those senses reveals

that only the first Context “The little boys eat green apples” of the first sense respects the rules of this Grammar. The latter segments this context into SA: “the little boys”: the (S), “eat”: the (V) and “green apples”: the (C). For the “e12P2” sense, only the context “John is late for the meeting because the photocopier ate his report” respects the “SVC” SB. Regarding the “e12P3” sense, the only existing context “What’s eating you” fulfills the “SVC” SB. To conclude, the contexts related to the “SVC” SB are: “The little boys eat green apples”, “John is late for the meeting because the photocopier ate his report” and “What’s eating you”. The same treatment is performed on other SBs as described in Figure 5.

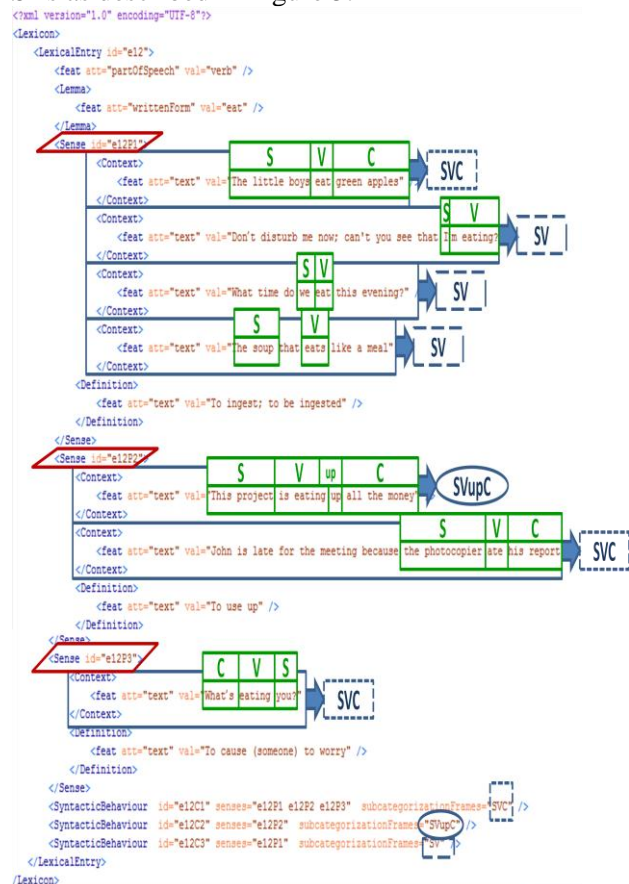


Figure 5: Application of the “Search for the contexts of the verb ‘eat’”

## 5 “Identifying the Syntactic Arguments of Contexts” Phase

At this stage, for a given SB we know the related Senses and more precisely the Contexts. Furthermore, for each Context, the SAs are identified. The purpose of the second phase of the

proposed approach is to determine the semantic argument corresponding to each context. As shown in Figure 6, this phase is composed of the “Segmentation of syntactic arguments”, the “Lemmatization of tokens” and the “Search for semantic classes by syntactic arguments” steps.

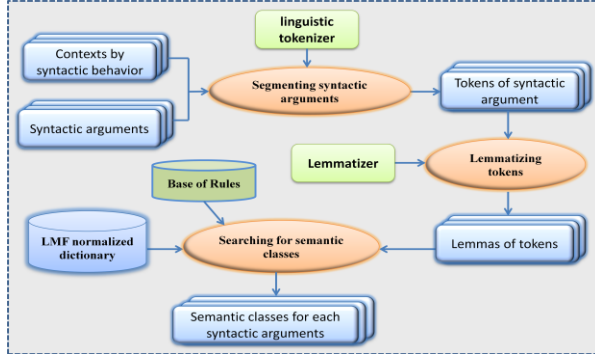


Figure 6: The “Identifying semantic arguments of contexts” phase

### 5.1 Segmenting Syntactic Arguments

An SA can be composed of one or many tokens. Indeed, the purpose of this step is to segment each SA into tokens. This segmentation is performed with a linguistic tokenizer.

In order to demonstrate the application of the “Segmenting syntactic arguments” step, we take “The little boys eat green apples” context of the first sense of the verb “eat” as illustrated in the following Figure 7. This context is associated to the “SVC” SB. In the last step, the SAs are: “The little boys” is the (S) of the sentence, “eat” is the treated lexical entry and “green apples” is the (C). The purpose of this step is to segment each SA into tokens. Thus, a linguistic tokenizer is used to parse the (S) into 3 tokens: “the”, “little” and “boys”. Regarding the (C), it is segmented into 2 elements: “green” and “apples”.

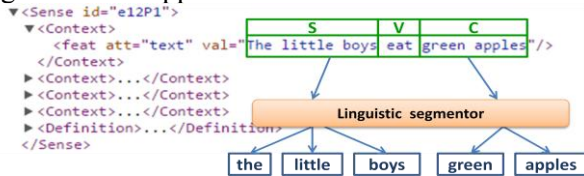


Figure 7: Application of the “Segmenting SAs” step

### 5.2 Lemmatizing Tokens

The step of “Lemmatizing tokens” of SAs puts the tokens of the SAs -recognized in the previous step- in input and uses a Lemmatizer in order to find their lemmas (gross forms). The Lemmas of tokens

are necessary to find the corresponding Semantic Classes (SC) from the LMF dictionary.

Figure 8 details the “Lemmatizing tokens” step. Indeed, the corresponding lemmas for the (S) “the little boys” are: “the”, “little” and “boy”. The Lemmas of the (C) “green apples” are: “green” and “apple”.

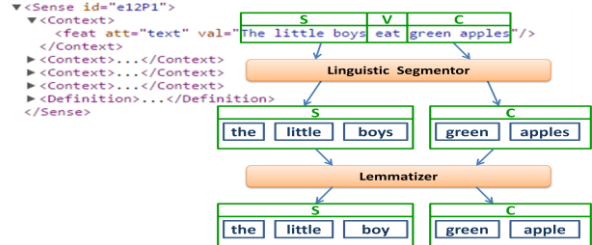


Figure 8: Application of the “Lemmatizing tokens” to the verb “eat”

### 5.3 Searching for Semantic Classes

As mentioned previously, the syntactico-semantic link is composed by the combination of the syntactic and semantic features. Since the syntactic content is already defined by the SBs, we have to find the SCs for each argument of the SB’s Context. To search for the SCs, we need all the lemmas of each token of the LMF normalized dictionary. As the SC is attached to the sense of the lexical entry in the LMF dictionary, this step must find the relevant SCs consistent to the meaning of the treated Context. For this purpose, a base of rules is used to find the relevant one among the SCs of the SA.

Figure 9 searches for SCs for each lemma of SA. Indeed, for the (S) “the little boy”, this step searches in the LMF normalized dictionary for the lexical entry “little”, which has one sense. This sense can be applied to the “human/animal/abstract/concrete” SC. Furthermore, the search for the second token, “boy”, of the (S) SA in the dictionary can identify two senses; both of them are applied to the “human” SC. So, the Rule R1: if the SA is composed of more than one token and a common SC is shared between tokens, then the relevant SC is the shared one. Thus, based on this rule, the corresponding SC of the (S) is “Human”. Regarding the “green apple” (C), the search for the lexical item “green” in the dictionary identifies five senses. Sense1 and Sense2 have the “plants” SC; Sense4 and 5 have the “human” SC and Sense3 has the “plants:aliments:fruit” SC. Also, the search for the

second token of the (C) “apple” in the dictionary finds two SCs: “plants:tree” and “plants:aliment:fruit”. Thus, the base of rules identifies the “aliment:fruit” SC for the (C).

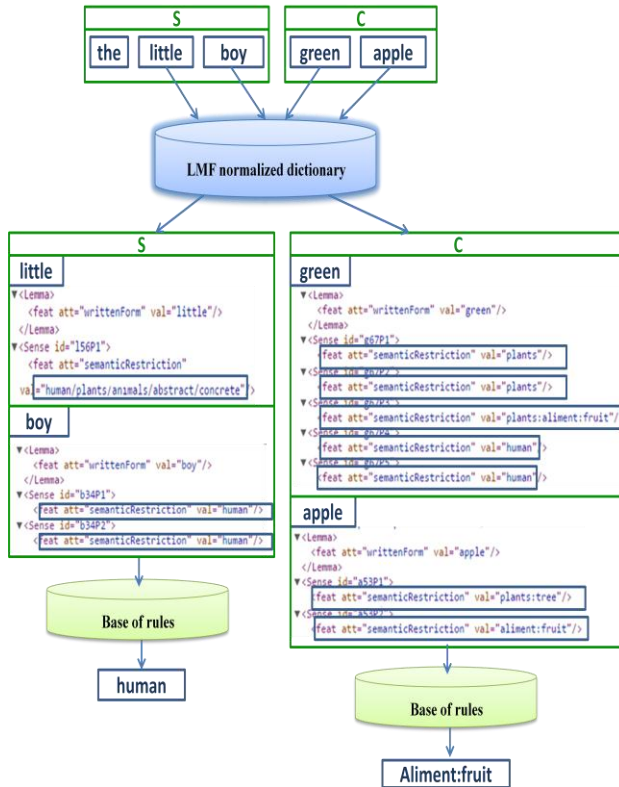


Figure 9: Application of the “search for the SCs” to the “the little boys eat green apples” context

## 6 The Establishment of Syntactico-Semantic Links Step

At this stage, for a given SB we know the related Context. The last phase of the proposed approach is the Establishment of syntactico-semantic links. At this stage, for a given SB, we know the related Senses and more precisely the Contexts. Furthermore, for each Context, the syntactic and semantic arguments are identified. The purpose of the third phase is to associate syntactic and semantic arguments through a syntactico-semantic links. As shown in Figure 10, two steps mark this phase: the “Construction of Semantic Predicates” and the “Association of syntactico-semantic links” steps. The details of each of the steps are given, with examples, in the following sections.

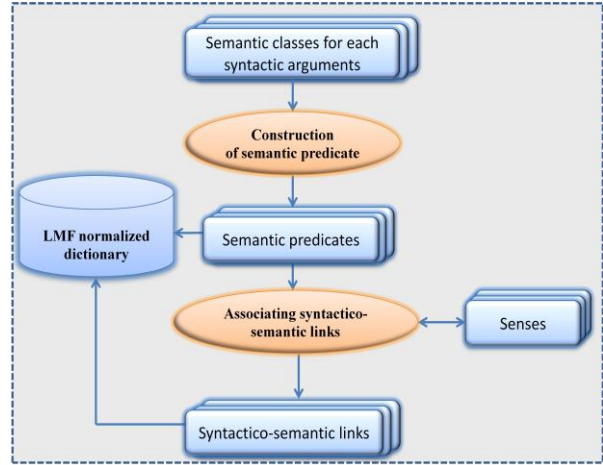


Figure10: the “Establishment of syntactico-semantic links” phase

### 6.1 Construction of Semantic Predicates

The LMF standard reserves Semantic Predicate (SP) class that represents the common meaning between different senses. A SP instance may be used to represent the common meaning between different senses. The purpose of this step is the construction of the SP class identified by the recognition of SCs of semantic arguments. Thus, the combination of those classes composes the SP.

The construction of the corresponding SP to the treated Context is given in Figure 11. Indeed, the SP is identified by the “humfru” identifier that is composed of two SAs; the first has the “human” “restriction” and the second has the “fruit” “restriction”.

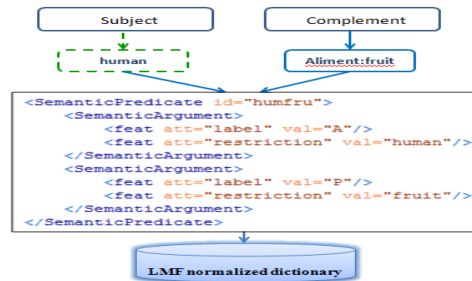


Figure 11: Application of the “Construction of SPs” step

### 6.2 Associating Syntactico-Semantic Links

At this stage, for one Sense, we have the corresponding SB, the compliant Context and the suitable SP. The last step aims to establish the syntactico-semantic link. It consists of two parts. The first part aims to construct the SynSemCorrespondence (SSC) class, which

represents a set of SynSemArgMap (SSAM) instances representing the links between a semantic argument and an SA. The second part intends to introduce the PredicativeRepresentation (PR) class, which represents the link between the Sense and the SP classes.

Figure 12 demonstrates the unwinding of the last step of the proposed approach. This step constructs the SSC class identified by the id="SVC\_humfru". It consists of two SSAMs that associate the (S) SA to the "A" semantic argument and the (C) SA to the "P" semantic argument. After that, the addition of the SP class to the treated first sense, "e12P1", takes place. The latter includes two elements: the SP "humfru" and the Correspondences "SVC\_humfru".

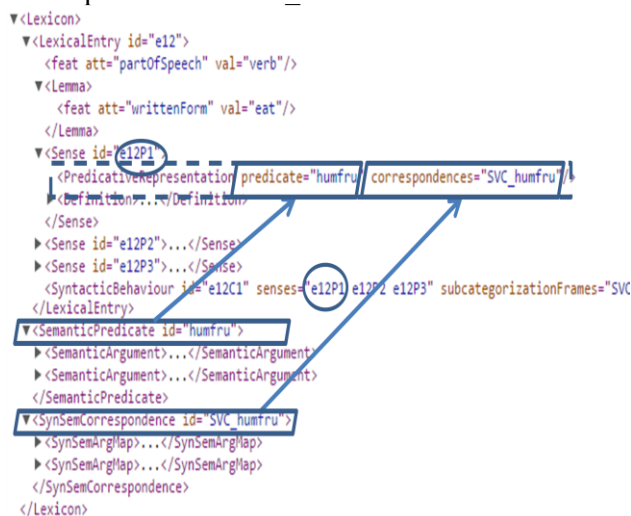


Figure 12: Syntactico-semantic links of the context: “the little boys ate a green apple”

## 7 Experimentation

In spite of the generality of our proposed approach, we chose to experiment it on the Arabic language through an available LMF normalized dictionary named El-Madar. In this section, we will present the El-Madar Arabic LMF dictionary and we will detail the obtained results.

### 7.1 The LMF Normalized Arabic Dictionary

An Arabic LMF dictionary named El-Madar was developed by (Khemakhem et al, 2015). This dictionary takes into account the specificities of the Arabic language and covers the morphological, syntactic, semantic and syntactico-semantic levels. The current version of this dictionary contains about 37,000 lexical entries: 10,800 verbs, 3,800

roots and 22,400 nouns. These lexical entries comprise syntactic knowledge. Indeed, it includes 155 syntactic behaviors (Elleuch et al, 2013) of Arabic verbs and 9,800 verbs are linked to those syntactic behaviors (Elleuch et al, 2015). Concerning semantic features, this dictionary is expanded by semantic classes assigned to the Senses of lexical entries (Elleuch et al, 2014). This study is limited to assigning the following semantic classes: “Animal”, “Insect”, “Plant”, “Aliment”, “Furniture” and “Clothes” object classes.

### 7.2 Evaluation and Results

The experimentation that we carried out could not be applied to all semantic classes. Indeed, we have chosen to treat the “Clothes”, “Aliment” and “Furniture” semantic classes (Elleuch et al, 2014) in the El-Madar dictionary because it is the most coverage and finest classes regarding the semantic content. In this experimentation, we have dealt with 406 verbs. For these verbs, syntactico-semantic links have been implemented and synthesis conclusions about SBs have been detected. A human linguistic expert evaluated the resulting assignments concerning the syntactico-semantic links.

Concerning the semantic predicative classes that represent effectively the syntactico-semantic links added to Senses of processed lexical verbal entries, the number of assignments made is equal to 790. Human linguistic experts evaluate the resulting assignments approves that 90 missed assignments were detected and 180 incorrect ones were discovered.

The resulting Recall and Precision measurement evaluation is presented in the following Table 1.

	Semantic classes		
	“Clothes”	“Aliment”	“Furniture”
Assigned syntactico-semantic links	360	280	150
Incorrect assignments	96	40	44
Missed assignments	30	24	36
Recall	0.89	0.90	0.74
Precision	0.73	0.85	0.70

Table 1: The obtained results

The erroneous assignments can be owed to the following reasons:

- Some syntactic behaviors – already existing and assigned to some Senses of the lexical entries in the Arabic dictionary are incorrect and don't reflect the exact meaning.
- The base of rules that makes the decision concerning the relevant SC related to the processed meaning generates more than one SC.

## 8 Conclusion

We proposed in this paper an approach to enrich LMF normalized dictionaries with syntactico-semantic links. This approach consists of three phases based on the analysis of the Context content presented in the LMF normalized dictionary. The first phase aims to determine the syntactic arguments of Contexts related to a specific syntactic behavior of a lexical entry by using Grammars of syntactic behaviors. The second phase intends to define the semantic arguments of these Contexts by means of the semantic classes of the lexical entries featured in the LMF dictionary. Concerning the third phase, it associates the syntactic and semantic arguments in order to establish the corresponding syntactico-semantic links.

We performed an experiment using an available Arabic LMF dictionary. The obtained results are satisfying concerning the verbal predicates of the “Clothes”, ”Aliment” and “Furniture” semantic classes .

In the future, we plan to complete the experimentation on the other domains of Arabic verbal predicates. Finally, we foresee that the resulting enrichments of the LMF dictionary can be incorporated in different NLP applications.

## References

- Baker, Kathryn, Bloodgood, Michael, Callison-Burch, Chris, J., Dorr, Bonnie, W., Filardo, Nathaniel, Levin, Lori, Miller, Scott & Piatko, Christine, (2010), *Semantically-Informed Machine Translation: A Tree-Grafting Approach*. Biennial Conference of the Association for Machine Translation in the Americas. Denver, Colorado, pp.411-438.
- Carroll, John & Fang, Alex C. (2004). The automatic acquisition of verb subcategorisations and their impact on the performance of an HPSG parser. In *Proceedings of the 1st International Conference on Natural Language Processing*, Sanya City, China. pp. 107– 114.
- Carroll, John & Fang, Alex C. (2004). The automatic acquisition of verb subcategorisations and their impact on the performance of an HPSG parser. In *Proceedings of the 1st International Conference on Natural Language Processing*, Sanya City, China. pp. 107– 114.
- Elleuch, Imen, Gargouri, Bilel, & Ben-Hamadou, Abdelmajid, (2013), *Syntactic enrichment of Arabic dictionaries normalized LMF using corpora*. *Language & Technology Conference (LTC)*. Poznan, Poland. pp.314-318.
- Elleuch, Imen, Gargouri, Bilel, Ben-Hamadou, Abdelmajid, (2014), *Towards automatic enrichment of standardized electronic dictionaries by semantic classes*, In *proceeding of the 26th International Conference on Computational Linguistics and Speech Processing (ROCLING)*, 25-26 September 2014, Zhongli, Taiwan. pp. 96-109.
- Elleuch, Imen, Gargouri, Bilel, Ben-Hamadou, Abdelmajid, (2015), *Self-Enrichment of Normalized LMF Dictionaries through Syntactic-Behaviours-to-Meanings Links*, In *proceeding of the 18th International Conference Text Speech and Dialogue (TSD)*, 14-17 September 2015, Plzen, Czech Republic. pp. 603-610.
- Francopoulo, Gil & George, Monte (2008), *Language resource management-Lexical markup framework (LMF)*. Technical Report, ISO/TC 37/SC 4 (N330 Rev.16).
- Gross, Maurice, (1975), *Méthodes en syntaxe : Régimes des constructions complétives*. Hermann, Paris, France.
- Khemakhem, A., Gargouri, B. and Ben-Hamadou, A. 2015. 'ISO standard modeling of a large Arabic dictionary'. *Natural Language Engineering*, Available on CJO 2015 doi:10.1017/S1351324915000224.
- Kipper, Karin, Korhonen, Anna, Ryant , Neville & Palmer, Martha (2008). *A large-scale classification of English verbs*. *Language Resources and Evaluation Journal*. Volume 40. pp. 42-21.
- Levin, Beth (1993), *English Verb Classes and Alternations a Preliminary investigation*, University of Chicago Press, Chicago and London.
- Medelyan, Olena, Witten, Ian H., Divoli, Anna & Broeksra, Jeen. (2013). *Automatic construction of lexicons, taxonomies, ontologies, and other knowledge structures*. *Wiley Interdisciplinary*



Reviews: Data Mining and Knowledge Discovery. Volume 3, Issue 4, pp. 257–279.

Mousser, Jaoud (2010), A large Coverage Verb Taxonomy For Arabic. International Conference on Language Resources and Evaluation (LREC), Italy, Malte. pp.2675- 2681.

Sagot, Benoît (2010), The Lefff, a freely available and large-coverage morphological and syntactic lexicon for French. Proceedings of the International Conference on Language Resources and Evaluation, LREC 2010, 17-23 May 2010, Valletta, Malta. European Language Resources Association 2010, ISBN 2-9517408-6-7.

Snider, Neal & Diab, Mouna (2006), Unsupervised Induction of Modern Standard Arabic Verb Classes using syntactic Frames and LSA. International Conference on Computational Linguistics COLING/ACL, Sydney. pp.795-802.

Surdeanu, Mihai, McClosky, David, Smith, Mason R., Gusev, Andrey & Manning, Christopher D. (2011). Customizing an Information Extraction System to a New Domain. In Proceedings of the ACL 2011 Workshop on Relational Models of Semantics (RELMS 2011), Portland, Oregon, USA, June 23, 2011. pp. 2–10.

Tolone, Elsa & Sagot, Benoit, (2011), Using Lexicon-Grammar tables for French verbs in a large-coverage parser. Human Language Technology. Challenges for Computer Science and Linguistics LNCS Volume 6562, 2011, pp.183-191.