Abstract
Arabic is a highly inflectional language, with a rich morphology, relatively free word order, and two types of sentences: nominal and verbal. Arabic natural language processing in general is still underdeveloped and Arabic natural language generation (NLG) is even less developed. In particular, Arabic natural language generation from Interlingua was only investigated using template-based approaches. Moreover, tools used for other languages are not easily adaptable to Arabic due to the Arabic language complexity at both the morphological and syntactic levels. In this paper, we report our attempt at developing a rule-based Arabic generator for task-oriented interlingua-based spoken dialogues. Examples of syntactic generation results from the Arabic generator will be given and will illustrate how the system works. Our proposed syntactic generator has been effectively evaluated using real test data and achieved satisfactory results.

1 Introduction
Arabic is the fourth most widely spoken language in the world. It is a highly inflectional language, with a rich morphology, relatively free word order, and two types of sentences (Shaalan, 2005b; Ryding, 2005): nominal and verbal. Arabic morphological and syntactic analyses have gained the focus of Arabic natural language processing research for a long time in order to achieve the automated understanding of Arabic (Al-Sughaiyer et al., 2004). On the other hand, Arabic generation has received little attention although the generation problems are as complex as those of the analysis (Habash, 2004).

In this paper, we follow a rule-based grammar generation approach for generating Arabic text within framework of the NESPOLE! (NEgotiating through SPOken Language in E-commerce) multilingual speech-to-speech MT project. The advantages of the approach used in this research are that it is easy to incorporate domain knowledge

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1 See Carnegie Mellon University (CMU) web site for NESPOLE, http://www.is.cs.cmu.edu/nespole
The syntactic generator uses an Arabic morphological generator that we developed. The morphological generator (Shaalan et al., 2006a) is responsible for the synthesis of inflected nouns, verbs, and particles. In this paper, we address major issues in the realization of the target Arabic sentence such as ensuring agreement among constituents of the sentence.

The rest of the article is structured as follows. First we briefly highlight a background on the aspects of the Arabic language. Then, the focus turns to discuss our Arabic morphological generator. Next, we introduce the Arabic syntactic generator. The subsequent section presents the results of measuring the quality of the system output using an automatic evaluation methodology. In the last section, we draw some conclusions and discuss future work.

2 Aspects of the Arabic language

Arabic language is written from right to left. It has 28 letters. Some characters, like "د", has one form, while others have two forms ("ستا"; "ست", "チャ"; "チャ"), three forms ("ى"; "ى"; "ى"; "ى") or four forms ("ع"; "ع"; "ع"; "ع") (Rafea et al., 1993). Arabic words are generally classified into three main categories (Shaalan, 2005b):

- A noun (اسم) category in Arabic includes any word that describes a person, thing, or idea. Traditionally, the noun class in Arabic is subdivided into derivative (مشتق) and primitive (جامد) nouns. Derivatives are nouns that are derived from verbs, other nouns, and particles. Primitives are nouns that are not so derived. These nouns could be further sub-categorized by number (singular, dual and plural), gender (masculine, feminine and neutral), definiteness (definite and indefinite), and case (nominative, accusative and genitive). Possessive clitics can be attached to nouns. The noun class also includes: participles, adjectives, adverbs, circumstantial accusatives, pronouns, relatives, and interrogatives.

- A verb (فعل) category includes any word that indicates the occurrence of an action. Traditionally, the verb in Arabic is subdivided into two classes: strong (عاصي) and weak verbs. Strong (aka sound) verbs can be categorized into three subclasses: regular (الاسم), hamzated (مموز)
and doubled (مضعف). Hamzated verbs are those that contain a hamza letter in their roots. In some conjugations this hamza changes to other different realizations. Doubled verbs are those that end with two identical letters. Weak verbs are verbs whose roots contain one or more weak letters. In some conjugations these weak letters may be lost or changed. Weak verbs can be categorized into three subclasses depending on the position of the weak letter in the root: assimilated (aka first weak) (مثال), hollow (aka middle weak) (أجوف), and defective (aka last weak) (نافص). A fourth weak verb is the enfolding (ثقة) verb that contains two possible cases of weak letters: middle and final or first and final weak letters. Verbs can be further sub-categorized by tense (past, present and future), case (nominative, accusative and genitive), with respect to transitivity (intransitive and transitive), aspect (perfective, imperfective and imperative), with respect to the subject (person, number and gender) and, voice (active and passive).

A particle (حرف) category refers to function words that cannot be considered either as a verbs or nouns. In Arabic, particles are divided into three categories according to the type of word they can precede. They can either precede a noun, a verb, or both. The particle class includes: prepositions, conjunctions, interrogative particles, exceptions, and interjections.

Arabic is a language of rich and complex morphology, both derivational and inflectional. Word derivation in Arabic involves three concepts: root, pattern, and form. Word forms (e.g., verbs, verbal nouns, agent nouns, etc.) are obtained from roots by applying derivational rules to obtain corresponding patterns. Generally, each pattern carries a meaning which, when combined with the meaning inherent in the root, gives the target meaning of the lexical form. For example, the meaning of the word form "كاتب" (writer) is the combination of the meaning inherent in the root "كتاب" (write) and the meaning carried by the pattern (sometimes called template) ""(fa'il) which is the pattern of the doer of the root. The Arabic inflectional morphology involves adding morpho-syntactic features such as tense, number, person, case, etc. Arabic has some more morphological peculiarities. For example, an indefinite word can be made definite by attaching the prefix definite article "" (the) to it, but there is no indefinite article. As another example, a verb can take affix pronouns such as "سأعطيكما" (will-I-give-you). The later example shows also that the verb is conjugated with the dual suffix pronoun "" (you). An Arabic inflected verb can form a complete sentence, e.g., the verb "" (heard-I-you). This one word sentence contains a complete syntactic structure. Moreover, the rich morphology of Arabic allows dropping the subject pronoun (called pro-drop), i.e., to have a null subject, when the inflected verb includes subject affixes.

There are two types of Arabic sentences (Ryding, 2005):

- A nominal sentence (جملة اسمية) starts with a noun and is composed basically of two constructions: Inchoative, or subject, (منتهى) and Enunciative, or predicate, (خبر). For example, "" (my-wife is a doctor—the auxiliary "is" is implicit in Arabic). It may embed a verbal/nominal sentence as its enunciative, e.g., "" (I study Arabic language).
- A verbal sentence (جملة فعلية) starts with a verb and is composed basically of two constructions: a verb and a subject, e.g., "" (saffar أبي) (travelled my-father). If the verb is transitive, it needs to have an object, e.g., "" (حجز أبي تذكرة السفر بالطائرة) (book my-father an-airline ticket).

An Arabic compound sentence is formed from a simple sentence followed by a complementary sentence (Mace, 1998), such as a conjunction form (كأن) (e.g., "" (We want to rent a car and we-will-need to park near the-hotel), or a quasi-sentence (كأن) (e.g., "" (I want to eat)).

Agreement is a major syntactic principle that affects the generation of an Arabic sentence. Agreement in Arabic is full or partial and is determined by word order (Ryding, 2005). An adjective in Arabic usually follows the noun it modifies (الوصف) and fully agrees with it in number, gender, case, and definiteness. The verb in Verb-Subject-Object (VSO) order agrees with the subject in gender, e.g., " (came the-....)
boy/the-boys) versus "جارات البلد / الابنات" (came the-girl/the-girls). In SVO the verb agrees with the subject in number and gender, e.g., "الرجل جاء / الأولاد", "كجاء" (came the-boy/the-boys) versus ""ئجاء" (wife—single feminine noun). For more details regarding aspects of the Arabic language, including agreements in Arabic, we refer the reader to (Attia, 2008).

3 **Arabic Morphological Generation**

With our morphological generator, we are able to derive an inflected Arabic word from a stem and morphosyntactic features using an Arabic monolingual lexicon and Arabic morphological rules.

An Arabic lexicon was needed to successfully implement the morphological generator. The Arabic word is represented as a feature-structure (FS). The noun FS includes the following features: stem, category, gender, number, sub-category, definiteness, case, and the irregular plural form. The Verb FS includes the following features: tem, category, pattern, subject_gender, subject_number, subject_person, tense, aspect, structure, voice, case, transitivity, sub-category, and the irregular past form. The particle FS includes the following features: stem, category, and sub_category.

Arabic morphological generation rules encode linguistic rules for constructing morphologically correct Arabic words. Each rule is responsible for applying a single feature on a given stem, yielding an inflected form. The input consists of a stem, represented as an FS, and the feature-value pair corresponding to the inflectional operation to be applied, represented as a feature: value pair (e.g., gender:feminine to feminize a given word). Each rule has conditions (or constraints) and actions. When the condition is met, the action is applied which results in updating the FS to reflect this change. Generating an inflected form using multiple features (e.g., to get definite plural noun) is applied one rule at a time. Morphological generation rules can be classified into rules that are responsible for synthesis of inflected nouns, particles, and verb forms.

The Arabic morphological generation process is clarified by the following example. Consider the translation of the source English expression "my wife" into the target inflected Arabic word "زوجتي". The English-to-Interlingua analyzer produces the Interlingua representation \( \text{(spouse, sex=female, whose=I)} \) that includes the value "spouse" and two features: gender feature, represented by the argument "sex=" with the value "female" that indicates feminine, and possession feature represented by the argument "whose=" with the value "I" that indicates first person singular pronoun. A deterministic lexical mapper will transform this Interlingua expression into Arabic lexemes. So, the value "spouse" is mapped to "زوج" (husband—singluar masculine noun) and the value "I" is mapped to the corresponding pronoun "الاي".

Two morphological generation rules are applicable: inflect feminine noun and inflect a noun with suffix pronoun, respectively. The former rule takes both the value "زوج" (husband—single masculine noun) and the parameter gender:feminine as input and produces the inflected feminine noun "زوجة" (wife—single feminine noun). Notice the attachment of the suffix feminine letter "ة" (called "ن" in Arabic morphological — Teh Marboutah) to get the feminine gender form from the masculine form. Then, similarly, the latter rule takes this output and the parameter possessive:'ة" as input and produces the target inflected Arabic word "زوجتي" (wife—my—single feminine noun+single singular possessive suffix pronoun) Notice that the final letter form "ة" is changed to the medial letter form "ة" (called "ن" in Arabic morphological—Teh Maftouhah) after the attachment of the final possessive suffix pronoun.

Rules for synthesis of inflected Arabic verbs are provided to conjugate the verb form with respect to tense, number, and suffix pronoun. Arabic verb morphology is central to the generation of Arabic sentence because it is very rich in form and meaning. Figure 1 shows a rule for synthesizing a first person plural form of a hollow verb in the active voice. In order to get the perfect form, the rule should remove the middle weak letter before attaching the suffix pronoun. The middle weak letter is recognized by matching the stem of the hollow verb with its pattern. For example, consider the perfect verb "ع" (could) as an input. This rule generates "عنا" (could-we).

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Rule: synthesize first person plural hollow verb
Input: first person singular verb (past, present, future)
Output: inflected verb
Example: "ع" - "عنا" - "استطاعت" - "إستطاع" - "استطاعا"

If verb.tense = future
then replace_prefix("ع"), "عائ", "استطاعت")
else if verb.tense = present
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then replace_prefix(verb.stem,"ال","")
else match_stem_pattern(verb.stem, verb.pattern, weak_letter_pos)
    remove_middle_weak(verb.stem, weak_letter_pos, PastWeakWord)
attach_suffix(PastWeakWord,"ال")

Figure 1: A morphological generation rule for synthesizing a first person plural form of a hollow verb

4 Arabic Syntactic Generation

The syntactic generation consists of two steps: 1) Determining the syntactic structure the Arabic sentence, and 2) generating grammatically correct Arabic sentence.

4.1 Determining the syntactic structure

Structural mapping rules are used to determine the syntactic structure of the Arabic sentence (Shaalan et al., 2006b). These rules follow the transformation grammar formalism (Geist, 1971) to construct the Arabic FS that reflects the syntactic structure of the Arabic surface sentence. The following is an example rule that uses the current FS as input to produce the FS that conforms to the following syntax:

$$S ::= \text{Coord Subj Verb Comp} | \text{Subj Verb Comp}$$

In order to do this transformation, the structural mapper extracts the constituents that correspond to the grammatical categories of the right hand side of the syntactic rule from the current FS. Then, it constructs the FS that reflects the syntactic structure of the Arabic surface sentence. For example, the following is a syntactic structure that is produced by applying this rule:

$$[\text{Subj: the-boys.masc.pl.nom, Verb: visit.past.sg, Comp: February twelfth}]$$

4.2 Agreement

Agreement rules ensure the relations between various elements in the sentence. Arabic is rich in agreement. In our presentation, we show rules for different type of agreement relationships, such as verb–subject, noun–adjective, demonstrative pronoun–noun, and number–counted noun, along with their agreement features.

Verb–subject agreement

In Arabic, verbs and subjects agree. The following example shows the application of a rule for synthesizing a verb that fully agrees with its subject, a pre-verbal NP, in gender and number. Consider the following sentence.

"الأولاد زاروا المتحف"
the-boys.masc.pl.nom visit.past-the-museum
The boys visited the museum

In above sentence, the pre-verbal NP, "الأولاد" (the-boys [the-boys.masc.pl.nom]) and the verb "زار" (visit [past.sg]), need to agree in number and gender. The generated Arabic sentence would therefore be.

"الأولاد زاروا المتحف"
the-boys.masc.pl.nom visit.past.3.masc.pl the-museum
The boys visited the museum

Noun–adjective agreement

In Arabic, the adjective agrees with the noun it modifies in number, gender, and definiteness. However, in case of irregular (broken) plural, it usually agrees in gender and definiteness. The following example shows the application of a rule for synthesizing an adjective that agrees with the noun it modifies. Consider the following sentence.

"الأولاد زاروا المتحف قديم"
the-boys visited-they the-museum.fem.pl old.masc.sg
The boys visited the old museums

In this case, the adjective, "قديم" (old [masc.sg]) and the (broken plural) noun it modifies "المتحف" (the-museums [the-museum.fem.pl]), should agree in gender and definiteness. The generated Arabic sentence would therefore be.

"الأولاد زاروا المتحف قديم"
the-boys visited-they the-museum.fem.pl the-old.fem.sg
The boys visited the old museums

Demonstrative pronoun–noun agreement

In Arabic, the demonstrative pronoun should agree with the noun it modifies. The following example shows the application of a rule for synthesizing a noun that agrees with the demonstrative pronoun in number and gender. Consider the following sentence.

"الأولاد زاروا هذا حديقة"
the-boys visited-they this.masc.sg garden.fem.sg
The boys visited this garden
In this case, the demonstrative pronoun "هذا" (this [masc.sg]) and the noun it modifies "الحديقة" (garden [fem.sg]), should agree in gender and definiteness. The generated Arabic sentence would therefore be.

الأولاد زاروا هذا الحديقة

the-boys visited-they this.fem.sg the-
garden.fem.sg

The boys visited this garden

Number–counted noun agreement
Number–counted noun agreement is governed by a set of complex rules for determining the literal number that agrees with the counted noun in gender and definiteness. In Arabic, the literal generation of numbers is classified into the following categories: digits, compounds, decades, and conjunctions. The case markings depend on the number–counted name expression within the sentence. The following example shows the application of a rule for synthesizing a number, between 3 and 9, that agrees with its counted noun in gender. In this rule, the gender of the literal number is the opposite of the gender of the singular form of the counted noun. Consider the following sentence.

الأولاد زاروا خمس متحف

the-boys visited-they five.masc.sg museum.fem.pl

The boys visited five museums

In this case, the number "خمس" (five [masc.sg]) and the (broken plural) counted noun "متحف" (museums [fem.pl]), need to agree in gender and definiteness. The generated Arabic sentence would therefore be.

الأولاد زاروا خمس متحف

the-boys visited-they five.fem.sg museum.fem.pl

The boys visited five museums

4.3 Reconstructing missing prepositions
Prepositions are heuristically generated according to certain verbs, nouns, or arguments. To make the issue close to the English reader, a source sentence such as this, "I'm looking for a tour from November twelfth to December twelfth", would be rendered in Arabic as "أنا أبحث عن جولة سياحية الثاني عشر من ديسمبر (I'm looking for a tour from the-twelfth of November to the-twelfth of December). So, the Interlingua has to be analyzed to derive heuristic rules that would reconstruct the missing prepositions. It is worth noting that the introduction of these prepositions at the syntactic generation would affect the case marking of the words that follow them. Hence, these words should be handled at this phase.

5 Experiment
To meet the demands for a rapid MT evaluation method, various automatic MT evaluation methods have been proposed in recent years. These include the BiLinguual Evaluation Understudy (BLEU) (LDC, 2004; Akiba et al., 2004). BLEU has attracted many MT researchers, who have used it to demonstrate the quality of their novel approaches to developing MT systems.

BLEU is an automatic scoring method based on the precisions of N-grams (uni-grams, bi-gram, tri-grams, and 4-grams). The precision of N-grams is calculated against multiple reference translations, which are correctly translated by humans.

In our automatic evaluation we used version 09 of the machine translation kit provided by NIST. To use this tool, we have to prepare three different files: a file containing the source document (300 English SDUs from the NESPOLE! Travel & Tourism database), a file containing the reference translations (previous and additional reference translation were provided by a professional expert translator), and a file containing the system output. The results of BLEU is a score in the range of [0,1]. We show the automatic evaluation results in Table 1.

| # of references translations | BLEU Score |
|-----------------------------|------------|
| 1                           | 0.65       |
| 2                           | 0.82       |

Table 1. Results of automatic evaluation

From Table 1, we notice that the results of the automatic evaluation are improved by increasing the number of reference translations. In BLEU score, the multiple reference translations are used to increase the accuracy of the system. Due to the available budget we could only fund up to two reference translations.
6 Conclusion

In this paper, we described the development of a novel Arabic syntactic generator. The paper shows how we successfully added a morphologically and syntactically rich language into a task-oriented Interlingua-based MT project. The Arabic generator is developed for generating an Arabic sentence from the Interlingua specification used by the NESPOLE! project, using a rule-based Interlingual approach. Arabic NLG from Interlingua was only investigated using template-based approaches. Moreover, rule-based tools and techniques used for these languages are not easily adaptable to Arabic as these tools cannot handle peculiarities of Arabic.

A set of real 300 SDUs, from spoken dialogues of the travel domain, has been used for evaluating the approach and the quality of the output of the Arabic generator. We followed the standard automatic evaluation methodologies for measuring the quality of the system output. The results of using this methodology are promising and indicate that it is sufficient for achieving effective communication with real users. The automatic evaluation under one reference set achieved 0.65 BLEU score whereas for two reference sets achieved 0.82 BLEU score.

Future work will include the other languages supported by NESPOLE! Another interesting challenge would be to enhance the Arabic generator by automating the diacritization or vowelization of the generated Arabic sentence. This is particularly critical for Arabic Text-to-Speech (TTS) system where an Arabic TTS system might mispronounce one word due to incorrect vowelizations.

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