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Rapid development and deployment of bi-directional expert systems using machine translation technology

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ABSTRACT

The present work reports our attempt in developing an English–Arabic bi-directional machine translation tool in the agriculture domain. It aims to achieve automated translation of agricultural expert systems. In particular, we describe the translation of domain knowledge base, including, prompts, responses, explanation text, and advices. In the Central Laboratory for Agricultural Expert Systems (CLAES) where many successful agricultural expert systems have been developed, this tool is found to be essential in developing bi-directional (English–Arabic) expert systems because both English and Arabic versions are needed for development, deployment, and usage purpose. The tool also helps knowledge engineers in overcoming the language barrier by acquiring knowledge from either English or Arabic speaking domain experts. This paper discusses our experience with the developed machine translation tool and reports on results of its application on real agricultural expert systems.

1. Introduction

Agriculture production has evolved into a complex process requiring the accumulation and integration of knowledge and information from many diverse sources including marketing, horticulture, insect management, disease management, weed management, accounting and tax laws. Expert systems have been used as a tool for agriculture management since it can provide the site-specific integrated and interpreted advice that farmers and consultants need to more efficiently management concerns.

Agriculture development in Egypt depends on the connection between the three sides of the extension process (Rafea & Shaalan, 1996): (1) research, (2) extension and (3) farmers. The reporting of problems and finding solution to them are the main concern of the cooperative extension programs. Through the different stages of technology development and information transfer to farmers, the extension sector works with the research component to narrow the gap between research results and its application in the field. In the last two decades, the Central Laboratory of Agricultural Expert Systems (CLAES[1]) has gained a considerable experience in developing knowledge based systems in the agricultural domain at the national level (Dahab, Hassan, & Rafea, 2008; Rafea, Hassan, & Hazman, 2003; Shaalan, El-Badry, & Rafea, 2004; Shaalan, Rizk, Abdelhamid, & Bahgat, 2004). These knowledge based systems cover different agricultural production management problems and applied for different crops (Cucumber, Citrus, Tomato, Wheat and Lime) (Rafea, 1994). The overall production management problems involve among other aspects, water and fertilizer requirements, pest control, farm evaluation, variety selection. Examples of expert system systems used for agricultural management are: CUcumber cultivation under Plastic Tunnels (CUPTEX) (Rafea, El-Azhari, Ibrahim, Edres, & Mahmoud, 1995), CITrus cultivation in open fields (CITEX) (El-Azhary, Edrees, Rafea, & Tawfic, 1997), and TOMATo cultivation (TOMATEX) (Tomatex, 1995), respectively.

Computer technology has been applied in technical translation in order to improve speed and cost of translation (Trujillo, 1999). Translation by or with the aid of machines can be faster than manual translation. Computer aids to translation can reduce the cost per word of a translation. In addition, the use of machine translation (MT) can result in improvements in quality, particularly in the use of consistent terminology within a scientific text or for a specific domain.

The objective of an expert system is to transfer expertise from an expert to a computer system and then on to other humans (non-experts), (Shaalan, Rizk, et al., 2004). These two steps reveal a language barrier when they involve different natural language speakers, e.g. native and non-native speakers, or first and second language speakers. The main objectives of this research are to:

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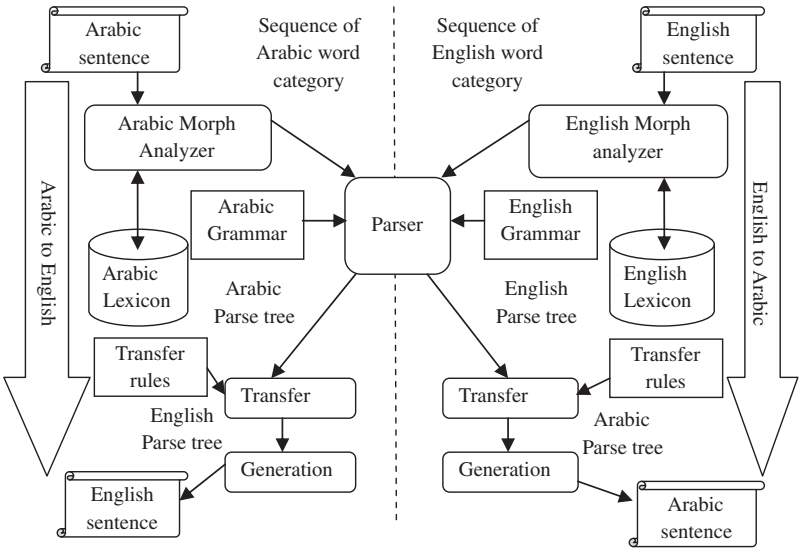

Fig. 1. Overall structure of English–Arabic bi-directional sentence translator.

(1) describe how to rapidly develop expert systems for either English or Arabic speaking users when one version is available, and (2) help knowledge engineers in acquiring knowledge from either English or Arabic speaking domain experts.

The proposed MT tool described here is part of an ongoing research to automate the translation of expert systems between Arabic and English. This knowledge translation process translates the domain knowledge base, including, responses, explanation text, and advices. In CLAES, this tool is found to be essential in developing bilingual (English–Arabic) agricultural expert systems because both English and Arabic versions are needed for development, deployment, and usage purpose. These expert systems were developed using the Knowledge Representation Object Language (KROL), cf. (Shaalan, Rafea, & Rafea, 1998). The KROL's development environment allows a knowledge engineer to collaborate directly with the machine translation tool without the need for assistance from a human translator.

The study described in this article addresses the use of machine translation technology for rapid development and deployment of bi-directional expert systems. The next section gives a background on English–Arabic machine translation. It is followed by an outline of the overall architecture of the proposed English–Arabic bi-directional MT tool with illustration of simple and complex translation examples. Next, we discuss the results of evaluation experiments. In a concluding section, we present some final remarks.

2. Background on English–Arabic machine translation

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 (Ryding, 2005): nominal and verbal. Arabic natural language processing has been the focus of research for a long time in order to achieve an automated understanding of Arabic (Al-Sughaiyer & Al-Kharashi, 2004). With globalization and expanding trade, demand for translation is set to grow.

With the recent technological advances in MT, Arabic has received attention in order to automate Arabic translations (Farghaly & Shaalan, 2009). In this paper, we follow a transfer-based MT approach (Shaalan, Hendam, & Rafea, 2010). In the transfer approach, the translation process is decomposed into three steps: analysis, transfer, and generation. In the analysis step, the input sentence is analyzed syntactically (and in some cases semantically) to produce an abstract representation of the source sentence, usually an annotated parse tree.[2] In the transfer step, this representation is transferred into a corresponding representation in the target language; a collection of tree-to-tree transformations is applied recursively to the analysis tree of the source language in order to construct a target-language analysis tree. In the generation step, the target-language output is produced. The (morphological and syntactic) generator is responsible for polishing and producing the surface structure of the target sentence. For each natural language processing component, i.e., analysis, transfer, and generation, we followed the rule-based approach. The advantage of the rule-based approach over the corpus-based approach is clear for (Abdel Monem, Shaalan, Rafea, & Baraka, 2008): (1) less-resourced languages, for which large corpora, possibly parallel or bilingual, with representative structures and entities are neither available nor easily affordable, and (2) for morphologically rich languages, which even with the availability of corpora suffer from data sparseness.

English is a universal language that is widely used in the media, commerce, science and technology, and education. The size of the modern English content (e.g. literature and web content) is far larger than the amount of Arabic content available. Consequently, English-to-Arabic MT is particularly important. English–Arabic MT systems are mainly based on the transfer approach. For example, Ibrahim (1991) discussed the problem of the English-to-Arabic translation of embedded idioms and proverb expressions with the English sentences. Rafea, Sabry, El-Ansary, and Samir (1992) developed an English-to-Arabic MT system which translates sentences from the domain of political news from the Middle East. Pease (1996) developed a system which translates medical texts from English-to-Arabic. El-Desouki and Saleh (1996) discussed the necessity of modular programming for English-to-Arabic MT. Translation of an English subset of a knowledge base to the corresponding Arabic phrases is described in (El-Saka & Rafea, 1999). Mokhtar and Rafea (2000) developed an English-to-Arabic MT

[2] A *parse tree*-also called syntax tree- is a tree or hierarchy that represents the syntactic structure of a sentence or expression according to the language grammar. A grammar defines the syntax of a language. The language is the set of all strings that can be derived by some parse tree for the grammar. A program that produces such trees is called a parser.

Table 1
Examples of English–Arabic textual knowledge.

	English	Arabic
Prompts	What is the abnormal leaves color in the tunnel?	ما لون الأوراق الغير الطبيعى فى الصوبة؟
	What is the level of the nitrogen in the soil surface?	ما مستوى النتروجين فى سطح التربة؟
Responses (legal values)	Bean mottle virus	فيروس تبقع الفول
	White growth with large black sclerotia	نمو أبيض مع أجسام حجرية سوداء
Advices (decisions)	Get rid of the remnants of the previous crop	تخلص من بقايا المحصول السابق
	Spray when the number of nymphs is 3 on leaf	رش عندما يكون عدد الحوريات 3 على الورقة
Explanation	The unit of micro element for manganese during the second vegetative growth stage	وحدة العناصر الصغرى من المنجنيز خلال مرحلة النمو الخضرى الثانية
	The added fertilization elements are determined during the flowering stage by using the watery fertilization elements index	تحدد عناصر التسميد المضافة خلال مرحلة التزهير بإستخدام ترتيب عناصر التسميد المائية

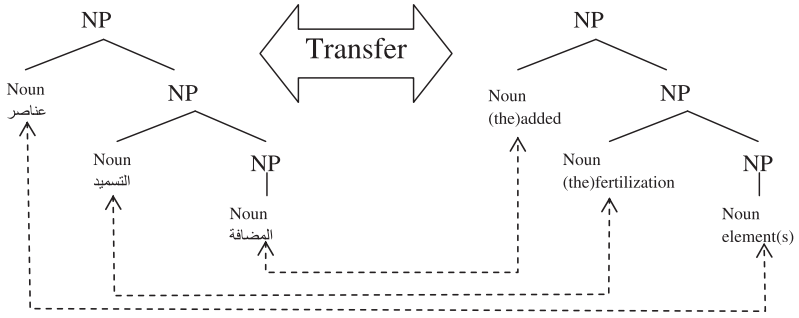

Fig. 2. Simple transfer of noun phrase (عناصر التسميد المضافة <-> added fertilization manure).

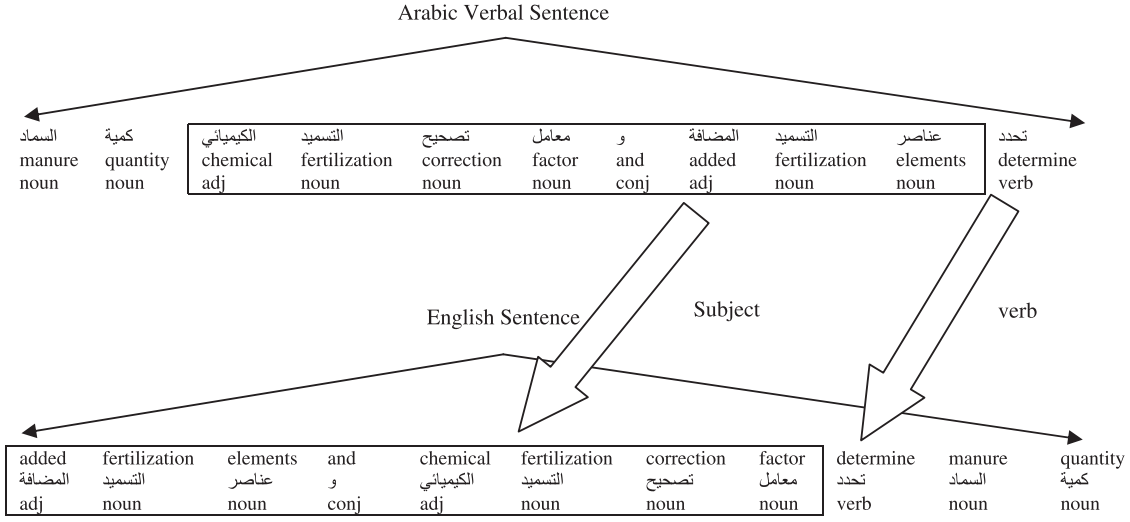

Fig. 3. Compound transfer of verb and subject of a sentence.

system, which is applied on abstracts from the field of artificial intelligence. Shaalan et al. (2004) developed an MT system for translating English noun phrases into Arabic that was applied to titles of theses and journals from the computer science domain. On the contrary, little work has been done in developing Arabic-to-English MT systems. Al-barhamtoshy (1995) proposes a translation method for compound verbs. Shaalan (2000) described a tool for translating the Arabic interrogative sentence into English. Chalabi (2001) presented an Arabic-to-English MT engine that allows any Arabic user to search and navigate through the internet using the Arabic language. Othman and Rafea (2003) developed an efficient chart parser that will be used for translating Arabic sentence.

Table 2
Results of automatic evaluation in Experiment I.

	BLEU score
Advices	0.5147
Prompts	0.4433
Explanation and responses	0.4703
Overall	0.4504

Table 3
Classification of problems in Experiment I.

1. Difference due to using a synonym of the target Arabic noun	The added fertilization elements are determined during the flowering stage by using the watery fertilization elements index	Source
	يحدد عناصر التسميد المضاف خلال مرحلة التزهير باستخدام **فهرس** عناصر التسميد المائي	Reference
	يحدد عناصر التسميد المضاف خلال مرحلة التزهير باستخدام **ترتيب** عناصر التسميد المائي	Output
2. Different translation of a preposition	The melted fertilization elements index in water for nitrogen during the second vegetative growth stage in kgm Fert/m^3	Source
	ترتيب عناصر التسميد المذابة فى الماء من النيتروجين خلال مرحلة النمو الخضرى الثانية **فى** كجم تسميدة/متر^3	Reference
	ترتيب عناصر التسميد المذابة فى الماء من النيتروجين خلال مرحلة النمو الخضرى الثانية **بكجم** تسميدة/متر3	Output
3. Misinterpret Arabic conjunction of words as English conjunction of phrases	The used fertilizers units total quantity determines the season length based on current and previous quantity of manure	Source
	يحدد أجمالى كمية وحدات الاسمده المستخدمه طول العروه بناء على **الكميه الحاليه و الكمية السابقه للسماد**	Reference
	يحدد اجمالى وحدات الاسمدة المستخدمة طول العروة بناء على **الحالية و كمية سابقة للسماد**	Output
4. An optional pronoun might come after the Arabic interrogative particle	What is the abnormal growth color on the fruits?	Source
	ما **هو** لون النمو الغير طبيعى للثمار؟	Reference
	ما لون النمو الغير طبيعى للثمار؟	Output
5. Some words may have either sound plural feminine noun or broken (irregular) plural	What is the shape of the irregular fruits?	Source
	ما شكل **الثمار** غير المنتظمة؟	Reference
	ما شكل **الثمرات** غير المنتظمة؟	Output
6. Non-standardization of the Arabic written letters	"soil", "second", etc.	Source
	"تربه" "الثاني"	Reference
	"تربة" "الثاني"	Output
7. Disagreement in present tense prefix of an Arabic verb	The added fertilization elements quantity and the chemical fertilizer correction factor determines the manure quantity and the unit during the flowering stage	Source
	تحدد كمية عناصر التسميد المضافة و معامل تصحيح السماد الكيميائى كمية و وحدة السماد خلال مرحلة التزهير	Reference
	يحدد كمية عناصر التسميد المضافة و معامل تصحيح السماد الكيميائى كمية و وحدة السماد خلال مرحلة التزهير	Output
8. Disagreement in gender between the adjective and the noun it modifies	The fertilization quantity from magnesium during the second vegetative growth stage in kg Fert/m^3	Source
	كمية التسميد من الماغنسيوم خلال مرحلة النمو الخضرى **الثانية** بكجم تسميدة/متر^3	Reference
	كمية التسميد من الماغنسيوم خلال مرحلة النمو الخضرى **الثاني** بكجم تسميدة/متر^3	Output
9. Missing definite article in the Arabic noun	The drippers number and the dripper flow rate determine the irrigation motor time in minutes	Source
	يحدد عدد النقاطات و معدل تصرف النقاط وقت موتور الرى **بالدقائق**	Reference
	يحدد عدد النقاطات و معدل تصرف النقاط وقت موتور الرى **بدقائق**	Output

3. The system architecture

The structure of the bi-directional MT tool is shown in Fig. 1. In this figure the arrows indicate the flow of information. The rounded rectangles blocks indicate the basic modules of the system. Rectangular blocks represent the linguistic knowledge. This architecture describes the translation of a knowledge base in the agricultural domain, in particular, see examples in Table 1: (1) prompts: noun phrases in the form of interrogative expressions, (2) responses: legal values in the form of noun phrases, (3) advices: in the form of imperative expressions and noun phrases, and (4) explanation text: in the form of sentences. Notice that Arabic has two types of sentences (Ryding, 2005): nominal[3] and verbal.

The proposed system is based on the transfer approach with three main components for each direction of translation: analysis,

[3] An example of a nominal sentence is "مزرعتي مصابة" (my-farm [is] infected—the auxiliary "is" is implicit in Arabic).

Table 4
Results of automatic evaluation in Experiment II.

	BLEU score
Advices	0.7673
Prompts	0.6549
Explanation and responses	0.6156
Overall	0.6427

Table 5
Results of automatic evaluation in Experiment III.

	BLEU score
Advices	0.4019
Prompts	0.4988
Explanation and responses	0.5616
Overall	0.4581

Table 6
Classification of problems in Experiment III.

1. Difference due to synonyms of a target English noun	كمية السماد العضوى	Source
	The organic fertilizer quantity	Reference
	The organic manure quantity	Output
2. Selecting ambiguous category of a source Arabic word	رش المساحة المصابة فقط	Source
	Spray the infected area only	Reference
	The infected area was sprayed only	Output
3. Misinterpret English conjunction of words as Arabic conjunction of phrases	حساب كمية المياه الكلية فى كل مرحلة بإستخدام تاريخ البداية و النهاية	Source
	The total water quantity calculation for every stage by using the start and the end date	Reference
	The total water quantity calculation for every stage by using the start date and the end	Output
4. Variant translation without the preposition "of"	كمية السماد	Source
	The quantity of fertilizer	Reference
	The fertilizer quantity	Output

Table 7
Results of automatic evaluation in Experiment IV.

	BLEU score
Advices	0.8682
Prompts	0.7851
Explanation and responses	0.8169
Overall	0.8122

transfer, and generation. The analysis component consists of two steps morphological analysis and parsing. For accomplishing morphological analysis the lexicon is necessary, which is a repository of word stems (i.e., vocabularies). As Arabic is morphologically rich language, the morphological analysis of Arabic-to-English MT is an important step that is needed before we proceed with parsing the input sentence (Rafea & Shaalan, 1993). The transfer component has a collection of tree-to-tree transformations to the analysis tree of source sentence in order to construct a target analysis tree. The generation component generates the target language words according to the semantic features of the source language words.

In our bi-directional English–Arabic translator, the actual translation occurs in the transfer phase. To explain how the sentence transfer process is performed by our translation system, we provide illustrative examples in Figs. 2 and 3 to show a simple transfer of a noun phrase and a compound transfer of a complete sentence, respectively. The former is an example showing that the syntactic transfer between English and Arabic noun phrase parse trees yields a representation in which word order is reversed. The later is a wider example showing the syntactic transfer between English sentence parse tree and Arabic verbal sentence parse tree that yields a representation in which the Arabic[4] VSO (verb-subject-object) order is transformed into the English SVO order, and vice versa.

4. Automatic evaluation

To meet the demands of a rapid MT evaluation method, various automatic MT evaluation methods have been proposed in recent years. These include the BiLingual Evaluation Understudy (BLEU) (Akiba, Federico, Nakaiwa, & Tsujii, 2004; Papineni & Ward, 2002). 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 that is calculated against reference translations produced by human translators. The results of BLEU is a score in the range of [0, 1], with one indicating a perfect match. In order to evaluate the quality of our MT system by the BLEU tool we conducted experiments in each direction of translation, i.e., from English to Arabic, and vice versa.

A set of real parallel 100 phrases and sentences from both English and Arabic versions of agricultural expert systems at CLAES, was used as a gold standard reference test data. This set consists of 23 advises, 46 prompts, and 31 explanation and responses. The evaluation methodology is performed as follows: (1) run the system on the test data, (2) automatically evaluate the system output against the reference translation and get results of the BLEU score, (3) classify the problems that arise from mismatches between the two translations, (4) for problems that needs an alternative reference translation, such as synonyms, prepare a second reference translation for the identified problems, and (5) rerun the system on the same test data using both reference translations and present the results of improvements.

4.1. English to Arabic evaluation

The automatic evaluation results of Experiment I are shown in Table 2. There are nine classifications of problems that arise from the divergences and mismatches between system output and reference translation which is shown in Table 3. As for problems 1, 4, 5, and 6, we made the changes on a second reference translation but for the remaining problems they are not solved at the moment as more research is needed to decide on their translations. Table 4 presents the automatic evaluation results of Experiment II which shows an improvement from 0.4504 to 0.6427.

4.2. Arabic to English evaluation

The automatic evaluation results of Experiment III are shown in Table 5. There are four classifications of problems that arise from the divergences and mismatches between system output and reference translation which is shown in Table 6. As for problems 1 and 4, we made the changes on a second reference translation but for problems 2 and 3 they are not solved at the moment as more research is needed to decide on their translations. Table 7 presents the automatic evaluation results of Experiment IV which shows an improvement from 0.4581 to 0.8122.

[4] Notice that Arabic script is written from right to left. So, in Fig. 3 the Arabic verb is at the beginning (i.e. rightmost) of the sentence.

5. Conclusions

In this paper, we described the development of a novel English–Arabic bi-directional rule-based transfer MT tool in the agriculture domain. The translation between monolingual English and Arabic expert systems leads to rapid development and deployment of agricultural expert systems when one version is available. Moreover, this tool has the advantage of facilitating the knowledge acquisition process to be either in English when international agricultural domain experts are available or in Arabic from local domain experts, which lead to bridging the gap of the language barrier without the need for assistance from a human translator.

A set of gold standard parallel English–Arabic phrases and sentences randomly selected from agricultural expert systems developed at CLAES, is used to evaluate our approach, as well as the quality of the output of the MT tool. The problems found are classified, explained, and possible improvements, to some extent, are dealt with. The overall evaluation results, according to the presented evaluation methodology, were satisfactory. The automatic evaluation under one reference set achieved a BLEU score of 0.4504 for English-to-Arabic direction and 0.4581 for Arabic-to-English direction, whereas for two reference sets achieved 0.6427 for English-to-Arabic direction and 0.8122 for Arabic-to-English direction. However, in the current version we might need to resort to minor post editing which is easily predictable by a native language speaker.

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