Tel Aviv University's System Description for IWSLT 2010

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Abstract

Our submission is a non-structural Example-Based Machine Translation system that translates text from Arabic to English, using a parallel corpus aligned at the paragraph / sentence level. Each new input sentence is fragmented into phrases and those phrases are matched to example patterns, using various levels of morphological information. Source-language synonyms were derived automatically and used to help locate potential translation examples for fragments of a given input sentence. We participated in the BTEC task for translating Arabic sentences to English.

1. Introduction

The presented system exploits a bilingual corpus to find examples that match fragments of the input source-language (Modern Standard Arabic-MSA, in this case) text, and imitates its translations. In the matching step, the system uses various levels of morphological information in order to broaden the amount of matched translation examples and to generate new translations based on morphologically similar fragments. In addition, we forced the matching algorithm to work on the phrase level only. The operant definition of a phrase for us is a combination of adjacent base-phrases of the input sentence.

In the transfer step, those matched phrases are translated using the target-language (English, in our case) version of the parallel corpus, using a GIZA++ [1] based alignment table.

In the recombination step all the translated fragments are pasted together to form a complete target-language text, usually by preferring larger translated fragments since they use more context. Figure 1 shows high level architecture of our system.

Like many other Semitic languages, Arabic is highly inflected; words are derived from a root and pattern (the stem), combined with prefixes, suffixes and circumfixes. The root consists of 3 or 4 consonants and the pattern is a sequence of consonants and variables for root letters. Using the same root with different patterns may yield words with different meanings. For instance, the combination of the root ك.ت.ب (k.t.b) and the pattern mXXX (here, X is a variable) results in the word مكتب (*mktb*, "office"). Combining the same root with the pattern XXAX, results in the word كتاب (*ktAb*, "book"). In working with a highly inflected language, finding an exact match for an input phrase with reasonable precision presumably requires a very large parallel corpus. Since we are interesting in studying the use of relatively small corpora for translation, matching phrases to the corpus is done on a spectrum of linguistic levels, so that not only exact phrases are discovered but also related ones. In addition, we examined the possibility of matching fragments based on source-language synonyms. For this purpose, we automatically extracted a thesaurus for Arabic, using the stem list provided by the Buckwalter (version 1.0) morphological analyzer [2], organized into levels of perceived synonymy. The quality of the system's resultant translations was measured for each of the different levels.

The system described here is non-structural: it stores translation examples as textual strings, with some additional linguistic features. Currently, the system translates each fragment separately and then concatenates those translations to form an output target-language sentence. Recombining those translations into a final, coherent form is left for future work.

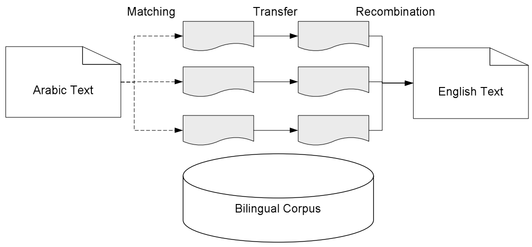

Figure 1: System Architecture

The following section gives a short description of some previous work. Sections 3-6 contain a general description of our system. In Section 7, we provide some experimental results using common automatic evaluation metrics. Some conclusions are suggested in the last section.

2. Related Work

The initiator of the example-based approach applied to machine-translation is Nagao [3], who investigated a structural Japanese-to-English example-based system. Other influential works include Sato and Nagao, 1990 [4]; Maruyama and Watanabe, 1992 [5]; Sumita and Iida, 1995 [6]; Nirenburg et al., 1994 [7]; Brown, 1999 [8].

Several works deal with morphologically rich languages such as Arabic. Nevertheless, we could not find any specific work that measures the effect of using synonyms in the matching step. Among relevant works there is [9], an example-based Basque-to-English translation system. That system focuses on extracting translation examples using the marker-based approach integrated with phrase-based statistical machine translation to translate new given inputs. As reported, that combined approach showed significant improvements over state-of-the-art phrase-based statistical translation systems.

The work by Lee [10] is on improving a statistical Arabic-to-English translation system based on words as well as on phrases by making the parallel corpus syntactically and morphologically symmetric in a preprocessing stage. This is achieved by segmenting each Arabic word into smaller particles (prefix, stem and suffix), and then omitting some of them in order to make the parallel corpus as symmetric as possible. That method seems to increase evaluation metrics when using a small corpus. Similar conclusions were reached by Sadat and Habash [11] in their work on improving a statistical Arabic-to-English translation system. In that research, several morphological preprocessing schemes were applied separately on different sizes of corpora.

In work on Japanese-to-English example-based machine translation [12], synonyms were used in the source language for matching translation examples, similar to the idea presented in this paper. However, the effect of this idea on the final results was not measured.

There are also several works that use synonyms in the target language for improving example alignments. A well-known work of this nature is [13].

In recent work [14], an Arabic-to-English example-based system is presented. Similar to our work, they broaden the way the system performs matching. That system matches words based on their morphological information, so as to obtain more relevant chunks that could not otherwise be found, and showed some improvement over state-of-the-art example-based Arabic-to-English translation systems. This matching approach also resulted in additional irrelevant matched fragments, which had to be removed in later stages.

There are a number of works on automatic thesaurus creation. Some of them use parallel corpora for finding semantically-related source-language words based on their translations. One interesting work is [15], which uses an English-Norwegian parallel corpus for building a lattice of semantically-related English and Norwegian words. It then discovers relations like synonyms and hyponyms. Another related work [16] uses a multilingual sentence-aligned parallel corpus for extraction of synonyms, antonyms and hyponyms for Dutch.

Our own system focuses on matching translation examples using various levels of morphological information plus synonyms, keeping the number of matched fragments for the transfer step as low as possible. We also measure the effect of allowing the system to match on the synonym level.

3. Translation Corpus

All the Arabic translation examples were extracted from the IWSLT BTEC Arabic-English training corpus. Each translation example was morphologically analyzed using the Buckwalter morphological analyzer, and then part-of-speech tagged using AMIRA [17] in such a way that, for each word, we consider only the relevant morphological analyses with the corresponding part-of-speech tag. Each translation example was aligned on the word level, using the GIZA++ system, which is an implementation of the IBM word alignment models [18]. Although we did not provide the GIZA++ algorithm with a word-based dictionary file, for each unaligned Arabic word in the translation example, we look up its English equivalents in a lexicon, created using the Buckwalter glossaries, and then expand those English words with synonyms from the English WordNet [19]. Then we search the English version of the translation example for all instances of these words at the lemma level, augmenting the alignment table with additional one-to-one entries.

The Arabic version of the corpus was indexed on the word, stem and lemma levels (stem and lemma, as defined by the Buckwalter analyzer). So, for each given Arabic word, we are able to retrieve all translation examples that contain that word on any of those three levels.

4. Matching

Given a new input sentence, the system begins by searching the corpus for translation examples for which the Arabic version matches fragments of the input sentence. In the implementation we are describing, the system is restricted to fragmenting the input sentence so that a matched fragment must be a combination of one or more complete adjacent base-phrases of the input sentence. The base-phrases are initially extracted using the AMIRA tool. Fragments also must contain at least two words. For instance, take the following sentence:

يكون المعهد قادرا على القيام ببحوث مستقلة

(*ykwn AlmEhd qAdrA ElY AlqyAm bbHwv mstqlp*, "The institute is able to pursue independent research"). Its AMIRA base-phrases are:

[VP ykwn] [NP AlmEhd] [ADJP qAdrA]
[PP ElY AlqyAm] [PP bbHwv mstqlp]

That means, for example, that the fragment ykwn AlmEhd qAdrA is possible, but the fragment ElY AlqyAm bbHwv is not allowed, because it is not a combination of complete adjacent base-phrases. Note that matching the complete input sentence is allowed. Currently, we have not taken the types of base-phrases into consideration, but it seems that using this kind of information, compiled into several pattern rules (e.g. matching the sequence PP NP), will improve the matching results, by forcing the system to only consider reasonable sequences of base-phrases.

The same fragment can be found in more than one translation example. Therefore, a match-score is assigned to each fragment-translation pair, signifying the quality of the matched fragment in the specific translation example.

Fragments are matched word by word, so the score for a fragment is the average of the individual word match-scores. To deal with data sparseness, we generalize the relatively small corpus by performing fuzzy matching on words by considering the text, stem, lemma, morphological features, cardinal, proper-noun, and synonym levels, with each level assigned a different score. These match-levels are defined as follows:

Text level means an exact match. It credits the words in the match with the maximum possible score.

Stem level is a match of word stems. For instance, the words الدستورية (*Aldstwryp*, "the constitutionality") and دستوريتي (*dstwryty*, "my constitutional") share the stem دستوري (*dusotuwriy*). This match-level currently credits words with somewhat less than a text-level match only because we do not have a component that can modify the translation appropriately.

Lemma level matches are words that share a lemma. For instance, the following words match in their lemmas, but not stems: مارق (*mAriq*, "apostate"); مراق (*mur~Aq*, "apostates"). The lemma of a word is found using the Buckwalter analyzer. For the same reasons as stem-level matches, an imperfect match score is assigned in this case. When dealing with unvocalized text, there are, of course, complicated situations when both words have the same unvocalized stem but different lemmas, for example, the words كتب (*katab*, "wrote") and كتب (*kutub*, "books"). Such cases are not yet handled accurately, since we are not working with a context-sensitive Arabic lemmatizer, and so cannot unambiguously determine the correct lemma of an Arabic word. Actually, by "lemma match", we mean that words match on any one of their possible lemmas. Still, the combination of the Buckwalter morphological analyzer and the AMIRA part-of-speech tagger allows us to reduce the number of possible lemmas for every Arabic word, so as to reduce the amount of ambiguity. Further investigation, as well as working with a context-sensitive morphology analyzer [20], will allow us to better handle all such situations.

Cardinal level matches apply to all numeric words. Correcting the translation of the input word is trivial.

Proper-noun level matches are words that are both tagged as proper nouns by the part-of-speech tagger. In most cases the words are interchangeable and, consequently, the translation can be easily fixed in the transfer step.

Morphological level matches are words that match based only on their morphological features. For example, two nouns that have the definite-article prefix ال (*Al*, "the") at the beginning constitute a morphological match. This is a very weak level, since it basically allows a match of two different words with totally different meanings. In the transfer step, some of the necessary corrections are done, so this level appears, all the same, to be useful when using a large number of translation examples.

Synonym level matches are words that are deemed to be synonyms, according to our automatically extracted thesaurus (based on Buckwalter's data). Since synonyms are considered interchangeable in many cases, this level credits the words with 0.95, which is almost the maximum possible. Using a score of 1.0 reduces translation results because sometime synonym based fragments hide other text based fragments, and the latter are usually more accurate.

At this point in our experiments, we are using ad-hoc match-level scores, with the goal of a qualitative evaluation of the effect of including the synonym level for matching. Exact-text matches and cardinal matches receive full weight (100%); synonyms, just a tad bit less, namely 95%; stems and proper nouns, 90%; lemmas and stems are scored at 80%; morphological matches receive only 40%.

Fragments are stored in a structure comprising the following: (1) source pattern – the fragment's Arabic text, taken from the input sentence; (2) example pattern – the fragment's Arabic text, taken from the matched translation example; (3) example – the English translation of the example pattern; (4) match score – the score computed for the fragment and its example translation. Fragments with a score below some predefined threshold are discarded, since passing low-score fragments to the next step would dramatically increase the total running time and sometimes make it unfeasible to process all fragments.

4.1. Thesaurus Creation

Since Arabic WordNet is still under development, we have developed an automatic technique for creating a thesaurus, using the Buckwalter gloss information, extended with English WordNet relations.

Currently, the thesaurus we built contains only nouns. Synonyms for other word types, such as verbs, are planned. Dealing with verbs seems to be more difficult than nouns, since the meaning of an Arabic verb usually changes when used with a different preposition.

Every noun stem in the Buckwalter list was compared to all the other stems when looking for synonym relations. Each Buckwalter stem entry provides one or more translations. Sharing an English translation, however, is insufficient for determining that two stems are synonymous, because of polysemy; we do not know which of a translation's possible senses was intended for any particular stem. Therefore, we need to attempt to determine stem senses automatically. We ask the English WordNet for all (noun) synsets (sets of synonyms) of every English translation of a stem. A synset containing two or more of the Buckwalter translations is taken to be a possible sense for the given stem. This assumption is based on the idea that if a stem has two or more different translations that semantically intersect, it should probably be interpreted as their common meaning. We also consider the hyponym-hypernym relation between the translations' senses and understand a stem to have the sense of the shared hyponym in this case.

Based on the above information, we define five levels of synonymy for Arabic stems: Level 1 – two stems have more than one translation in common. Level 2 – two stems have more than one sense in common, or they have just one sense in common but this sense is shared by all the translations. Level 3 – each stem has one and the same translation. Level 4 – each stem has exactly one translation and the two translations are English synonyms. Level 5 – the stems have one translation in common. Every stem pair is assigned the highest possible level of synonymy, or none when none of the above levels applies. The resultant thesaurus contains 22,621 nouns, 20,512 level-1 relations, 1479 relations on level 2, 17,166 on level 3, 38,754 on level 4, and 137,240 on level 5.

The quality of the translation system was tested for each level of synonymy, individually, starting with level 1, then adding level 2 and so forth. Figure 2 shows an example of a relation between two Arabic stems. In this example, the stem اعادة (*AEAdp*, "return") is matched to the stem كرور (*krwr*, "return") on level 2 because the first stem is translated as both "repetition" and "return", which share the same synset. The second stem is translated as "return" and "recurrence", which also share the same synset as the first stem. Therefore level 2 is the highest appropriate one. Table 1 shows some extracted synonyms and their levels.

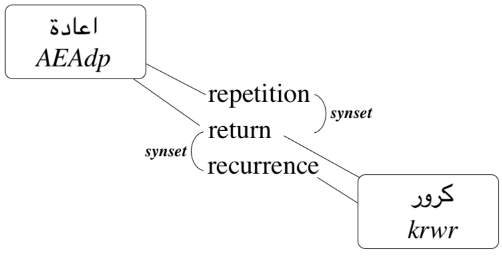

Figure 2: Synonym relation level-2 example

Synonyms	Level
n$yj / dmE ("crying")	4
sTH / sqf / ("ceiling")	5
zlEwm / Hlqwm ("throat")	1
njdp / AEAnp ("help;support")	2
AbtdA' / ftH ("beginning")	5
AxtrAE / AbtkAr ("invention")	3

Table 1: Examples of extracted synonyms

The extracted thesaurus was used for matching source-language fragments based on synonyms. Finding a synonym for a given word is not a simple task, considering that input sentences are not given with word senses. Matching input words based on synonymy without knowing their true senses is error-prone, because one might match two synonym words based on a specific sense that is not the one used by the author. One way to handle this issue would be to use a word-sense-disambiguation tool for Arabic to uncover the intended sense of each input sentence word. Although there has been some research in this area, we could not find any available tool that produces reasonable results.

Another option for matching synonyms is to use the immediate context of a candidate word for matching. Given a pair of words, a window of several words appearing around each may be compared on several WordNet levels and a final score can be computed on that basis. Candidate pairs crossing a predefined threshold can be considered as having the same sense. This direction was left for future investigation.

In the current implementation we classify each input sentence by topic, as well as all the corpus translation examples. For each translation example, we consider synonyms only if its topic-set intersects with that of the input sentence. Since in this task, the sentences are all dealing with the same general topic, we could not expect that the classification would help reducing problematic synonym-based matches. Thus, this problem was left unhandled at this point and the system was tested on the different levels of synonymy, without considering the context at all.

5. Transfer

The input to the transfer step consists of all the collected fragments found in the matching step, and the output is a set of translations for those fragments. Translating a fragment is done in two main steps: (1) extracting the translation of the example pattern from the English version of the translation example; (2) fixing the extracted translation to form a translation of the corresponding input fragment.

5.1. First Step – Translation Extraction

The first step is to extract the translation of a fragment's example pattern from the English version of the translation example. Here we use the prepared alignment table for every translation example within our corpus. For every Arabic word in the pattern, we look up its English equivalents in the table and mark them in the English version of the translation example. Recall that the English equivalent may be composed of more than one token. Next, we extract the shortest English segment that contains the maximum number of corresponding parts. Sometimes a word in an Arabic example pattern has several English equivalents, which makes the translation extraction process complicated and error prone. For this reason, we also restrict the ratio between the number of Arabic words in the example pattern and the number of English words in the extracted translation, bounding them by a function of the ratio between the total number of words in the Arabic and English versions of the translation example.

For example, take the following translation example:
A: الخدمات الاستشارية والتعاون التقني في ميدان حقوق الإنسان
E: "Advisory services and technical cooperation in the field of human rights."
Table 2 is the corresponding alignment table.

English	Arabic	
Services	*AlxdmAt*	الخدمات
Advisory	*AlAst$Aryp*	الاستشارية
Cooperation	*wAltEAwn*	والتعاون
Technical	*Altqny*	التقني
In	*fy*	في
Field	*mydAn*	ميدان
Rights	*Hqwq*	حقوق
Human	*AlAnsAn*	الإنسان

Table 2: Alignment table

Now, suppose the example pattern is ميدان حقوق الإنسان (*mydAn Hqwq Al<nsAn*, "the field of human rights"), and we want to extract its translation from the English version of the example. Using the extracted look-up, we mark the English equivalents of the pattern words in the translation example, "Advisory services and technical cooperation in the field of human rights", and then we extract the shortest English segment that contains the maximum number of corresponding words, viz. "field of human rights".

This is, of course, a simple instance. More complicated ones would have more than one equivalent per Arabic word.

5.2. Second Step – Fixing the Translation

Recall that the match of a corpus fragment to the input fragment can be inexact, since words may be matched at several levels. Exactly matched words or synonyms may be assumed to possess the same translation, whereas stem- or lemma-matched words may require modifications of the extracted translation (mostly inflection and preposition issues). These "massaging" issues are left for a future enhancement.

Words matched on the morphological level, however, require a complete change of meaning. For example, take the input fragment مجلس الامن (*mjls AlAmn*, "the Security Council") matched to the fragment مسؤولية الامن (*ms&wlyp AlAmn*, "the security responsibility") in some translation example. The words مجلس (*mjls*, "council") and مسؤولية (*ms&wlya*, "responsibility") match only on the morphological level (both are nouns). Assume that the extracted translation from the translation example is "the security responsibility", which is actually a translation of مسؤولية الامن (*ms&wlyp AlAmn*), not the translation of the input pattern at all. But, by replacing the word "responsibility" from the translation example with the translation of مجلس (*mjls*, "council") from the lexicon, we get the correct phrase, namely, "the Security Council". Our lexicon is constructed using glossaries extracted from the Buckwalter morphological analyzer and expanded with WordNet synonyms, as explained above.

For each final translated fragment, we calculate a translation-score, which is the ratio between the number of covered words and the total number of words in the Arabic pattern. The total-score of a fragment is the average of the match-score and the translation-score multiplied by the ratio between the number of input tokens covered by the fragment and the total amount of the input sentence tokens. This formula is the result of several adaptations, based on experiments, and resulted in the best performance.

6. Recombination

In the recombination step, we paste together the extracted translations to form a complete translation of the input sentence. This is generally composed of two subtasks. The first is finding the best recombination of the extracted translations that covers the entire input sentence, and the second is smoothing out the recombined translations to make a fully grammatical English sentence. Currently, we handle only the first subtask, which chooses the recombination obtaining the best cover of the given input source-language sentence. This is obtained by preferring long translated fragments to short ones, as well as preferring covers composed of fewer fragments. Finding the best cover is performed in a dynamic-programming fashion. By multiplying the total scores of the comprised fragments, we calculate a final translation-score for each generated recombination.

7. Results

Experiments were conducted on the given BTEC AE corpus. 19,972 translation examples were extracted. The system was tested on all levels of synonyms relations on the provided development sets as well as the task's test set.

Despite the fact that our system still does not perform the last, smoothing stage of the translation process, we evaluated the results under BLEU [21]. Table 3 shows some experimental results on the given development sets as well as the final test set.

From these results, one can observe that, in general, the system performs slightly better when using synonyms. The most prominent improvement in the BLEU score was achieved when using all levels, 1 through 5. Although level 5 gives synonyms of low confidence, in most of the development sets the system performs better when they were included probably because of the small corpus the system uses, which produces a relatively small amount of fragments. Thus, the ones based on synonyms can cover ranges of the input sentence that were not covered by other fragments.

8. Conclusions

The system we are working on has demonstrated the potential for using synonyms in an example-based approach to machine translation--for Arabic, in particular. We believe that using the context within which a potential synonym match may occur should be carefully considered.

More work is still needed for better aligning the translation examples. Sometimes, even if the system succeeds in matching examples based on synonyms, the final translation was wrong due to a sparse alignment table for the retrieved translation example. Trying to use a word-based dictionary for GIZA++ is one direction, but we intend to also explore other alignment methods.

Of course, smoothing out the output translations is an essential step toward understanding the real potential of our system. This step is currently being investigated and planned for implementation in the near future.

Though the scores achieved by our system remain low, primarily because of the above-mentioned alignment and smoothing issues, a detailed examination of numerous translations suggests that the benefits of using matches based on synonyms will carry over to more complete translation systems. What is true for our automatically-generated thesaurus is even more likely to hold when a quality Arabic thesaurus will become available for mechanical use. In the meanwhile, we are working on different methods for automatic extraction of thesauri for Arabic. We have begun to investigate the potential of also using verb synonyms for Arabic. We have already realized that the prepositions used with the verbs should also be taken into account, as they might change the sense, when trying to find synonyms. That could be difficult, since we have not found any freely available thesaurus for Arabic containing this information on verbs. Considering semantically-related expressions (paraphrases) in example-base machine translation is another direction we intend to explore.

In general, we believe that the example-based method is an interesting way to find realistic translations for parts of the given input. Small corpora should be better exploited, especially when dealing with languages with few available large parallel corpora.

Level / Set	DEV-1	DEV-2	DEV-3	DEV-6	DEV-7	Test-set 10	Test-set 09
Level 1	0.3672	0.3333	0.3267	0.2921	0.2800	Not Submitted	
Levels 1 – 2	0.3672	0.3333	0.3267	0.2921	0.2800		
Levels 1 – 3	0.3672	0.3334	0.3273	0.2924	0.2799		
Levels 1 – 4	0.3676	0.3333	0.3273	0.2924	0.2799		
Levels 1 – 5	0.3656	0.3333	0.3279	0.2935	0.2845	0.2321	0.2927
No synonym	0.3656	0.3332	0.3267	0.2910	0.2800	Not Submitted	

Table 3: Experimental Results, BLEU Scores

9. References

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