Issues in Generating Turkish from Interlingua

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Abstract

This report presents the generation of Turkish text from the interlingua representations used in the KANT knowledge-based machine translation system, and some issues that we have encountered during the development of this system. The target language, Turkish, can be considered as a *subject-object-verb* (SOV) language, in which constituents can change order rather freely. Morphologically, Turkish is an agglutinative language with very productive inflectional and derivational suffixation processes. In this system, the interlingua representations are mapped to Turkish f-structures, which are the inputs of the Turkish sentence generation system. Then the surface form of the sentences are realized by the morphological generation system. This study is the first application of knowledge-based machine translation from English to Turkish, and the results are very promising. For an example set of 52 sentences, the system was able to translate 44 of them correctly and completely.

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1 Introduction

In the framework of an ongoing large-scale research project on natural language processing for Turkish, a morphological generation system [12] and a tactical sentence generation system [3, 4] have already been designed and implemented for Turkish. A system which produces an interlingua representation from an English sentence was also developed for the KANT project at Carnegie Mellon University–Center for Machine Translation [9, 10]. In order to combine these systems, and build a prototype knowledge-based machine translation system from English to Turkish, it is necessary to design and implement a mapping system, which transforms the interlingua representation of a sentence to an f-structure for Turkish, which will be input to the sentence generator. This integration of modules is feasible, since each one has been developed as an independent component. Each system has its own interface, and the mapper software enables us to write a prototype mapping system with both grammatical and lexical mapping rules.

This report presents the generation of Turkish text from an interlingua representation, using the independent systems mentioned above.

Before the description of the components of this system, we would like to give a brief introduction to Turkish in the following section. In section 3 we present the design and implementation of the Turkish generation system, whose input is an interlingua representation and whose output is a Turkish sentence. Then we give some experimental results. In section 5 we discuss some issues that we encountered during the design and implementation of this system.

2 Turkish

In the following subsections, we will present some basic and interesting properties and characteristics of Turkish relevant to this work, like the agglutinative nature of the Turkish morphology, word order variations in Turkish sentences, and basic sentence types.

2.1 Morphology

Morphologically, Turkish is an agglutinative language with very productive inflectional and derivational suffixation processes. In Turkish, it is possible to generate thousands of forms from a given root word. An exaggerated example of a Turkish word formation is the following adverb:

(1) Ankaralılaştıramayabileceklerimizdenmişsinizcesine
Ankara-lı-laş-tır-ama-yabil-ecek-ler-imiz-den-miş-siniz-cesine
as if you were of those whom we might consider not converting into a citizen of Ankara.

Turkish morphotactics are finite-state, and the surface realization of words are constrained by morphographemic processes like vowel harmony, etc.

An example for the vowel harmony is given below. In both of the words, there is a locative marker, but it is either "de" or "da" depending on the last vowel of the stem.[1]

(2) a. ev - de
`house` - LOC

b. masa - da
`table` - LOC

For the details of Turkish grammar and word formations rules one can refer to a number of books [8, 17], and [12] for a finite-state description of Turkish morphology.

2.2 Word Order

Turkish can be considered as a *subject-object-verb* (SOV) language, in which constituents can change order rather freely, at almost all sentential phrase levels, depending on the constraints of text flow or discourse. The grammatical roles of constituents can be identified by the explicit morphological case markings on them, without relying on their order. For example, the word 'masa' (table) case marked accusative is a definite direct object, however the same word when case marked dative expresses a goal (unless it is accompanied by an idiosyncratic verb which subcategorizes for a dative complement):

masa-yı (Definite direct object – usually theme)
`table-ACC`

[1] In the glosses, `3SG` and `1SG` denote third person singular and first person singular verbal agreement, `P3SG` denote first person plural and third person singular possessive agreement, `WITH` denotes a derivational marker deriving adjectives from nouns, `LOC, ABL, DAT, GEN, ACC` denote locative, ablative, dative, genitive, and accusative case markers, `PAST` denotes past tense, and `INF` denotes a marker that derives an infinitive form from a verb.

masa-ya (Dative object – usually goal)
table-DAT

Word order variations in Turkish are, for the most part, dictated by the information structure constraints which capture and encode, to a certain extent, discourse-related factors. The *information structure* of a sentence captures and encodes the speaker's communicated information relative to his/her beliefs about the hearer's information state [18]. This information is captured by three main indicators:

1. the topic,
2. the focus, and
3. the background.

In free word order languages, these are indicated by order variations, contrary to fixed word order languages, in which intonation, stress, and/or clefting are used [5].

Erguvanlı [1], has examined the word order variations of Turkish sentences. In Turkish, the information which links the utterance to the previous context, the *topic*, is in the sentence initial position. For example, the topic of sentence (b) below, is the direct object, which is a pronoun:

(3) a. Tarih kitabım ikinci rafta.
history book-P1SG second shelf-LOC
'My history book is on the second shelf.'

b. Onu da getirebilir misin?
it-ACC too bring-ABILITY-QUES-2SG
'Could you bring it too?'

The information which is new or emphasized, the *focus*, is in the immediately preverbal position. For example, in the answer to the following question, the subject, "the cat", is the focus:

(4) Q: Vazoyu kim kırdı?
vase-ACC who break-PAST-3SG
'Who broke the vase?'

A: Vazoyu kedi kırdı.
vase-ACC cat break-PAST-3SG
'The cat broke the vase.'

The additional information which may be given to help the hearer understand the sentence, the *background*, is in the post-verbal or sentence final position. For example, in sentence (b.) below, the subject, "Ayşe", which is also the subject and the topic of the first sentence, is the background.

(5) a. Ayşe bütün kitaplarını eve götürmek
`Ayşe all book-PLU-P3SG-ACC home-DAT bring-INF`

istedi.
`want-PAST-3SG`
'Ayşe wanted to bring all her books home.'

b. Fakat, tarih kitabını okulda unuttu
`But history book-P3SG-ACC school-LOC forget-PAST-3SG`

Ayşe.
`Ayşe`
'But, she, Ayşe, forgot her history book at school.'

2.3 Sentence Types

Turkish sentences can be grouped into three types:

1. *existential sentences,*
2. *attributive sentences.*
3. *predicative sentences,*

Existential sentences have verbs denoting existence ('var' in Turkish) or nonexistence ('yok' in Turkish). These correspond to *'There is/are ...'* sentences in English, and sentences whose verbs are 'have'. The following is an example existential sentence:

(6) Benim iki kalemim var.
`I-GEN two pencil-P1SG existent`
'I have two pencils.'

Attributive sentences have nominal verbs which express some property of the subject noun phrase. Syntactically, nominal verbs are formed from nouns, adjectives, etc., by some sort of derivation. These correspond to the sentences, whose verbs are 'be' or 'become' in English. The following are some example attributive sentences:

(7) a. Bu çay çok sıcak.
`this tea very hot`
'This tea is very hot.'

b. Kitaplar masamın üzerinde.
`book-PLU table-P1SG-GEN on-P3SG-LOC`
'The books are on my table.'

Predicative sentences have predicative verbs inflected in the verb paradigm. These sentences can be thought as any sentence which is neither an attributive nor an existential sentence. The following are some example predicative sentences:

(8) a. Kitaplarımı sınıfta unuttum.
`book-PLU-P1SG-ACC classroom-LOC forget-PAST-1SG`
'I forgot my books in the classroom.'

b. Çocukları okula anneleri getirdi.
`child-PLU-ACC school-DAT mother-P3PL bring-PAST-3SG`
'Their mother brought the children to the school.'

3 Generation of Turkish from Interlingua

The system generating Turkish sentences from interlingua representations consists of 4 subsystems (see Figure 1):

- the mapping system,
- the sentence generation system,
- the interface between the sentence generation system and the morphological generation system, and
- the morphological generation system.

In the following subsections, we will present these components in detail. In order to demonstrate the function of each component, we will use an example sentence:

"Tosco will become the nation's largest independent refinery."

whose interlingua representation is as follows:

```
(*A-BECOME
   (PUNCTUATION PERIOD)
   (FORM FINITE)
   (TENSE FUTURE)
   (MOOD DECLARATIVE)
   (ARGUMENT-CLASS BENEFICIARY+GOAL)
   (BENEFICIARY
      (*PROP-TOSCO
         (NUMBER MASS)
         (IMPLIED-REFERENCE +)
         (PERSON THIRD)))
   (GOAL
      (*O-REFINERY
         (NUMBER SINGULAR)
         (REFERENCE NO-REFERENCE)
         (PERSON THIRD)
         (UNIT -)
         (POSSESSOR
            (*O-NATION
               (NUMBER SINGULAR)
               (REFERENCE DEFINITE)
               (UNIT -)
               (PERSON THIRD)))
         (ATTRIBUTE
            (*G-COORDINATION
               (CONJUNCTION NULL)
               (CONJUNCTS
                  (:MULTIPLE
                     (*P-LARGE
                        (COMPARISON MOST)
                        (DEGREE SUPERLATIVE))
                     (*P-INDEPENDENT (DEGREE POSITIVE)))))))))
```

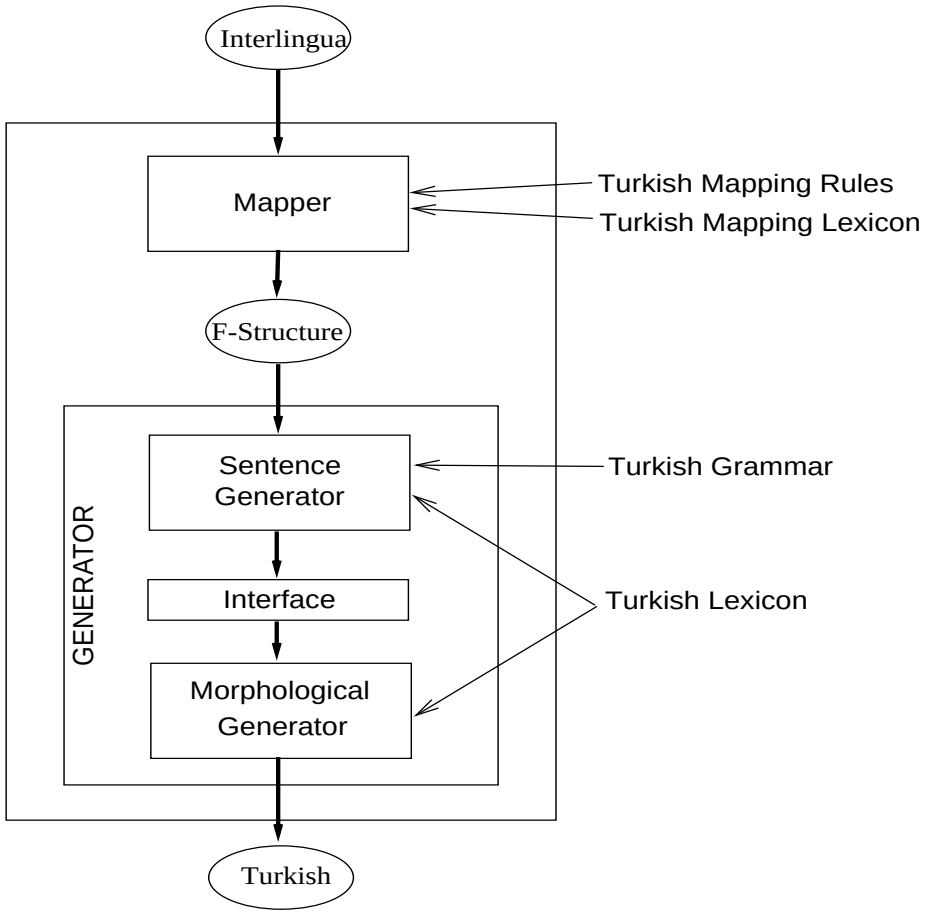

Figure 1: The outline of the Turkish generation system.

3.1 Mapping System

The mapping system produces f-structures for Turkish from the interlingua representations, using a set of mapping rules and a mapping lexicon, which are input to the KANT mapper module, implemented by Leavitt, at Carnegie Mellon University–Center for Machine Translation [7].

The Turkish mapping system consists of 178 mapping rules and 227 mapping lexicon entries.

For the example interlingua given above, the mapping system produces the Turkish f-structure:

```
((REL IS-A)
 (ARGUMENTS
  ((SUBJECT
```

```
   ((SPECIFIER ((DETERMINER ((DEFINITE +)))))
    (REFERENT ((AGR ((NUMBER SINGULAR) (PERSON 3)))
               (RPROPER +)
               (ARG ((CONCEPT "tosco")))))))
  (PRED-OBJ
   ((SPECIFIER ((DETERMINER ((DEFINITE +)))))
    (MODIFIER ((QUALITATIVE ((ELEMENT (*MULTIPLE*
                                       ((P-NAME "geniS")
                                        (INTENSIFIER ((DEGREE EN))))
                                       ((P-NAME "baGImsIz"))))
                               (CONJ " "))))))
    (REFERENT ((SEM ((COUNTABLE +)))
               (ARG ((CONCEPT "rafineri")))
               (AGR ((NUMBER SINGULAR) (PERSON 3)))))
    (POSSESSOR ((REFERENT ((SEM ((COUNTABLE +)))
                           (ARG ((CONCEPT "Ulke")))
                           (AGR ((NUMBER SINGULAR) (PERSON 3)))))
                (SPECIFIER ((DETERMINER ((DEFINITE +)))))))))))
(VERB
 ((ROOT TO-BE)
  (SENSE POSITIVE)
  (TENSE FUTURE)))
(SPEECH-ACT DECLARATIVE)
(VOICE ((ACTIVE +)))
(PUNCTUATION PERIOD)
(S-FORM FINITE)
(CLAUSE-TYPE ATTRIBUTIVE))
```

In this section, instead of dealing with every detail of the mapping system, we present the mapping of some basic concepts in a sentence, such as verb form mappings, argument mappings, and noun phrase mappings, as well as some general mappings.

3.1.1 General Mappings

There are three types of sentences in Turkish, as also mentioned in the previous sections. However, there is no such classification for English, and the KANT interlingua does not make this distinction. Therefore, the type of the sentence in Turkish is determined from the root of the verb. If the verb is "to be" or "to become", then the sentence maps to an attributive Turkish sentence, else if the verb is "to have", it maps to an existential Turkish sentence, otherwise it maps to a predicative Turkish sentence.

General features like sentence form or punctuation are directly mapped to their counterparts in the Turkish f-structure.

3.1.2 Verb Form Mappings

In order to realize a verb in Turkish, it is necessary to determine the voice, polarity, tense, aspect, mood, and agreement features of the verb, besides its root. The voice and polarity information can be directly obtained from the interlingua. The agreement depends on the subject of the sentence. Aspect, mood and tense features depend on the tense, perfective, progressive, and conditional information in the interlingua. A table is provided in Appendix A for these mappings. The root of the verb is obtained by the lexical mappings.

3.1.3 Argument Mappings

In the interlingua representation there is a semantic argument class feature which states the possible arguments each verb may have. While mapping the arguments of the sentence, this information is used to determine the counterpart of each argument in the f-structure for Turkish, but for some cases, this information is not enough; the verb's subcategorization information and the type and the voice of the sentence in Turkish are also required.

In Appendix B, a table showing the argument mappings for predicative sentences of active voice is given, in order to give some idea about these mappings.

3.1.4 Noun Phrase Mappings

Most of the features for a noun phrase in the interlingua, like definiteness, agreement, quantifier, quantity, and possessor are directly mapped to their counterparts in the Turkish f-structure.

The attribute feature in the interlingua is mapped to the classifier feature in the f-structure if it is nominal, and mapped to the qualitative feature if it is adjectival.

3.1.5 Prepositional Phrase Mappings

The prepositional phrases which are attached to a noun phrase in the interlingua are mapped to one of the modifiers or specifiers depending on the preposition.

The ones which are attached to the verb are mapped to either an argument of the sentence, or a postpositional phrase in Turkish. This selection depends on the preposition, and some semantic conditions. The preposition 'for' is a good example for this selection. Further explanation is given in section 5.1.

3.2 Sentence Generation System

The sentence generation system was originally designed and implemented by Hakkani *et. al.* [3, 4] to be used in a prototype transfer-based human-assisted machine translation system from English to Turkish [16]. This component is based on a recursively structured finite state machine (much like a recursive transition network) for handling the constituent order variations of Turkish, implemented as a right-linear grammar backbone. The implementation environment is the GenKit system, developed at Carnegie Mellon University–Center for Machine Translation [15].

The sentence generation system gets as input an f-structure[2] representing the content of the sentence, where all lexical selections have been made, and produces as output an f-structure for each word of the sentence, encoding relevant abstract morphological features such as: *agreement, possessive,* and *case* markers for nominals and *voice, polarity, tense, aspect, mood,* and *agreement* markers for verbal forms, *in addition to markers for all productive derivations.*

3.3 Morphological Generation System

Morphological realization has been designed and implemented by Oflazer [12] using an external morphological analysis/generation component which:

1. performs concrete morpheme selection, dictated by the morphotactic constraints and morphophonological context,
2. handles morphographemic phenomena such as vowel harmony, and vowel and consonant ellipsis, and
3. produces an agglutinative surface form.

For example, the following feature structures are the outputs of our generator for nominal, verbal, and adjectival forms, in the items (a), (b), and (c), respectively. These are sent to the

[2]The term 'f-structure' is used as a synonym of case-frame in the sentence generation system

morphological generation system, which then performs morpheme selections and converts them into the intermediate forms below, and produces the agglutinative surface forms from these intermediate forms:

(a.)

$$\begin{bmatrix} \text{CAT} & \text{NOUN} \\ \text{ROOT} & \text{kalem} \\ \text{AGR} & \text{3SG} \\ \text{POSS} & \text{1SG} \\ \text{CASE} & \text{GEN} \end{bmatrix}$$

$$\downarrow$$

kalem-∅-Hm-Hn

$$\downarrow$$

kalemimin

(b.)

$$\begin{bmatrix} \text{CAT} & \text{VERB} \\ \text{ROOT} & \text{gel} \\ \text{SENSE} & \text{POS} \\ \text{TAM1} & \text{PROG1} \\ \text{AGR} & \text{1SG} \end{bmatrix}$$

$$\downarrow$$

gel-∅-Hyor-Hm

$$\downarrow$$

geliyorum

(c.)

$$\begin{bmatrix} \text{CAT} & \text{ADJ} \\ \text{STEM} & \begin{bmatrix} \text{CAT} & \text{NOUN} \\ \text{ROOT} & \text{boya} \\ \text{AGR} & \text{3SG} \\ \text{POSS} & \text{NONE} \\ \text{CASE} & \text{NOM} \end{bmatrix} \\ \text{SUFFIX} & \text{WITH} \end{bmatrix}$$

$$\downarrow$$

boya-∅-∅-∅-lH

$$\downarrow$$

boyalı

3.4 Interface

The interface is a combination of C and Lisp programs, which forms the interface between the sentence and morphological generation systems. The main task of the interface is to send the

feature structures to the morphological generation system in the required format, and then print out the surface form of the sentence. In order to achieve this task, the interface:

- generates the punctuation markers since they can not be realized by the morphological generation system,
- adds or removes brackets or spaces in the feature structure to convert it into the required format,
- handles the multiword roots, since only one word can be generated by the morphological generation system at a time. For the verb:

  (9) a. yorum yapmak
  comment make-INF
  'to comment'

  only *"yapmak"* is sent to the morphological generation system and the initial part i.e. *"yorum"* is not sent to the morphological generation system, but immediately concatenated to the surface form of the sentence by the interface. This functionality is also used for the multiword proper names, e.g. Terry Keenan.

  For the feature structure of the example sentence

  "Tosco will become the nation's largest independent refinery."

  the interface produces the following from the output of the sentence generation system:[3]

```
[[CAT=NOUN][ROOT=tosco][TYPE=RPROPER][AGR=3SG][POSS=NONE][CASE=NOM]]
[[CAT=NOUN][ROOT=Ulke][AGR=3SG][POSS=NONE][CASE=GEN]]
[[CAT=ADVERB][ROOT=en]]
[[CAT=ADJ][ROOT=geniS]]
[[CAT=ADJ][ROOT=baGImsIz]]
[[CAT=NOUN][ROOT=rafineri][AGR=3SG][POSS=3SG][CASE=NOM]]
[[CAT=VERB][ROOT=ol][SENSE=POS][TAM1=FUTURE][AGR=3SG]]
[PUNC=PERIOD]
```

  After sending each word to the morphological generation system, the surface form of the sentence appears as follows:

  tosco Ulkenin en geniS baGImsIz rafinerisi olacak.

[3]Upper case in the morphological output indicates one of the non-ASCII special Turkish characters: e.g., `G` denotes ğ, `U` denotes ü, etc.

3.5 Example Translations

The following are some examples to demonstrate the generation system.

```
> (translate "THEY ADDED 1 1/4 POINTS.")

"Turkish Sentence Generated is:"

 onlar 1 1/4 puan eklediler.

; cpu time (non-gc) 57,390 msec user, 8,130 msec system
; cpu time (gc)     4,000 msec user, 1,340 msec system
; cpu time (total)  61,390 msec (00:01:01.390) user, 9,470 msec system
; real time  101,431 msec (00:01:41.431)
; space allocation:
;  6,557,549 cons cells, 4,480 symbols, 1,532,248 other bytes

> (translate "TOSCO WILL BECOME THE NATION'S LARGEST INDEPENDENT REFINERY.")

"Turkish Sentence Generated is:"

 tosco Ulkenin en geniS baGImsIz rafinerisi olacak.

; cpu time (non-gc) 57,320 msec user, 8,790 msec system
; cpu time (gc)     6,650 msec user, 4,150 msec system
; cpu time (total)  63,970 msec (00:01:03.970) user, 12,940 msec system
; real time  158,264 msec (00:02:38.264)
; space allocation:
;  7,538,554 cons cells, 5,451 symbols, 1,855,952 other bytes

> (translate "the company says they have sealed the deal.")

"Turkish Sentence Generated is:"

 Sirket onlarIn anlaSmayI imzaladIklarInI sOylUyor.

; cpu time (non-gc) 58,570 msec user, 70 msec system
; cpu time (gc)     520 msec user, 10 msec system
; cpu time (total)  59,090 msec user, 80 msec system
; real time  63,174 msec (00:01:03.174)
; space allocation:
```

```
;  8,731,270 cons cells, 5,429 symbols, 1,966,368 other bytes

> (translate "tosco had sealed the deal in world war II.")

"Turkish Sentence Generated is:"

 tosco II. dUnya savaSInda anlaSmayI imzalamIStI.


"Turkish Sentence Generated is:"

 tosco II. dUnya savaSIndaki anlaSmayI imzalamIStI.


; cpu time (non-gc) 82,180 msec (00:01:22.180) user, 1,870 msec system
; cpu time (gc)     920 msec user, 260 msec system
; cpu time (total)  83,100 msec (00:01:23.100) user, 2,130 msec system
; real time  91,404 msec (00:01:31.404)
; space allocation:
;  12,104,483 cons cells, 7,943 symbols, 2,720,344 other bytes
```

4 Results

As an example set, we have used 52 sentences (646 words) from a television program about the stock market. Of these 52 sentences, this system was able to translate 44 sentences (84.6%) correctly and completely. 2 sentences (3.9%) had missing phrases (not more than 20% of the sentence) because of problems with the mapping and sentence generation systems. 6 sentences (11.5%) could not be translated because of some problems with the interlingua and the mapper.

The reasons of the missing translations can be summarized as:

1. Structural Problems: There are problems in the interlingua of some sentences such as incorrect prepositional phrase attachments.
2. Feature Mismatches: The values are stored under wrong features. For example, instead of a PURP-QUAL feature, there can be a COMPLEMENT feature in the interlingua.
3. Mapper Limitations: The mapper has some limitations, that disable making some operations.

We provide the translation of these sentences as well as the analysis of the missing ones with respect to the reasons summarized above in the appendix C.

5 Issues

In this section, we will discuss some issues related to the generation of Turkish text from an interlingua representation, and present how we have handled them. These issues can be categorized into 3 groups according to their origin.

5.1 Issues Related to the Differences between English and Turkish

- There are some differences between Turkish and English tenses. Some English tenses do not have exact Turkish counter-parts, and vice-versa. An example is the *narrative past tense* of Turkish, which is used when the speaker is talking about an event, which s/he has heard about from somebody else. Similarly, the past perfect and present perfect tenses of English have no one-to-one correspondences in Turkish, so they are mapped to the closest possible Turkish tenses, which are presented in Appendix A. We also consider the type of the sentence while mapping the verb forms. For example, for the present tense in English with no progressive, conditional and perfective markers, we selected present progressive form in Turkish if the sentence type is predicative, otherwise this verb form is mapped to the present aorist[4] form.

- There are two demonstrative pronouns in English for demonstrating singular concepts: 'this' and 'that', used for showing near and far objects, respectively. However, in Turkish, there are three demonstrative pronouns for this purpose: 'bu', 'şu', and 'o', used for showing near, far, and very far objects, respectively. 'This' always maps to 'bu', but 'that' sometimes maps to 'şu', and sometimes 'o', depending on the context. Since the distance information cannot be deducted as both "far" and "very far" from English, 'that' is always mapped to 'o' in this system.

- The KANT interlingua categorizes verbs according to their argument classes, and this eases the job of the mapping system. For example, the agent of a verb of argument class AGENT+THEME usually maps to subject and the theme usually maps to accusative object. But, there are also some verbs that belong to the AGENT+THEME argument class, whose theme maps to dative object. For example, both verbs 'break' and 'cause' belong to the AGENT+THEME arguments class, but 'break' subcategorizes for an accusative object, whereas 'cause' subcategorizes for a dative object:

[4]Aorist is the habitual present tense which describes some truth which holds always.

(10) a. Kedi vazoyu kırdı.
`Cat vase-ACC break-PAST-3SG`
'The cat broke the vase.'

b. Kedi bir kazaya sebep oldu.
`Cat a accident-DAT cause-PAST-3SG`
'The cat caused an accident.'

Since this subcategorization information cannot be deducted from the interlingua, we introduced a SUBCAT feature. This feature stores the subcategorization information of the verb, and is stored in the mapping lexicon entry of the verb. We map the arguments according to this feature, in addition to the argument class of the verb and the voice of the sentence.

- Because of the prepositional phrase attachments, some sentences are inherently ambiguous in English. For example, for the English sentence "I saw the woman in the theater." it is possible to have 2 different interlingua representations. But, these 2 interlingua representations have different translations in Turkish as shown below. In the second one, 'the theater' is attached to 'the woman'.

(11) a. Sinemada kadını gördüm.
`theater-LOC woman-ACC see-PAST-1SG`
'[I] [saw] [the woman] [in the theater].'

b. Sinemadaki kadını gördüm.
`theater-LOC-REL woman-ACC see-PAST-1SG`
'[I] [saw] [the woman [in the theater]].'

Since the parser produces both interlingua, our system produces 2 surface forms for such sentences.

- Some prepositional phrases map to different structures in Turkish. A typical example is the preposition 'for'. If it is used for stating the price of something, it maps to a dative object in Turkish, else it maps to a Turkish postpositional phrase, whose postposition is 'için'.

(12) a. John kitabı 7 dolara satın aldı.
`John book-ACC 7 dollar-DAT buy-PAST-3SG`
'John bought the book for 7 dollars.'

b. John şirket için önemliydi.
`John company for important-PAST-3SG`
'John was important for the company.'

- There are some verbs whose argument classes depend on the sentential context. For example, the verb 'finish' belongs to THEME/AGENT+THEME argument class in English. In the following sentence, it belongs to the THEME argument class:

  (13) Film bitti.
  `film finish-PAST-3SG`
  'The film finished.'

  while it belongs to the AGENT+THEME argument class in the sentence:

  (14)
  O okulu bitirdi
  `he school-ACC finish-CAUS-PAST-3SG`
  'He finished the school.'

  These verbs have different surface realizations in Turkish, depending on their argument classes. For example, in sentence 14, the verb has a CAUSATIVE marker, which is absent in the sentence 13, although they have the same form in English. This is the case for all of the verbs in this argument class. In order to handle such a case, we make a test in the lexicon and add the causative marker if this verb has an AGENT+THEME argument class, as shown below:

```
(node ?A-FINISH
      :PARENTS (VERB)
      :ENCODES (*A-FINISH)
      :RULES ((:TEST (:sem (ARGUMENT-CLASS AGENT+THEME))
       :ADD ((VOICE ((CAUS 1))))
       :LEX "bit-verb")
      (:LEX "bit-verb")))
```

- Lexical selection is also an important issue for an MT system. A basic example for such a lexical selection is given below. In the first sentence, the verb "say" is mapped to Turkish verb "söyle", while in the second one, it is mapped to the verb "de". The rationale for this selection is that, if there is a THEME feature in interlingua representation of the sentence, "say" maps to the verb "de", else if there is a complement, it maps to the verb "söyle".

  (15) a. John şirketin Ankara'da olduğunu söyledi.
  `John company-GEN Ankara-LOC exist-INF-ACC say-PAST-3SG`
  'John said the company was in Ankara.'

  b. John Mary'e olmaz dedi.
  `John Mary-DAT no say-PAST-3SG`
  'John said no to Mary.'

- The current KANT parser does not deal with idioms; they are usually parsed as normal sentences. In this case, the Turkish sentence generated can be misleading, and even nonsense.

5.2 Issues Related to the Interlingua

- The current KANT parser does not resolve anaphora, and leaves resolution to the generation system. This resolution is critical for Turkish. For the sentence *'john read his book twice.'*, if the writer or owner of the book is John himself, the Turkish sentence that must be generated is:

  (16) John kitabını iki kere okudu.
  `John book-POSS-3SG-ACC two times read-PAST-3SG`

  else (i.e. the book belongs to or is written by another person), there must be an explicit pronoun with a genitive marker:

  (17) John onun kitabını iki kere okudu.
  `John` he-GEN `book-POSS-3SG-ACC two times read-PAST-3SG`

  Currently we produce the first form by default, since we think this is usually the case.

- Since the parser is specific to a domain, many noun phrases are parsed as a single item. An example is *'stock repurchase plan'*:

  (18) yeniden stok satın alma planı
  `again stock purchase-INF plan-P3SG`

  There are two problems with this case. The first one is that the morphological generation system can only generate one word at a time, it cannot generate phrases. In order to handle this case, the interface between the sentence generation and the morphological generation systems only sends the last token to the morphological generator. It keeps the previous words as they are, and adds them to the surface form of the sentence. This facility is also used for multi-word proper names, verbs which map to more than one word in Turkish, etc.

  The second problem is the possessive marker at the end of the last token, "plan". The lexical mappings normally do not have possessive marker, and we have to somehow enforce this. As we did in adding the causative marker to some verbs in the lexicon, we added the possessive marker to these phrases as a solution, which will be used for only the last word of the phrase. The following is the lexicon entry for this noun phrase.

```
(COUNTABLE-NOUN "stok yeniden satIn alma planI"
((REFERENT
  ((POSS ((NUMBER SINGULAR)(PERSON 3)))
   (ARG ((CONCEPT "stok_yeniden_satIn_alma_plan")))))))
```

- In English, sentences with a purpose qualifier also have a parse with an infinitival complement. An example is the sentence *'John used a hammer to break the door.'* The generated Turkish sentences for such a sentence is given below. The parse of this sentence with a purpose qualifier results in a more correct surface form (and sometimes, the other surface form is unacceptable), which is the first sentence below.

  (19)a. John kapıyı kırmak için çekiç kullandı.
  `John door-ACC break-INF for hammer use-PAST-3SG`
  '[*John*] [[*used*] [*a hammer*]] [*to break the door.*]'

  b. ? John kapıyı kırmaya çekiç kullandı.
  `John door-ACC break-INF-DAT hammer use-PAST-3SG`
  '[*John*] [[*used*] [*a hammer*] [*to break the door*]].'

5.3 Issues Related to the Generation and Mapping Systems

- The mapping system does not currently produce an information structure which encodes word order information. So, all sentences are produced in the default order in Turkish. The information structure of a sentence can be obtained using syntactic clues in the source language in machine translation [2, 13] or using algorithms that determine the topic and focus of the target language sentences using Centering Theory [14], and given versus new information [6]. Hajičová *et al.* [2] have used the input information on definiteness and lexical semantic properties of words, word order and the systemic ordering of kinds of complementations in order to automatically identify topic and focus. Similarly, Steinberger [13] suggested a method to automatically recognize the categories *theme, rheme,* and *contrastive focus* which determine the word order of constituents. Styś *et al.* [14] tried to identify word order information analyzing the discourse to generate communicatively adequate sentences in English-Polish machine translation. Hoffman [6] present algorithms which use contextual information to determine the topic and focus of Turkish sentences which are translated from English.

  The mapping system could be extended so that it makes centering analysis or uses syntactic clues, to produce an information structure embedded in the f-structure it outputs. However, some further analysis should be made on this to see whether the interlingua contains all the information required for such a process.

- The sentence generation system was developed for a machine translation system in the domain of computer manuals. Although we developed this generator bearing in mind

that it can also be used for other domains and in other applications, it had some missing parts, like detailed treatment of numbers. So, we tried to add these missing parts during the development of the mapping system.

- Features belonging to the same category are stored in the same slot in the interlingua, using a `:multiple` flag. The problem is that features belonging to the same category in the interlingua may map to different categories in Turkish. For example, as also mentioned in the previous sections, the attribute of a noun phrase may map to either a classifier or a determiner, depending on whether it is nominal or adjectival. Currently, the mapper does not support the operation of extracting individual features under the `:multiple` flag.

6 Conclusions and Future Work

We have presented a system which generates Turkish sentences from interlingua representations. This study is important in that, it proves the feasibility of combining independent systems developed at Carnegie Mellon University and Bilkent University. With the design and implementation of a Turkish mapping system, we were able to construct a prototype English to Turkish machine translation system in two months.

The coverage, accuracy, and fluency of this machine translation system can further be extended, by adding new and more detailed mapping rules. For example, the word order variations can be controlled in a better way, by using the techniques mentioned previously, because currently the sentences are generated in a default order in Turkish.

For the example set of 52 sentences, the performance of this system is comparable with the KANT machine translation system [11]. For a more robust machine translation system, the system should be tested on a large corpus and extended accordingly.

This study is the first application of knowledge-based machine translation from English to Turkish, and the current results are very promising.

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A Verb Form Mappings

Features in Interlingua				Features in Turkish F-Structure		
Perf.	**Cond.**	**Prog.**	**Tense**	**Aspect**	**Mood**	**Tense**
+	-	-	Past	Perfect	Narrative	Past
+	-	-	Present	Progressive	—	Past
-	+	+	Present	Progressive	Conditional	Present
-	+	-	Past	Perfect	Conditional	Past
-	+	-	Present	Aorist	Conditional	Present
-	+	-	Future	—	Conditional	Future
-	-	+	Past	Progressive	—	Past
-	-	+	Present	Progressive	—	Present
-	-	-	Past	Perfect	—	Past
-	-	-	Present	Aorist/ Progressive[5]	—	Present
-	-	-	Future	—	—	Future

[5] This is aorist if the sentence maps to an attributive or an existential sentence in Turkish, else it is progressive.

B Argument Mappings for Active Voice

The following table shows the argument mappings for predicative sentences of active voice. For example, a THEME in the interlingua is mapped to a GOAL in the Turkish f-structure, if the ARGUMENT-CLASS of the verb is BENEFICIARY+THEME, and it subcategorizes for a DATIVE object.

Role in Interlingua	**Verb Subcat.**	**Argument Class**	**Role in F-Structure**
AGENT	—	*[6]	SUBJECT
THEME	—	THEME	SUBJECT
		THEME+COMPLEMENT	
		THEME+LOCATIVE	
		THEME+GOAL	
		THEME+ATTRIBUTE	
		THEME+SOURCE	
		THEME+OBJECT	
		THEME+OBJECT+COMPLEMENT	
		THEME+BENEFICIARY	
	NOM	BENEFICIARY+THEME	DIR-OBJ
		AGENT+THEME	
		BENEFICIARY+THEME+GOAL	
		AGENT+THEME+BENEFICIARY/ AGENT+THEME	
		AGENT+GOAL+THEME	
		AGENT+THEME+PREDICATE	
		AGENT+THEME+ATTRIBUTE	
		AGENT+THEME+OBJECT	
		AGENT+THEME+SOURCE+INSTRUMENT	
		AGENT+THEME+COMPLEMENT	
	DAT	BENEFICIARY+THEME	GOAL
		AGENT+THEME	
		BENEFICIARY+THEME+GOAL	
		AGENT+THEME+BENEFICIARY/ AGENT+THEME	
		AGENT+GOAL+THEME	
		AGENT+THEME+PREDICATE	
		AGENT+THEME+ATTRIBUTE	
		AGENT+THEME+OBJECT	
		AGENT+THEME+SOURCE+INSTRUMENT	
		AGENT+THEME+COMPLEMENT	
BENEFICIARY	—	BENEFICIARY	SUBJECT
		BENEFICIARY+THEME	
		BENEFICIARY+GOAL	
	NOM	THEME+BENEFICIARY	DIR-OBJ
	DAT	THEME+BENEFICIARY	GOAL

[6] The symbol * indicates all argument classes containing the corresponding role; e.g. AGENT in this case.

Role in Interlingua	**Verb Subcat.**	**Argument Class**	**Role in F-Structure**
SOURCE	—	*	SOURCE
OBJECT	—	*	DIR-OBJ
LOCATIVE	LOC	THEME+LOCATIVE	LOCATION
	NOM		DIR-OBJ
PATIENT	DAT	AGENT+PATIENT	GOAL
	NOM		DIR-OBJ
GOAL	NOM	AGENT+GOAL	DIR-OBJ
		THEME+GOAL	
		BENEFICIARY+GOAL	
	DAT	AGENT+GOAL	GOAL
		THEME+GOAL	
		BENEFICIARY+GOAL	
COMPARISON-THEME	NOM	THEME+COMPARISON-THEME	DIR-OBJ
	DAT		GOAL
ATTRIBUTE	—	*	PRED-ADJ
RECEPIENT	—	*	GOAL

C Translations of the Sentences in the Example Set

The following is a list of correct and complete translations of the sentences in the example set:

1. TERRY:
   terry:
2. YOU ARE WATCHING "MARKET WRAP" AT HALF PAST THE HOUR.
   sen 30. dakikada market (wrap'i — wrap'I) izliyorsun.
3. I AM TERRY KEENAN.
   ben terry keenan'Im.
4. SUSIE:
   susie:
5. AND I AM SUSIE GHARIB.
   ve ben susie gharib'im.
6. ON WALL STREET THE DOW INDUSTRIALS MISSED "RECORD NUMBER NINE" BY JUST ONE POINT.
   dow endUstrileri wall street'te dokuz numaralI kaydI sadece bir puanla kaCIrdI.
7. IT WAS A SCHIZOPHRENIC KIND OF DAY OF TRADING ALL DAY LONG:
   o bUtUn gUn boyunca Sizofren bir ticaret gUnUydU:
8. LET'S RUN DOWN THE FINAL NUMBERS NOW FROM WALL STREET.
   Simdi son rakamlarI wall street'ten verelim.
9. AND TOPPING TODAY'S BUSINESS HEADLINES:
   ve bugUnUn iS baSlIklarInI geCiyorum:
10. IT CERTAINLY WAS ANOTHER MERGER MONDAY.
    o muhakkak baSka bir pazartesi birleSmesiydi.
11. TOSCO SEALED A DEAL TO BUY THE WEST COAST OPERATIONS OF UNOCAL FOR ABOUT $1.4 BILLION.
    tosco unocal'In batI kIyIsI iSlemlerini yaklaSIk 1.4 milyar dolara satIn almak iCin bir anlaSma imzaladI.
12. TOSCO WILL BECOME THE NATION'S LARGEST INDEPENDENT REFINERY.
    tosco Ulkenin en geniS baGImsIz rafinerisi olacak.

13. UNOCAL SAYS IT WILL USE SOME OF THE PROCEEDS TO PARE DOWN DEBT AND WILL CONSIDER A STOCK REPURCHASE PLAN.
unocal onun bazI gelirleri borC indirmeye kullanacaGInI, ve onun bir yeniden stok satIn alma planI gOz OnUnde tutacaGInI sOylUyor.

14. SHARES OF TOSCO CLOSING THE DAY UP 12 3/8.
tosco'nun hisse senetleri gUnU 12 3/8 yukarIda kapIyor.

15. UNOCAL SHARES ALSO HIGHER ON THE SESSION.
unocal hisse senetleri de seansta daha yUksek oluyor.

16. THEY ADDED 1 1/4 POINTS.
onlar 1 1/4 puan ekledi.

17. ANOTHER DEAL CERTAINLY NOT CHILD'S PLAY:
baSka bir anlaSma muhakkak Cocuk oyunu olmuyor:

18. MATTEL BUYING TYCO TOYS FOR $755 MILLION.
mattel tyco oyuncaklarInI 755 milyon dolara satIn alIyor.

19. THAT DEAL WILL BE IN STOCK.
o anlaSma stokta olacak.

20. KELLOGG IS BROADENING ITS REACH INTO THE FOOD INDUSTRY.
kellogg menzilini yiyecek endUstrisine geniSletiyor.

21. IT WILL BUY LENDERS BAGELS FROM KRAFT FOR ABOUT $455 MILLION.
o lenders bagels'i kraft'tan yaklaSIk 455 milyon dolara satIn alacak.

22. ANALYSTS SEE THE DEAL AS A PERFECT FIT FOR KELLOGG'S FAST-GROWING CONVENIENCE FOODS BUSINESSES.
analistler anlaSmayI kellogg'un hIzla bUyUyen hazIr yemek iSleri iCin Cok uygun gOrUyor.

23. KELLOGG SHARES ENDING THE DAY DOWN 1/8.
kellogg hisse senetleri gUnU 1/8 aSaGIda kapIyor.

24. PHILIP MORRIS WHICH OWNS KRAFT CLOSING UP 1/4 OF A POINT.
kraft'a sahip olan philip morris 1/4 puan yukarIda kapIyor.

25. AND BILLIONAIRE MARVIN DAVIS HAS SWEETENED HIS TAKEOVER OFFER FOR CARTER-WALLACE.
ve milyarder marvin davis carter wallace iCin yOnetimi ele alma Onerisini tatlandIrIyordu.

26. THE COMPANY HAS NOT COMMENTED.
Sirket yorumda bulunmuyordu.

27. SHARES OF CARTER-WALLACE CLOSING WITH A GAIN OF 1 1/4 AT 16 DOLLARS A SHARE.
carter wallace'nin hisse senetleri hisse senedi baSIna 16 dolarda 1 1/4 bir kazanCla kapIyor.

28. LOCTITE SAID A FIRM NO TO GERMAN-BASED HENKEL.
loctite alman kOkenli henkel'e kesin bir hayIr dedi.

29. THE HARTFORD CONNECTICUT FIRM REJECTING A 1.19 BILLION DOLLAR OFFER, CALLING IT INADEQUATE.
hartford connecticut firmasI ona eksik (deyerek — deyerekten) bir 1.19 milyar dolar teklifi reddediyor.

30. LOCTITE SAYS IT IS LOOKING AROUND FOR OTHER BUYERS.
loctite onun baSka bir mUSterilere bakIndIGInI sOylUyor.

31. AND SHARES OF LOCTITE TODAY CLOSING UNCHANGED.
ve loctite'nin hisse senetleri bugUn deGiSmeden kapIyor.

32. THEY CLOSED AT 59 7/8.
onlar 59 7/8'de kapadI.

33. SHARES OF MCDONNELL DOUGLAS GOT SLAMMED TODAY.
McDonnell douglas'In hisse senetleri bugUn Cok dUStU.

34. MCDONNELL DOUGLAS HAS BEEN SHUT OUT OF THE LARGEST MILITARY CONTRACT IN US HISTORY.
McDonnell douglas ABD tarihindeki en geniS askeri anlaSmasIndan dISarI atIlIyordu.

35. AS CNBC'S TIM TINDALL REPORTS, THE DECISION IS A STUNNING DEFEAT FOR MCDONNELL DOUGLAS AND A SURPRISE WIN FOR BOEING.
cnbc'den tim tindall'In bildirdiGine gOre karar McDonnell douglas iCin aGIr bir yenilgi, ve boeing iCin harika bir kazanCtIr.

36. FOR McDONNELL DOUGLAS THE PENTAGON'S DECISION WAS A SIGNIFICANT LOSS, ESPECIALLY SINCE THE ST. LOUIS-BASED COMPANY DERIVES MORE THAN HALF ITS REVENUE FROM ITS DEFENSE BUSINESS.
Ozellikle st. louis kOkenli Sirket gelirinin ekseriyetini savunma iSinden elde ettiGi iCin pentagon'un kararI McDonnell douglas iCin mUhim bir zarardI.

37. IT IS CLEARLY A PAINFUL BLOW.
o aCIkCa acIklI bir darbedir.

38. THIS PROGRAM WAS THE LAST CLEARLY VISIBLE OPPORTUNITY TO EXPAND McDONNELL DOUGLAS'S LEADERSHIP IN COMBAT AIRCRAFT BEYOND THE F-18.

bu program McDonnell douglas'In savaS uCaGIndaki liderliGini f-18'in Otesine geniSletmek iCin son aCIkCa belli fIrsattI.

39. THE NEWS STUNG EVEN HARDER BECAUSE THEIR COMMERCIAL AIRCRAFT BUSINESS HAS SOURED LATELY AS WELL, UNDER PRESSURE FROM INTENSE COMPETITION.
haberler daha kOtU acIttI CUnkU onlarIn ticari uCak iSleri son zamanlarda yoGun rekabetten baskInIn altInda zayIflIyordu.

40. IT IS A HUGE LOSS.
o muazzam bir zarardIr.

41. WE HAVE STRONG PROGRAMS RIGHT HERE IN ST. LOUIS.
(bizin — bizim) hemen burada St. louis'te saGlam programlarImIz vardIr.

42. WE ARE A STRONG COMPANY AND WE WILL PULL UP OUR SOCKS AND GET ON WITH LIFE FROM HERE.
biz saGlam bir Sirketiz, ve biz CoraplarImIzI yukarI CekeceGiz, ve biz buradan hayata devam edeceGiz.

43. BUT WHEN DEFENSE SECRETARY WILLIAM PERRY ANNOUNCED THE WINNERS ON SATURDAY IT WAS A DIFFERENT REACTION AT LOCKHEED MARTIN.
fakat o cumartesi gUnU savunma sekreteri william perry galipleri ilan ettiGi zaman lockheed martin'de deGiSik bir tepkiydi.

44. THESE CONTRACTORS ARE LOCKHEED MARTIN.
Bu Ustenciler lockheed martin'dir.

The following is a list of incomplete translations:[7]

1. THE COMPANIES WILL BUILD THE TEST MODELS FOR A FINAL SELECTION IN THE YEAR 2001, THE FIRST JETS ARE SCHEDULED FOR DELIVERY (TO THE MILITARY) IN 2008.
Sirketler 2001 yIlIndaki son bir seCim iCin deneme modellerini kuracak, ilk uCaklar 2008'de teslim iCin (planlanIlIyor — planlanIyor).

2. HE UPPED THE ANTE TO 20 DOLLARS A SHARE JUST TWO WEEKS AFTER THE CONSUMER PRODUCTS MAKER TURNED DOWN HIS INITIAL (18 DOLLARS A SHARE) BID.
o tUketici UrUnleri fabrikatOrU ilk teklifini geri Cevirdikten sadece iki hafta sonra hisse senedi baSIna 20 dolara bahsi artIrdI.

[7]The phrases that can not be translated are indicated by paranthesis.

The following is a list of missing translations along with a reason:

1. THE BLUE CHIPS WERE UP AS MUCH AS 24 POINTS, AND DOWN AS MUCH AS 20, FINALLY CLOSING ON THE DOWNSIDE.

   Reason: Structural Problems

2. FOR LOCKHEED THE DECISION ENFORCES ITS DOMINANCE AS THE NUMBER ONE DEFENSE CONTRACTOR AFTER THEIR MERGER WITH LORAL.

   Reason: Structural Problems

3. LOOKING AT HOW THOSE TWO STOCKS FARED SHARES OF MATTEL SLIPPING 3/4 OF A POINT WHILE SHARES OF TYCO SOARED 4 1/2.

   Reason: Mapper Limitations

4. THE DEFENSE DEPARTMENT HAS CHOSEN BOEING AND LOCKHEED MARTIN TO DEVELOP PROTOTYPES OF A NEW COMBAT AIRCRAFT TO BE USED BY THE U.S. AIR FORCE, NAVY AND MARINES, AS WELL AS THE BRITISH ROYAL NAVY.

   Reason: Feature Mismatches

5. THE NATION'S NUMBER-ONE TOYMAKER, KNOWN FOR ITS BARBIE DOLLS, WILL TIE THE MERGER KNOT WITH THE COMPANY FAMOUS FOR ITS MATCHBOX CARS.

   Reason: Structural Problems

6. BUT THE NEWS WAS MORE OF A BOOST FOR BOEING, THE LARGEST COMMERCIAL AIRCRAFT MAKER WHICH HAS NOT BUILT A FIGHTER PLANE SINCE WORLD WAR II.

   Reason: Structural Problems