

## **Transfer-Driven Machine Translation**

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### **Abstract**

Transfer-Driven Machine Translation (TDMT) is a method in which the translation process is driven by properties of each input utterance. In TDMT, transfer knowledge applied to each input sentence, is central to the translation process. When necessary, the transfer module utilizes various other kinds of information by cooperating with other autonomous modules. TDMT makes the most of the example-based framework which describes knowledge consistently and makes translation efficient. In addition, the system's TDMT knowledge is constructed based on statistical observation of paired source-target sentence translations. The prototype system, which translates spoken Japanese dialogues into English, has shown great promise.

**Keywords:** machine translation, transfer, example, cooperation

### **1 Introduction**

In human translation when translating an easy sentence, the result is produced quickly using only surface-level knowledge. When translating a complex sentence, a more elaborate process is performed, using syntactic, semantic, and contextual knowledge. Many machine translation (MT) systems have syntactically and semantically analyzed input sentences according to a conventional grammar. However, spoken-language expressions tend to deviate from conventional grammar. Many applications dealing with spoken-language, such as automatic telephone interpretation, need efficient and robust processing to handle diverse input.

In the meantime, empirical approaches like the statistical framework of (Brown et al. 90) and the example-based framework of (Nagao 84; Sato et al. 90; Sumita et al. 91) have drawn attention in natural language processing as large-scale corpora emerge. In the field of MT, translation examples can be collected from a large bilingual corpus using a consistent framework, and can serve as empirical data about linguistic phenomena for translation in a specific domain.

This paper proposes a method called Transfer-Driven Machine Translation (TDMT), which carries out efficient translation processing by determining the necessary translation processes according to the nature of the input sentence. TDMT makes the most of the example-based framework which describes knowledge consistently and achieves efficient translation. For this reason, the knowledge of TDMT is built based on the statistical observation of a domain corpus.

TDMT enhances the advantage of an example-based framework with other mechanisms. For instance, the example-based framework can be strengthened by also utilizing a rule-based framework. Namely, TDMT performs efficient and robust translation using various kinds of strategies in order to treat diverse input.

Section 2 explains the basic idea of TDMT. Section 3 explains a lexical distance calculation which is the central mechanism of the example-based framework. Section 4 explains the TDMT prototype system, and Section 5 reports on the various kinds of experimentation.

The explanations in the following sections are based on Japanese-to-English translation.

## 2 Configuration of TDMT

Translation is essentially converting a source language expression into a target language expression. In TDMT, translation is performed by the transfer module using stored empirical transfer knowledge. Other modules, such as lexical processing, analysis, generation, and contextual processing, help the transfer module to apply transfer knowledge and produce correct translation results. In other words, TDMT produces translation results by utilizing different kinds of knowledge cooperatively and by centering on transfer.

In TDMT, transfer knowledge consists of various kinds of bilingual information. It is the primary knowledge used to solve translation problems.

Figure 1 shows the configuration of TDMT components. Basically, translation is performed by the transfer module using transfer knowledge. In the sequential prototype system, the flow of processing control is fixed. However, on a parallel computer, a distributed mechanism can be achieved in which each module works autonomously and sends its results to the transfer module when appropriate.

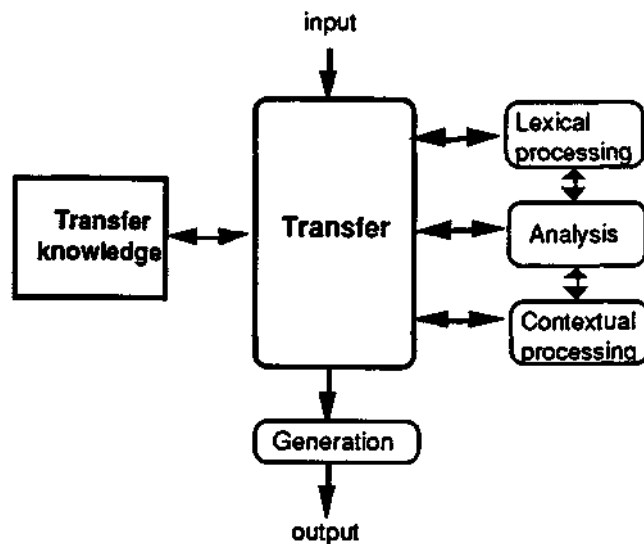


Figure 1 Configuration of TDMT

## 3 Processing based on Distance Calculation

An example-based framework is useful for quickly translating and consistently describing knowledge. The example-based approach for machine translation was advocated by Nagao (Nagao 84). Recently, research following this line has emerged, including Example-Based MT (Sumita et al. 91), Memory-Based MT (Sato et al. 90), and Analogy-Based MT (Sadler 89).

Most of the knowledge in TDMT is described by the example-based framework. The central mechanism of the example-based framework is the distance calculation measured in terms of a

thesaurus hierarchy. This framework achieves the best match for the input from among a stored set of source-target example utterance pairings. It selects the most plausible target expression in transfer and revised source expression in analysis. The distance is calculated quickly because of the simple mechanism employed. Through providing examples, various kinds and levels of knowledge can be described in the example-based framework.

### 3.1 Distance Calculation using Thesaurus Codes

The distance between two words is reduced to the distance between their respective semantic attributes in a thesaurus. Words have associated thesaurus codes, which correspond to particular semantic attributes. The distance between the semantic attributes is determined according to the relationship of their positions in the hierarchy of the thesaurus, and varies from 0 to 1. The distance between semantic attributes  $x$  and  $y$  is expressed as  $d(x, y)$ . Provided that the words  $X$  and  $Y$  have the semantic attributes  $x$  and  $y$ , respectively, the distance between  $X$  and  $Y$ ,  $d(X, Y)$ , is equal to  $d(x, y)$ . That is, the distance between the words is defined as the computed distance between their semantic attributes.

The hierarchy of the thesaurus is in accordance with the thesaurus of everyday Japanese [Ohno et al. 84], in which 60,000 words are classified into one-thousand categories and arranged in a four-layer hierarchy based on the intuitions of the two lexicography authors. When two semantic attributes are dominated by a third semantic attribute in the  $k$ -th layer from the bottom, the distance  $k/3$  ( $0 \leq k \leq 3$ ) is assigned (Figure 2). The value 0 indicates that two codes belong to exactly the same category, and 1 indicates that they are unrelated. For instance, the attributes 'writing' and 'book' are abstracted by the immediate upper attribute 'document'. The distance between 'writing' and 'book' is given as  $1/3$ . Thus, the word "*ronbun*" {*technical paper*} which has the thesaurus code 'writing', and "*yokoushuu*" {*proceedings*} which has the thesaurus code 'book', are assigned a distance of  $1/3$ .

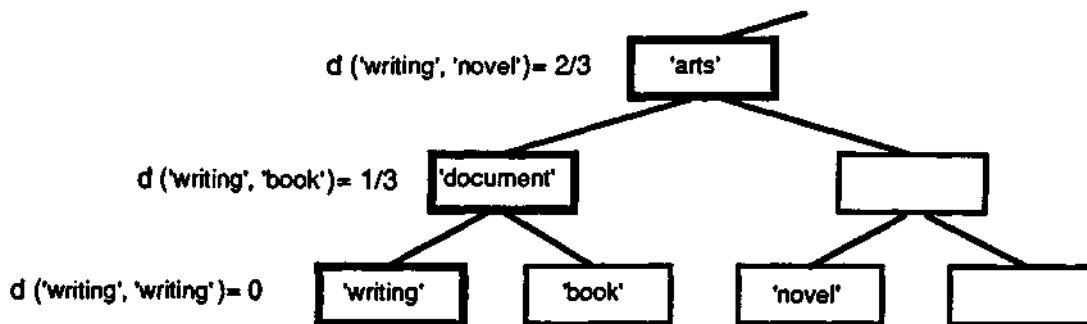


Figure 2 Distance between thesaurus codes

### 3.2 Description of Knowledge

Transfer knowledge describes the correspondence between source language expressions (SEs)

and target language expressions (TEs). Transfer knowledge in an example-based framework is described as follows:

$$\begin{array}{lcl} \text{SE} & \Rightarrow & \text{TE1} \quad (\text{E11}, \text{E12}, \dots), \\ & & \vdots \\ & & \text{TE}_n \quad (\text{En1}, \text{En2}, \dots) \end{array}$$

Analysis knowledge is also described using examples as follows:

$$\begin{array}{lcl} \text{SE} & \Rightarrow & \text{Revised-SE1} \quad (\text{E11}, \text{E12}, \dots), \\ & & \vdots \\ & & \text{Revised-SE}_n \quad (\text{En1}, \text{En2}, \dots) \end{array}$$

Analysis knowledge enables the application of transfer knowledge by revising the SE, when translation cannot be performed by transfer knowledge alone, as will be explained in Section 5.5. Although the form of the knowledge descriptions is virtually the same, transfer knowledge descriptions map onto TEs, whereas analysis knowledge descriptions map onto revised SEs. Each TE and Revised-SE is associated with examples.  $E_{ij}$  indicates the  $j$ -th example of  $TE_i$  or Revised- $SE_i$ . In order to select a TE or Revised-SE we input important words within the SE or Revised-SE and compare them respectively with words in the TE examples or Revised-SE ones. The most appropriate TE or Revised-SE is selected according to the calculated distance between the input words and the example words.

Let us suppose that an input,  $I$ , and each example,  $E_{ij}$ , consist of  $t$  elements as follows:

$$\begin{array}{l} I = (I_1, \dots, I_t) \\ E_{ij} = (E_{ij1}, \dots, E_{ijt}) \end{array}$$

Then the distance between  $I$  and  $E_{ij}$  is calculated as follows:

$$d(I, E_{ij}) = d((I_1, \dots, I_t), (E_{ij1}, \dots, E_{ijt})) = \sum_{k=1}^t d(I_k, E_{ijk}) * W_k$$

The attribute weight,  $W_k$ , expresses the importance of the  $k$ -th element in the translation.  $W_k$  is given for each  $I_k$  by the TE distribution or Revised-SE distribution resulting from that  $I_k$ 's semantic attribute.

The distance from the input is calculated for all examples. Then the example with the least distance from the input is chosen, and the TE of that example extracted. The most plausible TE or Revised-SE corresponds to the closest  $E_{ij}$  to  $I$ .

Further, if there is only one TE or Revised-SE, but no example close to the input, the application of the item of knowledge is rejected.

For instance, the sentence pattern, "X wa Y desu" ( $X$  topic-particle  $Y$  be),<sup>1</sup> has two variables. Suppose that it is translated into English as follows.  $X'$  denotes the transferred

<sup>1</sup> ( $X_1, \dots, X_n$ ) is the list of corresponding English words.

expression of X:

$X wa Y desu \Rightarrow X' be Y' ^2$   
((*watashi*{I}, *Suzuki*), (*koko*{here},*jimukyoku*{office}), ...),  
X' *may be paid* by Y'  
((*hiyou* {expense} , *genkin* {cash}), ...),  
X' *will be done* by Y'  
((*kouen*{speech} ,*sama*{Mr.}),...),  
:

The sentence (1) has the pattern "X wa Y desu":

(1) "*kochira wa kaigi-jimukyoku desu.*"  
{this} {conference office}

The input of "X wa Y desu" in (1) is (*kochira, kaigi-jimukyoku*), and the distance to each example is as follows;

$d((kochira, kaigi-jimukyoku), (watashi, Suzuki)) = 0.75 ^3$   
 $d((kochira, kaigi-jimukyoku), (koko, jimukyoku)) = 0.08$   
:  
 $d((kochira, kaigi-jimukyoku), (hiyou, genkin)) = 0.92$   
:  
 $d((kochira, kaigi-jimukyoku), (kouen, sama)) = 1.00$   
:

"X' be Y' " is selected as the TE of "X wa Y desu" because it contains (*koko,jimukyoku*), which is the closest example to (*kochira, kaigi-jimukyoku*). Thus, we get the following translation after generation:

(1') "*this is the conference office*"

## 4 Japanese-to-English Prototype System

A Japanese-to-English TDMT prototype system has been designed to confirm the feasibility of TDMT principles. The system is running on a Genera 8.1 Symbolics Lisp Machine and can quickly translate inputs in the domain of inquiries concerning international conferences.

### 4.1 Control of Translation Process

The prototype system is designed to process sequentially, and our current method for determining when to invoke necessary procedures is incomplete. Currently, the following

<sup>2</sup> In this paper, variables and actual words are expressed in capital letters and italics, respectively.

<sup>3</sup> These values were computed based on the present transfer knowledge of the prototype TDMT system.

sequential control mechanism is used to obtain the most efficient processing possible.

- Translation is attempted by first applying only transfer knowledge; when this fails, the system tries to apply analysis knowledge.
- The surface matching between an input string and transfer knowledge item is preferred. In other words, the application of transfer knowledge is attempted in the order string-level, pattern-level, grammar-level.
- The highest level unit of the input sentence is transferred first; then units at lower levels are transferred, etc.

## 4.2 Knowledge

At present, the TDMT prototype system provides string-, pattern-, and grammar-level transfer knowledge, which operate by string matching, pattern matching, and grammatical matching, and are selectively utilized based on the nature of an input sentence. Also, the system performs pattern matching on syntactic and semantic markers derived by the analysis module.

The effectiveness of transfer knowledge and analysis knowledge is an important problem in TDMT. The authors are investigating a corpus of about 270,000 words in the domain of inquiries concerning international conferences for a prototype translation system. The frequencies of occurrence of these Japanese and English sentences in the corpus were determined and analyzed, and transfer knowledge and analysis knowledge to cover the domain are being compiled. Our corpus was constructed for the purpose of analyzing linguistic phenomena and gathering statistical information. It includes the results of morphological and syntactical analysis for each sentence, and the English equivalents (Ehara et al. 90). For instance, the top ten canned sentences cover 22% of the corpus, and the top ten sentence patterns cover 35%. These results indicate the high coverage with string- and pattern-level knowledge.

## 5 Sketch of Translation

This chapter shows various translation strategies using the TDMT prototype system.

### 5.1 String-matching

At the string level, certain frequent SEs can determine the TE unconditionally. For instance, the Japanese sentence "*moshimoshi*" is translated into "*hello*" with only the following transfer knowledge:

*moshimoshi => hello*

Figure 3 shows this translation that only uses string-matching.

### 5.2 Pattern-Matching

Pattern-level transfer knowledge has variables. The binding words of the variables are regarded as input. For instance, "*X o o-negai shi masu*" {X, particle, *ask-for*, *do*, *will*} contains the variable X. Suppose that it is translated into the four kinds of English expressions shown below:

*X o o-negai shi masu* => *may I speak to X* ((*sama*{Mr.}),(*kyoku*{station}),...),  
*please give me X'* ((*bangou* {number}),...),  
*please X'* ((*kakunin-suru* {confirm}),...),  
*could you reserve X'* ((*heya*{room}),...)

The following two sentences have the pattern "*X o o-negai shi masu*":

- (1) "*kaigi-jimukyoku* {conference office} *o o-negai shi masu.*"
- (2) "*daimoku* {title} *o o-negai shi masu.*"

The closest example to (*kaigi-jimukyoku*) belongs to the example set that the TE "*may I speak to X'*" has, while the closest example to (*daimoku*) belongs to the example set that the TE "*please give me X'*" has. Thus, we get the following translations illustrated in Figures 4 (a) and (b):

- (1') "*may I speak to the personnel section.*"
- (2') "*please give me the title.*"

### 5.3 Grammatical-matching

Translation cannot always be accomplished with the surface information alone. A further alternative is to apply transfer knowledge to the input string based on grammatical properties. For instance, assuming PPN stands for proper noun, the grammatical pattern "PPN PPN PPN numeral", which occurs 39 times in our corpus, without exception expresses an address as follows:

*Toukyou-to Minato-ku Shimbashi 1* => *1 Shimbashi Minato-ku Tokyo-to*

Therefore, the following grammar-level transfer knowledge is built.

PPN1 PPN2 PPN3 Numeral => Numeral' PPN3' PPN2' PPN1'  
 ((*Toukyou-to, Minato-ku, Shimbashi ,1* ),...)

This transfer knowledge allows the following translations, illustrated in Figure 5.

*Osaka-shi Kita-ku Chaya-machi 23* => *23 Chaya-machi Kita-ku Osaka-shi*

### 5.4 Structural Disambiguation

When there are several ways to apply transfer knowledge to the input sentence, structural ambiguity occurs. For instance, when the pattern "*X no Y*" is applied to the sentence "*ichi-man en no hoteru* {hotel} *no yoyaku* {reservation}", there are two possible structures:

- (1) *ichi-man en no (hoteru no yoyaku)*
- (2) *(ichi-man en no hoteru) no yoyaku*

In such cases, the most appropriate structure is selected by computing totals for all possible combinations of partial translations and selecting the combination with the best total score. If the input does not have a closely corresponding example, a TE with a large distance is selected. The structure with the least total distance is judged most consistent with empirical knowledge, and is chosen as the most plausible structure. The pattern " X no Y " corresponds to several possible TEs, such as the following:

X no Y	=>	Y' of X'	((ronbun {technical paper}, daimoku {title}),...),
		Y' for X'	((hoteru{hotel} ,yoyaku{reservation}),...),
		Y' in X'	((Kyouto{Kyoto} , kaigi{conference}),...),
		X' Y'	((en{yen} , heya{room}),...),
		:	:

The translation of "*ichi-man en no hoteru no yoyaku*" is shown in Figure 6.

In structure (1), " X' Y' " with the distance value of 0.5 and " Y' for X' " with the distance value of 0.0, generates (1') with a total distance value of 0.5. The total distance for structure (2) is 0.0, and the translation based on (2) is (2'). (2') is selected as the translation result because it has the least total distance value. In (1), (*en*, *yoyaku*) is semantically distant from the examples of "X no Y ", which increases the total distance.

- (1') "*10,000 yen reservation for hotel*"
- (2') "*reservation for 10,000 yen hotel*"

Transfer based on a distance calculation prefers the common result, but nonetheless accepts the uncommon one if necessary, and is thus a robust translation method. The enrichment of examples increases the accuracy of determining the TE because conditions become more detailed (Sumita et al. 91).

## 5.5 Analysis

For some structurally complex sentences, translations cannot be performed by applying transfer knowledge alone. In such cases, the analysis module is also invoked. The transfer module receives the information from the analysis modules and then applies transfer knowledge on the basis of that information.

The analysis described in this paper is not the understanding of structure and meaning on the basis of a parsing of the input sentence according to grammar rules, but rather the extraction of the information required to apply transfer knowledge to the input and to produce the correct translation from the input sentence.

Since the case order is relatively free in Japanese, the position of a wh-case constituent in a sentence is not fixed. On the other hand, in English the position of wh-case is an important constituent for determining the sentence mood, and its position is constrained. For instance, the sentence (1) contains the wh-case "*dono-youni*" {*in what manner*}.



(1) " *sanka-ryou wa dono-youni o-shiharai ni nan masu ka*"  
 { *attendance fee, particle, in what manner, pay, particle, do, will, interrogative* }

The following analysis knowledge identifies wh-case:

*dono-youni X => dono-youni wh-case X* (a set of examples)

Also another analysis knowledge item normalizes to the revised SE (1') the wh-case position so that the transfer knowledge about wh-mood can be applied. By these analysis knowledge items the input sentence

(1') " *dono-youni wh-case sanko-ryou wa o-shiharai ni nari masu ka*"

When the transfer module receives the information about the application of this analysis knowledge, it applies the transfer knowledge needed for translation and the (1'') is generated shown in Figure 7.

(1'') " *how will you pay the attendance fee ?*"

### 5.6 Preliminary Parallel System

In order to achieve flexible processing which exchanges necessary translation information, a preliminary implementation on a tightly-coupled parallel computer called Sequent Symmetry is under study based on the results from the prototype sequential system.

At present, transfer and analysis proceed autonomously and cooperatively using our example-based framework (Furuse et al. 92) as shown in Figure 8.

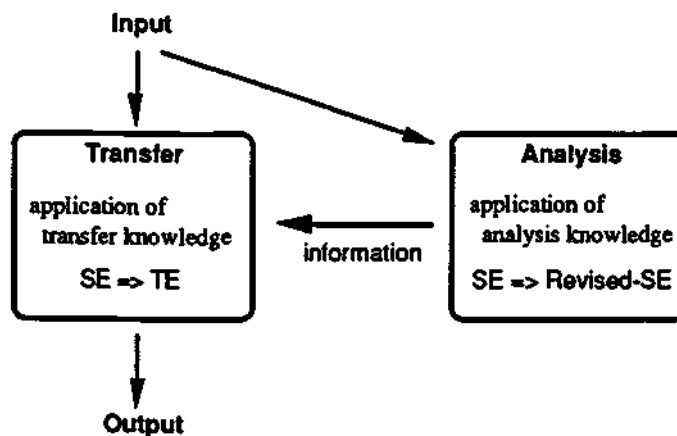


Figure 8 Cooperation between transfer and analysis

Figure 9 shows the translation results from this preliminary implementation.

The translation strategies of (a) and (b) in Figure 9 have been explained in Sections 5.2 and 5.5, respectively. Some sentences can be translated without resorting to invoking the analysis module shown in (a), while the analysis module sends information to the transfer module when appropriate. See Figure 9 Part (b).

A well-balanced load on each process can be achieved by the integration of transfer and analysis in an example-based framework.

## 6 Concluding Remarks

TDMT (Transfer-Driven Machine Translation) has been proposed. The prototype TDMT system which translates Japanese to English spoken dialogues, has been constructed with an example-based framework. The consistent description by example which smooths the cooperation between transfer and analysis, have shown the high feasibility. However, to make TDMT more effective, many kinds of important future work are left. Some of them will be mentioned below.

First, a flexible translation mechanism must be achieved which effectively controls the translation process via distributed cooperative processing by a parallel computer, and incorporating various kinds of processing such as rule-based into the cooperation mechanism. In the preliminary parallel system explained in Section 5.6, the simple cooperation mechanism between transfer and analysis is used. To achieve a flexible translation mechanism, a distributed cooperative translation mechanism should be studied by dividing translation functions and communicating them effectively. Also, distance calculations for selecting the most plausible TE or Revised-SE, and total distance calculations for structural disambiguation, can be processed more quickly under a parallel environment.

Secondly, the TDMT prototype system presently provides string-, pattern-, and grammar-level transfer knowledge. The study of more abstract transfer knowledge, such as semantic-level knowledge, is an important direction for future work. Additionally, the integration of an example-based framework with other frameworks that will handle more abstract knowledge, should be considered.

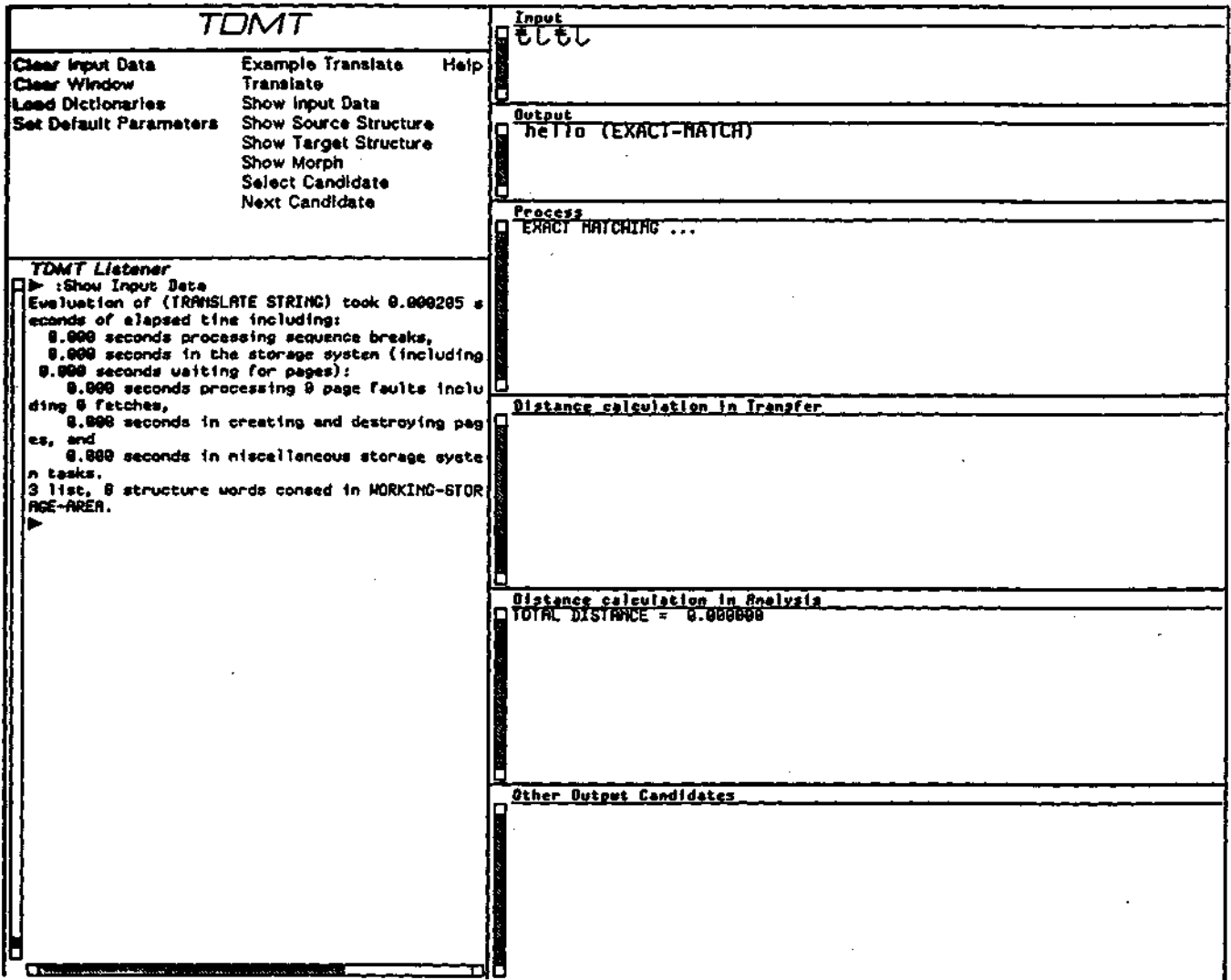
Thirdly, building knowledge that covers the domain effectively is important for TDMT. We are now concentrating on building transfer knowledge and analysis knowledge from statistical observation of the domain corpus. TDMT knowledge, especially transfer knowledge, is built from a bilingual corpus that has correspondences between Japanese and English. When the correspondences between the two languages are not supplied, the sentence alignment technique in two parallel corpora (Brown et al. 91; Gale et al. 91) that gives the correspondences between two languages, will play an important role in building knowledge in TDMT. Also, contextual knowledge should be built to incorporate contextual processing into TDMT.

Finally, knowledge acquisition mechanisms will become important for adaptation, since TDMT adopts an example-based framework that is one empirical approach. If an input is unfamiliar to the system due to a shortage of empirical knowledge, there is the possibility that the system will fail. In this case, by adding the feedback to the database of translated utterances in the form of new translation examples, transfer knowledge can be easily updated, and the system will learn to translate correctly by using this improved empirical knowledge. The more examples the system

learns, the better the system performance will become.

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The input Japanese sentence is as follows:

もしもし  
 moshimoshi  
 {hello}

This translation can be performed only by string-matching.

Figure 3

TDMT		
Clear Input Data	Example Translate	Help
Clear Window	Translate	
Load Dictionaries	Show Input Data	
Set Default Parameters	Show Source Structure	
	Show Target Structure	
	Show Morph	
	Select Candidate	
	Next Candidate	
<b>TDMT Listener</b> ▶ :Show Input Data Evaluation of (TRANSLATE STRING) took 0.154089 s seconds of elapsed time including: 0.003 seconds processing sequence breaks, 0.001 seconds in the storage system (including 0.000 seconds waiting for pages): 0.000 seconds processing 0 page faults inclu- ding 0 fetches, 0.001 seconds in creating and destroying pag- es, and 0.000 seconds in miscellaneous storage syste- m tasks. 1,371 list, 1,649 structure words consed in WORK		
<b>Input</b> 会議事務局をお願いします		
<b>Output</b> may I speak to the conference office (1.0e-30)		
<b>Process</b> >>> first attack ... translate ... (会議事務局 を お 願 い し ます)		
<b>Distance calculation in Transfer</b> 0.000000 : (?X を お 願 い し ます) => (may I speak to ?X) 0.000000 : (会議事務局) => the conference office <b>TOTAL DISTANCE = 0.000000</b>		

(a) The input Japanese sentence is as follows:

会議事務局 を お 願 い し ます  
*kaigi-jimukyoku o o-negai shi masu*  
 { conference office , particle , ask-for , do , will }

TDMT		
Clear Input Data	Example Translate	Help
Clear Window	Translate	
Load Dictionaries	Show Input Data	
Set Default Parameters	Show Source Structure	
	Show Target Structure	
	Show Morph	
	Select Candidate	
	Next Candidate	
<b>TDMT Listener</b> ▶ :Show Input Data Evaluation of (TRANSLATE STRING) took 0.150673 s seconds of elapsed time including: 0.004 seconds processing sequence breaks, 0.002 seconds in the storage system (including 0.000 seconds waiting for pages): 0.000 seconds processing 0 page faults inclu- ding 0 fetches, 0.002 seconds in creating and destroying pag- es, and 0.000 seconds in miscellaneous storage syste- m tasks. 1,269 list, 1,245 structure words consed in WORK		
<b>Input</b> 題目をお願いします		
<b>Output</b> please give me the title (0.555555)		
<b>Process</b> >>> first attack ... translate ... (題目 を お 願 い し ます)		
<b>Distance calculation in Transfer</b> 0.555555 : (?X を お 願 い し ます) => (please give me ?X) 0.000000 : (題目) => the title <b>TOTAL DISTANCE = 0.555556</b>		

(b) The input Japanese sentence is as follows:

題目 を お 願 い し ます  
*daimoku o o-negai shi masu*  
 { title , particle , ask-for , do , will }

The above translations result in different TEs for "X o o-negai shi masu" based on distance calculation results. The numbers attached to the output English expressions indicate total distance values.

Figure 4

TDMT		
Clear Input Data Clear Window Load Dictionaries Set Default Parameters	Example Translate Translate Show Input Data Show Source Structure Show Target Structure Show Morph Select Candidate Next Candidate	Help Translate Show Input Data Show Source Structure Show Target Structure Show Morph Select Candidate Next Candidate
<b>TDMT Listener</b> ▶ :Show Input Data Evaluation of (TRANSLATE STRING) took 0.148163 seconds of elapsed time including: 0.003 seconds processing sequence breaks, 0.002 seconds in the storage system (including 0.000 seconds waiting for pages): 0.000 seconds processing 0 page faults including 0 fetches, 0.002 seconds in creating and destroying pages, and 0.000 seconds in miscellaneous storage system tasks. 1,751 list, 1,562 structure words consed in WORKING-STORAGE-AREA.		
<b>Input</b> 住所は大坂市北区茶屋町二十三です		
<b>Output</b> The address is 23 Chaya-machi Kita-ku Osaka-shi (1.5e-30)		
<b>Process</b> >>> first attack ... translate ... (住所は大坂市北区茶屋町二十三です)		
<b>Distance calculation in Transfer</b> 0.000000 : (7X <字>) => (1X) 0.000000 : (7X は 7Y) => ((SUB 1X) 2BE 1Y) 0.000000 : (住所) => the address 0.000000 : (大坂市 北区 茶屋町 二十三) => (23 Chaya-machi Kita-ku Osaka-shi) TOTAL DISTANCE = 0.000000		
<b>Distance calculation in Analysis</b> TOTAL DISTANCE = 0.000000		

The input Japanese sentence is as follows:

住所	は	大坂市	北区	茶屋町	二十三	です
<i>juusyo</i>	<i>wa</i>	<i>Osaka-shi</i>	<i>Kita-ku</i>	<i>Chaya-machi</i>	<i>23</i>	<i>desu</i>
( address,	particle,	PPN,	PPN,	PPN,	Numeral,	be )

PPN stands for proper noun. This translation can be performed by grammatical matching of "Osaka-shi Kita-ku Chaya-machi 23", a typical Japanese address expression.

Figure 5

TDMT		
Clear Input Data Clear Window Load Dictionaries Set Default Parameters	Example Translate Translate Show Input Data Show Source Structure Show Target Structure Show Morph Select Candidate Next Candidate	Help
<b>TDMT Listener</b> ▶ :Show Input Data Evaluation of (TRANSLATE STRING) took 0.433816 seconds of elapsed time including: 0.009 seconds processing sequence breaks, 0.018 seconds in the storage system (including 0.000 seconds waiting for pages): 0.000 seconds processing 0 page faults including 0 fetches, 0.018 seconds in creating and destroying pages, and 0.000 seconds in miscellaneous storage system tasks. 3,096 list, 4,981 structure words consed in WORKING-STORAGE-AREA. ▶ :Show Source Structure <pre>           (JOSHI-NO (?R の ?Y))           /      \          /        \         /            \        /              \       /                \      /                  \     /                    \    /                      \   /                        \  /                            \ (1万円)                    (ホテル) </pre> ▶ :Show Target Structure <pre>           (0.0 (1Y for 1X))           /      \          /        \         /            \        /              \       /                \      /                  \     /                    \    /                      \   /                        \  /                            \ reservation                (0.0 (1X 1Y))                              /      \                             /        \                            /          \                           /            \                          /              \                         /                \                        /                  \                       /                    \                      /                      \                     /                        \                    /                          \                   /                            \                  /                              \                 /                                \                /                                  \               /                                    \              /                                      \             /  \            /  \           /  \          /  \         /  \        /  \       /  \      /  \     /  \    /  \   /  \  /  \ reservation                (10000 yen) </pre>		
<b>Input</b> 1万円のホテルの予約		
<b>Output</b> reservation for 10000 yen hotel (0.0)		
<b>Process</b> >>> first attack ... translate ... (1万円のホテルの予約)		
<b>Distance calculation in Transfer</b> 0.000000 : (?R の ?Y) => (1Y for 1X) 0.000000 : (予約) => reservation 0.000000 : (?R の ?Y) => (1X 1Y) 0.000000 : (1万円) => (10000 yen) 0.000000 : (ホテル) => hotel TOTAL DISTANCE = 0.000000		
<b>Distance calculation in Analysis</b> LEXICAL-TRANSFORMATION ... 0.000000 : (1万) => (1万) TOTAL DISTANCE = 0.000000		
<b>Other Output Candidates</b> 10000 yen reservation for hotel (0.5)		

The input Japanese sentence is as follows:

1-万    円    の    ホテル    の    予約  
*ichi-man    en    no    hoteru    no    yoyaku*  
 { ten thousands, yen, particle, hotel, particle, reservation }

Currently, the system cannot generate articles well, as seen in this translation.

In this translation a structural ambiguity occurs in the course of applying transfer knowledge

"X no Y => ....". By comparing the total distance values, "reservation for 10,000 yen hotel" is preferred over

"10,000 yen reservation for hotel". The tree structures in the left window show the preferred Japanese structure and corresponding English structure.

Figure 6

TDMT		Input
Clear Input Data	Example Translate	参加料はどのようにお支払いになりますか
Clear Window	Translate	
Load Dictionaries	Show Input Data	
Set Default Parameters	Show Source Structure	
	Show Target Structure	
	Show Morph	
	Select Candidate	
	Next Candidate	
TDMT Listener		Output
▶ Show Input Data Evaluation of (TRANSLATE STRING) took 0.958904 seconds of elapsed time including: 0.828 seconds processing sequence breaks, 0.811 seconds in the storage system (including 0.800 seconds waiting for pages): 0.000 seconds processing 0 page faults including 0 fetches, 0.011 seconds in creating and destroying pages, and 0.000 seconds in miscellaneous storage system tasks. 9,272 list, 11,101 structure words consed in WORD-KIND-STORAGE-AREA.		how will you pay the attendance fee (2.8e-38)
		Process
		>>> first attack ... translate ... (参加料はどのようにお支払いになりますか) >>> second attack ... LOCAL-TRANSFORMATION ... (参加料はどのようにWH-CASEお支払いになりますか) TOTAL-TRANSFORMATION ... (どのようにWH-CASE参加料はお支払いになりますか)
		Distance calculation in Transfer 0.000000 : (?X WH-CASE ?Y) => (IX IY) 0.000000 : (どのように) => how 0.000000 : (?X ますか) => (will you IX) 0.000000 : (?X に ?Y) => (IX) 0.000000 : (?X は ?Y) => (IY (OBJ IX)) 0.000000 : (お支払い) => pay 0.000000 : (参加料) => the attendance fee TOTAL DISTANCE = 0.000000
		Distance calculation in Analysis LOCAL-TRANSFORMATION ... 0.000000 : (どのように お) => (どのように WH-CASE お) TOTAL-TRANSFORMATION ... 0.200000 : (参加料はどのようにWH-CASEお支払いになりますか) => (どのようにWH-CASE参加料はお支払いになりますか) LEXICAL-TRANSFORMATION ... 0.000000 : (どのように) => (どのように) TOTAL DISTANCE = 0.200000

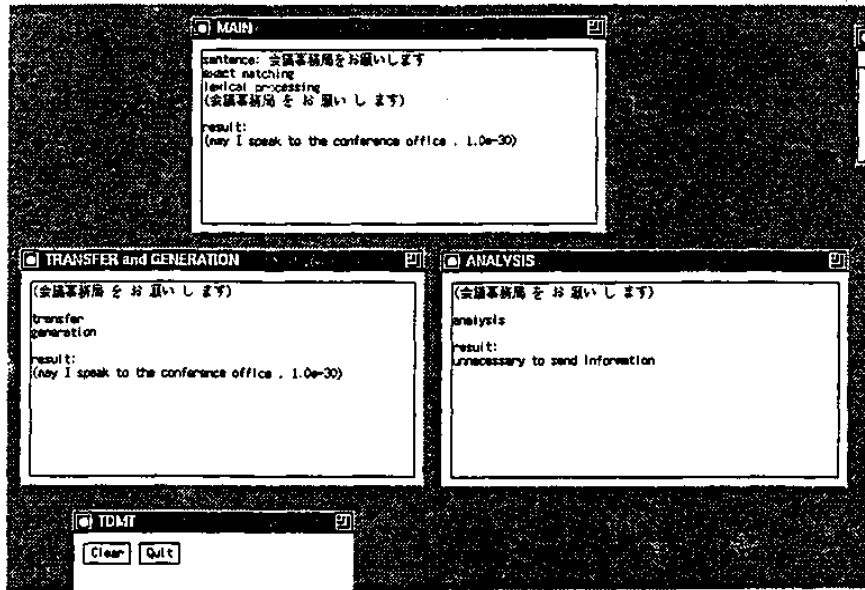
The input Japanese sentence is as follows:

参加料      は      どのように      お支払い      に      なり      ます      か  
*sanka-ryo      wa      dono-youni      o-shiharai      ni      nari      masu      ka*  
 { attendance fee , particle , in what manner , pay , particle , do , will , interrogative }

This translation utilizes analysis knowledge about wh-case. For instance, "dono-youni" can occur legally in various sentence positions.

Figure 7

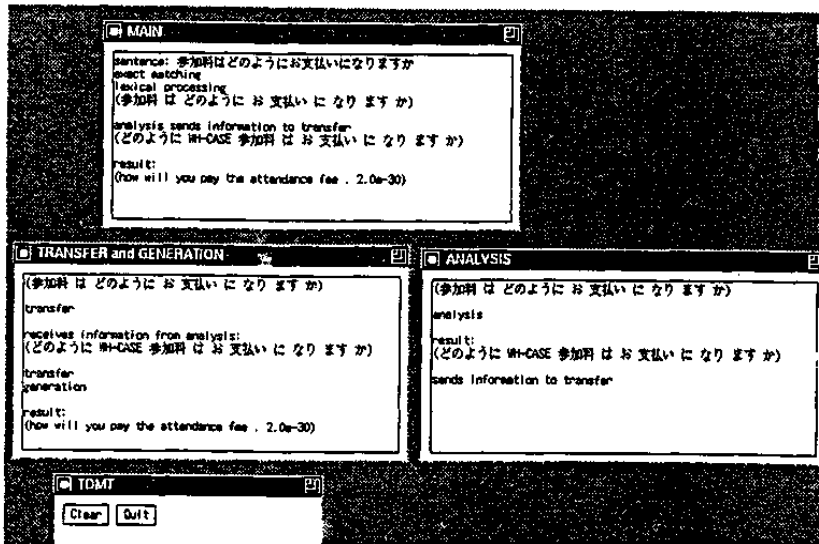




The input Japanese sentence is as follows:

会議事務局 を お 願 い し ま す  
*kaigi-jimukyoku o o-negai shi masu*  
 { conference office , particle , ask-for , do , will }

(a) Translation without resorting to analysis



The input Japanese sentence is as follows:

参加料 は どのように お 支 払 い に な り ま す か  
*sanka-ryo wa dono-youni o-shiharai ni nari masu ka*  
 { attendance fee , particle , in what manner , pay , particle , do , will , interrogative }

(b) Translation by sending information from analysis to transfer

Figure 9

