PAPER

Incremental Transfer in English-Japanese Machine Translation

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SUMMARY Since spontaneously spoken language expressions appear continuously, the transfer stage of a spoken language machine translation system have to work incrementally. In such the system, the high degree of incrementality is also strongly required rather than that of quality. This paper proposes an incremental machine translation system, which translates English spoken words into Japanese in accordance with the order of appearances of them. The system is composed of three modules: incremental parsing, transfer and generation, which work synchronously. The transfer module utilizes some features and phenomena characterizing Japanese spoken language: flexible word-order, ellipses, repetitions and so forth. This is influenced by the observational facts that such characteristics frequently appear in Japanese uttered by English-Japanese interpreters. Their frequent utilization is the key to success of the exceedingly incremental translation between English and Japanese, which have different word-order. We have implemented a prototype system Sync/Trans, which parses English dialogues incrementally and generates Japanese immediately. To evaluate Sync/Trans we have made an experiment with the conversations consisting of 27 dialogues and 218 sentences. 190 of the sentences are correct, providing a success rate of 87.2%. This result shows our incremental method to be a promising technique for spoken language translation with acceptable accuracy and high real-time nature.

key words: *machine translation, incremental interpretation, Japanese spoken language, linguistic phenomena*

1. Introduction

With the advance of communication technology in recent years, there have appeared new requirements of spoken language processing systems. In particular, on spoken language translation, which is a basic technology for advanced real-time machine translation systems such as automatic telephone interpretation and speech dialogue interpretation, a number of studies have been made. Spontaneously spoken language, different from written language with which most traditional machine translation systems have dealt, has the following characteristic features: (1) ill-formed expressions appear frequently [8], (2) expressions appear continuously [7]. It is thus important to consider the above two features for the purpose of the development of practical spoken language machine translation systems.

In order to cope with the first feature, that is, robustly translate ill-formed expressions including extragrammatical phenomena, fragment expressions and so forth, many corpus-based approaches have been proposed. This framework, which includes example-based translation [6], [14], statistics-based translation [3], [4], has achieved some degree of accuracy. Most machine translation systems which have been developed so far, however, do not cope with the continuous nature of speech. These systems, because of their sentence-by-sentence-based approaches, cannot transfer it until the end of the utterance sentence, which inhibit real-time nature of processing. To satisfy the requirement of the second feature, it is necessary to develop a technique for incremental translation whose processing synchronizes with the input [12]. Moreover, in spoken language machine translations, the high degree of incrementality [1] is preferred to that of quality.

This paper proposes an incremental machine translation system which translates English input words into Japanese in accordance with the order of appearances of them. The system is composed of three modules: incremental parsing, transfer and generation, which work synchronously. Since it translates English sentences in an incremental way, the system can be expected to be available for an advanced real-time machine translation system with simultaneous interpretation [9].

The incremental transfer frequently utilizes some features and phenomena characterizing Japanese spoken language, that is, makes up Japanese translations including flexible word-order, ellipses, repetitions and so forth. The utilization of these characteristics is the key to success of the exceedingly incremental transfer to Japanese speech. So far, Amtrup has introduced a technique for incremental chart-based transfer in English-German machine translation [2]. German and English are, however, similar in word-order. On the other hand, our technique makes possible the translation between English and Japanese, which have different word-order. The features and linguistic phenomena used in our system frequently appear in human dialogue. Consequently, the user can understand the translations with ease.

We have implemented a prototype system named Sync/Trans which can parse English dialogues on a word-by-word basis and generate Japanese speech immediately. To evaluate the effectiveness of Sync/Trans, we have made an experiment with all the dialogues which appear in an English textbook for the seventh grade in Japan. The results have shown our incremen-

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tal method to be a promising technique for spoken language machine translation with acceptable accuracy and high real-time nature.

This paper is organized as follows: Sect. 2 explains the typical characteristics of Japanese spoken language and provides the idea for generating Japanese speech incrementally and synchronously. Section 3 introduces the technique for incremental English-Japanese machine translation and shows an example. Section 4 reports on experimental results on Sync/Trans.

2. Incremental Translation: Issue, Idea and Advantage

2.1 Fundamental Issue

Incremental translation makes up target languages in a way of word-by-word according to the order of appearances of source languages. The important keys to succeed in such the translation are incrementality of the processing and accuracy of the results. However, there exists a trade-off between them.

Provided that incrementality is stressed, the appropriate translations might not be made up. For example, translating the following English sentence:

E1 I met her in the park yesterday.

into Japanese from left to right, then we would obtain the translation J1-1 whose both quality and accuracy are very low.

J1-1 *watashi-wa* (I) *atta* (met) *kanojo-ni* (her) *koen-de* (in the park) *kinoo* (yesterday).

Provided accuracy is stressed, the order of appearances of English words cannot be considered. For example, the Japanese appropriately corresponding to E1 is as follows:

J1-2 *watashi-wa* (I), *kinoo* (yesterday), *koen-de* (in the park) *kanojo-ni* (her) *atta* (met).

It is, however, impossible to generate "*kinoo koen-de kanojo-ni atta*" before the end of E1. Because the word "yesterday" appear at the end of E1.

There exists an essential difference between English and Japanese in word-order. This issue is fatal to incremental translation. To achieve the incremental translation, it is necessary to develop newly an appropriate technique.

2.2 Characteristics of Japanese Spoken Language

To solve the issue pointed out in the previous section, it is an effective way to adopt an approach based on human interpretation processes. We have studied on features and phenomena characterizing Japanese spoken languages uttered by English-Japanese interpreters [11].

Table 1 Bilingual dialogue data

Number of dialogues	12
Domain	Inquiries about conference/travel
Participants	1) English speaker, 2) E-J interpreter, 3) Japanese speaker, 4) J-E interpreter
Object of study	Utterances by 2) E-J interpreter
Number of utterances	512

We used the bilingual dialogue data in ATR Dialogue Database (ADD) [5]. Table 1 shows the features of the data. The dialogue domain is inquiries about an international conference or travel, and 512 utterances by English-Japanese interpreters have been studied. The results of their studies have clarified that characteristic features and extra-grammatical phenomena appear frequently: division (11 utterances), flexible word-order (26 utterances), repetitions (31 utterances) and ellipses (74 utterances). They have also reported these phenomena appear more frequently in Japanese speech by interpreters than in the usual one†. These facts are just considered to characterize incrementality of the interpretation process, and also suggest that humans can easily understand the utterances including the above mentioned phenomena.

2.3 Basic Idea

Let us now try to accurately and incrementally translate **E1** into the Japanese. Table 2 shows the process of the incremental translation, which we propose in this paper. Details of the process are as follows: For the first input word "**I**," the Japanese "*watashi*" is generated, and for second "**met**," a suffix "*wa*" and a verb "*met*." Since in Japanese a verb generally appears at the end of a sentence, here ends the first translation sentence once. That is, the translation is *divided* into two sentences. Although the translation "*watashi-wa atta* (I met ⋯.††)" does not specify whom, where, and when I met, it includes the content to be translated at least.

Next, we turn to the second translation sentence. For an input word "**her**," the target expression "*kanojo-ni*" is generated. Moreover, after the prepositional phrase "**in the park**," "*koen-de*," and for the last word "**yesterday**," "*kinoo*." Finally, in order to arrange the style of the translation sentence the target verb "*atta*" is generated again. The word "*atta*" is *repeated* to add more detailed information to the first sentence. The sentence "*kanojo-ni koen-de kinoo atta*." can be easily understood because of high *flexibility of word-order* in Japanese. Although the second sentence *omits* the person who met her, it can be restored from the first sentence.

†Compare with [15].

††This means the sentence whose objective case is omitted.

Table 2 Example of incremental translation process.

I	met	her	in	the	park	yesterday	.
watashi	*wa atta.*	*kanojo-ni*			*koen-de*	*kinoo*	*atta.*

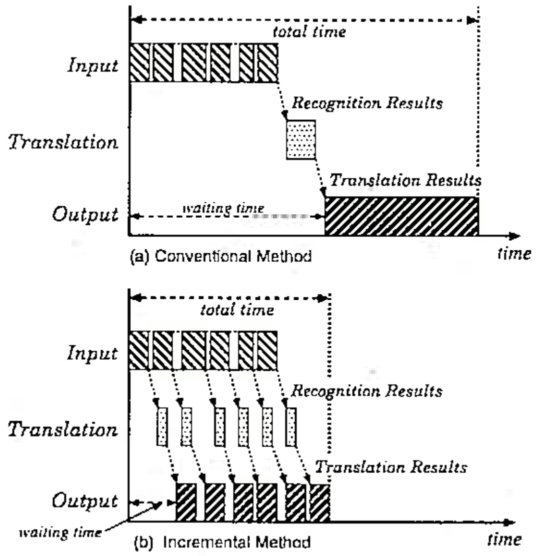

Fig. 1 Comparison between a conventional method and an incremental method.

As explained above, we can expect that incremental English-Japanese translation with acceptable accuracy can be achieved by utilizing the characteristics of Japanese spoken language.

2.4 Advantage

In spontaneously spoken dialogue, both real-time utterance comprehension and generation are essential to smooth communication. In any spoken dialogue interpretation system, it is also required to process dialogues without preventing their coherence. Thus, the system with less waiting time of the users is desirable.

To clarify the difference between a conventional method and our incremental method, a comparison of the timing of the translation processing is shown in Fig. 1. Here, we call the total processing time and the time from the input start to the output start as *total time* and *waiting time* respectively. Since the conventional method can not start the translation processing until the end of the input, the waiting time is long, and therefore the total time necessarily becomes long (Fig. 1 (a)). On the other hand, since the incremental method can start translating before the end of the input, the waiting time is getting shorter. As the result, the total time also becomes shorter (Fig. 1 (b)), and hence our framework can be expected to be available for a real-time spoken language machine translation system.

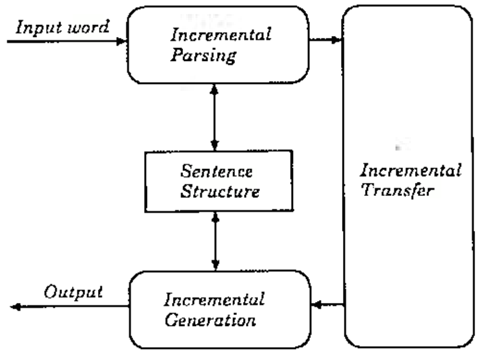

Fig. 2 Configuration of the incremental English-Japanese machine translation system.

3. An Incremental English-Japanese Machine Translation System

An incremental English-Japanese machine translation system which we propose in this paper is composed of three modules: incremental parsing, transfer and generation. Figure 2 shows the basic configuration of the system. These three modules work synchronously with appearances of the source input.

In the spoken language translation, the source expression transferred once does not have to be transferred any longer. Therefore, the incremental generation also operates on the source sentence structure, and marks it as *transferred*. Henceforth, we call the structure for the source sentence, simply, *sentence structure*.

The incremental machine translation system work as follows:

(I) It makes a sentence structure for each input word.

(II) It transfers from the sentence structure to the target structure.

(III) It transforms the target structure into the character string, and marks the transferred source in the sentence structure.

The system makes up the translations by repeating the above processing for every additional word. These processing (I), (II) and (III) are executed in the parsing, transfer and generation respectively. We will explain (I)-(III) in order, and present a translation example.

3.1 Incremental Parsing

For the purpose of parsing on a word-by-word basis, the incremental parsing module adopts both top-down and bottom-up chart parsing framework. Our chart parsing is based on an orthodox framework which Kay has introduced [10]. However, the parser selects the most plausible one among them even if it constructs some

input: the initial sentence structure $[?]_S$ and a sequence of words $w_1, \dots, w_n$
output: a sentence structure

Incremental Chart Parsing
  for i:=1 **to** last **do begin**
    1 **Scan of an input word** w_i**:**
      If $w_i = \alpha$, then add a structure $[w_i]_\alpha$ to a chart.
    2 **Bottom-up parsing:**
      Let the leftmost empty substructure of the sentence structure be γ, then for each structure in the chart, e_a such that $e_a = \alpha$ and each grammar rule of the form $\beta \rightarrow \gamma_1\gamma_2\cdots\gamma_n$ such that $\gamma_1 = \alpha$, add a structure of the form $[e_a[?]_{\gamma_2}\cdots[?]_{\gamma_n}]_\beta$ to the chart if this structure does not exist in the chart. Do this step until the structure whose category is γ are added to the chart.
    3 **Top-down parsing:**
      For a leftmost empty substructure of the sentence structure e_i, $[?]_\delta$ and a structure in the chart, e_b such that $e_b = \alpha$, replace $[?]_\delta$ in the sentence structure e_i with e_b if $\delta = \alpha$.
  $i := i + 1$
end.

Fig. 3 Algorithm for incremental chart parsing.

sentence structures for a word†.

Let us explain shortly the processing mechanism of incremental chart parsing. Figure 3 shows an algorithm for the incremental chart parsing. The parser constructs a complete sentence structure (i.e. sentence structure with no "?") step by step. That is, for the incomplete sentence structure (i.e. sentence structure with "?") $[?]_S$, which is an initial structure before analizing the source, it constructs a new sentence structure for every additional word, and finally obtains a complete sentence structure.

Here, let us consider the following simple English sentence:

E2 He threw the ball.

The sentence structure after the analysis of a word "he" is:

$$[[he]_{NP}[?]_{VP}]_S \quad (1)$$

Since the category of the left-most [?] is VP, the parser constructs the structure (2) for a word "threw," and replaces the $[?]_{VP}$ with (2).

$$[[threw]_V[?]_{NP}]_{VP} \quad (2)$$

As the result, it obtains a new sentence structure (3).

$$[[he]_{NP}[[threw]_V[?]_{NP}]_{VP}]_S \quad (3)$$

Figure 4 shows the process of incremental chart parsing for E2. Table 3 shows sentence structures constructed for each input word††. If the parsing module cannot obtain a new sentence structure for any input word, it fails to parse the source sentence.

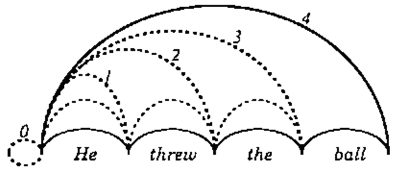

Fig. 4 Incremental chart parsing process.

Table 3 Construction process of sentence structure.

No.	input	sentence structure
0		$[?]_S$
1	he	$[[he]_{NP}[?]_{VP}]_S$
2	threw	$[[he]_{NP}[[threw]_V[?]_{NP}]_{VP}]_S$
3	the	$[[he]_{NP}[[threw]_V[[the]_{Det}[?]_N]_{NP}]_{VP}]_S$
4	ball	$[[he]_{NP}[[threw]_V[[the]_{Det}[ball]_N]_{NP}]_{VP}]_S$

3.2 Incremental Transfer

The transfer module transforms the source structure into the target structure by applying the transfer rules. How the module utilizes the characteristics presented in Sect. 2.2 is defined as transfer rules.

In general, the usual transfer operates on completely analyzed source language. On the other hand, our incremental transfer module also operates on incomplete structures, and obtains the incomplete target structure. For example, to the sentence structure (3), it applies the following rule first.

$$\begin{bmatrix} \text{t-rule} & \text{S} \\ \text{source} & \text{(S1) = NP} \quad \text{(S2) = VP} \\ \text{target} & \text{(T1) = NP} \quad \text{(T2) = VP} \\ & \text{phon : (T1) (T2)} \\ \text{subseq} & \begin{bmatrix} \text{st-rule} & \text{NP} \\ \text{source} & \text{(S1)} \\ \text{target} & \text{(T1)} \end{bmatrix} \begin{bmatrix} \text{st-rule} & \text{VP} \\ \text{source} & \text{(S2)} \\ \text{target} & \text{(T2)} \end{bmatrix} \end{bmatrix}$$

This rule means that the source (S1) with a category NP is transformed into the target (T1), (S2) with VP into (T2), and their targets are generated according to the order. Each transfer is defined as the sub-transfer rule. In this case, the transfer transforms $[he]_{NP}$ into "*kare*" by applying the following rules:

$$\begin{bmatrix} \text{source} & \begin{bmatrix} \text{NP} & \\ \text{phon} & \text{he} \end{bmatrix} \\ \text{target} & \begin{bmatrix} \text{NP} & \\ \text{phon} & \textit{kare} \end{bmatrix} \end{bmatrix}$$

Moreover, to $[[threw]_V[?]_{NP}]_{VP}$, it applies the following transfer rule:

† At present, our prototype system decides the plausibility by using appropriate heuristics. The development of the method and timing of disambiguation is future work.

†† The numbers assigned to the arcs in Fig. 4 correspond to those for the sentence structures in Table 3 respectively.

Table 4 Trace of the translation of E3.

No.	English	constructed sentence structure	Japanese	marked sentence structure
				$[?]_S$
(1)	I	$[[I]_{NP}[?]_{VP}]_S$	*watashi*	$[[!]_{NP}[?]_{VP}]_S$
(2)	met	$[[!]_{NP}[[met]_V[?]_{NP}[?]_{ADV}]_{VP}]_S$	*wa atta.*	$[[!]_{NP}[[!]_V[?]_{NP}[?]_{ADV}]_{VP}]_S$
(3)	her	$[[!]_{NP}[[!]_V[her]_{NP}[?]_{ADV}]_{VP}]_S$	*kanojo-ni*	$[[!]_{NP}[[!]_V[!]_{NP}[?]_{ADV}]_{VP}]_S$
(4)	yesterday	$[[!]_{NP}[[!]_V[!]_{NP}[yesterday]_{ADV}]_{VP}]_S$	*kinoo*	$[[!]_{NP}[[!]_V[!]_{NP}[!]_{ADV}]_{VP}]_S$
(5)	.	$[[!]_{NP}[[!]_V[!]_{NP}[!]_{ADV}]_{VP}]_S$	*atta.*	$[[?]_S$

$$\left[\begin{array}{ll} \text{t-rule} & \text{VP} \\ \text{source} & (\text{S1}) = \text{V} \quad (\text{S2}) = \text{NP} \\ \text{target} & (\text{T1}) = \text{V} \quad (\text{T2}) = \text{NP} \\ & \text{phon}: \textit{wa}\,(\text{T1}).\ (\text{T2})\ \textit{wo}\,(\text{T1}) \\ \text{subseq} & \left[\begin{array}{ll} \text{st-rule} & \text{V} \\ \text{source} & (\text{S1}) \\ \text{target} & (\text{T1}) \end{array}\right] \left[\begin{array}{ll} \text{st-rule} & \text{NP} \\ \text{source} & (\text{S2}) \\ \text{target} & (\text{T2}) \end{array}\right] \end{array}\right]$$

The transfer module transforms the partial structure $[threw]_V$ into "*nageta*" by applying a transfer rule. However, $[?]_{NP}$ is not transformed because it is empty. By these steps, the following target structure is obtained:

$$(kare)(wa(nageta).(?)wo(nageta).) \tag{4}$$

3.3 Incremental Generation

The generation module transforms the target structure into the character string, and generates the target expression. For example, it generates "*kare-wa nageta*" for the target structure (4). Here, as Sect. 2.3 has presented, the verb "*nageta*" is generated at the end of translations again.

In the incremental translation, as we have mentioned before, the source expression translated into the target expressions once does not have to be translated any longer. Accordingly, the incremental generation transforms the sentence structure by replacing the translated source expression with the symbol "!." For example, it transforms (3) into (5).

$$[[!]_{NP}[[!]_V[?]_{NP}]_{VP}]_S \tag{5}$$

The incremental chart parser analizes the next input word under this sentence structure.

3.4 An Example

Table 4 shows the trace of incremental machine translation for the following simple English sentence:

E3 I met her yesterday.

Table 4 demonstrates that the system can generate the corresponding Japanese for every additional English word. Though the generated translation J3 includes some extra-grammatical phenomena peculiar to Japanese spoken language, it represents the appropriate semantic content of E3.

J3 *watashi-wa atta. kanojo-ni kinoo atta.*

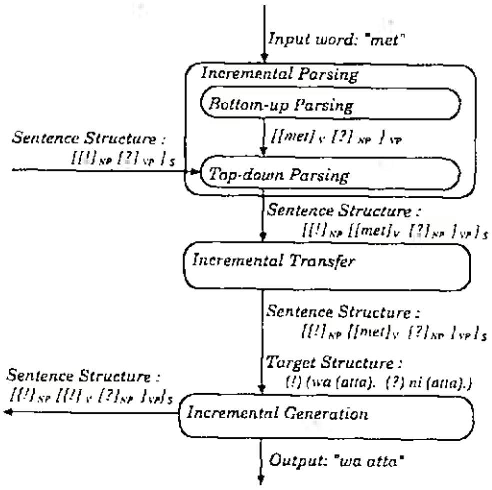

Fig. 5 Translation process of "met" in E3.

To explain the process in more detail, Fig. 5 illustrates the process of translation for an input word "**met**" in E3. The sentence structure before the input of "met" is:

$$[[!]_{NP}[?]_{VP}]_S \tag{6}$$

The incremental chart parsing module constructs the structure (7) by applying a grammar rule to the structure for "met," $[met]_V$.

$$[[met]_V[?]_{NP}[?]_{ADV}]_{VP} \tag{7}$$

Moreover, it constructs the sentence structure (8) by replacing $[?]_{VP}$ in (6) with (7).

$$[[!]_{NP}[[met]_V[?]_{NP}[?]_{ADV}]_{VP}]_S \tag{8}$$

Next, the transfer module applies the transfer rules to (8) in a top-down way. As the result, it constructs the target language structure:

$$(!)(wa(atta).(?)ni(?)(atta).) \tag{9}$$

The incremental generation module executes the output of Japanese "*wa atta.*" by transforming (9) into the character string. Furthermore, it replaces "met" in (8) with "!." The obtained sentence structure is

$$[[!]_{NP}[[!]_V[?]_{NP}[?]_{ADV}]_{VP}]_S \tag{10}$$

and the system analizes the next word "her" under (10).

Table 5 Translation results of 218 sentences.

type	sentences	rate
(A) correct	171	78.5%
(B) correct but unnatural	19	8.7%
(C) incorrect	9	4.1%
(D) failed	19	8.7%

4. Sync/Trans and Its Evaluation

To demonstrate the feasibility and the effectiveness of the incremental machine translation system proposed in the previous section, we have developed a prototype system Sync/Trans in Common Lisp on a Unix workstation. The system has been implemented in the scale of English lexicon 500 words and 60 grammar rules, and the transfer rule has been established corresponding to each grammar rule. Sync/Trans executes the synchronous speech output with the input.

We have made an experiment on Sync/Trans. The conversations consisting of 27 dialogues and 218 sentences which appear in an English textbook for the seventh grade in Japan, have been used. As Table 5 shows, we have classified the English sentences according to the translation results.

English sentences classified into (A) and (B) are successful in translation. 190 of the sentences are semantically correct, providing a success rate of 87.2%. This reveals that our technique can obtain acceptable accuracy on incremental translation. Table 6 shows the typical correct translations, and demonstrates that the utilization of linguistic phenomena such as flexible word-order, repetitions and ellipses makes possible generating Japanese translations incrementally. The translations on Sync/Trans are different, in the sense that they include such the phenomena, from those on a conventional system. Their translations, however, represent exactly the semantic contents of the source sentences.

Since some of the translations which Sync/Trans generates include extra-grammatical language phenomena naturally, it is necessary to examine whether they are practical as the results by a spoken language translation system. In order to evaluate the quality of the translations on Sync/Trans, we have tried to compare the appearance rates of extra-grammatical phenomena with those on English-Japanese interpreters. Figure 6 shows the relation between the length of 190 successful inputs and the appearance rates of flexible word-order, repetitions and ellipses. Likewise, Fig. 7 shows the relation for 190 of the English sentences reported in Sect. 2.2. Both of these figures reveal the tendency that the higher their appearance rates become as the source sentences are getting longer. In addition, there is not very large difference between both appearance rates with regard to sentences shorter than 4 words, which occupy more than a half of 190 sentences in Fig. 7. It follows from this that the results on Sync/Trans achieve

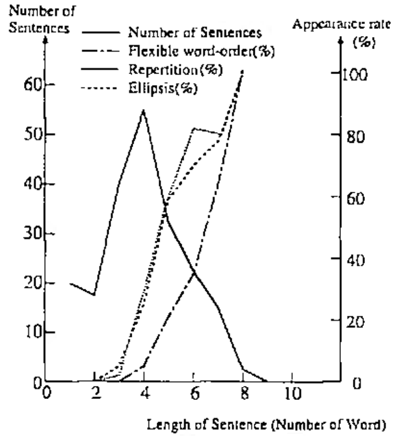

Fig. 6 Appearance rates of extra-grammatical phenomena in translations on Sync/Trans.

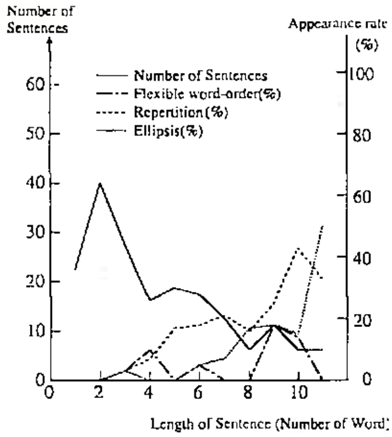

Fig. 7 Appearance rates of extra-grammatical phenomena in translations on interpreters.

the acceptable quality to some extend. Generally speaking, the appearance rates in translations on Sync/Trans are, however, apparently higher than those on interpretations. The main reason is that the transfer stage in Sync/Trans is strongly restricted to the way of word-by-word. The parsing and transfer based on the bigger translation units (e.g., phrase, clause) seem to be valid for generating translations with higher quality.

Unsuccessful 28 sentences, which are classified into (C) or (D) in Table 5, can be also classified according to the causes as Table 7 shows. We analize their causes below. However, since it is also difficult for ordinary machine translation system to correctly translate "ambiguous sentence," we do not analize them here. The causes which are peculiar to incremental machine translation are as follows:

- **Parallel phrase (6 sentences)**
  Sync/Trans cannot analize the source sentence including a parallel phrase. Because it is impossible to clarify the structure of the parallel phrase just when a conjunction is inputed.

Table 6 Typical correct translations.

(source)	I often eat tofu at dinner .
(target)	*watashi wa yoku tabe-masu. tofu-wo yushoku-de tabe-masu.*
(source)	Soccer is very popular in Singapore .
(target)	*sakka wa totemo ninki-ga aru. singaporu-de ninki-ga aru.*
(source)	We have a good teacher .
(target)	*watashi-tachi wa motte-iru. yoi sensei-wo motte-iru.*
(source)	Please, come in .
(target)	*onegai-shi-masu haitte-kudasai.*
(source)	Do you play baseball ?
(target)	*anata-wa shi-masu-ka. yakyu-wo shi-masu-ka.*
(source)	Yes I do .
(target)	*hai* .
(source)	Who is he ?
(target)	*dare desu-ka ? kare-wa.*
(source)	What else can you make ?
(target)	*nani-ka hoka-no-mono wo anata-wa tsukure-masu-ka.*

Table 7 Incorrect translations.

level	cause	sentences	rate
Parser	parallel phrase	6	2.8%
	garden path sentence	3	1.4%
Transfer	ambiguous sentence	15	6.9%
	idiomatic phrase	4	1.8%

Example: I change clothes and eat dinner.

- **Garden path sentence (3 sentences)**
  Sync/Trans might fail to analize an input word with the several possible categories. Because it is difficult to decide which sentence structure is the most plausible just when the several sentence structures are generated.
  Example: Are these books yours?
- **Idiomatic phrase (4 sentences)**
  Sync/Trans cannot generate the appropriate translation for idiomatic phrases.
  Example: I beg your pardon.

5. Concluding Remarks

This paper has proposed the system for incremental English-Japanese machine translation which utilizes the characteristics of Japanese spoken language. Our system is composed of three modules: chart-based parsing, rule-based transfer and generation, and they work incrementally and synchronously. The utilization of characteristics of Japanese spoken language has been the key to success of the exceedingly synchronous output on the machine translation between English and Japanese, which have different word-order.

We have implemented a prototype system Sync/Trans in Common Lisp to evaluate the feasibility and the effectiveness of our incremental method. The experiment with Sync/Trans has shown our incremental method to be a promising technique for spoken language translation with acceptable accuracy and high real-time nature. The following points are left as future work.

- Section 4 has revealed the causes of the errors by Sync/Trans. These issues are certainly fatal to the incremental translation. However, even though the system generates the incorrect translations, it could correct the errors of the translations by utilizing self-repairs. In fact, a human speaker makes self-repairs very frequently in spontaneous speech [13]. We are studying the technique to naturally correct the errors by self-repairs at present, and will report about this at a later date.
- We have used very simple English spoken dialogues in the experiment with Sync/Trans. They consist of only *simple sentences*, and the average length of them is 4.0 words†. In spontaneous dialogues, however, more complex sentences would also often appear. A study on incremental transfer for such sentences is required.

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†The average length of English sentences used for the studies in Sect. 2.2 is 4.9 words.

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