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Chart-based Parsing and Transfer in Incremental Spoken Language Translation

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Abstract

This paper describes a method of implementing the incremental English-Japanese spoken language translation which the authors have proposed so far. To satisfy the requirement that each module in translation has to work synchronously, incremental parsing and transfer are designed on the basis of a chart processing paradigm. Whenever a spoken word is inputed, the parsing module constructs a chart and the transfer is carried out using one of the structures constituting the chart. Some techniques introduced into the incremental parsing could be used for spoken language processing systems with high interactivity.

1 Introduction

In order to develop a system behaving like a simultaneous interpreter, a technique for translating spoken language incrementally and synchronously is essential (Menzel 94). However, it is difficult to incrementally translate between languages which are different in word-order. In fact, both English-Japanese simultaneous interpretation (Kitano 90) and incremental German-English machine translation (Amtrup 95) do not achieve high degree of incrementality and synchronicity owing to such the reason.

To overcome this difficulty, we have proposed an idea of utilizing grammatically ill-formed expressions as the results of English-Japanese translation (Matsubara and Inagaki 97). That is, the system outputs Japanese speech including expressions such as repetitions, inversions, ellipses, errors, repairs and hesitations (Matsubara et al. 97). Since these expressions appear frequently in human dialogues, it seems to be quite all right for speech-to-speech systems to produce grammatically ill-formed sentences.

The purpose of this paper is to provide a method of implementing the incremental spoken language translation system. Many of machine translation systems on a sentence-by-sentence basis have adopted an approach called *structural transfer*. They commonly consist of three stages: parsing, transfer and generation, which work sequentially (Landsbergen and Jong 94). On the other hand, since the incremental translation system needs to output the target language synchronously with the input of the source language, each stage has to work incrementally and synchronously.

This paper concentrates on the stages of the incremental English-Japanese spoken language system. To satisfy the above requirement and make the process of the system clear, the system mainly consists of two stages: parsing and transfer which work synchronously. The transfer stage directly transforms the source language structure into the target language. For the purpose of processing partially inputed sentences halfway through speech, we have adopted a chart processing technique (Kay 80). A chart is a graph in which each label represents an incomplete phrase structure. It is used not only for the parsing but also for the transfer. To put it concretely, each stage works as following:

(1) Whenever a spoken word is inputed, the parsing module constructs a chart consisting of the structures of the sentence which has

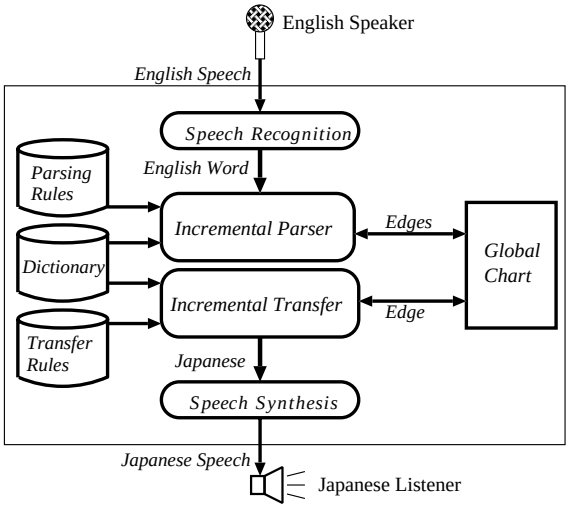

Figure 1: Configuration of the system

been inputed up to the point of time.

(2) Whenever a new chart is constructed, the transfer module selects a structure from the chart and produces a target expression by applying transfer rules to the structure.

2 An Overview

Figure 1 shows the configuration of the incremental English-Japanese spoken language translation system. The system is composed of eight components: speech recognition, speech synthesis, incremental parsing, incremental transfer, parsing rules, transfer rules, a dictionary and a global chart. Both incremental parsing and transfer are based on a chart processing technique (Kay 80). The global chart, which will be explained in the following section, is the data which represents the source language structures formed halfway through the input.

Whenever an English word is inputed, the system executes (1)-(4) sequentially.

(1) Recognition of an English input word
(2) Construction of a global chart
(3) Transformation of a term into Japanese
(4) Production of the Japanese speech

These processes (1)-(4) are executed in the stages of speech recognition, incremental parsing, incremental transfer and speech synthesis respectively. The next section describes the incremental parsing stage in detail and the incremental transfer stage is illustrated with an example in Section 4.

function Chart_Parsing(G_chart, w)
  begin
    $L\_chart := \{\ \}$;
    $temp := \{\ \}$;
    step 1 Consulting Dictionary:
      for each $\alpha \in Cat$
        if $w = \alpha$ **and** $\alpha \rightsquigarrow G\_chart$ **then**
          $L\_chart := L\_chart \cup \{[w]_\alpha\}$;
    step 2 Applicating Rules:
      for each $\sigma \in L\_chart$ **and**
        $\beta \rightarrow \beta_1 \beta_2 \cdots \beta_n \in Parsing\_rules$
        if $\sigma = \beta_1$ **and** $\beta \rightsquigarrow G\_chart$ **then**
        $L\_chart :=$
          $L\_chart \cup \{[\sigma[?]_{\beta_2} \cdots [?]_{\beta_n}]_\beta\}$;
    step 3 Replacing Terms:
      for each $\phi \in G\_chart$ **and** $\psi \in L\_chart$
        if $\exists\gamma\ \gamma = lut(\phi) \wedge \gamma = \psi$ **then**
          begin
            replace $lut(\phi)$ with ψ;
            $temp := temp \cup \{\phi\}$;
          end;
    $G\_chart := temp$;
    if $G\_chart = \{\ \}$ **then**
      error
  else
      Chart_Parsing:= G_chart;
  end.

{main}
$G\_chart := \{[?]_S\}$;
for $i := 1$ to $last$
begin
  w_i :=input_word;
  G_chart :=Chart_Parsing(G_chart, w_i);
  $i := i + 1$;
end.

Figure 2: Algorithm of incremental chart parsing

3 Incremental Chart Parsing

3.1 Global Chart and Local Chart

This study introduces the *chart* (Kay 80) [1] into representing parsing results. Since the chart can represent a partial sentence structure as an active edge, it is effective to utilize charts for incremental parsing. The chart parsing is carried out apply-

[1] Let us complement the small explanation of the chart parsing method. The chart is defined as a labeled directed graph. The label means a phrase structure called a *term*. For example, the term for a word "met" whose category is v can be represented as $[[met]_v[?]_{np}]_{vp}$ using an *undecided term* $[?]_{np}$. The edge whose term includes an undecided term is called *active*.

Table 1: Incremental parsing process of (3.1)

input	local chart				global chart			
word	#	*loc*	*term*	use	#	*loc*	*term*	use
					(1)	0-0	$[?]_s$	
Ken	(2)	0-1	$[Ken]_{np}$					
	(3)	0-1	$[[Ken]_{np}[?]_{vp}]_s$	(2)	(4)	0-1	$[[Ken]_{np}[?]_{vp}]_s$	(1)(3)
met	(5)	1-2	$[met]_v$					
	(6)	1-2	$[[met]_v[?]_{np}]_{vp}$	(5)	(7)	0-2	$[[Ken]_{np}[[met]_v[?]_{np}]_{vp}]_s$	(4)(6)
her	(8)	2-3	$[her]_{np}$		(11)	0-3	$[[Ken]_{np}[[met]_v[[her]_{np}]_{vp}]_s$	(7)(8)
	(9)	2-3	$[her]_{da}$					
	(10)	2-3	$[[her]_{da}[?]_n]_{np}$	(9)	(12)	0-3	$[[Ken]_{np}[[met]_v[[her]_{da}[?]_n]_{np}]_{vp}]_s$	(7)(10)
aunt	(13)	3-4	$[aunt]_n$		(14)	0-4	$[[Ken]_{np}[[met]_v[[her]_{da}[aunt]_n]_{np}]_{vp}]_s$	(12)(13)

ing to edges two main rules: bottom-up rule and fundamental rule. According to our chart parsing algorithm which will be given in the following subsection, the edge formed by a fundamental rule could be used for the transfer processing and the one formed by a bottom-up rule is not. To distinguish between them, we call the chart consisting of the formers *global* and the one consisting of the latters *local*.

3.2 Algorithm

Incremental chart parsing is initialized as a graph consisting of a node labeled 0 and an edge labeled a term $[?]_s$. Figure 2 shows the algorithm of the incremental chart parsing. Let us here introduce a few notations. Let α, β be categories and σ, ϕ, ψ be terms. The notation $\alpha \rightsquigarrow G\_chart$ denotes that α is reachable for the category of the leftmost undecided term of at least one term in G_chart. $lut(\phi)$ denotes the leftmost undecided term of ϕ.

To illustrate the parsing mechanism, let us consider the following simple sentence:

(3.1) Ken met her aunt.

Table 1 shows the parsing process of (3.1). The rows in the local chart and the global chart correspond to the edges. "#" means the order of constructing edges. The parser constructs a new global chart by executing the replacement operation. Since at least one edge is added to the global chart whenever a word is inputed, the transfer can be carried out using the edge. The final results of the local chart and the global chart are given in Figure 3 and 4 respectively. We can see from the figures that the local chart consists of the edges whose length is 1 and the global chart consists of the edges whose initial node is labeled 0.

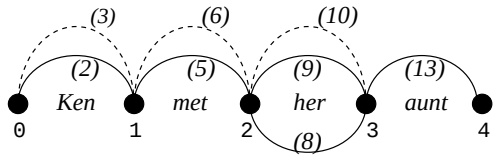

Figure 3: Local chart

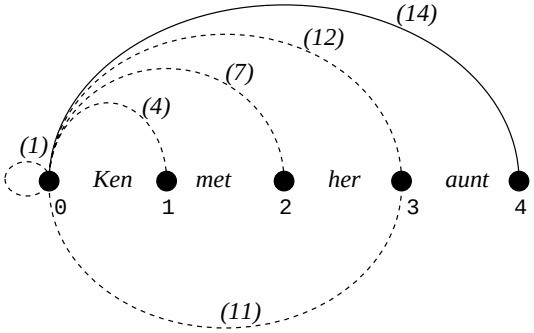

Figure 4: Global chart

3.3 Discussion

This method is a kind of the so-called mixed mode left-corner chart parsing method based on reachability relations. However, the method differs from the others in the point that the operations of applying a parsing rule to an active edge and replacing the leftmost undecided term in an active edge with the term of another active edge are introduced. The latter operation is just corresponding to applying a *composition* rule of combinatory categorial grammar (Steedman 87) which is well known as a framework of incremental parsing. Since introducing the operation makes it possible to construct a new global chart whenever a word is inputed, the system can carry out both synchronous and incremental transfer processing.

4 Incremental Transfer

The system utilizes repairs positively (Matsubara et al. 97). Since we do not have enough space to describe many of the incremental transfer stage, we will explain only a method of producing repairs with an example. The forthcoming literature of the authors will be available for the details.

The system outputs the following Japanese:

(4.1) *ken-wa* (Ken) *atta* (met). *kanojo-ni* (her) *kanojo-no oba-ni* (her aunt) *atta* (met).

synchronously with the input of (3.1). Note that an error "*kanojo-ni*" is corrected by producing "*kanojo-no*" afterward. The reason why the system makes the error is that it selected (11) from two edges (11) and (12) in Table 1. In general, it is difficult to select the correct edge because it is not clear what the next word is. Selecting a variant of (11), $[[!]_{np}[[!]_{v}[her]_{np}]_{vp}]_{s}$ [2] , the transfer module produces the error "*kanojo-ni*". For the next word "aunt", $[[!]_{np}[[!]_{v}[[her]_{da}[aunt]_{n}]_{np}]_{vp}]_{s}$ is newly formed. The transfer result is the repair expression "*kanojo-no oba-ni*". Thus, the system can produces repairs with no extra processing.

5 Concluding Remarks

This paper has described a method of implementing an incremental English-Japanese spoken language translation system. A new method of chart parsing has been introduced for translating spoken language incrementally. The parser behaves like combinatory categorial grammar (Steedman 87) which is known as a framework for incremental parsing. We have discussed that the global chart plays a key role in the incremental parsing and transfer. The technique for making repairs has been showed with an example.

We have implemented a prototype system in Common Lisp. The small scale experiment has showed the system to be available for spoken language translation with highly real-time nature (Matsubara et al. 97). Currently, we are developing a large scale system for interpreting spontaneous speech. However, the serious problem that the structural ambiguities on the way of processing may explode would arises on the system. Since active edges include the prospects of the forthcoming words, too many edges could be formed. It is thus no longer easy for the transfer stage to select an appropriate edge. The technique for disambiguating semantically as early as possible seems to be worthwhile subject to investigate.

[2] The symbol ! means the inputed English word has already been translated into Japanese.

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