This paper reports some trials on mechanical translation from English to Japanese through a case structure constructed on Hornby's verb patterns. Though the general theory of case structures is still at the beginning of study, it provides partial sentential patterns with rough but reasonable classification labels. After determination of schematic dependency relations, multi-vocal problems for choosing appropriate equivalents are dissolved using subcategories of terms and cases. Case structures of English are transformed into those of Japanese if necessary, and from those, Japanese sentences are generated by a Japanese grammar.

1. Introduction

English and Japanese are fairly different languages from each other. Accordingly, it will be necessary to make translation based on a kind of deep structures of sentences which determines sentential forms schematically in respective languages. The case structure used here is a conventional one which is closely related to surface structures. But it was found that the case structure is fairly useful by adding some new means in construction and usage of it.

The parsing for obtaining the case structure from English sentences is done by category-matching on a fairly precise verb pattern given by A.S. Hornby. It dissolves most of multi-syntactic and semantic category problems of words and phrases, and determines global dependency relations among constituents of English sentences.

Subsequently, it determines the appropriate Japanese equivalents and post-positions among several candidates by using subcategories of terms and individual prepositional words.

The case structure thus obtained contains the modal part which represents various characteristics of the predicate part in almost independent form of respective languages. It also embeds idiomatic expressions in itself.

At the level of the case structure, the difference between both language expressions is not so large. Transformations of sentential forms such as those of non-living subjects and those of principal clauses followed by long subordinate ones for readability are processed at this stage without difficulty. From the case structures transformed into Japanese, translated sentences are generated under control of various involved parameters.

2. Case structures

2.1 Case structures of verbs

Many English words have multi-syntactic and semantic categories. However, these multi-categories of a word in a sentence should be able to be dissolved in a context of the sentence, namely, in syntactic and semantic relations to the neighboring words. A.S. Hornby has given comparatively precise verb patterns. The use of verb patterns at parsing is fairly effective to identify the syntactic categories of words and phrases as well as their syntactic roles such as complements and adverbial infinitives.

On the other hand, an efficient introduction of semantic information about words is very important in order to identify their semantic roles and appropriate Japanese equivalents as well as to dissolve the still remaining syntactic ambiguities after a syntactic analysis. For this purpose, there are several approaches based on the case grammar. It is still in an incomplete state for general purpose of thorough comprehension of sentences. But if it is used on detailed syntactic rules of the conventional word usage with the aids of categories of an appropriate level at various stages of mechanical translation, these approaches based on the case grammar will serve fairly well to assign reasonable
semantic roles to various constituents in a source sentence as well as to choose their appropriate equivalents and sentential forms in the target language.

From the above considerations, a case structure is assigned to a sentence based on Hornby’s verb patterns. Events of discourse are classified by categories of predicates. Fig. 1 shows the upper part of the categorical tree used here. The categories used for describing case structures are, in many cases, those appearing at the rightmost in Fig. 1.

Semantic roles of constituents are described using case labels shown in Table 1.

Table 1 Case labels

| Predicte, Agent, Object, EXPERIence, RECIPient, Source, Goal, INSTRUMENT, DEGREE, COMPARISON, LOCATION, TIME, RANGE, MANNER, ROLE, CAUSE, RESULT, MEANS, PURPOSE, CONDITION, MODAL (FORM, TENSE, ASPECT, Affirmation, MOOD, VOICE), |

By using several pairs of categories and case-labels chosen from the above the main parts of each event are schematically described and called case-frames of events. The first row of Table 2 is the main case-frame of the PTRANS event.

The main part of a case structure based on a case-frame is transformed into a surface structure using a verb which has a sufficient number of links to describe the main part and belongs to an appropriate verb pattern. Table 2 shows verb patterns used for English description of PTRANS.

On the other hand, if a verb pattern is given, pairs of categories and case labels of dependents are almost determined every category of the predicate verb as shown in Table 3. Hence, if the verb patterns and as well as the categories of a verb are recorded in a word dictionary, the possible case structure can be retrieved at parsing immediately. Table 4 shows a part of pairs of verb patterns and categories about ‘take’.

Example 1 shows several examples of case structures obtained by parsing with the aids of Table 4.

After determination of a case structure or a dependency relation of a sentence, there still remain several problems to be solved. One of them is the choice of an appropriate equivalent or a subcategory. The word ‘take’ with the verb pattern VP6A and the case structure has fairly many Japanese equivalents. However, this kind of multi-vocal problems can be dissolved in many cases by looking up subcategories of a few designated dependents involved in the case structure and hence in advance by recording them for each equivalent in the word dictionary as shown in Table 4.

The other is the choice of an appropriate Japanese postposition corresponding to a case label and a category of a dependant of a verb. Though a good correspondence generally holds between them, there are some exceptions. For these cases, the postposition is recorded at the item of the associated verb in the dictionary and picked up at parsing.

Example 1

(1) VP6A : BODily Action

‘He took bread.’

(PRED-BOD.ACT: eat, MOD:(TENSE: past VOICE: active), AG-HUM: he, OBJ-FOOD: bread)

‘He took a taxi.’

(PRED-BOD.ACT: get-on, MOD: (TENSE: past, VOICE: active), AG-HUM: he, OBJ-VEHICLE: a-taxi)

(2) VP6A : Mental TRANSfer

‘I took his speech.’

(PRED-MTRANS: make-a-record-of, MOD: (TENSE: past, VOICE: active), AG-HUM: i, OBJ-EVENT: his-speech)

(3) VP15A : Physical TRANSfer

‘I took the children to the park.’

(PRED-PTRANS: go-leading, MOD: (TENSE: past, VOICE: active), AG-HUM: i, OBJ-HUM: the-children, GO-LOCAT: the-park)
Table 4 A part of the item 'take' in the word-dictionary

| Verb patterns | Categories   | Meanings (and the designated conditions) |
|---------------|-------------|------------------------------------------|
| VP6A          | BOD·ACT     | 1. get into one's hand (OBJ-PHYS-OBJ)    |
|               |             | 2. eat (OBJ-FOOD)                       |
|               |             | 3. get on (OBJ-VEHICLE)                 |
| PTRANS        |             | 1. go carrying (OBJ-NON-LIVING)         |
|               |             | 2. go leading (OBJ-LIVING)              |
| POSS·TRANS    |             | 1. receive (OBJ-COMMODITY)              |
| MTRANS        |             | 1. make a record of (OBJ-MENT·OBJ EVENT) |
| VP22          | PERCEP·ACT  | 1. suppose (OBJ-EVENT)                  |

(4) VP22 : PERCEP·ACT
'I took her intelligent.'
(PRED-PERCEP·ACT:suppose, MOD:(TENSE:past, VOICE:active), EXP(E-HUM):1, OBJ-EVENT:
(PRED-ATTR:intelligent, OBJ-HUM:she))

2.2 Optional cases

Adverbial phrases and clauses outside verb patterns constitute optional cases. Most of idiomatic phrase prepositions such as 'with respect to' and many subordinate conjunctions such as 'when' and 'although' determine the case labels and the Japanese postpositions of the following phrases and clauses. On the other hand, many prepositional phrases which respectively have only one prepositions such as 'with' and 'for' require the information about frame of discourse for determination of the case label and the appropriate Japanese postposition. These information is the categories of the object term of the phrase and those of main verb of the governor and furthermore, in some cases, other information about case structure of the verb pattern.

For example, an adverbial phrase consisting of a prefixed preposition 'in' and an object term with category 'PHYSical LOCATION' can be assigned a case label 'LOC' or 'GOAL', but the appropriate postposition and case label are determined by referring to the semantic category of the main verb.

The necessary information for determining them are recorded each preposition and subordinate conjunction in the word dictionary.

2.3 Case structures of noun phrases and clauses

Case structures of noun phrases and clauses have similar forms to those of sentences as follows;

\[ t (K_1 \cdot C_1 : t_1, \ldots, K_L \cdot C_L : t, \ldots, K_N \cdot C_N : t_N) \] (1)

where \( t \) is the main term, \( t_i \)'s are the dependants and \( K_j \cdot C_j \) is a pair of a case label and a category.

The case structure only consisting of several individual objects and prepositions are determined by referring to the categories of the objects and their syntactic patterns linked with the individual prepositions.

If a noun phrase contains some verbal nouns, the case structure is constructed based on the verbalized words of some of them.

Example 2

(1) 'receipt of his letter'
C-EVENT: receive(PRED-POSS·TRANS: *, OBJ-PHYS·OBJ:letter(OBJ: *, POSS-HUM:his))

(2) 'punctual arrival of trains'
C-EVENT: arrive(PRED-PTRANS: *, AG-VEHICLE:trains, MANN-MODAL:punctual)

where C denotes a certain case for the outside governor and the symbol * denotes the prefixed term to the case frame containing it.

3. Parsing

First, processing of negative expressions and idioms are described. They are processed in a somewhat special manner.

3.1 Negative expressions

Negative expressions of English are fairly different from those of Japanese at the points where negative adjectives or adverbs of English correspond to some negative modifiers and a negative auxiliary verb in Japanese. Hence, it
will be better to express the negative expression of an English sentence in a language-free form at the modal part of the case structure and to generate the corresponding Japanese sentence from that anew. The types of negation are classified to intensified total, total and partial ones.

At parsing, the value of type is put in the modal part of the case structure together with the terms directly negated except the case when the terms belong to the predicate part of the sentence.

Example 3

(i) ~No student can solve the problem~
      (PRED-THINK.ACT:solve, MOD:(AF:(INT.TOT.NEG, student), MOOD:can), AG-HUM:student, OBJ-MENT.OBJ:problem(OBJ:*, DET:def))
(ii) ~Converses are not always true.~
      (PRED-ATTR:true, MOD:(AF:(PAR'NEG, always)), OBJ-MENT.OBJ:converses, FREQuency:always)

Most of terms of modal cases are omitted here and hereafter except important terms for simpli-

3.2 Idiomatic expressions

For an efficient parsing, idiomatic expressions are processed with some priority. They are re-
corded near the heading of the leftmost word among multivocal constituents of the idiom in the word dictionary. If the idiom has a separated form \(s_1 \sim s_n\) as shown in Eq. (2),

\[ t_1, s_1 \cdots s_n, t_2 \]  

the syntactic and semantic conditions on the strings of words or phrases \(s_1, \ldots, s_n\) lying between \(t_1\) and \(t_2\) are recorded together with the partial case structure and the Japanese equivalent of the idiom in the word dictionary as follows;

\begin{equation}
\text{so } \varphi \text{ that } \varphi_3 \quad \text{(DEG-QUALity:so[ADVerb] very\textsuperscript{a}, PRED-ATTR: AdJ [ADjective], RESULT(that[SUBORDinate CONJunction]-EVENT: \varphi_2[SENTence])),}
\end{equation}

where 'very\textsuperscript{a}' denotes the Japanese word equivalent to the English word 'so'.

When a constituent word of an idiom is found in a sentence at parsing, it is examined whether, or not there exist the rest parts of the idiom in the sentence by reading the sentence ahead or by examining the partial case structure already constructed. If there is, and if the intermediate part \(s_1, \ldots, s_n\) satisfies specified conditions by parsing, the partial case structure and the Japanese equivalent of the idiom are added to those already constructed by referring to the word dictionary. Otherwise, ordinary mode of parsing restarts from term \(t_1\).
In such a manner, the number of partial case structures decreases or increases as a term is added to partial case structures and, in many cases, it reduces to unity at the end of parsing.

4. Case transformation

Some typical differences between English and Japanese sentential forms do not require any case transformation. One of them is negative expressions and processed as already mentioned in section 3.1. The others are compound noun expressions containing some verbal nouns which are preferred to be verbalized in Japanese sentences. However, these Japanese sentences are directly generated from the case structure obtained by parsing since the case structure of a compound noun expression is constructed in the same way as a sentence when it contains some verbal nouns as mentioned in section 2.3. Hence, the main differences which require some case transformations are those as mentioned as follows.

4.1 Case transformation for non-causative and state oriented descriptions

Japanese sentences avoid sentential forms in which non-living objects bring actions such as causative and perceptive ones especially when the actions directly affect human beings and some events associated with them. In Japanese, these sentential forms are replaced by non-causative sentences or by resulted-state expressions using state-oriented verbs. This problem is well known as the non-living subject problems and has been fairly well studied by many linguists. 5

It is shown here that the transformation of the expressions can be processed in terms of case structures in a systematic way. First, the value of the voice in the modal case of such a sentence is set passive, because in such a situation a passive form is generally a little bit more acceptable than an active form in Japanese. Second, depending on the category of the main verb and the agent, the agent case is renamed to a more appropriate case so that a more natural Japanese sentence is generated. Third, if possible, the equivalent of the predicate part is modified into a more appropriate form such as state-oriented descriptions.

Some examples of this modification are shown in Table 5.

Table 5 Case transformations

| Category of predicate | Instances of predicate | Case label for agent | Modification of predicate |
|----------------------|-----------------------|----------------------|--------------------------|
| CAUSE                | cause, make           | CAUSE                | DELETion                 |
| ENABLE               | enable                | MEANS                | INTRANS VERB             |
| ENABLE               | allow, permit         | MEANS                | CAUSE                    |
| ENABLE               | prevent               | MEANS                | CAUSE                    |
| PERCEPtual ACTION   | look                  | SOURCE               | INTRANS VERB + capable verb |
| PERCEPtual ACTION   | overlook              |                      |                          |
| EMOTive ACTION      | surprise, please      | CAUSE                | INTRANS VERB             |
The third column of this table designates some candidates of case labels to be renamed for an agent. The appropriate case label and postposition are determined by the category of the term to be filled.

The fourth column designates the version into which the equivalent of the predicate part is to be modified. The versions are classified into two kinds. One of them is REPLacement of the predicate part by a new intransitive verb. The other is some modification of a passive Japanese predicate part. The latter is subdivided into DEletion of a causative verb, INTRANSitive VERBalization and addition of the meaning 'capable' to it.

The version is coded and the code is recorded together with a new Japanese intransitive verb for REPLacement in the word dictionary. In Table 5, the words with a symbol * denote the equivalent written in Japanese.

At the execution of case transformation, the routine designated by the code is called and carries out the necessary processing.

Example 5

By case transformation using Table 5, two English sentences
- (1) 'The weight of snow caused the shed to collapse'
- (2) 'Our limited budget did not allow us to start a new project'

are translated to Japanese sentences corresponding to
- (1)'Owing to the weight of snow, the shed collapsed'
- (2)'Owing to our limited budget, we could not start a new project'

respectively.

The main case transformations used here are as follows:

1. (PRED-CAUSE: cause, AG-QUANT: weight(D1),
   OBJ-EVENT: (PRED-PHYs-act: collapse,
   OBJ-PHYs-OBJ: shed(D2)))

   $\rightarrow$ (PRED-PHYs-act: collapse,
   OBJ-PHYs-OBJ: shed(D2), CAUSE-QUANT: weight(D1))

   where $D_1 := OBJ-QUANT: *$, DET: def,
   POSS-PHYs-OBJ: snow,
   $D_2 := OBJ-PHYs-OBJ: *$, DET: def

2. (PRED-ENABLE: allow, MOD: (TENSE: past, AF: TOT-NEG),
   AG-QUANT: budget(D3), OBJ-EVENT: (PRED-ACT: start,
   AG-HUM: we, OBJ-MENT-act: project(D4)))

   $\rightarrow$ (PRED-ACT: start,
   MOD: (TENSE: past, AF: TOT-NEG, MOOD: can*), AG-HUM: we,
   OBJ-MENT-act: project(D4), CAUSE-QUANT: budget(D2))

   where $D_3 := OBJ-QUANT: *$, POSS-HUM: we,
   PRED-ATTR: limited,
   $D_4 := OBJ-MENT-act: *$, DET: indef,
   PRED-ATTR: new

Beside the above type of case transformations there are miscellaneous types of them. A kind of verbs such as 'bring' requires reference of the category of a term in the object case as well as the one about the recipient or goal case.

A sentence containing a main verb such as 'force' is transformed to a more preferable form in Japanese which has a new manner case filled with a term like 'inevitably' instead of the main verb.

A sentential form which includes the verb 'have' as a main verb is transformed to a more

| Category of predicate | Instances of predicate | Referred case category | Change or addition of case | Modification of predicate |
|-----------------------|-----------------------|------------------------|----------------------------|--------------------------|
| PTRANS                | bring, take           | GOAL-PHYs-LOC          | REPL by 'arrive*'          |                          |
| MTRANS                | bring, take           | EXPER-HUM-UMENT-SUbj   | REPL by 'attain*'          |                          |
| CAUSE                 | force, compel         |                        | ADDITION of a MANNer case  | DELETION                 |
| POSsSession           | have                  | POSS-HUM, OBJ-HUM-UMENT-PHYs-OBJ: NATURAL-phenomenon | CHANGE from POSS to EXHIBITION | REPL by 'exists*'          |
preferable form in Japanese even in the case the 
PPOSessor is a HUMAN unless the expression is 
ike that 'a living POSSessor has a PHYSical OBJ-
act in his hand.' Some examples are shown in 
Table 6.

Example 6

By case transformation shown in Table 6, the 
following three English sentences

(1) 'A few minutes walk brought me the place'
(2) 'The fact led him the conclusion'
(3) 'We had heavy snowfall last year'

are translated into Japanese sentences corres-
ponding to

(1) 'By walking for a few minutes, we arrived
at the place'
(2) 'From the fact, he attained the conclusion'
(3) 'There was heavy snowfall last year'

respectively.

In sentence (1), the agent with the category
PTRANS action is verbalized in construction of
the case structure, and renamed as the case
'MEANS' by the case transformation.

4.2 Case transformation for target-clause
ordering

This section describes a case transformation by
which the order of clauses of a target sentence
corresponds to that of a source sentence to some
extent in the locative or temporal sense.

In general, an English sentence is translated
into a Japanese sentence so that dependency
relations in surface structure such as those of
subordinate clauses to the principal clause do
not change so much for preserving the stream of
the main subjects included in successive English
sentences.

However, there are several exceptions. One
of them has a comparatively definite type in
sentential forms as well as in translation. A
certain kind of English sentences do not corre-
spond to natural Japanese sentences unless the
relation of a subordinate clause to the princi-
pal one is reversed. For example, if a
resultant state is contained as a dependent in
an English sentence which describes an action or
a state, each of them is generally described in
Japanese as a dependent in a sentence which
describes the result as shown in Example 7.

Example 7

Two English sentences

'He awoke to find himself in a strange room'
and

'The problem was so difficult that no man
could solve it'

are translated to Japanese sentences correpon-
ding to

'When he awoke, he found himself in a strange
room'

and

'Because the problem was so difficult, no man
could solve it'

respectively.

The first of the above translation is done by
the case transformation;

(PRED-PERCEP-ACT: awake, EXPER-HUM: he, RESULT-
EVENT: (PRED-PERCEP-ACT: find, EXPER-HUM: he,
OBJ-HUM: himself, LOC-PHYS-LOC: in-room(D )))

--->(PRED-PERCEP-ACT: find, EXPER-HUM: he,
OBJ-HUM: himself, LOC-PHYS-LOC: in-room
(D), TIME-INSTANT: when(PRED-PERCEP-ACT:
awake, EXPER-HUM: he))

where D := OBJ-PHYS-LOC: #, DET: indef,
PRED-ATTR: strange.

The other exceptional translations do not
have definite type, but are desirable for
readability of translated sentences when Eng-
lish sentences have some long adjective or ad-
verbial subordinate clauses or phrases after
their rather short principal clause. These
subordinate clauses have generally more concrete
and essential meaning than the principal clause.

In such cases, if translation is done in the
ordinary way so that the relation of subordinate
clauses to the principal clause remains unchan-
ged, the generated Japanese sentence tends to
have a long essential subordinate part followed
by a short and rather introductory part of the
principal clause. The Japanese sentences thus
taken will often bring about difficulties in
immediate comprehension. Furthermore, when a
part of subordinate clauses is referred in the
next sentence, the immediate identification of
the anaphora will not be so easy owing to
increase of distance from the referring part as
shown in Fig. 3.

In such cases a continuative translation is
more preferable. It assigns a location suc-
ceeding to the principal clause for an equivalent
of the subordinate clause. The subordinate cla-
uses are classified to adverbial clauses and
adjective ones.

In the former case, the subordinate clause
is qualified as a sentence or a coordinate cla-
use in a continuative translation. For a coor-
dinate clause, the coordinate conjunction is
preceded which is determined by the case label
of the adverbial clause and more precisely by
the preposition or the subordinate conjunction.

In the latter case, syntactic roles of a pri-
ncipal clause and a relative clause are reversed
through a modified term as follows;

(K1 : t1 , K2 : t2 , ..., Kn : tn (K1 : s1 , ..., Kn : sn ))

--->(K1 : t1 (K1 : t1 , K2 : t2 , ..., Kn : tsn ,
K1 : s1 , ..., Kn : sn ))

(K1 : t1 , ..., Kn : tsn )

where the double-underlined case means that a
thematic fronting and addition of a certain
thematic postposition is done for the underli-
ned case in generation of a Japanese sentence
Fig. 3 Order of subordinate and principal clauses

Example 8

Two English sentences
'Science deals with sense impressions which are similar to make universal agreement possible' and
'That all men are all equal describes a proposition to which no sane human being has ever been given his assent' are translated into Japanese sentences corresponding to
'Sense impressions which science deals with are similar to make universal agreement possible' and
'To a proposition which describes that all men are all equal no sane human being has ever been given his assent' respectively.

A sentence which contains a kind of appositions is also transformed as follows;

$$\text{PRED:that}(K_1:t_1, \ldots, K_k:t_k),$$

$$K_i:it, \ldots, K_k:it, \ldots, K_l:it \quad \rightarrow \quad \text{OBJ:it}(K_1:t_1, \ldots, K_k:it, \ldots, K_l:it) \quad (6)$$

where $K_i$ is an apposition case to a case $K_j$.

Example 9

An English sentence
'We should make it clear that they lead the same conclusion' is translated to a Japanese sentence corresponding to
'That we should make clear is that they lead the same conclusion'.

5. Conclusion

The case structures obtained by parsing or the transformed case structure are expanded in an appropriate term-order by a Japanese grammar under various control of the involved parameters.

Some experimental results show that this approach is effective to dissolve multi-syntactic and semantic category problems of words and phrases and efficient to transform case structures.

From the viewpoint of more precise and multi-lingual translation, it is desirable that more precise, detailed and standardized definition is established for case structures and hierarchic category systems and also their codes are attached to some word dictionaries. It will not be impossible as far as mechanical translation of technical papers is concerned.

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