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An Evaluation Method for MT Systems and Its Application to ALT-J/E

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Summary

An evaluation method for a Japanese to English machine translation System which estimates trans lation quality based on translation technologies and source text characteristics is proposed. This method is applied to the translation of newspaper articles by the ALT-J/E system and further problems that need to be surmounted are discussed based on the results.
Assuming 70% acceptability to be a practical level of quality, it is shown that morphological and dependency analysis technologies would require accuracy rate per word and per "bunsetsu"(which are Japanese phrase, in most case, consisting of a noun and "joshi" or post-positional word) as high as 99.8% and 99.4%, respectively. Current tech nology has already reached this level. But the precision of translation for individual expres sions is lower than expected values and the ac ceptability rate for the entire sentence drops to

between 40% and 50%. To achieve an acceptability rate of 70%, it is necessary to achieve an average 7% improvement in 9 types of expressions and thus achieve a successful translation ratio of 96%.
To upgrade the translation rate of these ex pressions, it will be necessary to establish tech niques for meaning analysis of post-positional words, translation of expressions that combine noun clauses and compounded words, handling con nections and embedded clauses, and verification of ellipses and paratactical constructions.

1. Introduction
In the field of Japanese-to-English machine translation, numerous experimental systems(1),(2) and commercial systems(3)-(5) have been developed. Without exception, these systems require pre-editing and/or post-editing to be of practical use. Many technological problems have to be solved in order to develop a Japanese-English translation system capable of translating source text without pre-editing for monolingual users(6). To clarify these problems, an evaluation method has to be developed.
There have been some proposal for evaluating the quality of translation. The ALPAC Report(7) proposed a 9 level standard. Nagao(8) proposed two 5-level standards, one each for understandability and faithfulness, and applied it to the Mu-Project. However these methods are concerned with the results of translation. Translation results are dependent on the technologies involved as well as source text characteristics. This relation is so complicated that there has been no evaluation method for it.
Taking notice of the construction of the translation system, this paper proposes an evalua tion method which estimates translation quality based on translation technologies and source text characteristics. This method is applied to trans lation of newspaper articles by the ALT-J/E (Automatic Language Translator : Japanese to English) system (9) ,(10) and further problems to be surmounted are discussed based on the results. And it is also proposed that using this evaluation model, setting the translation acceptability rate at 70% as the target for translation quality will clarify the problem areas in the existing tech nology and identify the tasks to be faced.
The translation process is divided into the sentence analysis phase and the conversion /generation phase. The capability of the former phase is represented by the capability of the mor phological and dependency analysis phases, and

that of the latter phase is derived from the capability of English expression generation for several characteristic expressions in language. An evaluation method is proposed from this point of view.
Specially, 1,000 sentences of lead texts (which are typical introductory sentences sum marizing a newspaper article immediately following the headlines) were taken from the Nikkei Sangyo Newspaper. Sentence structures and characteristic expressions that would pose problems in machine translation were studied. Regarding the charac teristics of structuring, formal characteristics of typical newspaper articles, such as length of articles, number of ″bunsetsu″ and other such statistical features are studied. As characteris tics of expression, we consider 9 types of expres sion may pose problems in the formulation of algo rithms and investigate the frequency of their ap pearance in newspaper articles.
These characteristics of newspaper articles and the data quantity for each individual technol ogy are used in the evaluation method. Estimates of final translation quality are made and compared with the actual measured values to confirm the ac curacy of this evaluation method and examine tech nical problems which remain for solution in the future.

2. Statistical Characteristics Analysis of Newspaper Articles

From the viewpoint of existing machine trans lation technology, actual text (this excludes fic tion, essays, poetry and such artistic literature) for which demand is strong is to be desired for translation. Real text could include classroom textbooks, dissertations, manuals, and newspaper aticles. Of these texts, newspaper articles are read by many persons and are a popular form of text with a premium on speed of reporting. Hopes and expectations to be placed on translation without pre-editing* are great indeed, and this type of text has therefore been selected as the object for evaluation.
Specifically, 1,000 lead texts from the ″Information, Software and AI″ column and the ″Communication″ column of the Nihon Keizai Shim bun, February 1st to 28th,1988, have been selected as object texts. The ″lead text″ as mentioned previously, is the summary which follows the head line of an article. When there is no such sum mary, the first paragraph of the main text of the article is regarded as the lead text. Lead texts generally consist of anywhere from 3 to 5 sen

tences. Hereafter, the sample documents will be referred to as newspaper article texts.

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* Translations with pre-editing pose problems arising from the contents of pre-editing and evaluation becomes complicated. We shall there fore consider work without pre-editing.

2.1 Characteristics of Newspaper Article Forms
A study of the characteristics of the forms of newspaper articles in terms of average number of characters and average number of words per sen tence is summarized in Table 1.

2.2 Characteristics of Expression in Newspaper Articles
From current translation technology, a sen tence which has all of the necessary elements such as the subject, verb and object which constitute an English sentence and which allows application of translated words registered in a dictionary would pose no particular problem. Here we have taken up 9 types of expressions which would cause problems for current machine translation technol ogy and tabulated the frequency with which they appear in newspaper article sentences. The results shown in Table 2 indicate the following.
(1) Compounds consisting of successive nouns are numerous, appearing an average of 3 times per sentence. These are compounded as necessary from proper nouns, numerals and ordinary nouns. It would be difficult to anticipate such compounds and have them compiled and registered into a dic tionary beforehand.
(2) There is frequent usage of functional chain words consisting of compound words with a semantic or syntactic role. However, their numbers are limited when viewed from the types of compound words.
(3) There are many predicates accompanied by modality and compound predicates, which result from combination of subjects or objects directly with verbs to form new compounds. As in the case of compounds of successive nouns, this also is a method of compressing an expression.
(4) There are many expressions using sentences connected within sentences, quotations, and reporting types of expressions. With newspapers primarily playing the role of conveying reports, and following and reporting on events, there frequently arise expressions where the subject and the object are omitted and context analysis be comes neccesary.

3. Concepts of Evaluation Model
3.1 Basic Idea of Quality Evaluation Model
(1) Structure of MT System
ALT-J/E system consists of two major processes, source language analysis and target language generation as shown in Fig.1. These will be referred to as the analytical phase and the conversion/generation phase. The conventional translation system relying on the transfer method usually divides the processing phase into three phases such as the analytical, conversion and gen eration phases. ALT-J/E is already aware of con version to the target language at the analytic stage, so that the conventional stage of conver sion become a process that spans both the analytic and generation phases. Conversion is regarded here as a portion of the generation phase and divides the entire translation process into two phases. However, the conventional three phases can also be considered as same these two phase construction, if the conversion process can be evaluated for each expression.
The analytical phase consists of numerous processes. But as long as the morphological and dependency analyses are both executed accurately, there is little chance of failure in other processes. So for this evaluation model, the analytical phase is taken to consist of the mor phological and dependency analyses.
The conversion/generation phase also consists of numerous phases. But, if a source expression is correctly analyzed in the analytical phase and if the generation mechanism for each expression works correctly, translation results should become almost understandable, regardless of whether it is good English or not.
(2) Remarks for Evaluation Model
The essential meaning of the above thoughts on phase separation is as follows. There are nor mally numerous types of expressions mixed in a single actual sentence. These expressions have mutual reactions that would be brought about when they are combined together. Then the translation quality of the entire sentence cannot be broken down into evaluations of the expressions con tained. This method takes these mutual reactions into consideration and separates the evaluation of the analytical phase from the evaluation of the conversion/genaration phase. Various types of ex pression are mixed in the analytical phase and their reactions are taken into consideration. After this has been accurately analyzed, evalua tion of each individual expression can be con ducted.

3.2 Target Quality for a Practical Machine Translation System

(1) Target quality for translation

The objective of machine translation is to have a finished product in which the contents of an entire article can be understood almost without error. Normally, newspaper articles consist of a number of sentences and an understanding of the outline of an article does not require a completely accurate translation of all of the sentences.

As the passing line for a practical system, therefore, we shall seek as a quality target to have 70% of all the sentences contained in a translation be accurately understood and have nothing particularly inaccurate with the English language structuring.

[Remarks] With 70% as the passing grade, there should be among the unacceptable portion some 10 to 20% whose meaning can be grasped. It is estimated that translation which cannot be understood at all would be limited to about 10%. In Saeki(11), a translation ratio of 85% is judged from experience as being at a level that is practically usable. This ratio includes the portion of translation in which some dubious parts remain and therefore it is judged equal to the standards set forth in this dissertation.

(2) Technical Quality Target

In machine translation, a process error in any one of phases will result in an inaccurate product. In considering the probability of accuracy for each of the phases, the analytical phase consists of uniform processes whereas the conversion/generation phase consists of a variety of processes. It is relatively difficult to improve the accuracy of the latter phase. With these factors in mind, the target yield rate for each phase needed to arrive at a translation with an overall acceptability rate of 70% was calculated (Fig.2). Converting these rates, target processing accuracy values for each phase are as follows.

Morphological Analysis--------- 95%
Dependency Analysis---------- 94.7%
Coversion/Generation---------- 77.8%

4. The Machine Translation Quality Evaluation Model, and Its application to ALT-J/E

4.1 Analytical Phase Evaluation Model

(1) Accuracy of morphological analysis

Assume the average number of words in a sentence to be nm. Assume also that the probability of the words of interest being accurately isolated

from the rest of the sentence and of having the parts of speech, active code and other syntactic attributes accurately appraised (i.e. word accuracy) to be pm. When all of the words in a sentence have been accurately analyzed, mor phological analysis of the sentence can be said to be accurate.

Therefore the probability of accuracy of morp anhological analysis Pm can be expressed by the following equation.

$$Pm = pm \text{ then, } pm = \exp\left(\frac{1}{nm} \ln Pm\right) \quad (1)$$

Assuming from the target accuracy ratio for practical use of the product that Pm = 0.95 (See Fig.2), and from Table 1 that nm = 22.2, the ac curacy per word for purposes of morphological analysis needs to be over 99.8%.

(2) Accuracy rate of dependency analysis

In dependency analysis, dependent phrases are determined in relationship to all ″bunsetsu″. ″Bunsetsu″ are conceived of as pairs of dependent and supporting phrases. All bunsetsu become a de pendent phrase and all bunsetsu excepting the first one but including a period becomes a sup porting phrase. Thus, we can regard the number of steps required for dependent and support pairing to be the same as the number of bunsetsu.

If we assume the probability of each depen dent and support pair determined accurately to be pd, dependency analysis is accurate when all the dependent and support phrases have been accurately determined. Therefore, the probability of accurate dependent and support pairing is

$$Pd = pd \text{ then, } pd = \exp\left(\frac{1}{nd} \ln Pd\right). \quad (2)$$

From Fig.2, the value Pd=0.947 and from Table 1 the value nd = 8.35 are substituted. To achieve the practical target, the accuracy rate of the de pendent and support pair needs to be over 99.4%.

(3) Observation

The relation between Equation (1) and (2) in the case of newspaper articles is illustrated in Fig.3. The technical difficulty in improving both word accuracy in morphological analysis and pair accuracy in dependency analysis increase sharply in both cases above approximately the 98% level. However, it is confirmed from the experiments that the current level of technology has achieved this objective in ALT-J/E.

4.2 Accuracy Rate of the Conversion/Generation

Phase
(1) Conversion/generation accuracy rate
As described before, there seem to be no problems when all elements necessary for transla tion are complete within one sentence and each element is of a simplified form. We shall evaluate the conversion/generation rate by seeing whether the expressions taken up in Table 2 can be accurately translated or not.
We shall assume the number of types of expres sion to be i, and that i=1 to 9, i.e., any one of the 9 types of expression as listed in Table 2. Assume the maximum number of times each expression can appear in one sentence of the original to be Ni, and that the average number of times it ac tually appears to be ni. The probability of the type of expression will be translated accurately when it appears is assumed to be pi.
With a given sentence, let us consider the probability Pi of type i in this sentence being translated without error. The expression of type i has the chance of appearing Ni times and ac tually appears ni times. Therefore, for any one chance, it appears with the probability of ni/Ni. When it actually appears, the probability of error in translation is 1−pi. Thus, the probability of not making an error in translation for every ap pearance is:

$$1 - \frac{ni}{Ni}(1-pi).$$

When there is no error in all Ni chances, this sentence can be said to have cleared the type i expression. The probability of clearing type i expression is:

$$Pi=\{1 - \frac{ni}{Ni}(1-pi)\} \quad (3)$$

Thus, accuracy of processing PG of the con version /generation phase is:

$$PG = \prod_{i=1}^{9} Pi \quad (4)$$

(2) Application of Current Level Technology
Based on experience with the Japanese−English translation experiment system ALT−J/E, the feasibility of the above model is verified. The ni and Ni values are given in Table 3. Current rate of accuracies pi obtained from individual ex periments on various types of expression are as also listed in Table 3. Substituting these values

into Eq.(4), PG is obtained as:
PG =0.48 (5)
Translation experiments dealing with newspaper articles reveal current translation acceptability rates of about of 40% to 50%. Current analytical phase accuracy rate is about 90%. Thus, the translation/generation phase accuracy rate is es timated to be about 45% to 55%. This coincides with results of Eq.(5), which was obtained as ac curacy rate for the individual expressions above.
(3) Relationship between average translation of expressions under observation and the conver- sion/generation accuracy rate
Assuming the following relationship to hold true for translation accuracy pi for all 9 types of expression:
p1=p2= - - - p9=p (6)
the relationship between p and PG would be as shown in Fig.4.
Conversion/generation rate at the practical usage level according to Section 3.2 shows PG > 0.778; therefore the translation accuracy rate for all types of expressions necessary according to Fig.4 shows p>・_0.96. In contrast, current pi average accuracy rate p according to the same diagram shows p=0.89. A difference of about 7% between the two figures remains.
(4) Bottle Neck of Translation Quality of Each Ex- pression
In actual practice, weight of importance will differ according to which of 9 expressions is in volved. As a third case study, it is attempted to identify which of the 9 expressions would cause failure in achieving the target accuracy rate. This results in the graph shown in Fig.5. If one out of 9 expressions should fall below line shown in this figure, achievement of quality required of a practically applicable product would be impos sible.
(5) Conversion/generation accuracy improvement from improved individual expression transla- tion rates
To examine the effects of translation ef ficiency rates of various types of expression on the entire conversion/generation rate, changes in the accuracy rate pi of the types of expression under observation were assumed to be dpi, and changes in the conversion/generation accuracy rate PG were assumed to be dPG(i). Since the value of dPG(i) depends also on the value of pj(j=・/i), the following three cases need to be considered.
a) At current technical levels: dPG(1)(i)
When in relation to all i, pi is in the neighborhood of the present level (Table 2).

b) At average target levels: dPG(2)(i)
When p1=p2= - - - p9=0.96.
c) At maximum efficiency: dPG(3)(i)
When p1=p2= - - - p9=1.0.
Assuming pi=0.01(1%) and calculating dPG(i)
for the above 3 cases results in Fig.6. This
figure reveals that the effects dPG(i) vary,
depending on the type i, of expressions. However,
in the foregoing 3 cases the effects are ap
proximately equivalent.
dPG(2)(i)/dPG(1)(i)=1.8(approximately constant)
dPG(3)(i)/dPG(1)(i)=2.2(approximatety constant)
(7)

4.3 Summary of Quality Model Evaluation Results
(1) Analytical phase technology
To achieve the practical translation quality,
a word accuracy rate of over 99.8% for morphologi
cal analysis, and a dependence and supporting pair
accuracy rate of over 99.4% for dependency
analysis is necessary. Current technical levels
for both morphological and dependency analyses
have almost achieved these rates.
(2) Conversions/generation phase technology
To achieve the target rate of over 77.8% in a
conversion/generation phase, an average transla
tion accuracy rate of over 96% for individually
observed types expression is necessary. Current
values are at about 89%, so an average of about 7%
improvement is required.
With expressions for which translation rates
are already in excess of 90%, it would be dif
ficult to achieve an additional 7% improvement.
For specially structured sentences and connections
in compound sentences, further improvement in
successful translation ratios is necessary. For
consecutive noun compounds, current accuracy rates
range in the neighborhood of 90%. The frequency
of their appearance is high and therefore quality
improvement is vital. Without such improvements,
achievement of practical utility is impossible.

5. Considerations and Tasks to be Confronted
For expressions by types, processing based on
syntactical information will enable analysis and
translation of approximately 80% to 90% of expres
sions. However, when sentences involving a com
bination of such expressions are involved, the
translation rate of each expression needs to be
improved by an average of about 7% each. Also,
the combined expressions need to be appropriately
analyzed and individual expressions decomposed and
re-compounded. To conduct analytical research of
these problems, there is need for further improve

ment of functions which relate to the meaning and context of the sentences.
Major technical problems to be faced in upgrading the accuracy and precision of expression translations will be discussed in the passages to follow.
(1) Translation of the meanings of joshi and auxiliary verbs
Joshi are words normally positioned with nouns and are analyzed as expressing the status of the noun within the sentence. However, this primarily expresses the manner in which the speaker is grasping or handling the phenomenon which is rep resented by the noun in question; the concept of the status in terms of meaning and joshi do not necessarily correspond to each other.
e.g. ﾘﾝｺﾞ が 食べたい。
Ringo ga tabetai.
(I wish to eat an apple)
---"ga" is used as objective. However this is unusual. "wo" is used as an objective.
この 装置 は 寿命 が 長い
Kono sochi wa jumyo ga nagai
(This device has a long lifetime)
---In this case "wa" is not nominative, as it normally is.
The same can be said of auxiliary verbs. Nor mally, auxiliary verbs are processed with verbs and adjectives to express various modalities or tenses. However, Japanese tenses do not correspond exactly to English tenses. There is a major dif ference between Japanese and English in this regard.
e.g. この ランプ が ついたら、
Kono rampu ga tsuitara
(If this lamp goes on.)
---"ta", here does not represent the past tense.
Auxiliary verbs(in Japanese) are used to express the views of the speaker regarding dynamic attributes (expressed by verbs) or static at tributes (expressed by adjectives). There is a substantial difference between this and the views that are observed or grasped from English auxiliary verbs.
Errors in translations related to meanings of joshi and auxiliary verbs in many instances are caused by this difference in grasping the objec tives in the Japanese and English languages. In the future, there will be a need to understand the theory of language recognition and to review the English language expression of the meanings of ex pressions in Japanese.
(2) Translation of noun clauses and compound words
Noun clauses or compounded words with meanings

that are clear that express time, quantity, title and positions, personal names, or geographical names can be analyzed in terms of structuring, and can be translated by using the dependencies among the semantic attributes of each word. However, if these noun clauses and compounded words should be in a mixture of expressions or within the context of an entire text and the interpretation should change, there is difficulty in extracting noun clauses and compounded words and in selecting ap propriate translations which match the meanings within the context of the entire text. Especially when many ordinary words have been combined to form noun clauses or compounded words, it frequently becomes difficult to make a selection from a number of interpretations. Also, one characteristic of newspaper articles is to economize on space by frequently using noun clauses and compounded words that are compressed versions of normal sentences, which makes transla tion difficult.

(3) Connections and embedded sentences

Texts which have connections and embedded sen tences leave many a problem in the area of processing for both meaning and context. Previous translations handled this by translating each unit sentence one by one and later connecting these by appropriate conjunctions or relative pronouns. From the English side however, these do not always match each unit sentence; thus, it is frequently necessary to use participial or gerund construc tions to match the meanings or to substitute ad verbial or noun clauses to complete the transla tion. Occasionally, this type of distinction can not be made on semantic attributes alone; it be comes necessary to look at the relationships be tween phenomena combining subjects, objects and declinable words. A look at the speaker's value judgments regarding phenomena (such as the relationship between the main text and subordinate clause) is required to arrive at an appropriate translation.

(4) Ellipsis and paratactical constructions

When elements of texts which are felt to be necessary in English are missing in the original Japanese text, there is a need to supplement cer tain elements to the text when translating. With the current state of the art, if there should be elements in the preceding sentence of the same paragraph that can be referred to, translation can be handled by such supplementation. It is also possible to supplement ellipsis of indeclinable parts of speech and inflexions.

Example;

A社はBを発売する。Bは従来の装置を改良したものである。五月から発売する。(Company A will place B on sale. B is the equipment which is a version that #1 improved the previous version. #2 put #3 on sale from May.)
The first sentence has no need of supplemen tation because it has both the subject and object in place. The second sentence does not state who(#1) improved the previous product. The third sentence does not state clearly who(#2) will be selling what(#3). #2 and #3 can be supplied from the first sentence but #1 cannot be determined.

However, ellipsis of joshi and verbs are apt to disrupt analysis of the sentence structure it self, making translation difficult.
The same applies in the case of paratactical construction. Expressions consisting of a series of words in a row would be comparatively easy to handle (Example 1 below). However, when expres sions constituting elements of sentence structure follow one after another in a series, analysis of the structure itself becomes difficult (Example 2 below).
Example 1. A社、B社が共同開発した。(Company A and Company B undertook developpment jointly)
Example 2. A社がBを改良したC、Dに機能を追加したEならびにGと融合させたHなどの多くの新製品を発売した。(Company A placed on sale many new products, including C, an improved version of B, E with functions added to the conventional D, and H which is a conglutina- tion with G)

In sentences of paratactical construction, joshi and verbs are frequently omitted. This problem frequently coincides with the problem of interpretation of expressions containing ellipsis.

5. Summary
An evaluation method is proposed which es timate translation quality based on translation technologies and source text characteristics. Ap plying this method to translation of lead texts in newspaper articles with the purpose of achieving practical translations without pre-editing, problems which need to be solved in comparing characteristics of text expressions and current translation technology are identified.
Assuming 70% acceptability to be a practical level of quality, the number of words and bun setsu indicate that the morphological and depen dency analysis technologies would require accuracy rates per word and per bunsetsu as high as 99.8%

and 99.4%, respectively. Current technology has already reached these levels. But the precision of translation for individual expressions is lower than expected values so acceptability rates for the entire text drop to between 40% and 50%. To achieve an acceptability rate of 70%, it is neces sary to achieve an average 7% improvement in all 9 types of expressions mentioned in this study and thus achieve a individual translation ratio of 96%.
To upgrade the translation rates of these ex pressions, it will be necessary to establish tech niques for analysis of the meanings of joshi, translation of expressions that combine noun clauses and compounded words, handling connections and embedded phrases, and verification of ellipsis and paratactical construction.

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