AN ATTEMPT TO COMPUTERIZED DICTIONARY DATA BASES

M. Nagao, J. Tsujii, Y. Ueda, M. Takiyama

Department of Electrical Engineering
Kyoto University
Sakyo, Kyoto, 606, JAPAN

Summary

Two dictionary data base systems developed at Kyoto University are presented in this paper. One is the system for a Japanese dictionary (Shinmeikai Kokugojiten, published by Sansei-do) and the other is for an English-Japanese dictionary (New Concise English-Japanese Dictionary, also published by Sansei-do). Both are medium size dictionaries which contain about 60,000 lexical items. The topics discussed in this paper are divided into two sub-topics. The first topic is about data translation problem of large, unformatted linguistic data. Up to now, no serious attempts have been made to this problem, though several systems have been proposed to translate data in a certain format into another. A universal data translator/verifier, called DTV, has been developed and used for data translation of the two dictionaries. The detailed construction of DTV will be given. The other sub-topic is about the problem of data organization which is appropriate for dictionaries. It is emphasized that the distinction between 'external structures' and 'internal structures' is important in a dictionary system. Though the external structures can be easily managed by general DBMS's, the internal (or linguistic) structures cannot be well manipulated. Some additional, linguistic oriented operations should be incorprated in dictionary data base systems with universal DBMS operations. Some examples of applications of the dictionary systems will also be given.

1. Introduction

To computerize large ordinary dictionaries is significant from various reasons:

1) Dictionaries are rich sources of reference in linguistic processings of words, phrases and text. Algorithms for natural language processing should be verified by a large corpus of text data, and therefore, dictionaries to be prepared should be large enough to cover large vocabulary.

2) Dictionaries themselves are rich sources, as linguistic corpora. A data base system, when a dictionary data is stored in it, enables us to examine the data by making cross references from various view points. This will lead us to new discoveries of linguistic facts which are almost impossible by the printed version.

3) Computerized dictionaries have various applications in such areas as language teaching by computer, machine aided human translation, automatic key word extraction etc.(3)

We have been engaged in the construction of dictionary data base systems these three years, and have almost completed two such systems. One is the system for a Japanese dictionary (Shinmeikai Kokugojiten, Published by Sansei-do) and the other for an English-Japanese dictionary (New Concise English-Japanese Dictionary, also Published by Sansei-do). Both are medium size dictionaries which contain about 60,000 items. In Addition to these two dictionary systems, we are now developing a system for an English dictionary (Longman dictionary of Contemporary English, Published by Longman Publishing Company, England).(4)

Two topics will be discussed in this paper. The first is about the problem of data translation, that is, how to obtain formatted data which are more suitable for computer processings than their printed versions. The second is the problem of data organization, that is, how to organize the formatted data into data base systems. We will also give some examples of applications of these systems.

2. Data Translation from Printed Image to Formatted Data

We decided to input the dectionary contents almost as they are printed, and to translate them into certain formatted structures by computer programs rather than by hand.

Ordinary dictionaries usually contain varieties of information. The description in English-Japanese dictionary, for example, consists of

1. parts of speech
2. inflection forms
3. pronunciations
4. derivatives
5. compounds
6. translation equivalents in Japanese (Usually several equivalents exist and they correspond to different aspects of meaning of the entry word)
7. idioms and their translations
8. typical usages and their translations
9. antonyms and synonyms

etc.

An entry may have several different parts of speech (homograms) and to each part of speech, the other information 2-9 is described (even pronunciation may change depending on the parts of speech). 7, 8 and 9 are usually attached to one of the translation equivalents (see Fig. 1).

In such a way, the description for a dictionary entry has a certain structure, and the several parts of the dictionary descriptions are related to each other. In the printed dictionaries, these relationships are expressed implicitly in linearized forms. Various ingenious conventions

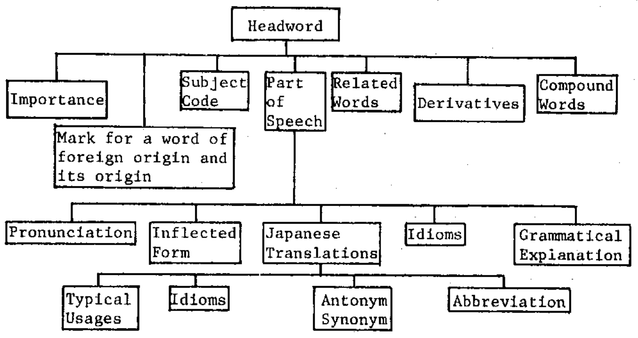


Fig. 1 Relationships among Lexical Descriptions

are used to distinguish the relationships, including several kinds of parentheses, specially designed symbols (𝕴 , 𝕲 , 𝕭 etc.) and character types (italic, gothic etc.). However, in order to utilize these relationships by programs, we should recognize them in the printed versions, and reorganize them appropriately so that the programs can manage them effectively. Instead of special symbols or character types, we should use formatted records, links or pointers to express such relationships explicitly. We call this sort of translation from the printed versions to computer oriented formats as data translation.

The printed version of a dictionary highly relies on human ability of intuitive understanding, and consists of many uncertain conventions. Gothic characters, for example, indicate that the phrases printed by them are idioms, and italic characters show that the entry words have foreign origins. In the input texts for computer, these different types of characters are indicated by a set of shift codes. Shift codes, together with various special symbols such as (,), [,], 𝕼 etc, give us useful clues for the data translation. However, these codes should be interpreted differently, when they are used in different parts of descriptions. " (" shows the beginning of the pronunciation when it appears just after a head word, and, on the other hand, when it is used in the midst of an idiomatic expression, it shows the beginning of an alternative expression of just the preceeding one. Such conventions, however, have many exceptions. Moreover, the fact that there may be errors in the input texts makes the translation process more difficult.

If we use an ordinary programming language like PL/1, the program for this purpose becomes a collection of tricky mechanisms and hard to debug. Data translation of this kind is inevitable whenever we want to process unformatted linguistic data by computer. It would be very useful if we could develop a universal system for data translation (in fact, our system described below has been used not only for dictionary data translations but also for the translations of bibliographic data in ethnology at the National Museum of Ethnology).

2-1. Data Translator/Verifier — DTV

The data translation can be seen as a translation from linearized character strings to certain organized structures. The relationships implicitly expressed in the linearized strings should be recovered and explicitly represented in the organized forms. It is basically a process of parsing. It has many similarities with parsing of sentences in artificial or natural languages. It has more similarities with natural language parsings in the sense that both are defined by many uncertain rules. Therefore, it is reasonable to expect that we can apply the same techniques to this problem that have been proven useful in natural language parsings. Several proposals have been made to define data syntax by using ordinary BNF notations (or CFG).(1,2,5) However, we adopted here the framework of ATN (Augmented Transition Network) instead of CFG by the following reasons:

(1) CFG is essentially a model of a recognizer. Although it is possible to check the syntactic correctness of input texts by CFG rules, we need another component that transduces the parsed trees into formatted records we want. ATN gives us an adequate model of a data transducer. It has provisions for setting up intermediate translation results in registers (registers in ATN are called 'buffers' in our system) and building them up into a single structure (called BUILDQ operation in ATN).

(2) CFG provides an adequate framework for managing recursive structures such as embedded sentences in natural languages. Though recursive structures are also found in dictionary data, they are not so conspicuous. The structures in dictionaries are rather flat. In this sense, CFG is too powerful to define data syntax of dictionaries.

(3) ATN provides a more procedural framework than CFG. Because a CFG based system assumes a general algorithm that applies the rules to the input text, the user who defines the rules cannot control the algorithm. This is a fatal disadvantage of CFG, when the input text contains many input errors. Whenever an input error is encountered during the translation process, a CFG system fails to produce a parsed tree. The system or the human user should trace back the whole process to find the input error which causes the failure. It would be a formidable task.

2-2. Definition of Rules, Codes, Buffers and Files

Based on ATN model, we modified it for data translation. In this section, we will explain the detailed syntax for the DTV (the formal definition of the DVT syntax is given in (8).

(A) Definition of Codes
In the case of syntactic analyses of natural language sentences, the basic units are parts

of speech of individual words or individual words themselves. Special checking functions such as CAT and WORD are prepared in the original ATN model. On the other hand, in the case of data translation, the basic units are individual characters.

A restricted set of characters such as the character set defined by ISO or ASCII are used and sufficient for ordinary computer applications. However, when we want to process real documents or linguistic data like dictionaries, we need much richer set of characters. Though, in principle, a single kind of parenthesis is sufficient for expressing tree-like structures, several different sorts of parentheses such as (, [, ⦅ , { , 、 etc. are used to identify different parts of descriptions in the published dictionaries. We also found out that a certain set of characters, for example, phonetic symbols, appear only in a certain specific position (the pronunciation in the case of phonetic symbols) in the dictionary descriptions. If we could recognize the scope of the pronunciation parts, we would not need to have extra sets of character codes for phonetic symbols. We could interpret ordinary ASCII codes in the pronunciation part not as usual alpha-numeric characters but as phonetic symbols, according to certain pre-defined rules.

However, these redundancies of descriptions are especially useful for detecting input errors. Whenever we find out the codes for phonetic symbols in the positions other than the pronunciation fields, or inversely, when we encounter, in the pronunciation fields, the codes for the characters other than phonetic symbols, something wrong would be in the input texts.

Because we have about 10,000 or more different Kanji-(Chinese) characters in Japanese, a standard code system such as ISO, ASCII etc. is no more adequate, and therefore, a special code system has been determined as JIS (Japanese Industrial Standard). The code system assigns a 2 byte code to each character. We have 752 extra codes which are not pre-defined by JIS and to which the user can assign arbitrary characters. Various types of parentheses, shift code, phonetic symbols etc. have been defined by using these extra codes. Because each character, including alpha-numeric, Kanji, specifically designed symbols, shift codes etc., correspond to a 2 byte code, we can assign a decimal

```
ALPHA-SMALL  =  9057 -  9082
ALPHA-LARGE  =  9025 -  9050
ALPHA        = ALPHA-SMALL, ALPHA-LARGE
KANJI        = 12321 - 20554
SHIFT-GOTHIC = 10273
```

Note : The lower case alphabet characters are defined as the decimal numbers between 9057 and 9087. The alphabet characters are defined as the union of ALPHA-SMALL and ALPHA-LARGE.

Fig. 2 Code Definition by Decimal Numbers

number to each character by interpreting the 2 byte code as an integer representation. By using this decimal number notation, we can define arbitrary subsets of characters as shown in Fig. 2. These subsets of characters play the same role for the data translation as the syntactic categories for sentence analysis. Notice that a character is allowed to belong to more than one character set.

(B) Definition of Rules
A rule of DTV is defined by a triplet as

(condition action next-state).

The condition-part is specified by using the code sets defined in (A). Two forms of specifications are possible.

1. < subset-1, ..., subset-n >
2. (subset-1, ..., subset-n)

The first notation means that the characters in the specified subsets should appear in this order. The second is the notation for specifying OR-conditions, that is, a character in one of the specified subsets should appear. Arbitrary combinations of these two bracketing notations are allowed such as

< (< >) ( ) > .

The action parts, which will be carried out when the condition parts are satisfied, are described by using a set of built-in functions. These are the functions for manipulating buffers and files. Some examples of such built-in functions are shown in Table 1.

Function	Argument	Result
WRITE	*[-number] BUF(Buf-name)	the currently scanned character(or the 'number' preceding chracter) is witten in the buffer.
	RECNO BUF(Buf-name)	the ID number of the current input record is written in the buffer.
	PTR BUF(Buf-name)	the position of the scanned character in the input record is written in the buffer.
	'arbitrary character string' BUF(Buf-name)	the specified character string is written in the buffer.

	BUF(Buf-name)
	FILE(File-name)
		the content of the buffer is written out to the external file.

	:	

MERGE	BUF(Buf-name1,...., Buf-name n)
	BUF(Buf-name)
		the contents of the n buffers are merged into a single buffer specified by the second arguement.

CLEAR	CTR(Counter-name) or BUF(Buf-name)	the counter is cleared to 0 or the buffer is cleared by blank characters.
ADD	CTR(Counter-name) Number	the counter is counted up by the number.

Table 1 Built-in Functions in DTV

Several actions can be specified and they will be executed in sequence.

The next-state specifies the state to which the control is to be transferred after the current rule is applied. A typical state-diagram is shown in Fig. 3.

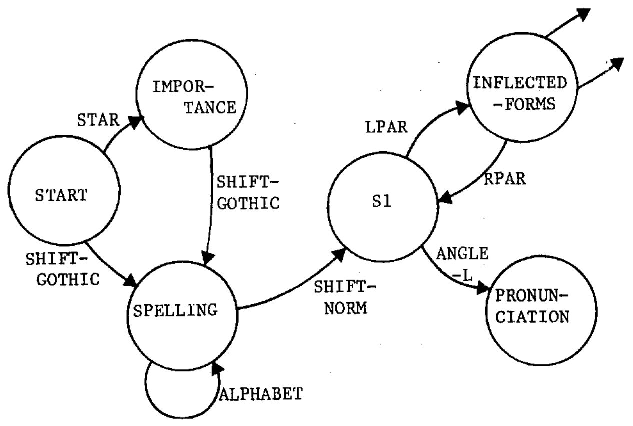


Fig. 3 Tyipical State-Diagram

(C) Definition of Buffers and Files
We can define arbitrary numbers of buffers with various sizes as follows.

BUF-NAME	SIZE(BYTE)	IF-OVERFLOW-STATE
SPELLING	40	SPELL-ERROR
IDIOM	30	IDIOM-EXPAND
.	.	.
.	.	.
.	.	.

One of the typical input errors is the omissions of delimiters which cause serious problems in data translation. Various characters play the roles of delimiters. They are shift codes, several sorts of parentheses, etc. and they are used in pairs (right vs. left parentheses, shift-in vs. shift-out etc.) to delimit scopes of specific data fields. When one of the pair is missing, two situations would occur: the buffers corresponding to the fields may overflow or illegal characters for the fields may be scanned. The latter case can be easily detected because no transition rules are defined for that character. DTV put a message to the error message file which tells at which position the illegal character is found. The former case is rather troublesome. Checking overflow conditions by rules makes the whole definition very clumsy. We can specify in the definition of a buffer, to which state the control makes a transition if the buffer overflows. In that state, some error messages are printed out.

2-3. System Configuration

Fig. 4 shows the overall construction of DTV. By the compiling component, the definitions of

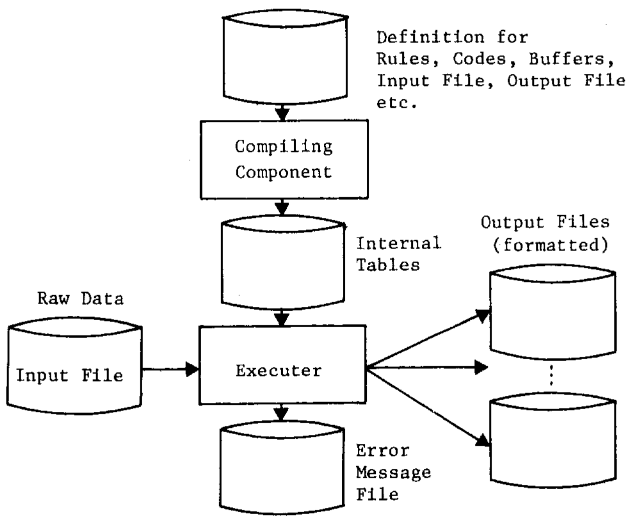
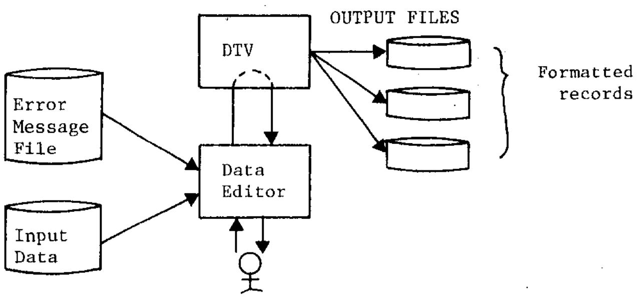


Fig. 4 Overall Construction of DTV

codes, buffers, files, formats of input and output, and translation rules are compiled into several internal tables. Based on these tables, the executer scans the input characters one by one from the input file and applies the rules. During the execution, the system will report various error messages such as 'buffer overflow', 'illegal characters' etc. into the error message files. Because the detailed information, such as the position of the error in the input text, is associated with these messages, human proofreaders can easily recognize the input errors.

A flexible editor has been developed for correcting input errors. Because this editor has a special command to call DTV, the reviser can check the data syntax immediately after the correction (see Fig. 5).



Note : Data Editor output an input record with the corresponding error message. The human proofreader can easily recognize the input error and revise it. After the revision, he/she can check whether the input record contain no more errors, by calling the DTV.

Fig. 5 Data Editor Accompanied by DTV

2-4. Experience with DTV

We used DTV for data translation of the English-Japanese dictionary. About 500 rules and 150 states were necessary to manage exceptional description format of the dictionary. Because DTV should scan and check every input character and because the dictionary consists of 6,500,000 characters, the whole process was very time consuming (it took about 130 min. for translating the whole dictionary by FACOM M200 at Kyoto University Computing Center).

In order to show the effectiveness of DTV, Table 2 is prepared, which shows the input errors detected in the initial input. Some of them can be corrected automatically only by augmenting DTV rules. Moreover, the data editor accompanied by DTV was so effective that all of the detected errors were completely removed by 3 man-month efforts. However, DTV can check mainly the consistency of delimiting characters. There still remain a lot of input errors in the text such as errors in spellings of words. The detection of such input errors requires certain semantic knowledge and is hardly done by DTV rules. Human proofreader should do it. Human proofreaders can easily recognize these errors, but tend to overlock the errors such as omissions of delimiting characters. Certain effective cooperations between man and machine seem to be inevitable in correcting errors in a large amount of linguistic corpora like dictionaries.

Another point to discuss is the relations between DTV and data entry systems. Though our attempt here is highly batch-oriented, some considerations about intractive data entry systems will be necessary in future to augment the dictionary data in evolutional ways. An ordinary data entry system usually guides the

Error Type	Explanations	Frequencies	
Missings of shift codes	Shift-out codes (the code for normal characters) are often missing.	792	
Confusions of similar characters	The phonetic symbol 'ʒ' is, for example, often confused with the number character 3.	5434	**
Fluctuations in character sequences	Certain functional character sequences can express a same thing. It is impossible to standardize them in the case that several key punchers work in parallel.	1166	*
Exceptional formats which were not expected beforehand.	The description formats for acronyms, for example, are quite different from those of ordinary words.	550	*
Misunderstandings of key punchers	Though the key punchers consented to several standardization rules for input, some of them misunderstood them.	1298	*
Miscellaneous errors		1276	
Total		10516	

Note 1: * shows that the errors of that type can be automatically corrected only by augmenting DTV rules.
** shows that some of them can be corrected automatically by augmenting DTV rules.
Note 2: The exceptional format errors are not input errors in a true sense.

Table 2 Error Frequencies in the Initial Data

user as to what he should input next, by printing prompting messages such as 'input the next word', 'input the part of speech of the word' etc. However, in the case that the input data have rich varieties in their description formats like the dictionary here, such a system becomes infeasible. Though some guidance by the entry system would be necessary, it is natural for the user to input data in arbitrary fashion. The data entry system should have the abilities of translating the texts into certain formatted structure, and of checking the existence of input errors. Our data editor accompanied by the DTV is the first step toward developing such data entry systems.

3. Data Base Systems for Dictionaries

A dictionary description has a certain hierarchical structure such as previously shown in Fig. 1. Such a structure can be well represented by a framework provided by ordinary DBMS's, because it is just a simple tree structure. However, the primitive data (or records) from which the whole structure is built have certain internal structures of their own. For example, idioms or typical usages in English-Japanese dictionary are the primitive records which are located at certain fixed positions in the whole structure and related to the other records such as translation equivalents, head words etc. They can be accessed as basic units through usual DBMS operations. At the same time, they are composite expressions which consist of several component words. These component words are related to each other inside the idioms. We call such structures inside the primitive records ' internal structures'. (See Fig. 6) In other words, the primitive records in a dictionary data base system are not primitive in a

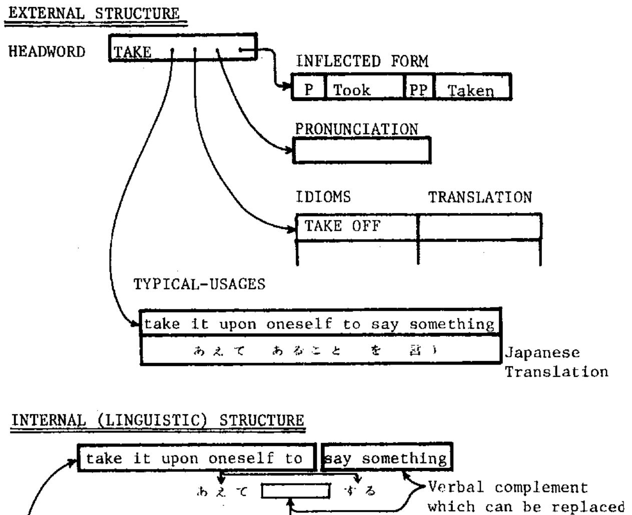

EXTERNAL STRUCTURE
HEADWORD
TAKE
INFLECTED FORM
P
Took
PP
Taken
PRONUNCIATION
IDIOMS
TRANSLATION
TAKE OFF
TYPICAL-USAGES
take it upon oneself to say something
あえて あることを 言う
Japanese Translation
INTERNAL (LINGUISTIC) STRUCTURE
take it upon oneself to
say something
あえて
する
Verbal complement which can be replaced with various expressions
Japanese Translation of the VC is inserted here
fixed expression which can be varied such as
'took it upon myself to'
'takes it upon himself to'

Fig. 6 External Structure and Internal Structure in a Dictionary Data

usual sense of DBMS. Though the external structures among primitive records can be managed by an ordinary DBMS, the internal linguistic structure, in some sense, cannot be well manipulated. Moreover, what we want to do on the dictionary data base systems is not only concerned with external structures, but also, in many cases, concerned with their internal, linguistic structures. Some additional operations should be incorporated with the usual DBMS operations for treating such intermixed structures.

3-1. Japanese Dictionary Data Base

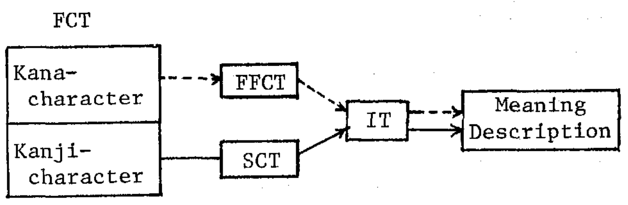
The first thing we have to do is to incorporate morpho/graphemic level of processings. Because Japanese has a very peculiar writing method, special techniques are required to utilize the dictionary. The main difficulty we encountered in developing the dictionary consultation system is from the fact that dictionary entries of Japanese usually have more than one spelling. They have basically two different forms of spellings, Kana-spellings (spellings by Japanese phonetic symbols) and Kanji-spellings (spellings by ideographs — Chinese characters). Corresponding to these two spellings, we have two types of printed dictionaries, one for Kana and the other for Kanji spellings. However, in actual sentences, there often appear mixed forms of these two spellings. (See Fig. 7) Though these mixed

Kanji-Spelling	Kana-Spelling	Mixed Spelling	Meaning
繰 返 す	くりかえす	く り 返 す	to Repeat
繰 り 返 す		繰 か え す	
		繰りかえす	

Fig. 7 Various Spellings of a Single Word

forms are not entered in the ordinary, printed dictionaries of both types, human readers are intelligent enough for converting them into one of the two basic spellings. As for a computerized dictionary system, a certain graphemic level of processing is necessary for consulting the system from these mixed forms.

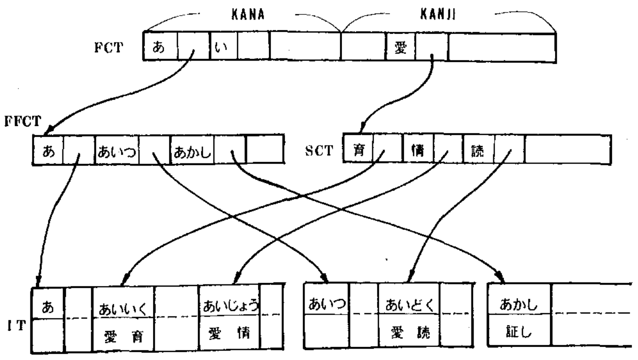
In our system, the intermediate indexing structures are provided for both Kana and Kanji-



FCT : First Character Table
FFCT : First Five Characters Table
SCT : Second Kanji Character Table
IT : Item Table

Fig. 8 Intermediate Indexing Structure for Japanese Dictionary

spellings (Fig. 8). The dotted line shows the access path for Kana-spellings and the bold line is for Kanji-spellings. The relationships among FCT, FFCT, SCT and IT are illustrated in Fig. 9, and the required memory spaces for these structures are given in Table 3.



Note : Each record in IT(Item Table) contains a pointer to the meaning description of the word. IT, FFCT and SCT are blocked and stored in the secondary memory (disc file). Each block contains 50 records. A SCT record contains a set of Kanji-characters which follow the same(first) Kanji-character.

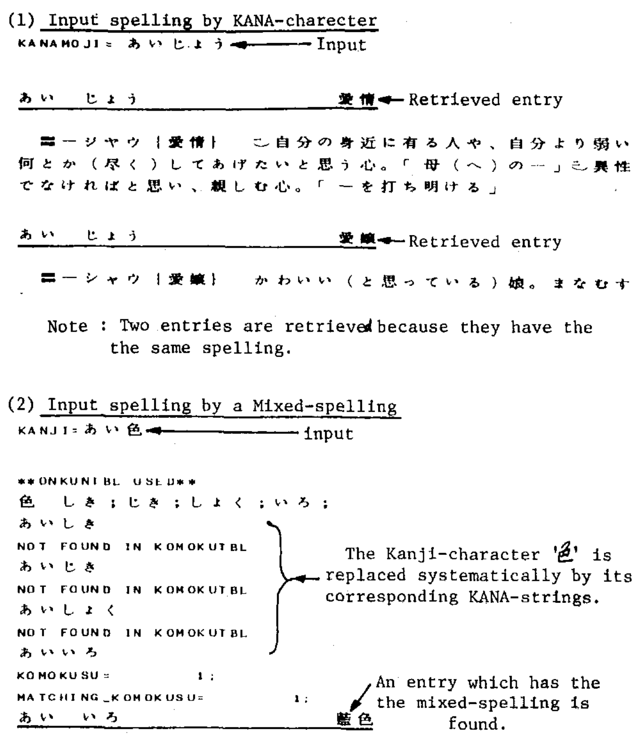
Fig. 9 Relationships among FCT, FFCT, SCT and IT

Index Table	Storage Requirement
FCT	24 KB
FFCT	18.6 KB
SCT	700 KB
I T	4.3 MB

Table 3 Required Memory Space

Mixed spellings are normalized into one of these basic spellings. We can obtain Kana-spellings from mixed ones, by systematically changing the Kanji-characters in the mixed spellings into corresponding Kana-strings. However, because each Kanji-character corresponds to three or four (or more) different Kana-strings (each Kanji-character has several pronunciations), the resultant Kana-strings are to be matched against the Kana-spellings in the dictionary. Some examples of retrieval results are shown in Fig. 10.

Another problem is the incorporation of the morphological analysis component. Because the word inflection system for Japanese is much richer than English, the morphological analysis component is indispensable for the Japanese dictionary system. The morphological analysis program developed for our another project, i.e., Machine Translation Project (7), has been incorporated into the system. The retrieval program has Japanese inflection rules in it and can convert inflectional variants to their



(1) Input spelling by KANA-charecter

```
KANAMOJI= あいじょう  ←——— Input

あい　じょう                  愛情 ← Retrieved entry

  ＝ージヤウ【愛情】　　こ自分の身近に有る人や、自分より弱い
何とか（尽く）してあげたいと思う心。「母（へ）の—」こ異性
でなければと思い、親しむ心。「—を打ち明ける」

あい　じょう                  愛嬢 ← Retrieved entry

  ＝ーシャウ【愛嬢】　　かわいい（と思っている）娘。まなむす
```

Note : Two entries are retrieved because they have the the same spelling.

(2) Input spelling by a Mixed-spelling

```
KANJI=あい色 ←——————— input

**ONKUNIBL USED**
色　しき；じき；しょく；いろ；
あいしき
NOT FOUND IN KOMOKUTBL
あいじき
NOT FOUND IN KOMOKUTBL
あいしょく
NOT FOUND IN KOMOKUTBL
あいいろ
KOMOKUSU=            1；
MATCHING_KOMOKUSU=          1；
あい　いろ                  藍色
```

The Kanji-character '色' is replaced systematically by its corresponding KANA-strings.
An entry which has the the mixed-spelling is found.

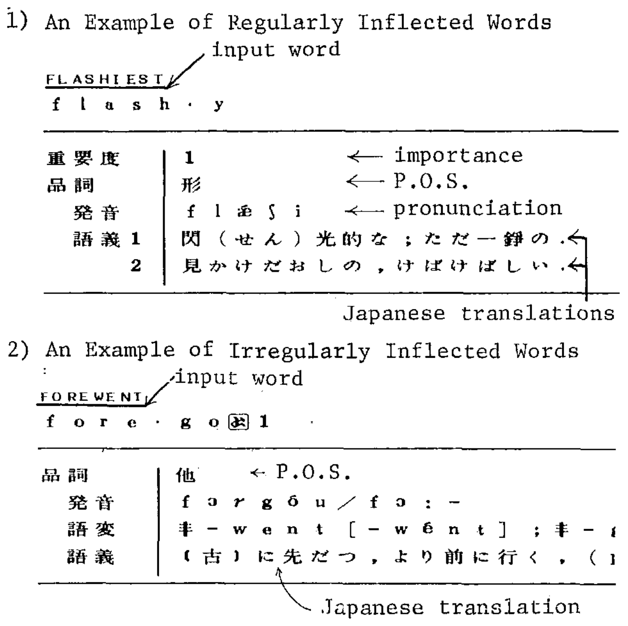
Fig. 10 Retrieval Results of Japanese Dictionary

infinitive forms. The rules are almost perfect, and more than 98% inflectional variants can be converted correctly to their infinitive forms.

3-2. English-Japanese Dictionary Data Base

The morpho/graphemic processings which are required for utilizing this dictionary are much simpler than for the Japanese dictionary. Because most of derivatives are generally adopted in the dictionary as head words, the processings for derivational suffixes are not necessary. We can retrieve the corresponding lexical entries from their own spellings. When we want to see the original word from which the derivative is derived, it is required only to traverse the external structure (that is, a record for a derivative always contains a pointer to its original word). Therefore, the current system only recognizes the inflectional suffixes of English to convert inflected forms to their infinitive forms. As for the irregulary inflected words, all of their inflectional variants are extracted from the dictionary, and are stored in the inverted files (all of the head words are also stored in the inverted files). Some results of retrieval are shown in Fig. 11.

As we described at the beginning of this section, some linguistic operations should be incorporated in a dictionary data base system besides usual operations provided by ordinary DBMS's. Morpho/graphemic processings are one of such operations. Another example is the retrieval of 'similar' expressions. English-Japanese



1) An Example of Regularly Inflected Words

```
FLASHIEST  ← input word
f l a s h · y
————————————————————————————————————
重要度    | 1                      ← importance
品詞      | 形                     ← P.O.S.
  発音    | f l æ ʃ i              ← pronunciation
  語義 1  | 閃（せん）光的な；ただ一瞬の．
       2  | 見かけだおしの，けばけばしい．
————————————————————————————————————
```

2) An Example of Irregularly Inflected Words

```
FOREWENT  ← input word
f o r e · g o 米 1
————————————————————————————————————
品詞      | 他      ← P.O.S.
  発音    | f ɔ r g ǒ u ／ f ɔ : −
  語変    | 非 − w e n t ［ − w ê n t ］；非 − ɪ
  語義    | ‹古› に先だつ，より前に行く，（ ɪ
————————————————————————————————————
```

Fig. 11 Retrieval Results of Inflected Variants

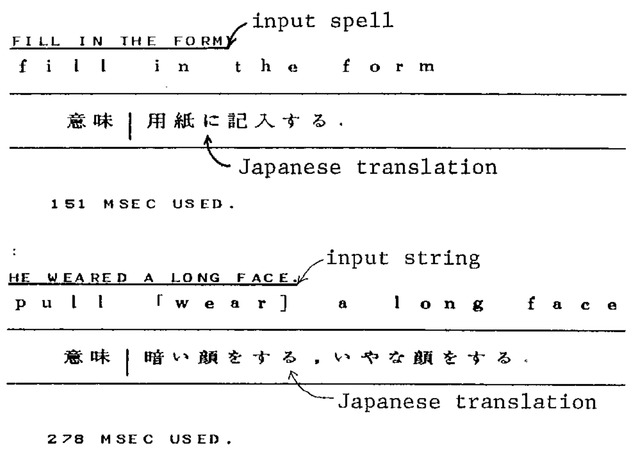
dictionary contains English idioms and their translations, and typical usages of each word and their translations. The effective utilization of these by computer is a very interesting topic, because this is one of the essential "reason-d'etres" of the dictionary. We have been developping some elementary programs to utilize the idioms in the dictionary. The system can retrieve idioms or usages which bear certain similarities to the input phrases. For example, when the user input a sentence such as 'He wore a long face', the system retrieves the idiom 'pull [make, wear] a long face' which have the highest similarity with the input. In this process, all of the words in the input are reduced to their infinitive forms (in this case, 'wore' is reduced to 'wear'), and all of the idioms and typical usages in the individual word entries are retrieved for the comparison with the input phrases. The comparison is currently performed as follows:

1. Each word in the retrieved idioms and usages are reduced to their infinitive forms.
2. Literal string matching is performed. In the matching process, extra words in the input and retrieved idioms or usages are ignored. Only the oder of words is taken into consideration.
3. Similarity value is computed for each idioms and usages.

The expressions with the highest value are printed out. In the current system, the similarity value is determined by a simple formula as

[the number of matched words] / [the number of words in idioms or typical usages].

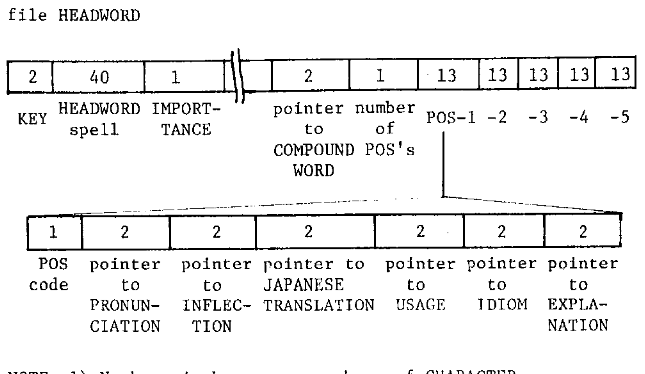
Some results are shown in Fig. 12. We should develop more sophisticated method of computing the similarity value. Especially, information



```
FILL IN THE FORM
f i l l   i n   t h e   f o r m
----------------------------------------
  意味 | 用紙に記入する.
----------------------------------------

  151 MSEC USED.

:
HE WEARED A LONG FACE.
p u l l 「w e a r ]  a  l o n g  f a c e
----------------------------------------
  意味 | 暗い顔をする，いやな顔をする.
----------------------------------------

  278 MSEC USED.
```

Fig. 12 Retrieval Results of Similar Expressions

about semantic relationships among words should be taken into consideration. Computerized thesauri will be useful. Certain words in idioms and usages play the role of variables. 'Oneself' in such a idiom as 'be a law unto oneself' is looked as a variable and should be able to be matched with 'myself', 'himself' etc. 'person' in 'take a person about a town' should be matched with any person such as John, he, and so on. In the latter case, 'a town' can also be replaced by many other words that have certain semantic features in common, for example, 'placehood'. We are now designing such semantically guided pattern matchings.



NOTE: 1) Numbers in boxes are numbers of CHARACTERs. (1 CHARACTER = 2 bytes)

2) For example, 'pointer to JAPANESE TRANSLATION' stands for the pair illustrated below.

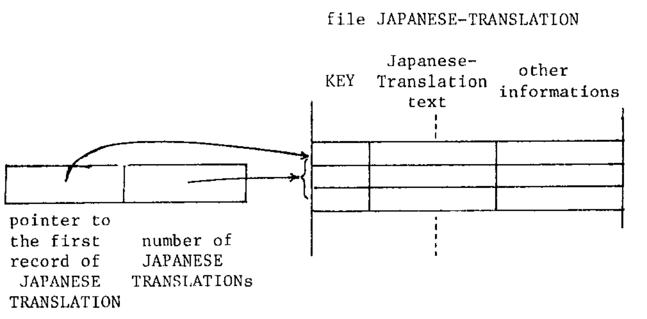
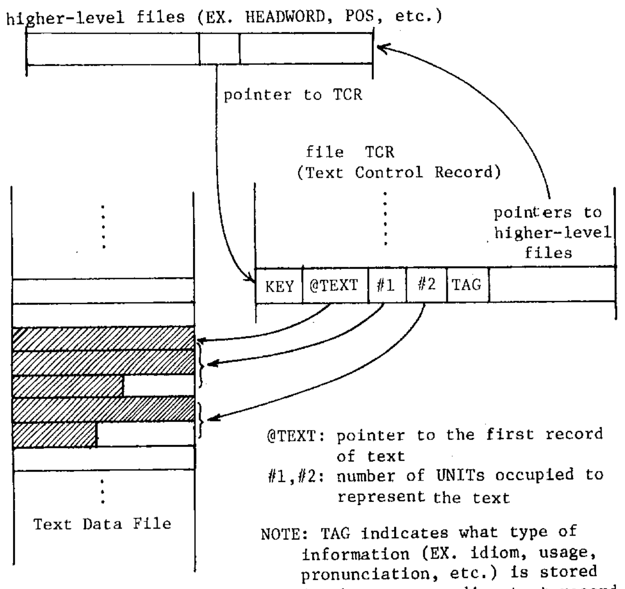

file JAPANESE-TRANSLATION
KEY
Japanese-Translation text
other informations
pointer to the first record of JAPANESE TRANSLATION
number of JAPANESE TRANSLATIONs

Fig. 13 Examples of Formatted Records

3-3. Data Structure for English-Japanese Dictionary Data Base

The formats of records which are obtained as the result of data translation are shown in Fig. 13. The records in these formats contain a large amount of extra spaces, because they are fixed in length and, on the other hand, the length of the descriptions in the dictionary varies very much, depending on individual words. The necessary memory size for these records amounts to 150 Mbyte. We have reorganized them for the purpose of reducing the memory size. The actual data organization is shown in Fig. 14, in which the required memory size is 35 Mbyte. All kinds of text data of variable length are maintained in the same place (the Text Data File) in this organization.


higher-level files (EX. HEADWORD, POS, etc.)
pointer to TCR
file TCR (Text Control Record)
pointers to higher-level files
KEY
@TEXT
#1
#2
TAG
Text Data File

@TEXT: pointer to the first record of text

#1,#2: number of UNITs occupied to represent the text

NOTE: TAG indicates what type of information (EX. idiom, usage, pronunciation, etc.) is stored in the corresponding text record.

Fig. 14 Data Structure of English - Japanese Dictionary

The information which is necessary for managing the records in the Text Data File is contained in a TCR. A TCR consists of a pointer to the corresponding text record, the number of occupied text data records, a tag field etc. The tag field indicates what kind of text data are stored in the record. Arbitrary numbers of text data can be linked together. The memory efficiency of this data structure is obvious. And, the average time for retrieving and displaying the result on the screen is 320 msec. About half of the time is spent on the display control (about 120 msec $\sim$ 160 msec, depending on the data size). To access a head word record from its spelling requires only 3 msec. The remainder is spent on retrieving the other records such as pronunciation, P.O.S. idioms etc.

4. Concluding Remarks

All the systems described in this paper have been implemented on FACOM M-200 (Kyoto University Computing Center) mostly by PL/1. Because the computing center has introduced an MSS (Mass Storage System) and will begin the service this summer, these systems are to be maintained on it. Several other groups in our university, especially a research group of the Faculty of Literature, are very interested in utilizing the dictionary systems for their own researches. Up to now, a set of utility programs have been developed. We hope that such a joint effort between computer scientists and linguists will lead us to new, fruitful research areas.

Acknowledgement

We would like to thank the other members of Prof. Nagao's laboratory, and in particular, Mr. Yukinori YAMAMOTO for his efforts of implementing the first version of DTV and for his valuable suggestions for the data organization of Japanese dictionary data base.

References

(1) Fry,J.P., Frank, R.L. et.al. : A Developmenal Model for Data Translation, ACM SIGFIDET Workshop on Data Description and Access, 1972

(2) Fry, J.P., Smith, D.P. et.al. : An Approach to Stored Data Definition and Translation, ACM SIGFIDET Workshop on Data Description and Access, 1972

(3) Michiels, A., Moulin, A., Mullenders, J., Noel, J. : Exploiting the Longman Computer Files for MT Lexicography and other Purposes, Technical Report, University of Liege, Belgium

(4) Michiels, A., Moulin, A., Noel, J. : Working with LDOCE, Technical Report, University of Liege, Belgium

(5) Liu, S., Heller, J. : A Record Oriented, Grammar Driven Data Translation Model, ACM SIGFIDET Workshop on Data Description, Access and Control, 1974

(6) Nagao, M., Tsujii, J.:Data Structure of a Large Japanese Dictionary and Morphological Analysis by Using It, Journal of Information Processing Society of Japan, Vol. 19, No. 6, in Japanese

(7) Nagao. M., Tsujii, J., et.al. : A Machine Translation System from Japanese into English, to be included in Proc. of this conference, 1980

(8) Ueda, Y. : A Study for English-Japanese Dictionary Data Base, BS Thesis, Kyoto University, 1980, in Japanese