Processing Natural Languages at Chiba University Hospital

by Marcio Biczyk do Amaral and Yoichi Satomura

Introduction

For a long time there have been many attempts to tackle the problems of international and multilingual applications. We have been working to develop medical dictionaries and natural-language processing tools to manage two languages, Japanese and English. Our research is part of a worldwide cooperative effort to construct an electronic library for multilingual representation of information. [1] The project includes the use of multiple national character sets, tools for translation between languages, the search for a language-independent representation, translation and mapping between international terminologies, and the development of a thesaurus, among other tasks. [2,3,4,5]

This article describes the characteristics, development, and use of medical dictionaries that can be applied to natural-language processing (NLP). At Chiba University Hospital in Japan, we have been using the *Systematized Nomenclature of Medicine* (SNOMED), the MEID (*Medical Intelligent Dictionary*), and additional dictionaries for NLP and indexing medical information. We will present the structures of these dictionaries, the particularities regarding their use in Japanese, and describe two applications that use these dictionaries and terminologies for medical NLP.

This article describes our approach regarding the development and structure of the medical dictionaries actually in use in our hospital, and their utilization for natural-language processing. The NLP programs tailor the analysis and indexing of medical texts to organizing the electronic medical record (EMR). The databases and programs were developed using M running on a UNIX platform. We use a Sun-4 workstations network.

Developing a Controlled Vocabulary

Representing and using concepts transmitted by natural language is complex, and it is not yet completely understood how the brain performs these cognitive phenomena. [6] The pioneers in the field of artificial intelligence assumed that computers could simulate the representation of knowledge and manipulate symbols written in natural language. [7]

Most research in human linguistics and computational linguistics has approached language either abstractly, by analyzing formal models of linguistic structure, or concretely, by selecting a particular instance of some linguistic phenomena and studying its properties. Noam Chomsky's work in the 1950s on the grammatical analysis of natural languages influenced many researchers to concentrate on competence models and language universals and to ignore variability in performance. Other applications in natural-language processing have resulted in systems with limited grammars that function effectively in limited contexts.

For our purposes, we approach language from the viewpoint of computational linguistics. More specifically, we will address the problems of developing and using a controlled vocabulary for implementing NLP programs. Our NLP tools use computerized dictionaries and medical terminologies to analyze and organize medical texts.

Dictionary development is central to information representation for NLP. [8] There are many ongoing efforts to develop and build resources for natural-language research. There is the Text Encoding Initiative (TEI), an international project to develop guidelines for the encoding and interchange of machine-readable text. The Data Collection Initiative (DCI) sponsored by the Association for Computational Linguistics will convert the collected data into an SGML (Standard Generalized Markup Language). [9] Another effort is that of the British National Corpus Project, with collaboration of the Oxford University Press, the Longman Group, the University of Lancaster, and the British Library. In North America, Rutgers and Princeton universities are cooperating to form a Center for Machine-Readable Texts in the Humanities, a more sharply focused text-cataloging and collection effort. The European Community sponsored the Eurotra study to determine the reusability of lexical and terminological resources. One result of the Eurotra study was the Multilex project, designed to develop a standard for a European multilingual and multifunctional lexicon and accompanying use. In Japan, the Electronic Dictionary Research Project (EDR)

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is developing a large multipurpose electronic dictionary composed of four dictionaries: word, concept, co-occurrence, and bilingual (Japanese-English). [10]

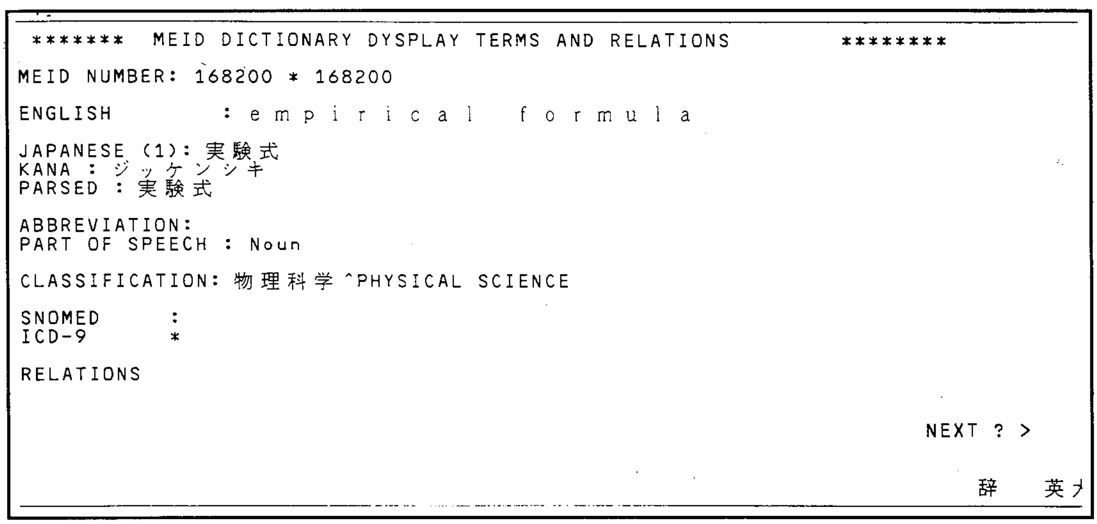
In the medical area, perhaps the most internationally used nomenclature is SNOMED. [11] It does not include definitions of terms but it does give useful information such as synonyms and hypernyms and organizes the terms into a multidimensional structure. (A hypernym is used in linguistics to describe a superordinating word for a group or class.) The UMLS (Unified Medical Language System) project of the National Library of Medicine (United States) is a large-scale effort to build a unified medical language—including all vocabulary from SNOMED, the *International Classification of Diseases* (ICD), *Medical Subject Headings* (MeSH), DSM, CPT, and the *Computer Stored Ambulatory Record* (COSTAR)—in its metathesaurus, together with semantic relationships linking the medical concepts. [12] (See also "Developing a Multilingual Index to Access Health-Care Terminologies," page 32.)

Combining Dictionaries and Nomenclatures

The *Medical Intelligent Dictionary* (MEID) is a bilingual dictionary (Japanese-English) of medical and nonmedical terms, containing medical and linguistic information, with about 230,000 terms. [13] The cooperation of diverse experts (physicians, computer scientists, library and publishing professionals, pharmacists, clinical technologists, medical record administrators, and professional translators) made this dictionary possible. The components of the dictionary are shown in figure 1.

SNOMED is an international nomenclature that allows for a comprehensive patient-description vocabulary. It can be considered relatively domain-complete. Another important characteristic is its modular structure as a set of independent taxonomies for representing conceptual categories within medicine. The present version (third) has ten axes for representing clinical information: T (topography), to describe anatomical location; M (morphology), to describe structural changes; L (living), to classify the animal kingdom; C (chemical), to describe drugs; F (function), related to signs, symptoms and laboratory data; D (diagnoses/diseases); O (occupation); P (procedure), to describe medical procedures such as surgeries; A (physical agents), to describe devices and activities; and G (general), a special axis to describe modifiers, qualifiers, and syntactic linkages. See figure 2. Two implemented NLPs that use SNOMED are described in the later section on diagnostic indexing in Japanese and English.

> ***. . . we had to extend [SNOMED] by building special dictionaries . . . The newest version of SNOMED contains many of the terms we had to add.***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******* MEID DICTIONARY DYSPLAY TERMS AND RELATIONS        ********
MEID NUMBER: 168200 * 168200
ENGLISH       : e m p i r i c a l   f o r m u l a
JAPANESE (1): 実験式
KANA : ジッケンシキ
PARSED : 実験式
ABBREVIATION:
PART OF SPEECH : Noun
CLASSIFICATION: 物理科学 ^PHYSICAL SCIENCE
SNOMED     :
ICD-9      *
RELATIONS
                                                      NEXT ? >
                                                      辞   英ナ
```

Figure 1. Information in the MEID includes a numeric code; the term in English, the term in Japanese (kanji), the term in kana; the term parsed (with spaces separating the words); the abbreviation; part of speech; the class according to modified MeSH categories; the SNOMED code; the ICD code; other relations.

SNOMED, however, does not contain all extant medical terms. Because of this, we had to extend it by building special dictionaries to include the adjectival form, modifiers, and synonyms. The newest version of SNOMED contains many of the terms we had to add.

Another criticism of SNOMED is that it lacks an associated syntax for constructing statements containing complex interrelationships. In fact, building links among its terms is required because such a structure serves to organize the medical information in a database format. Some authors have described how the theory of conceptual graphs can be applied to SNOMED to represent clinical information. [14] We use a different approach, based on semantic grammars, to identify relations in natural-language texts and represent the relevant clinical information in the Chiba University Hospital database.

not only individual words, but also the other components of the sentences, led us to define what we call "semantic patterns." These patterns are used to analyze and match the natural-language sentences into predefined templates.

The Essential Semantic Patterns

We define semantic patterns as the association of categories of terms in specific sequences to form a correct and/or meaningful statement. To understand this concept, let us draw a parallel with syntactical rules. In a grammatically correct statement, the sequence of the elements is determined by their classes and the syntactic rules. In English, for example, a typical sentence will have the form S V O (S for subject, V for verb, O for object). In Japanese, a typical sentence will have the form S O V. In our pattern, instead of using the class O (object), for example, a semantic classification will tell us

```
^TBSNMD("F","10000","1","1")="ELEMENT, PHYSIOLOGIC^生理学的要素 ^ｾｲﾘｶﾞｸﾃｷ ﾖｳｿ ^2
8723"
^TBSNMD("F","10002","1","1")="DISORDER OF PHYSIOLOGIC ELEMENT^生理的要素障害 ^ｾｲ
ﾃｷ ﾖｳｿ ｼｮｳｶﾞｲ ^161291"
^TBSNMD("F","10020","1","1")="ION^イオン ^ｲｵﾝ ^208732"
^TBSNMD("F","10022","1","1")="DISORDER OF ION^イオン異常 ^ｲｵﾝ ｲｼﾞｮｳ ^161284"
^TBSNMD("F","10022","2","1")="ELECTROLYTE IMBALANCE^電解質平衡異常 ^ﾃﾞﾝｶｲｼﾂ ﾍｲｺｳ
ｲｼﾞｮｳ ^167128"
^TBSNMD("F","10024","1","1")="ION DEPLETION^イオン枯渇 ^ｲｵﾝ ｺｶﾂ ^208738"
^TBSNMD("F","10030","1","1")="SIMPLE COMPOUND^単純化合物 ^ﾀﾝｼﾞｭﾝ ｶｺﾞｳﾌﾞﾂ ^290057
^TBSNMD("F","10032","1","1")="DISORDER OF SIMPLE COMPOUND^単純化合物異常 ^ﾀﾝｼﾞｭﾝ
ｶｺﾞｳﾌﾞﾂ ｲｼﾞｮｳ ^161299"
^TBSNMD("F","10040","1","1")="FREE RADICAL^遊離基 ^ﾕｳﾘ ｷ ^182037"
^TBSNMD("F","10050","1","1")="ALUMINUM^アルミニウム ^ｱﾙﾐﾆｳﾑ ^109467"

^TBSNMD("A",70014,1,1)="PRECEREBRAL^前脳 "
^TBSNMD("A",70016,1,1)="SUBLINGUAL^舌下の "
^TBSNMD("A",70017,1,1)="RETROPHARYNGEAL^後咽頭の "
^TBSNMD("A",70018,1,1)="PARAPHARYNGEAL^副咽頭の "
^TBSNMD("A",70019,1,1)="DENTOFACIAL^歯牙顔面領域 "
^TBSNMD("A",70020,1,1)="MEDIAN^中央の "
^TBSNMD("A",70021,1,1)="INTERNAL^内の "
^TBSNMD("A",70022,1,1)="EXTERNAL^外の "
^TBSNMD("A",70023,1,1)="INTRAPARIETAL^壁内の "
<>
                                                                      辞    英ｶ
```

Figure 2. SNOMED is stored as an M global. The node is defined by the SNOMED axis, the five-digit code, plus two additional numbers to define synonyms and other related terms. The term in English, in Japanese kanji, in kana, and the related MEID code is shown at top. Below is the SNOMED extended, using the new axis A that had to be built to include modifiers and other terms not included in SNOMED II.

Analyzing complete patient reports requires other categories of words such as verbs, conjunctions, prepositions, and adverbs, to be included in the vocabulary. These terms usually are not part of medical dictionaries, so we built special vocabularies to use in our NLP computer programs. In addition to these four categories, we considered other types of information present in medical texts. For example, we use only ASCII code to identify numerals. If the numeral describes a date, hour, or laboratory result, we used additional information from the analyzed statement. This necessity to analyze

if this object is a symptom, a disease, an etiology, or something else. Semantic identification is preferred since we intend to store the information in a format in the databases that will refer to the semantic relations, not to the syntactic structure.

The SNOMED statement for a diagnostic description is a kind of semantic pattern: a disease D or morphological alteration M, in topography T, caused by etiological agent E, combined with a functional disturbance F. In regard to symptoms, one general semantic pattern would be: symptom S, in topography T, of intensity I, and duration D, aggravated by factor A, relieved by factor R. This idea can be extended to include physical findings, laboratory data, and other parts of the medical narrative.

We use predominantly a semantic-pattern approach to analyze medical statements. More detailed explanations are described in other publications. [15,16] The methodology involves a search of words and medical terms in the dictionaries, coding using SNOMED, matching semantic patterns, and entering the medical information into the databases with a language-independent format.

Computerizing the Japanese Language

The Japanese language is peculiar in many aspects. First, it does not use spaces to separate words. Second, it uses three sets of characters, and frequently texts also contain words written with both the Latin alphabet and Japanese words. The three Japanese sets of characters are kanji, hira kana, and kata kana.

Kanji characters are the ideograms that originally came from China, and are quite similar to contemporary Chinese "hanzi." There are about two thousand kanjis used in daily Japanese, plus about three thousand used in technical-scientific Japanese. Kanjis are used mostly as roots of verbs, nouns, adjectives, and adverbs.

Hira kana (or hiragana) number about fifty. These are mainly conjunctions and prepositions (called "jyoshi" in Japanese and placed after the nouns) used in the conjugation of verbs. There are about fifty kata kana characters, used mainly for foreign words.

In Japanese computers, as with any type of personal computer, the data entry for the Japanese language is made using a normal alphabetic keyboard that converts alphabetic sounds into hiragana and subsequently into kanjis.

When analyzing Latin alphabet languages, the parser can easily identify the words, since they are separated by spaces. In Japanese, however, the parser must analyze character by character, concatenate with the next character, and then look in the dictionaries to see if it is a word.

There is another method to separate and identify words. Japanese uses a two-byte character code; that means the connection of two bytes to represent one Japanese letter. But we can identify the sets of characters in kanji, katakana, hiragana, and Latin alphabets looking at the first byte only. See figure 3. One word consists of the same type of characters, for example kanji, discriminated by other types of characters, in most cases. Therefore, if you identify a certain sequence of the same type of characters, you can identify it as a word.

カタカナ

2520	ァアィイゥウェエォオカガキギク
2530	グケゲコゴサザシジスズセゼソゾタ
2540	ダチヂッツヅテデトドナニヌネノハ
2550	バパヒビピフブプヘベペホボポマミ
2560	ムメモャヤュユョヨラリルレロヮワ
2570	ヰヱヲンヴヵヶ

"KATAKANA" - Complete Character Set

ひらがな

2420		ぁ	あ	ぃ	い	ぅ	う	ぇ	え	ぉ	お	か	が	き	ぎ	く
2430	ぐ	け	げ	こ	ご	さ	ざ	し	じ	す	ず	せ	ぜ	そ	ぞ	た
2440	だ	ち	ぢ	っ	つ	づ	て	で	と	ど	な	に	ぬ	ね	の	は
2450	ば	ぱ	ひ	び	ぴ	ふ	ぶ	ぷ	へ	べ	ぺ	ほ	ぼ	ぽ	ま	み
2460	む	め	も	ゃ	や	ゅ	ゆ	ょ	よ	ら	り	る	れ	ろ	ゎ	わ
2470	ゐ	ゑ	を	ん	ゔ											

"HIRAGANA" - Complete Character Set

タ

4230	他多
4240	太汰詑唾堕妥惰打柁舵楕陀駄騨体堆
4250	対耐岱帯待怠態戴替泰滞胎腿苔袋貸
4260	退逮隊黛鯛代台大第醍題鷹滝瀧卓啄
4270	宅托択拓沢濯琢託鐸濁諾茸凧蛸只
4320	叩但達辰奪脱巽竪辿棚谷狸鱈樽誰
4330	丹単嘆坦担探旦歎淡湛炭短端箪綻耽
4340	胆蛋誕鍛団壇弾断暖檀段男談

"KANJI" - Partial Character Set

Figure 3. Japanese character sets for katakana (upper part) and hiragana (middle), plus one set of kanjis (ideograms) organized by the sound "ta" (below). The numeric codes on the left are the JIS (Japanese Industrial Standard) codes. With only about one hundred kanjis, more than fifty kanji tables would be needed to represent the complete set of kanjis in Japanese. For Chinese, there are about three hundred tables like this, since there are more than thirty thousand kanjis.

Japanese-English Diagnostic Indexing

One implemented program regards the use of dictionaries to analyze natural-language descriptions of diagnoses, index the terms using SNOMED, and find the corresponding classification in the ICD-9. [17] Natural-language processing for both the Japanese and English descriptions is performed by different parsers. There is a search for the longest consistent match in SNOMED, using dictionaries for synonyms, adjectival forms, and abbreviations. After SNOMED terms are se-

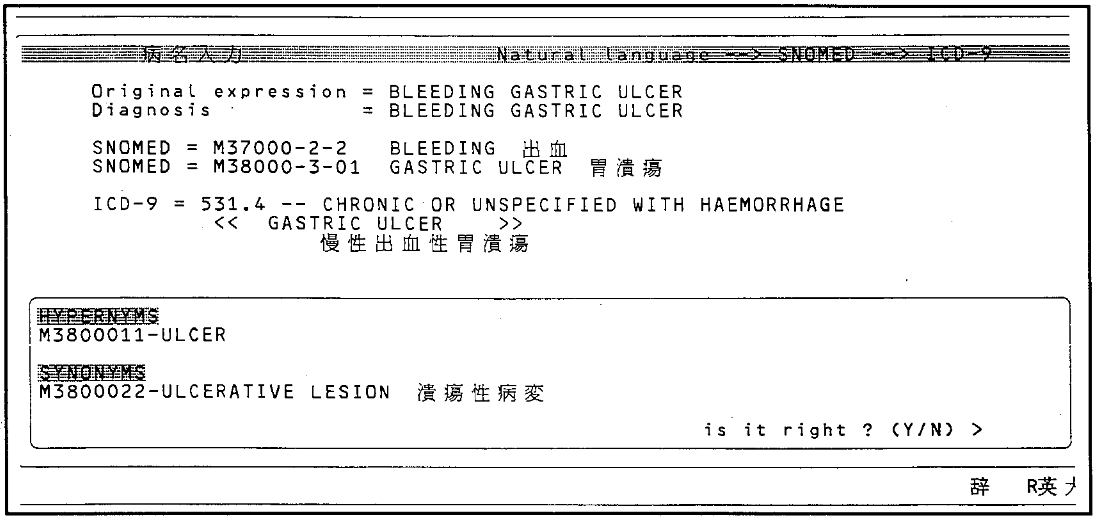

Figure 4. Screen of the program for diagnostic indexing showing SNOMED and ICD codes, synonymous terms, and hypernyms. This program is used for diagnostic encoding using natural-language, English or Japanese statements as input.

lected, they are compared with the ICD diagnostic descriptions. When one possible classification is selected, the results are displayed on the screen for the user to check. Other related information—such as synonymous descriptions for the diagnosis, SNOMED and ICD codes, and hypernyms—is also shown on the screen. The table connecting SNOMED with ICD is stored as a "couple" that contains the codes of the nomenclatures and the classification. See figure 4.

A program to analyze descriptions of symptoms uses a similar approach, except that it uses additional dictionaries for other categories of terms such as verbs, conjunctions, and prepositions. This program extensively uses semantic patterns for NLP and structuring the text. [18,19]

The procedures can be summarized as identifying terms and semantic categories, coding SNOMED, identifying semantic and structural patterns, and organizing the structured information into a language-independent database. The database is language-independent because it uses a frame-like format where the slots are the semantic categories identified during NLP. The frames' contents are also language-independent since they contain SNOMED codes instead of the original medical terms. [20] See figure 5.

Information stored in this format has many advantages. First, it permits storing further information extracted from the patients' records, perhaps temporal information in a retrievable format. Second, the electronic medical record (EMR) can be built with an international nomenclature. Another possibility is that it can be used for translations between languages that have a SNOMED version. The formulas are similar to the ones described by Moore, but modified to use semantic categories to translate between English and Japanese. [21] See figure 6.

The Need for Language-Independent Structure

Multilingual nomenclatures such as SNOMED are essential to maintain the databases in an international code. SNOMED alone cannot account for the complexity found in natural language, however. The development of auxiliary dictionaries specifically for the applications at Chiba University Hospital helped assure efficiency of the parsers. The semantic approach to analyzing the medical information has the advantage of being more practical than the syntactical approaches, and also the semantic categories can be used as slots in a frame-like database, permitting better-organized medical information in the EMR.

The database is language-independent because it uses a frame-like format where the slots are the semantic categories identified during NLP.

We have been searching for and working on database structures in our hospital that would be the same for any spoken language. Linguists call this structure an interlingua. There have been many attempts to define and design interlinguas. In natural languages such a structure is difficult to achieve

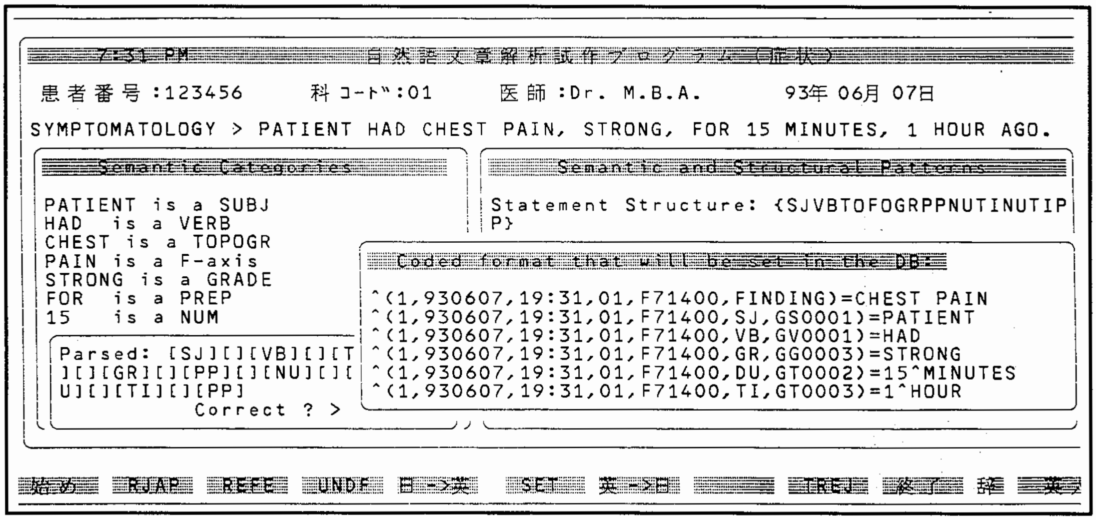

Figure 5. Screen showing some procedures performed by the natural-language processor for analysis symptoms' descriptions. The parser initially identifies individual words and attaches grammatical or semantic labels. After it checks the database for structural semantic patterns, it tries to identify semantic relations between the components of the statements. Finally, it sets the medical information into a language-independent database using the semantic labels and SNOMED codes.

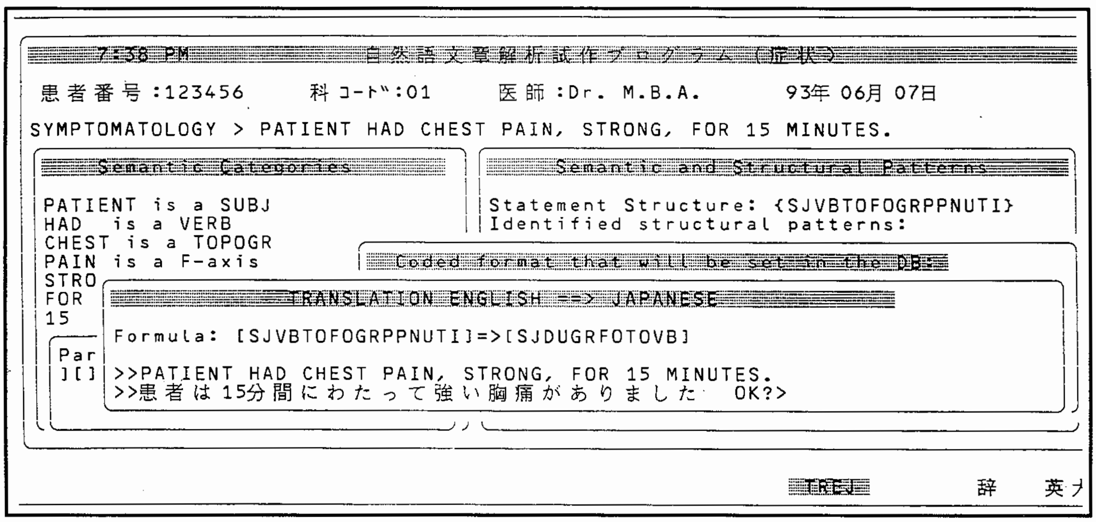

Figure 6. The semantic categories stored in the database are supposed to be the same for any language. SNOMED codes can be used for a quick translation between medical terms. This figure shows one module of the NLP program that uses the semantic categories, SNOMED codes, plus one additional database containing formulas to transform English statements into Japanese. The sequential order of the words is defined by syntactical rules.

because one word has many meanings. Even talking about similar concepts between languages raises the same problem because one concept can be described by many words, each of them with shared meanings but also with nuances. Therefore, defining a unique, general interlingua for one concept is complex. In the restricted field of scientific-medical sublanguage, there can be one interlingua because usually a medical term has only one meaning and is restricted in its use. In this case, it is possible to attach one numeric code to these terms and translate the terms into many languages, all using the same code. This is the philosophy behind SNOMED that has permitted its multilingual versions.

Defining an interchangeable, language-independent structure required consideration of the form, content, and charac-

Continued from page 13

ter set to store the data. SNOMED permits indexing texts in many languages, and the databases can be coded using the international character sets such as ASCII or Unicode. Presenting medical information within this framework might solve some problems presenting multilingual and interlingual medical information.

Dictionaries and nomenclatures are an important part of any NLP project. There are presently many techniques for developing terminologies, dictionaries, thesauri, nomenclatures, classifications, etc. Each has a particular application to the field of NLP and structuring information. We regard the organization of information into a language-independent format as an essential feature for structured, multilingual EMRs. **M**

The authors have been involved in an international effort to develop a multilingual medical dictionary. They may be contacted at the Division of Medical Informatics, Chiba University Hospital, Chuoko, 1-8-1 Inohano, Chiba 280, Japan. Dr. Satomura directs the division.

See endnotes on next page.

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