

The Nihongo Tutorial System An Intelligent Tutoring System for Technical Japanese Language Instruction

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ABSTRACT: The Nihongo Tutorial System is an intelligent tutoring system designed to assist English-speaking scientists and engineers in acquiring reading proficiency in Japanese technical literature. The system provides individualized lessons by matching a student's technical area of interest and Japanese language ability with the available instructional materials which are derived from actual technical articles. This approach is designed to maximize comprehension through context by assuring an appropriate amount of new material and by drawing on the student's expertise in the subject matter. The instructional texts are encoded in a data structure that maintains syntactic, semantic, phonetic, and morphological information that can be delivered to the student upon request. The system also provides on-line supplementary materials including a character dictionary, a general dictionary, a grammar dictionary, and several technical dictionaries for additional information. Thus the Nihongo Tutorial System provides an efficient aid for acquiring the vocabulary, syntax, and style of Japanese texts from a specific technical discipline.

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KEYWORDS: Japanese, technical literature, intelligent tutoring systems

INTRODUCTION

The emergence of Japan as an economic and technological leader has drawn attention to the so-called "information gap" which exists between the United States and Japan. The inability to read Japanese places American scientists and engineers at a severe disadvantage in the task of keeping abreast of recent technological advances as compared to their Japanese counterparts. In order to remedy this situation, a number of business, academic, and government groups have begun to extol the virtues of being proficient in Japanese. Unfortunately, the Japanese language is generally regarded as one of the most difficult languages for English-speaking people to learn. While the

number of individuals studying Japanese is increasing, there remains an extremely high attrition rate, estimated by some to be as high as 80% (Mills, Samuels, and Sherwood 1988). To counter this attrition rate and assist students in acquiring proficiency in Japanese, a number of Computer Aided Instruction (CAI) programs have been recently developed. These range from specialized programs to teach the Japanese phonetic syllabary (Hatasa 1991), Kanji characters derived from Chinese (Benedek 1990, Nakajima 1988) or verb inflections (Furugori 1990) to complete reading programs (Nara 1990, Hirata 1990).

While the existing CAI programs perform very well in their respective design domains, they are not specifically geared to the instruction of technical Japanese. This parallels the situation in more traditional instructional materials (until this year there was only a single textbook geared towards technical Japanese [Daub, Bird, and Inoue 1975]). Therefore, in addition to the already significant barriers to learning Japanese, scientists and engineers are faced with a lack of instructional materials, instructional materials that do not cover the style or vocabulary of their technical specialty, and a lack of instructors that are proficient in both Japanese and a technical discipline. Even the use of real Japanese technical journals for instruction is not feasible since only a small fraction are ever translated into English and most technical dictionaries are geared for Japanese scientists trying to learn English. These barriers to acquiring proficiency in technical Japanese are addressed by the Nihongo Tutorial System.

The Nihongo Tutorial System is an intelligent tutoring system specifically designed to assist English-speaking scientists and engineers acquire Japanese reading proficiency in their technical area of expertise. The system is composed of three separate programs: the Nihongo Tutor, the Parse Tree Editor, and the Administrator. The Nihongo Tutor is the delivery system software which assists students in learning the general concepts of usage, meaning, and pronunciation of Japanese text by providing technical Japanese articles that have been adapted as instructional material. The Nihongo Tutor also maintains a model of the student's current level of Japanese proficiency. The Parse Tree Editor is the authoring tool for the system. It allows the developer of instructional materials to adapt technical journal articles by incorporating syntactic, semantic, phonetic, and morphological information into a representation known as an augmented parse tree. The Administrator program is responsible for selecting an appropriate personalized instructional lesson by comparing the student's current language proficiency and technical area of interest with the content of the texts in the system. This presentation focuses primarily on the interaction of the student with the Nihongo Tutor. A detailed description of the Parse Tree Editor and the Administrator can be found in Leung (1990).

The following section provides a brief overview of the Japanese writing system in order to acquaint the reader with some of the issues involved in Japanese language instruction. The next section outlines the various interactions between the student and the tutor in a typical instructional session. This includes a description of the text selection process, the subject material representation, the information delivery system and the student modelling paradigm. Finally, conclusions are presented.

OVERVIEW OF THE JAPANESE WRITING SYSTEM

Much of the difficulty associated with acquiring proficiency in the Japanese language can be attributed to the Japanese writing system. Japanese text consists of two distinct orthographies, a phonetic syllabary known as Kana and a set of logographic characters, originally obtained from the Chinese, known as Kanji. The Kana are divided into two phonetically equivalent but graphically distinct sets, Katakana and Hiragana, both consisting of 46 symbols and two diacritic marks denoting changes in pronunciation. The Katakana are used primarily for writing words of foreign origin that have been adapted to the Japanese phonetic system although they are also used for onomatopoeia, colloquialisms, and emphasis. The Hiragana are used to write all inflectional endings and some types of native Japanese words that are not currently represented by Kanji. Due to the limited number of Kana, their relatively low visual complexity, and their systematic arrangement they do not represent a significant barrier to the student of Japanese. In fact, the relatively small effort required to learn Katakana yields significant returns to readers of technical Japanese due to the high incidence of terms derived from English and transliterated into Katakana (Maciejewski and Kang 1991).

In contrast, the ability to read the much more visually complex Kanji, which are used to write the vast majority of words functioning as nouns, verbs, or adjectives, presents a formidable task, even for native Japanese. An example of a three character Kanji

compound word 日本語 meaning "Japanese language" which could be phonetically transcribed as にほんご (Nihongo). A dictionary of all Kanji ever used would contain on the order of 50,000 entries. Fortunately, 99% of all the currently used Kanji can be found in the six to seven thousand entries specified under the Japanese Standard Association's JIS X 0208 standard. Furthermore, about 90% of the Kanji in standard texts belong to the approximately 2,000 "Joyo Kanji" designated by the Japanese Government as characters for daily use. Though frequently considered to be graphical representations of objects or concepts, in actuality very few Kanji belong to the category

of pictographs or ideographs. The vast majority (over 90%) can be classified as phonologograms, characters composed from the combination of a phonetic component and a general meaning component, called the radical. The phonetic component, however, does not uniquely specify the pronunciation of a character. This is due to the fact that Kanji have multiple readings depending on the context. These readings are generally classified as either native Japanese (Kun) or as being derived from the Chinese (On). The Kun readings are generally used for single-character Kanji or with inflected forms whereas On readings are more frequently

employed in multiple Kanji compounds. For example, the Kun reading of 語 is 語 (kata (ru)) which means "talk, relate" whereas the On reading is 語 (go) meaning "word" in Kanji compounds. The radical for this Kanji is the component on the left-hand side, 言, which is itself a Kanji character with a

general meaning of "word, speech, language, etc." Exceptions to these general characteristics abound and phonologograms are frequently used for their phonetic component while disregarding the meaning or vice versa (such compounds are called "ateji").

The difficulty of reading such a diverse and complicated character set is further magnified by the fact that Japanese text does not possess any unique character to specify lexical boundaries that correspond to the spaces used between words in Western languages. Thus a student has no idea whether a single Kanji is to be interpreted as a complete word or whether it is part of a compound. Likewise with Kana one must know whether it is being used to represent an inflectional ending or a separate word. Additional difficulty is presented by the fact that Japanese sentence structure is basically Subject-Object-Verb (SOV) as opposed to the more common SVO structure of English.

STUDENT-TUTOR INTERACTION

Article Selection

A student's initial interaction with the Nihongo Tutorial System is with the Administrator program. The Administrator contains information on all of the students using the system as well as on all of the available instructional texts. Thus new users must first identify themselves to the system with their user name and then specify their technical area of interest, which may be altered at any point in the future. The available technical areas are maintained in a hierarchical tree structure in order to be able to select a degree of specialization within a given subject area. Individual texts may also reside at more than one node of the tree in order to support inter-disciplinary instruction.

After identifying a technical area of interest, subsequent use of the Administrator program will result in a personalized instructional text being selected for the student. Information about the student and the text is then presented to the student on the screen, as is illustrated in Fig. 1. This information includes the identification of the student and the student's stated technical area of interest along with the subject area of the selected instructional text. The subject area of the text may or may not exactly match the technical area specified by the student. For example, if no articles are available in a particular area, or if a student has already mastered all of the articles in their area, the Administrator program will select an article from an area that is as closely related as possible, as defined by the hierarchical tree structure. The texts within an area are all ordered by an objective measure of difficulty based on their vocabulary and grammatical structures, in order to improve the efficiency of the search for an ideal match for the student. A comparison of the contents of the text with the proficiency of the student is presented in the form of three bar charts. These charts identify the percentage of the vocabulary and grammar in the text which the student has either mastered (known area), been exposed to but not fully grasped (review area), or has not seen

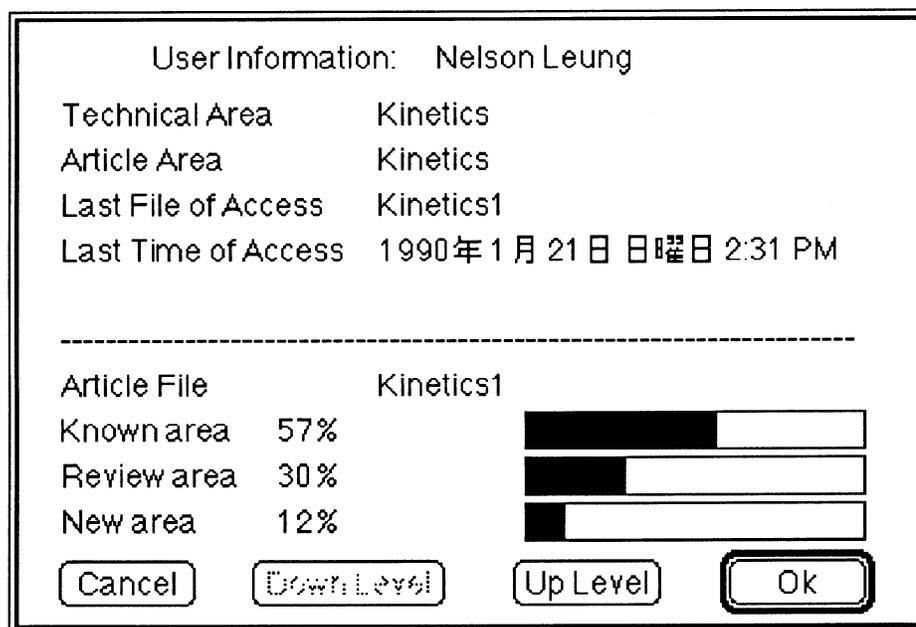


Figure 1. Instructional texts are personalized by comparing the student model, which contains information on both technical interests and Japanese proficiency, with the content of the available articles.

before (new area). The Administrator attempts to select articles with a relatively large amount of previously mastered material in order to improve comprehension through context and to promote reading rather than dictionary lookup. The Administrator's text selection can be manually overridden by the student either to choose a more basic or more advanced article by simply clicking on the "down level" or "up level" buttons, respectively.

Original Japanese sentence:

速度というのは速さと向きで表わされるものである。

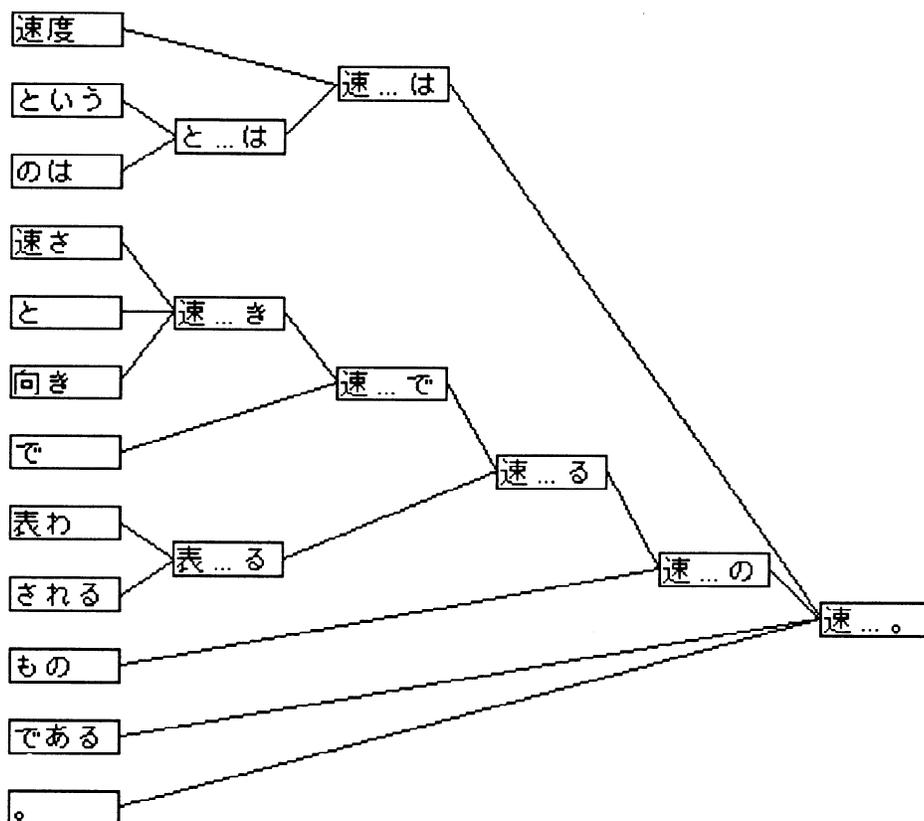


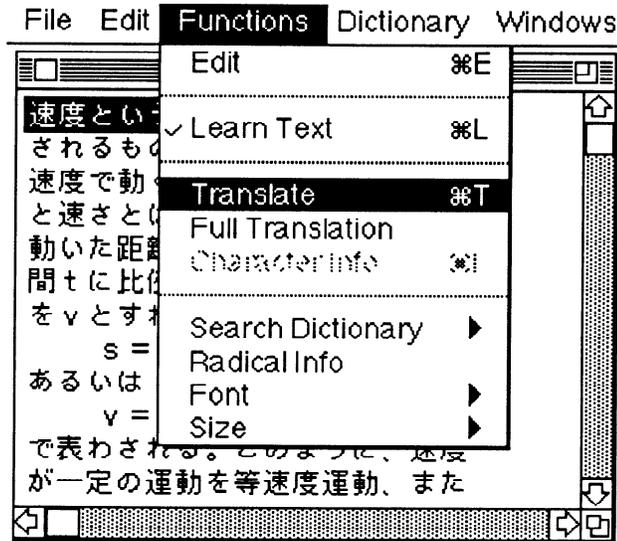
Figure 2. Every sentence in the instructional text is stored in a tree data structure which incorporates morphological, lexical, syntactic, and semantic information in each of the nodes.

Instructional Strategy

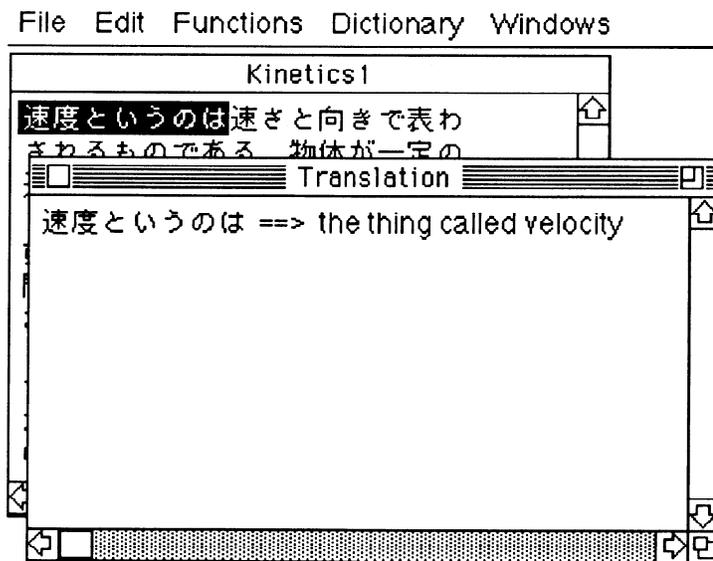
Once the Administrator program has selected an appropriate text, the student is ready to interact with the Tutor, which is the delivery system software for the Nihongo Tutorial System. The instructional strategy of the Tutor is primarily a passive one in which it provides phonetic, morphological, syntactic, or semantic information about the text being studied upon request from the student. It also makes available a range of supplementary material, including multiple electronic dictionaries and grammatical notes for unrestricted exploration by the student. The Tutor does not currently query or test the student concerning accurate comprehension of the text; however, it builds its model of the student's Japanese proficiency based on which information is requested by the student.

In order to more fully understand the operation of the Tutor, it is instructive to consider the data structures used to represent the articles available as instructional material. Every sentence of every text is stored in a data structure called an augmented parse tree with consecutive sentences arranged in a linked list. A schematic example of a parse tree, which is implemented as a doubly linked list, is presented in Fig. 2. The parse tree itself embodies the structure of the sentence as defined by the syntax of the Japanese language. Associated with each node is the grammar rule used to combine the node's children. In addition to this syntactic information, each node contains a phonetic representation for the Japanese text that appears in that node as well as a best contextual English translation for that text. Both the phonetic information and the English translation are stored as pointers into character strings in order to reduce the amount of memory Storage required. Additional information in the tree nodes is also available to identify where the Japanese text is located on the screen.

From the student's point of view, the text of the selected article is simply presented on the screen. The student proceeds to read the text until he encounters a word or phrase with which he is unfamiliar. At this point the student can use the mouse as a pointing device to highlight the unknown text on the screen and then select the "Translation" menu option to obtain the translation of the highlighted text as illustrated in Fig. 3. The computer, upon detecting the request for information from the student, identifies the highlighted region on the screen and consults the augmented parse tree for the English translation that is to be displayed. Due to the data structure of the augmented parse tree, the Tutor is able to handle a highlighted region of arbitrary length, from a single character to an entire sentence. The highlighted region is simply matched to the smallest node that encompasses all of the highlighted text. This technique also allows the Tutor to reasonably deal with meaningless requests from the student, such as, for example a translation of うの from the sentence in Fig. 2. Such errors are not uncommon to students of Japanese since there are no characters in the orthography that are used to delimit word boundaries.



(a) Select the Translate command



(b) Translation information

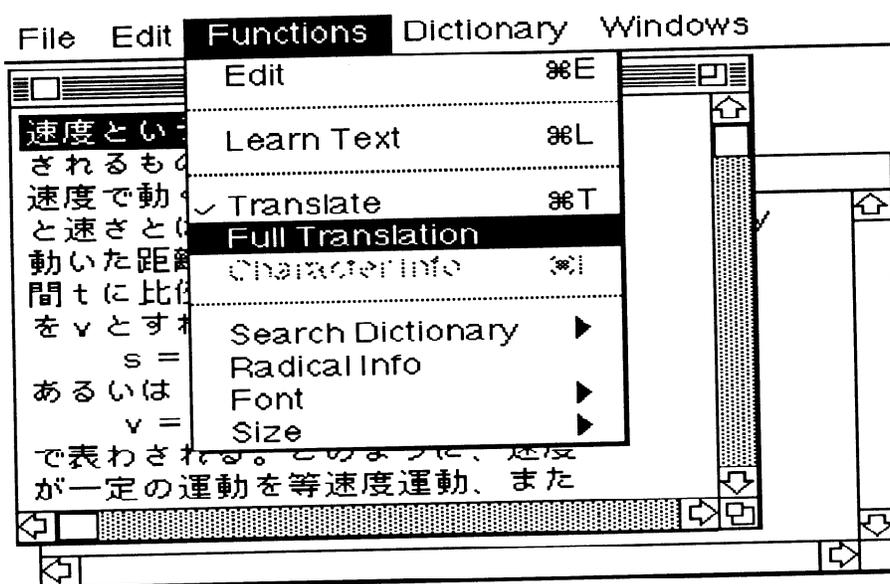
Figure 3. The student is able to obtain an immediate best contextual translation for any portion of highlighted text within a sentence.

The best contextual translation of the highlighted text obtained by requesting "Translation" is only one of the options open to the student. The student may wish to understand the structure of a phrase, or to explore how the meaning of the constituents of a phrase are altered when combined. This can be done by selecting the "Full Translation" option as illustrated in Fig. 4. Upon receiving this request the Tutor searches the parse tree as before to identify the smallest node that encompasses the highlighted text; however, it displays not only the information in this node but all of its children as well. This provides more information to the student and addresses one of the most commonly occurring complaints from students who use traditional dictionaries to translate sentences, i.e., when they "know" the meaning of all of the words but can't understand a sentence. Also note that the lowest level nodes that contain Kanji characters are provided with the pronunciation of those characters in Hiragana.

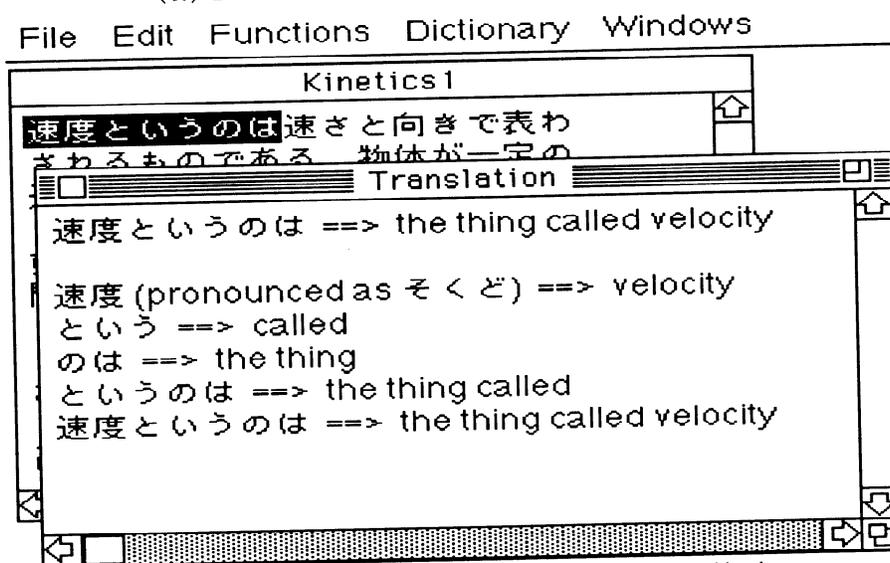
While the "Full translation" option provides syntactic information to the student, it does so in a purely textual manner. The Tutor provides an additional, and unique, method for conveying this information to the student. This option, which is illustrated in Fig. 5, allows the student to position the mouse at any point in the text and then obtain the word boundaries by double-clicking on the mouse button. If the student double-clicks once again on the word that has been highlighted, then a larger region becomes highlighted denoting how the original word is combined with others into a phrase. This process can be repeated to indicate how phrases are then combined to form larger phrases and finally entire sentences. This conveys the structure of Japanese grammar to the student in a more visual manner than the "Full translation" option. The computer is able to provide this information by simply determining which leaf node in the parse tree contains the text which surrounds the cursor at the time of the first double-click. Subsequent double-clicks are simply interpreted by the computer as requests to move up one level in the parse tree to the node's parent and then to highlight the text associated with the parent on the screen. It should also be noted that a completely graphical depiction of the parse tree, such as in Fig. 2, is also available to the student by invoking the Parse Tree Editor program.

Supplementary Materials

One of the design philosophies for the Nihongo Tutoring System was to make the language acquisition process in the desired technical domain as efficient as possible. Thus the texts within each discipline are selected on the basis of containing the most frequently occurring vocabulary for that particular discipline. Therefore, it is anticipated that the student would interact with the Tutor primarily in the mode described in the previous section. However, it was realized that some supplementary material, particularly several on-line electronic dictionaries, would provide an invaluable aid to the student, especially with regard to the study of Kanji. Therefore,



(a) Select the Full Translate command



(b) Translation information about all the constituents of the selected text

Figure 4. The Full Translation menu option provides syntactic as well as semantic information to the student.



(a) Position the cursor in a sentence



(b) Result of one double-click



(c) Result of two double-clicks



(d) Result of three double-clicks

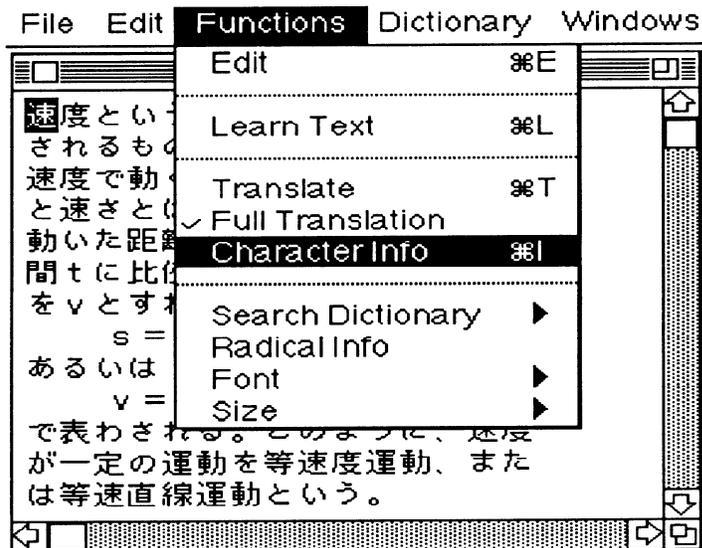
Figure 5. Using the mouse to double-click on the text provides a unique and convenient method for conveying both lexical information, on the first double click, and syntactic information on subsequent double-clicks.

the Tutor provides the student with constant access to four different types of dictionaries: a Kanji character dictionary, a general dictionary of Kanji compounds, a set of specialized technical dictionaries, and a grammar dictionary.

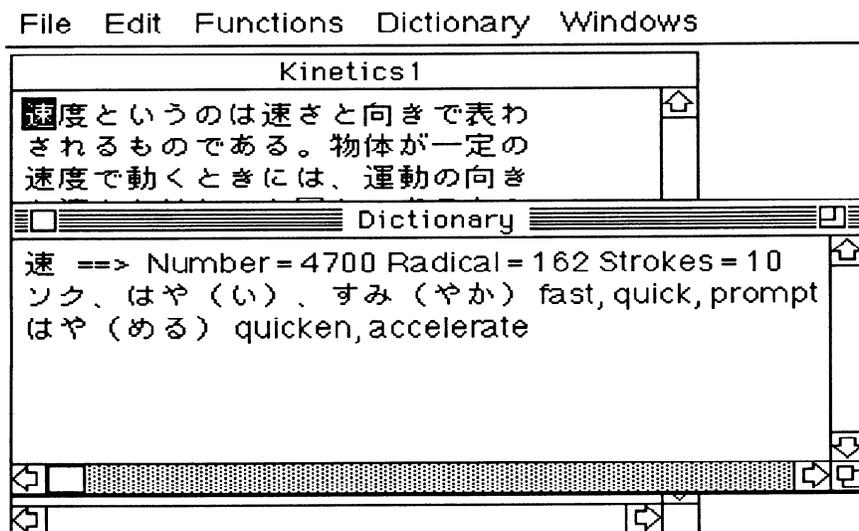
The Kanji character dictionary currently contains information on all of the approximately 2,000 Joyo Kanji. A sample entry, as shown in Fig. 6, contains the Kanji reference number, which is that assigned by Nelson (Nelson 1962), the radical number (a display of all of the radicals is also included), the number of strokes in the character, the On and Kun readings of the character denoted by Katakana and Hiragana, respectively, and the different possible meanings of this character. The student can get immediate access to this information for any Kanji character on the screen by simply highlighting that character and then selecting the "Character Information" menu option as illustrated in Fig.6. For those Kanji characters which are not currently on the screen, one can search the dictionary by any piece of information that is included in an entry. For example, all of the Kanji that have the same number of strokes or that possess the same radical can be displayed. This can be useful in itself by, for example, giving the student a feeling for the generic meaning of a radical or by resolving confusion between similar characters. Dictionary searches by the Nelson reference number, radical, and stroke count are particularly fast since they are implemented using ordered index tables. However, even searches based on the On or Kun readings or English translations are quite fast due to an efficient system level character string search function.

Note that there is an important distinction made between the information provided by the "Translation" option and the "Character Information" option. For the example in Fig. 6, choosing the "Translation" option when highlighting the single kanji

character 速 would provide the translation for the entire compound 速度 since this is the lexeme stored at the lowest level node in the parse tree. Therefore, the "Character Information" option provides additional morphological information by allowing the student to gain insight into the general meanings of individual characters and how these characters are combined to form semantically related compounds. The student can investigate further the role of an individual Kanji in determining the meaning of a compound by searching the general dictionary for all compounds which contain that Kanji, as illustrated in Fig. 7. Note that the Tutor provides all of the compounds which include the specified Kanji regardless of the position of that Kanji within the compound. This is in contrast to traditional character dictionaries that only provide compounds in which the specified Kanji is the initial character (Nelson 1962). As mentioned

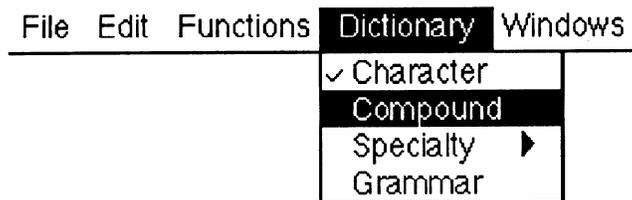


(a) Select the Character Info command

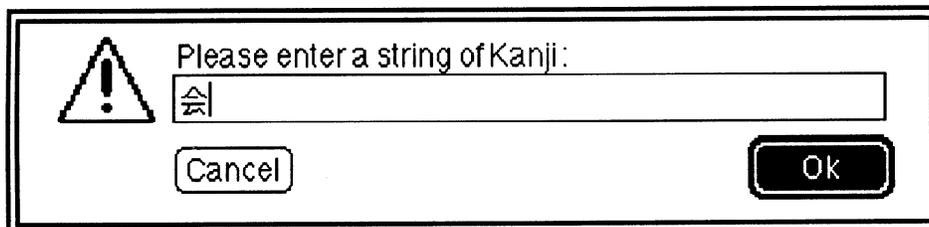


(b) Character Information

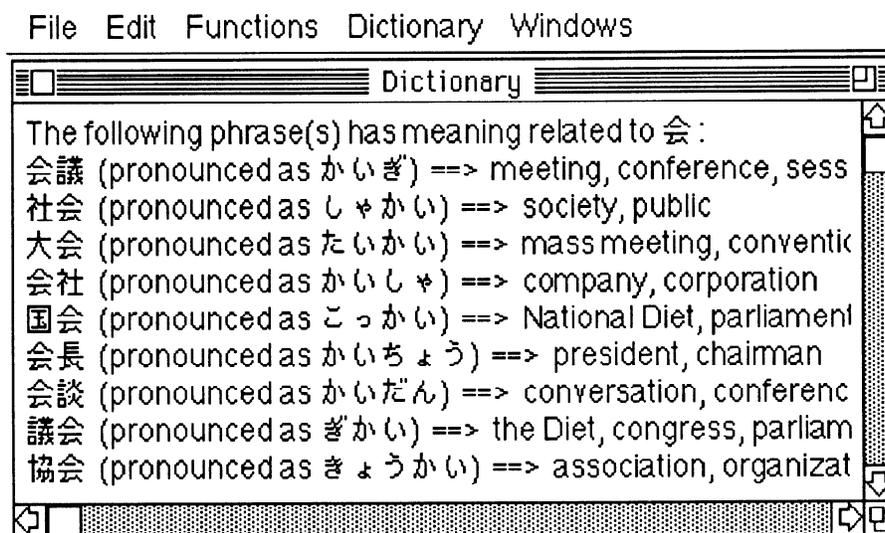
Figure 6. The Character Information menu option allows the student to investigate the properties of an individual Kanji character, including alternate meanings and pronunciations.



(a) Select the Compound dictionary



(b) Enter a Kanji



(c) All Kanji compounds containing the same Kanji

Figure 7. The Student is able to investigate the possible uses of an individual Kanji in various Kanji compounds.

previously, one of the additional barriers facing individuals that attempt to read technical Japanese documents is the specialized vocabulary that occurs within each discipline for which general purpose dictionaries are unsatisfactory. To address this issue, the Tutor provides a set of technical dictionaries for various different disciplines. These dictionaries also possess a very general search mechanism which allows the user to access items based on individual Kanji or Kanji compounds, phonetic transliterations, or English equivalents. An example of such a search for terms relating to "satellite communications" in the telecommunications dictionary is illustrated in Fig. 8. By accessing the appropriate technical dictionary before using the general dictionary, the student is assured of obtaining the correct contextual meaning for the text in question.

Finally, the supplementary materials include an on-line grammar dictionary for providing additional information on items of a grammatical nature. The format of this dictionary is based on the text by Makino and Tsutsui (1986) and is illustrated in Figs. 9 and 10. Upon highlighting a grammatical item in the text, the grammar dictionary provides an English description of the usage for that item, possible English translations, and additional examples of usage. Thus the student can compare the usage of the item in the article that is currently being studied with the information provided in the dictionary and reinforce the understanding of this usage by studying the extensive examples. The dictionary also provides information about additional usages for the same grammatical item that are different from the usage in the assigned article. This allows the student to resolve the frequent confusion caused by items which are orthographically identical but semantically distinct.

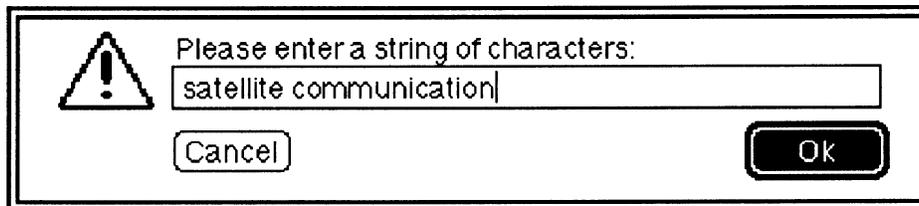
The Student Model

The Tutor's role in the instruction process is primarily a passive one in which it responds to requests for information from the student. Thus there is currently no testing module in which the Tutor evaluates the student's reading proficiency. However, the Tutor does maintain a model of the student's competence by recording all of the student's requests for information, correlating this information with its own knowledge base, and storing the results in the student's personal database.

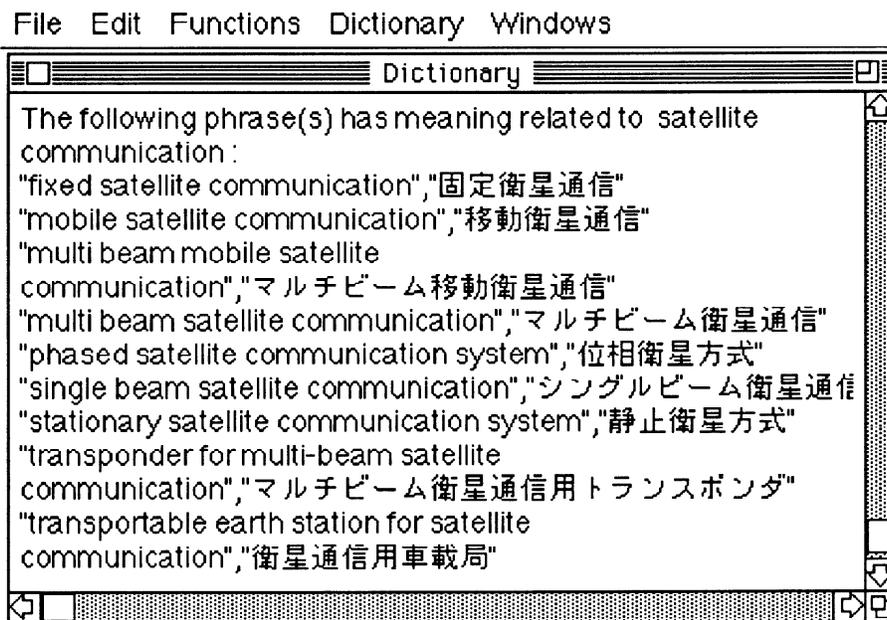
The student's database is divided into two fundamental categories, material which has been mastered and material which needs to be reviewed. After the student completes reading each instructional text that has been assigned, all of the material which is included in that text for which the student did not request information is stored in the mastered category. Any items in the text for which the student did request information are stored in the review area. If information is requested for an item which currently resides in the mastered area, that item is moved to the review area. Associated with



(a) Select the special Communications dictionary



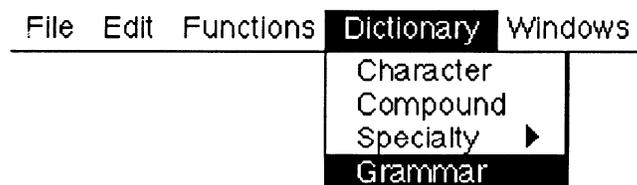
(b) Enter some English text



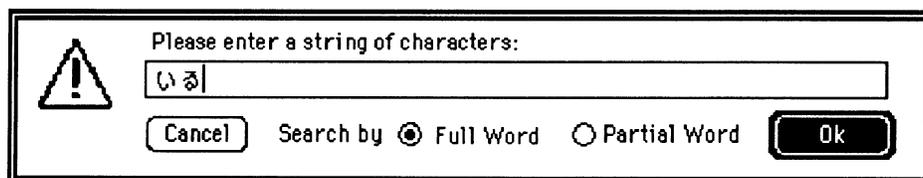
(c) All entries* containing the same English text

* The information in this figure is provided courtesy of the Nippon Telegraph and Telephone Corporation

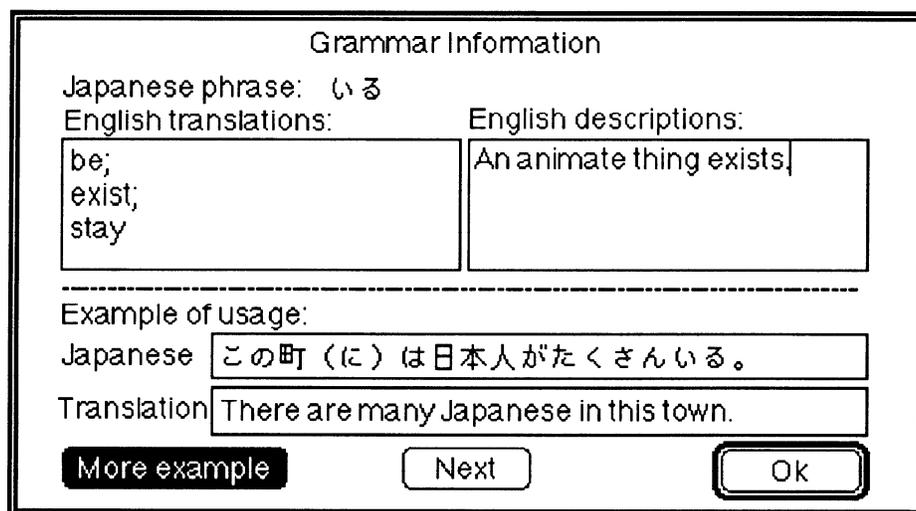
Figure 8. The technical specialty dictionaries like this telecommunications dictionary can also be searched by using English keywords.



(a) Select the Grammar dictionary



(b) Enter the full grammatical structure



(c) Information* about the grammatical structure

* The information in this figure is extracted from
A Dictionary of Basic Japanese Grammar by Makino and Tsutsui

Figure 9. Supplementary grammatical information and additional examples of usage are available through the Grammar Dictionary.

Grammar Information	
Japanese phrase: いる	
English translations:	English descriptions:
be; exist; stay	An animate thing exists.
Example of usage:	
Japanese	リーはこの茶にいます。
Translation	Lee is in this dom.
<input type="button" value="More example"/>	<input type="button" value="Next"/>
<input type="button" value="Ok"/>	

(a) Hit the Next button to get more information

Grammar Information	
Japanese phrase: いる	
English translations:	English descriptions:
be ~ing; have done something	Someone or something is doing something he or it started some time ago, or
Example of usage:	
Japanese	佐々木さんは酒を飲んでいる。
Translation	Mr. Sasaki is drinking sake.
<input type="button" value="More example"/>	<input type="button" value="Next"/>
<input type="button" value="Ok"/>	

(b) Hit the Ok button to finish

* The information in this figure is extracted from
A Dictionary of Basic Japanese Grammar by Makino and Tsutsui

Figure 10. The Grammatical Dictionary also provides immediate access to alternate uses of the same grammatical phrase to resolve potential confusion.

each item in the review area is a counter which keeps track of how many times the student has seen that item since last requesting information. When that counter reaches a predetermined value, the item is moved from the review area to the mastered category. Thus the Tutor is able to adapt to a student's improved reading ability as well as to a decline in ability, perhaps due to a long absence in instruction.

The items which are actually stored in the student's database can be words, inflectional endings, individual Kanji, or even general grammatical rules. Each item is designed to represent a unique piece of knowledge about the Japanese language so that, for example, the reading of a Kanji in the context in which it was highlighted is stored along with the Kanji. These items which reside in the student's personal database are compared with the contents of potential instructional texts by the Administrator when determining an appropriate lesson (See Fig. 1). The development of more sophisticated student models, particularly for the more abstract aspects of the foreign language acquisition process, is a continuing part of the research effort for improving the Nihongo Tutorial System (Maciejewski and Kang 1991).

Clearly, the Tutor's internal model of the student's reading proficiency can be grossly inaccurate if the student simply ignores any items that he does not comprehend. Thus the student model is in no way appropriate for assessing student capabilities in a classroom setting. However, since the Tutor is primarily designed for self-study, there is no motivation to intentionally mislead the system. The development of a formal testing module for the Tutor is currently under consideration.

CONCLUSIONS

The Nihongo Tutorial System represents a unique studying aid for individuals attempting to gain proficiency in reading Japanese technical literature. While the number of instructional texts available in the augmented parse tree data format is still small, work is underway to develop more fully automated techniques for processing technical journal articles into instructional material. A prototype version of the system has been distributed to select universities and testing in a classroom environment is currently being performed at the MIT summer program on technical Japanese. Demonstration versions of the system are currently available from the principal author upon request. It is hoped that this input from the user community will result in improved future generations of the system.

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