

A Multimedia Language Learning Environment with Intelligent Tutor

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Abstract: This paper presents an intelligent English learning environment, called HELEN which integrates traditional methods of learning English, audio-visual facilities and intelligent tutoring functions for suitable advice to each learner. HELEN consists of an authoring environment and a learning environment. HELEN provides a non-programming authoring environment for authors in the authoring stage, and a learner-initiative learning environment for learners in the learning stage. In order to support multimodal learning, at the authoring stage HELEN gets voice and video scenes from a video disc and text sentences from an image scanner, then analyzes the sentences both syntactically and semantically by a natural language processing module so that necessary information for conversation, error identification and example sentence retrieval may be extracted. Thus at the learning stage, besides supporting listening, reading and writing, HELEN is able to diagnose errors of a learner and give the learner suitable advice, in dictation and TQ (Test-Question).

Introduction

Up to now, many useful methods have been applied to learning foreign languages: e.g. memorizing spelling, pronunciation and meaning of words, looking up unknown words in a dictionary, learning grammar, answering questions and so on. Above all, listening to native speakers repeatedly to grasp the meaning is considered one of the most effective ways.

Recently, various electronic tools for listening to foreign languages, such as cassette tapes and video discs, have been widespread. When we learn foreign languages with these tools, we usually play them over and over to grasp the incomprehensible parts, refer to missed words in an accompanying textbook, look up unknown words in a dictionary and take notes if necessary.

These tools play indispensable roles to increase the learner's knowledge of situated usage of the language through listening and watching scenes pertinent to the topics at the same time; nevertheless she often overlooks necessary knowledge or fails to be aware of her weak points. As a result she may lose a chance to acquire good language skills. These difficulties would be resolved if an advisor

helped her throughout the learning process. For example, question-answering is one of the ways to help the learner. The advisor sets questions based on the necessary knowledge or the learner's weak points and the learner answers them in the foreign language. The method is very effective in learning the skills of hearing and speaking and in acquiring the ability of thinking in a foreign language.

This paper presents an intelligent English learning environment, called HELEN (Hypermedia Environment for Learning ENglish), which integrates all of the above functions, that is, traditional methods of learning English, audio-visual facilities and intelligent tutoring functions for suitable advice to each learner. In order to support multimodal learning, HELEN gets voice and video scenes from a video disc and text sentences from an image scanner, then analyzes the sentences both syntactically and semantically by a NLP (Natural Language Processing) module. Thus HELEN is able to aid learners to learn listening, reading, writing and consulting skills. Besides these facilities HELEN also supports facilities of dictation and TQ (Test-Question) to diagnose the learner's errors and give the learner suitable advice. The TQ facility is a question-answering and is used for inferring a learner's comprehension state with reference to the contents of given sentences. In the TQ facility HELEN generates questions using both information from the sentences extracted by the NLP module and the learner's comprehension state, and gives the learner suitable advice for her answers.

HELEN is basically a learner initiative environment, and the learner proceeds from lesson to lesson by using the above functions in a naturally situated video sequence. To give deep understanding, HELEN diagnoses and tutors in dictation and TQ.

HELEN is equipped with program-less authoring tools where a teacher can construct multimedia language learning environments by using the NLP module, selecting learning parts and integrating them based on her educational intentions.

In the following section the outline of HELEN is presented. In the third section, brief explanations about functions that support English learning are given. In the fourth section, functions of the NLP module including error identification in English are described. In the fifth section, a brief description of a student model and tutoring paradigm will be given. Discussions and conclusions are given in the final section.

The Outline of HELEN

In this section, the design goal and the outline of HELEN are presented.

Figure 1 gives the outline, which consists of three parts; an authoring part at the upper left, the NLP module at the lower left and a learning part.

Hardware configuration consists of a Macintosh™, a video disc, a voice synthesizer and an image scanner for a hypermedia interface, and a Sun™ workstation for NLP. HyperCard™ is used for interface description, and Prolog for NLP module. The Macintosh™ and the Sun™ communicate through Ethernet.

Design Goal of HELEN

The design goals of HELEN are as follows. Firstly to give authors easy operation so that the authors may easily create learning environments along with their educational intentions. Secondly to give all learners ease of operation of learning functions and suitable advice so that they may acquire language skills by themselves effectively.

To achieve these goals we introduce the following design principles for authoring and learning.
(1) Principles For Authoring

Principle 1 : *Authors should be able to construct learning environments without programming.*

In order that even novice authors at programming may construct learning environments easily, it

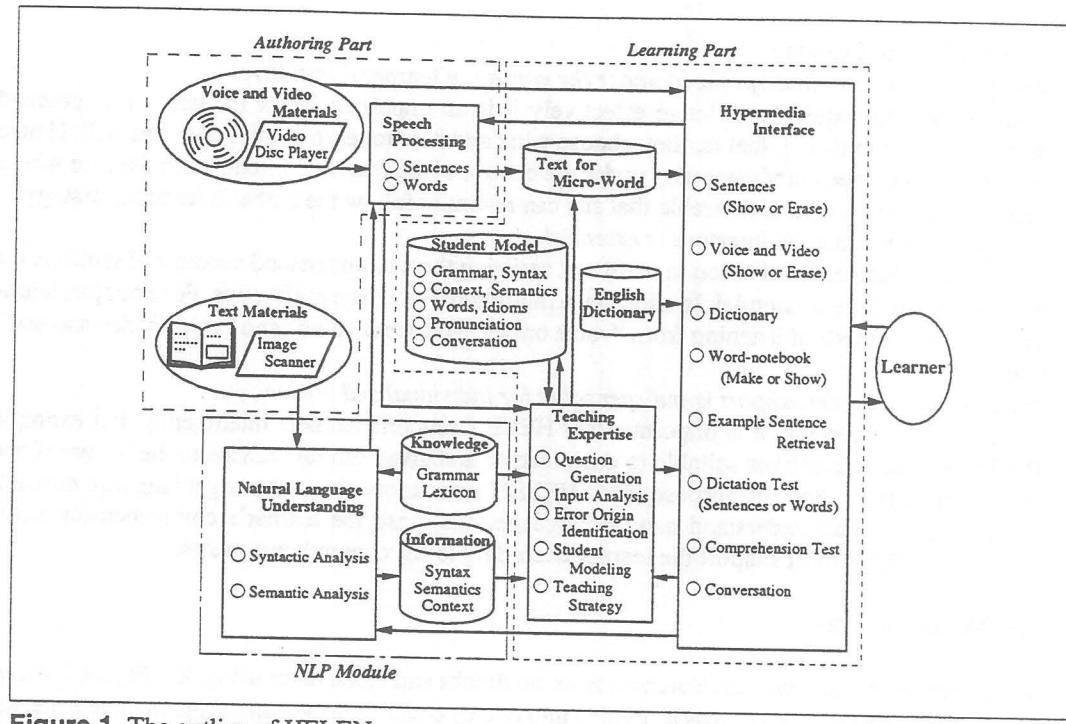


Figure 1. The outline of HELEN

is important in the authoring environment that authors can construct learning environments without programming. The following methodology enables program-less authoring.

a) Tools for the authoring process and parts for learning functions are required.

To reduce authors' burdens, HELEN has to be equipped with both AT (Authoring Tools) and LP (Learning Parts). AT are used to handle processes for authoring automatically or semi-automatically, and the interfaces of tools need to be user-friendly. LP have to be prepared for authors to create, with AT, a learning environment which has necessary learning functions, based on the authors' educational intentions. At a learning stage, LP correspond to learning functions used by learners. The standard learning functions such as play/stop-movie, display/hide-sentences and dictation-test are prepared in advance. If authors need tailored LP, they can program them using AT.

b) All authors have to do is to select necessary LP, and HELEN integrates them to achieve the desired result.

To construct learning environments easily, the final step of authoring should be automatic. In other words, HELEN integrates both LP selected by authors along with their educational intentions, and results of each process into a learning environment.

Principle 2 : Authoring should reflect authors' educational intentions.

To construct effective learning environments, it is indispensable for HELEN to make the best use of authors' educational intentions. Therefore authoring should be divided into two categories. One is *automated process* such as inputting sentences and NLP. The other is *author-intentional process* which needs authors' educational intentions such as deciding the number of sentences to teach at a time and selecting necessary LP. The former category is handled by HELEN automatically and the latter category is handled by an author's initiative.

(2) Principles For Learning

Principle 1 : *Lessons should proceed under the control of learners' initiative.*

In general, to acquire knowledge effectively it is an important factor for learners to proceed learning on their initiative, that is, they choose what and how to learn at their own free will. Hence lessons should proceed fundamentally under the control of the learners' initiative. In the case where a learner loses her way, it is desirable that she can naturally follow the author's teaching strategy.

Principle 2 : *A multimodal interface is essential.*

For giving learners motivation to learn and assisting them to understand contents of sentences, a multimedia interface is essential. In addition, a multimodal interface is effective. For example, learners can choose a mode of listening from "voice only," "voice and video" and "voice, video and text" freely.

Principle 3 : *Intelligent support is indispensable for individualized advice.*

For effective learning, it is important that HELEN supports learners intelligently. For example HELEN generates questions suitable to each learner and gives suitable advice to the learner if she reaches an impasse. For this purpose, first, HELEN must know about the target language domain, that is, HELEN must understand natural language, and grasp the learner's comprehension state. After that, HELEN must support the learner according to her comprehension state.

The Authoring Part

Authors make up a learning environment from textbooks and video discs using AT. Figure 2 shows the authoring process. The process is divided into two by complying the authoring principle 2, i.e. the *automated process* handled automatically by HELEN and the *author-intentional process* handled by

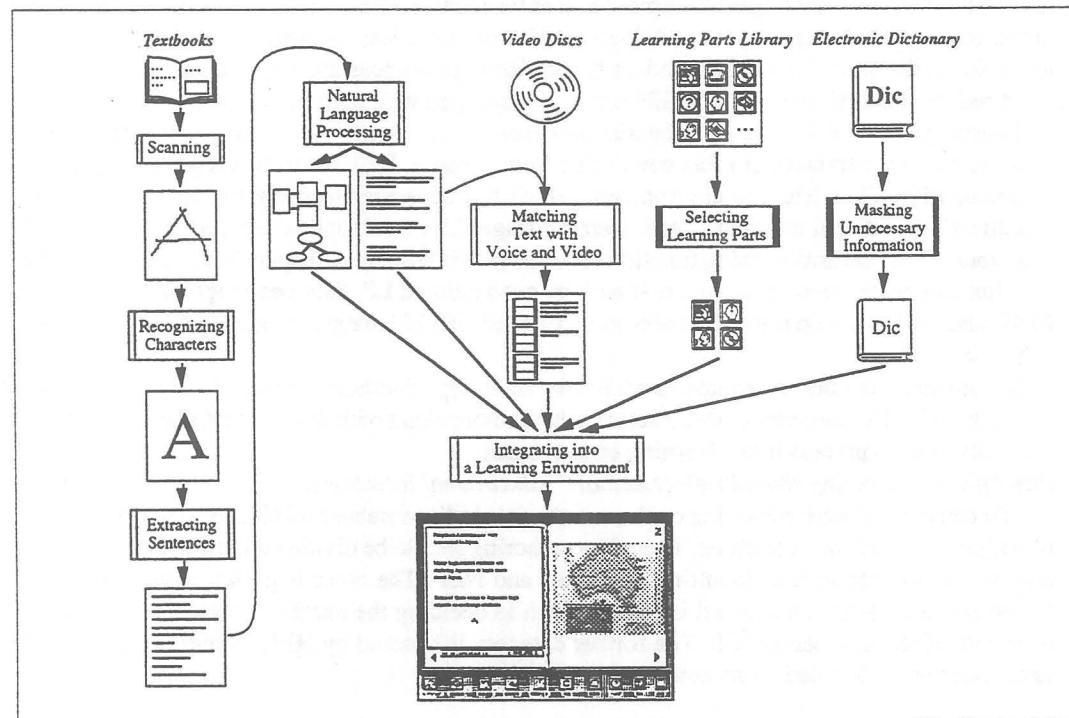


Figure 2. Authoring process

authors. The former category of processes is enclosed with double lines and the latter with thick lines in Figure 2. AT are prepared for each process. The authoring is processed in the following order.

(1) For Text Materials

First, an author selects a textbook. Using an image scanner HELEN gets sentences from the textbook in the form of pictures. Characters of the textbook are extracted from the pictures and transformed into sentences. Then, the NLP module is applied to the sentences so that necessary information concerning syntax, semantics, context, time and space may be extracted. If ambiguity exists, HELEN asks the author for correct interpretation. Finally, HELEN divides the sentences into groups according to semantic coherence; if necessary, the author corrects the division according to her educational intentions.

(2) For Voice and Video Materials

The author matches the text with voice and video by pointing to the starting and ending points of a scene which corresponds to a given text. Figure 3 shows a snapshot of the interface for matching text with voice and video. The multimodal interface given in learning principle 2 is realized by the process of synchronizing text, voice and video.

(3) For Learning Functions

As mentioned in the authoring principles, HELEN has a LP library which is a collection of functions such as display/hide-sentences, word-notebook and dictation-test. The author selects necessary LP for a learning environment from the parts library based on her educational intentions. Figure 4 shows a snapshot of the interface for selecting LP. If the author needs her own learning functions and she is good at programming, she can make and append them by herself.

(4) For an Electronic Dictionary

The author edits an electronic dictionary along with her educational intentions. Because the commercial electronic dictionary is too complicated for novice learners to use, the author may mask unnecessary information and rearrange items for them.

Finally, HELEN integrates the results of the above processes into a learning environment. Thus programming is unnecessary for authoring, so that even a novice author at programming

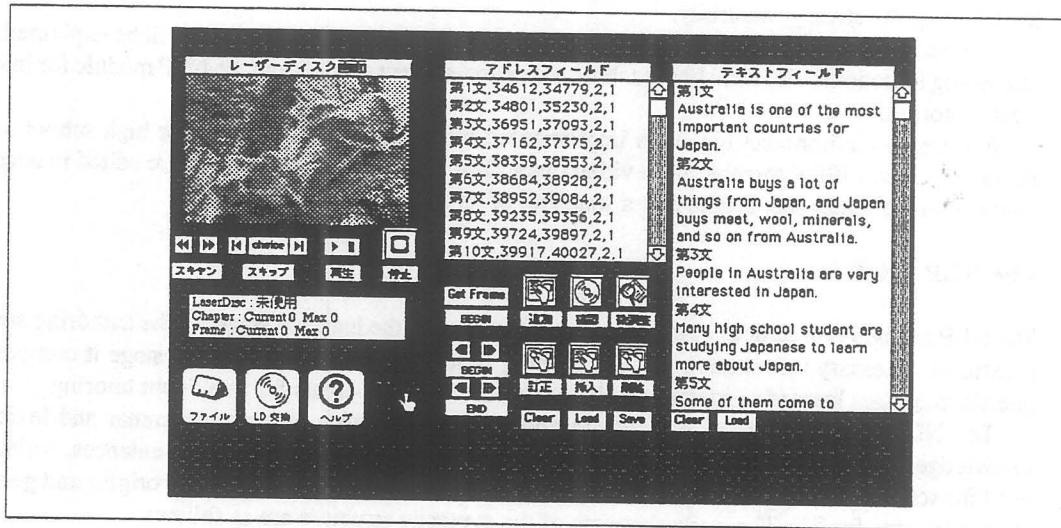


Figure 3. A snapshot of the interface for matching text with voice and video

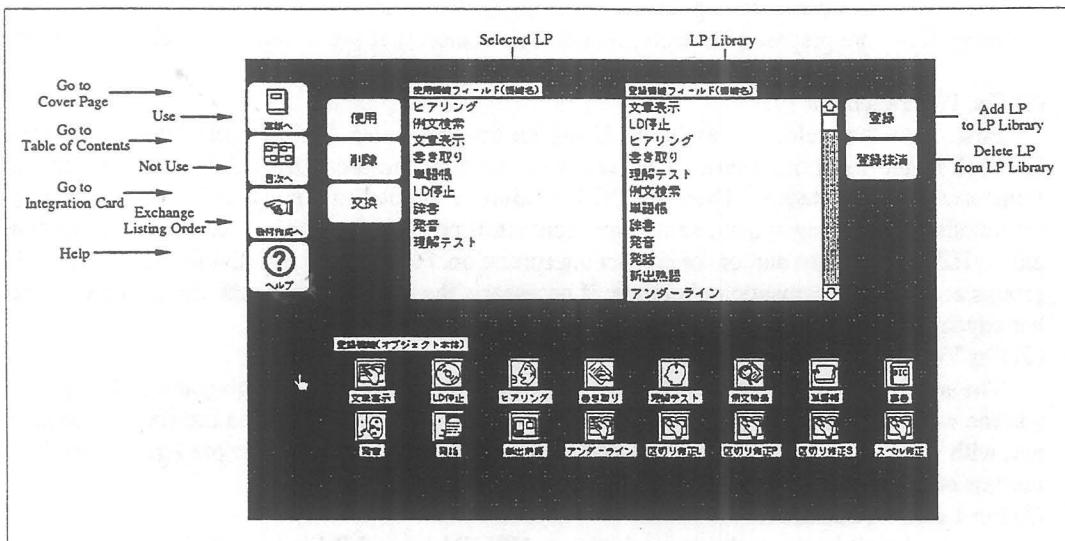


Figure 4. A snapshot of the interface for selecting Learning Parts

may construct learning environments easily. This characteristic agrees with the authoring principle 1.

The Learning Part

The learning part is composed of a hypermedia interface, learning materials of the text including voice and video, teaching expertise and student models.

Learning environments composed in the authoring processes satisfy the learning principle. Learners can select learning targets according to their will and learn freely. An author's strategy of learning sequence is expressed tacitly by a book metaphor, therefore if a learner loses her way, she learns along the strategy naturally.

The multimodal interface is composed by these materials and the LP which will be explained in "Learning Functions." HELEN has teaching expertise, student models and the NLP module for intelligent tutoring.

A learning environment has been implemented by using textbooks for junior high school students (Ota *et al.*, 1989) together with video discs (Tokyo Shoseki, 1990) which are edited in accordance with the textbooks. Figure 5 is a snapshot of its multimodal interface.

The NLP Module

The NLP module is used both in the authoring stage and in the learning stage. In the authoring stage it extracts necessary information for the learning functions, and in the learning stage it composes questions, judges learner's answers and identifies the learner's errors for intelligent tutoring.

The NLP module deals with syntactic and semantic analysis by using grammar and lexicon knowledge. The purpose of syntactic analysis is to extract syntactic structure of sentences, which is used for semantic analysis, example sentence retrieval, identifying learner's error origins and generating problems for TQ. The main elements of the syntactic structure are as follows.

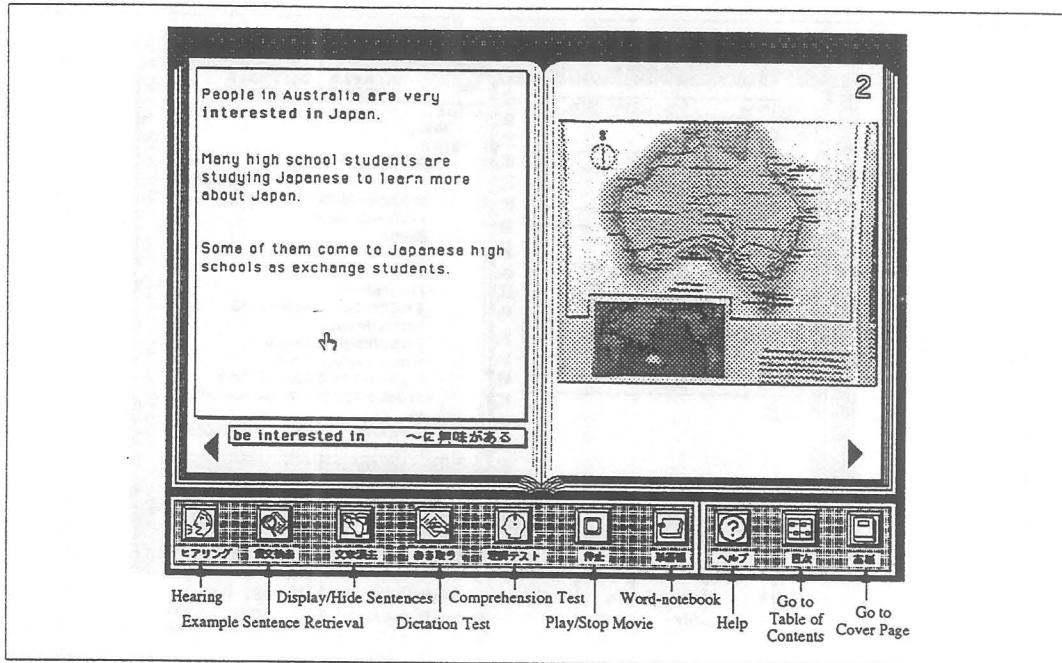


Figure 5. A snapshot of the multimodal interface

- a) Subject and predicate of a sentence.
- b) The relation between a modifier and a modificant.
- c) Syntactic information such as mood, tense, etc.

In the semantic analysis, the module extracts semantic information of each sentence and makes up context information that ranges throughout a lesson including time-space information. Details of the NLP are given in "Natural Language Processing."

Learning Functions

HELEN has the following six functions, each of which learners have initiative to drive by a simple operation such as pushing a button or selecting an item in a menu. The followings give the outline of the functions.

(1) A Table of Contents

A table of contents consists of a section number and a small video window for each section. Pushing a window, a learner hears and watches the video of the section, and pushing a section number, she moves into the section.

(2) Reading and Hearing

In each section, a learner can switch the "Display Sentences" button on or off in order to display or hide sentences, respectively. Thus she can choose listening with or without sentences. She can hear all the sentences on a page at a time or hear one sentence she has chosen. Reading and hearing sentences, together with watching video, aid the understanding of the situation and the atmosphere of the conversation.

(3) Dictation Test

Through dictation, a learner can confirm whether she has understood the sentence correctly or

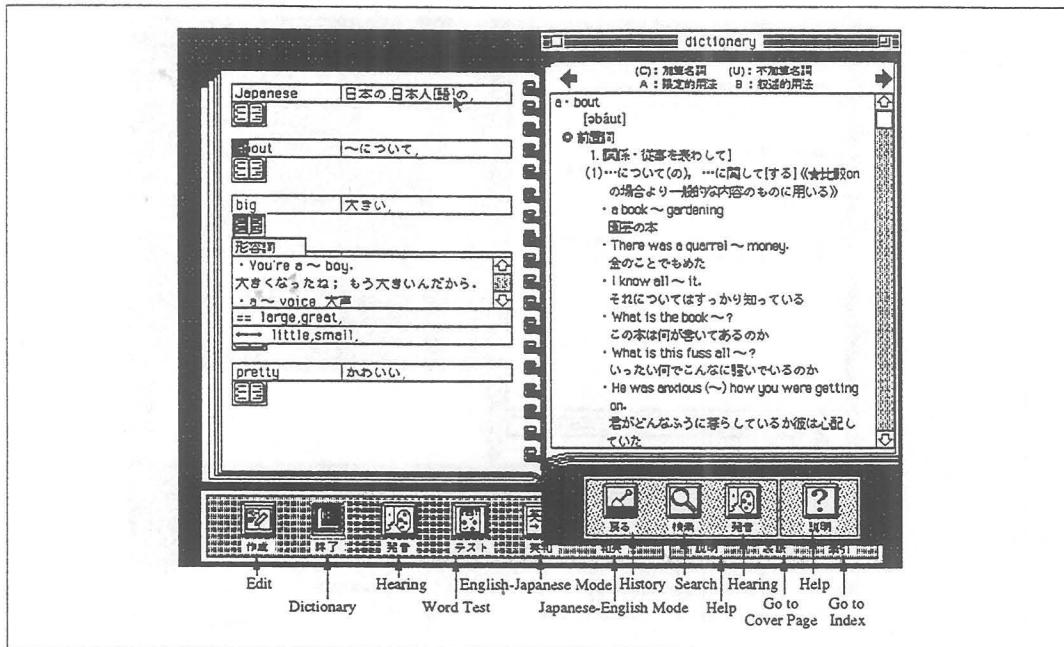


Figure 6. A snapshot of a word-notebook and a dictionary

not. When a learner inputs a sentence so far as she has understood it, HELEN indicates incorrect or lacking words in the input sentence. The learner can listen and write repeatedly in response to the indication.

(4) Dictionary and Word-notebook

HELEN is equipped with a dictionary which an author edited at the authoring stage by using the commercial electronic dictionary. Besides parts of speech, phonetic symbols, category and meanings, each word in the dictionary includes synonyms, antonyms and example sentences for hypermedia use.

Besides, HELEN supports learners to edit their own word-notebook specially situated to the pertinent usage. The word-notebook has the following features.

- A learner can switch to an English-Japanese or a Japanese-English word-notebook.
- When she clicks a word, she can get a translated word in Japanese or English and hear its pronunciation.
- The word-notebook supports a word test by detecting the learner's misuse, confusion, misspelling or slip of memory. Results are overlaid with the word-notebook. For the test, words are selected according to the probability in proportion to error frequencies so that the learner may learn by herself.

Figure 6 shows a snapshot of a word-notebook and a dictionary.

(5) Example Sentence Retrieval

HELEN helps a learner in learning new idioms or sentence structures in comparison with many other similar sentences, which are collected by using the function of example sentence retrieval.

By this function a learner can retrieve sentences by specifying sentence attributes as shown in Table 1. For example, when a learner is studying a sentence "He was looking for his pen," the learner can retrieve example sentences by designating keywords such as the idiom "look for" and/or past progressive form.

Table 1
Information Used for Example Sentence Retrieval

Items	Contents
Negation	affirmative, negative
Mood	indicative, subjunctive
Kind of Sentence	declarative, imperative, exclamative, interrogative
Tense	Primary present, past, future
	Others perfect, progressive, perfect progressive
Voice	active, passive
Auxiliary Verbs	will, shall, can, may, must, would, should, could, might, ...
Miscellaneous	idioms, participial construction, ...

(6) Comprehension Test (TQ)

The Comprehension Test is one of the intelligent tutoring functions in HELEN. The test is prepared for a learner to confirm how well she understands the context and contents of the sentences by hearing them. HELEN generates questions about the contents of a section depending on the learner's understanding state recorded in the student model. The learner's answer is processed by the NLP module and judged whether it is right or wrong. If it is wrong, the learner can refer to the scene which includes the content being tested. And if an answer is ill-formed syntactically, HELEN identifies the error origin and keeps it in the student model.

Natural Language Processing

The purpose of NLP is to extract both grammatical information which is used for the function of example sentence retrieval and contextual information concerning syntax, semantics and time-space structure. Generating questions for the Comprehension Test and judging correctness of the answers are processed through semantic analysis. Here we describe 1) the necessity for both syntactic and semantic analyses, 2) how to realize these analyses, 3) how to generating questions and 4) how to judge the correctness of answers on the Comprehension Test.

Syntactic Analysis

Necessity for Syntactic Analysis

The purpose of syntactic analysis is summarized in the following three points.

(1) To implement the function of example sentence retrieval.

To construct a database used for the retrieval function, all the sentences in the learning environment have to be analyzed and the necessary information shown in Table 1 has to be extracted at the authoring stage.

(2) Identification of syntactic errors in the learner's input.

It is indispensable for NLP to analyze sentences that include errors and to identify error origins which are used for advising and guiding a learner.

(3) Student modeling.

For realizing individualized learning environments, the student model plays a very effective role. The student model is constructed by identifying syntactic errors of a learner's input.

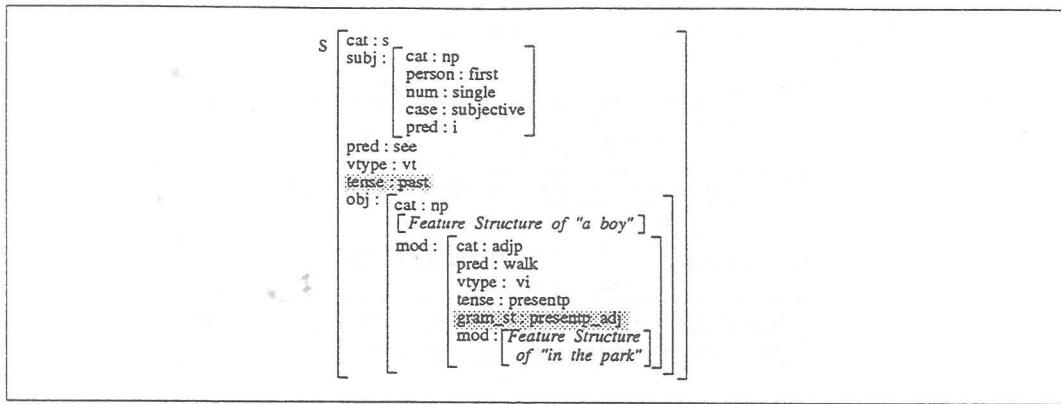


Figure 7. Feature structure

Method of Syntactic Analysis

Unification based bottom up parser implemented in Prolog was employed. Syntactic information is represented by the feature structure which consists of pairs: a feature name, and its value (Kaplan & Bresnan, 1982). For example, the feature structure of a sentence "I saw a boy walking in the park." is shown in Figure 7. In this example, we assume the prepositional phrase modifies the verb "walk." Hatched parts in Figure 7 indicate information used for the function of example sentence retrieval.

Syntactical Bug Identification Method

Syntactic errors observed among Japanese junior and senior high school students (Matsui 1979; Ono & Miyata, 1989; Ozasa, Fukazawa, & Yorozuya, 1983) were classified into two categories from the view point of identifying error origins; errors which can be identified only by syntactic analysis and errors which require semantic analysis. The former category is further classified into two groups. One is the group of errors caused by word transformation such as inflection and conjugation of verbs. The other is the group of errors of word order which includes extra words and missing necessary words. The errors of the word transformation are identified by extra conditions in DCG (Definite Clause Grammar) rules. The errors of word order are identified by buggy rules. The latter category of errors is treated in the limited cases which are marked with "*" in Table 2. The category is also identified by both extra conditions and buggy rules.

Figure 8 shows examples of grammar rules. Terms enclosed by "{}" are extra conditions of DCG rules. They are modified for readability in the examples. Figure 8 (a) is a grammatically correct rule for the progressive form. This rule also recognizes errors of conjugation by relaxing constraints

<pre>v(SynV, SemV) --> be_m (SynBe, SemBe), v (SynV, SemV), { if satisfy constraints then true else mark the error }.</pre>	<pre>v(SynV, SemV) --> do_m (SynDo, SemDo), v (SynV, SemV), { if satisfy constraints then mark the error }.</pre>
(a) A rule using extra condition	(b) A bug rule

Figure 8. Rules for the progressive form

Table 2
Classification and Identification Methods of Syntactic Error Origin

Error Origins	Identification Methods	
	By Syntactic Analysis Only	By Syntactic and Semantic Analysis
Personal Pronoun		
lack of pronoun	Bug Rule	
disagreement between personal pronoun and the antecedent	Extra Cond.	○
case usage error	Extra Cond.	
illegal order of direct and indirect objects	Extra Cond.	
Number		
errors on countable noun	Extra Cond.	
errors on uncountable noun	Extra Cond.	
disagreement between predicate verb and subject	Extra Cond.	
conjugation error of verb following auxiliary verb	Extra Cond.	
disagreement between verb and antecedent of relative pronoun	Extra Cond.	
Preposition		
lack	Bug Rule*	
redundancy	Bug Rule	
illegal use	Extra Cond.*	
Determiner		
countable noun with no article	☆	
lack of definite article		○
illegal use of indefinite article	Extra Cond.	
confusion of definite article and indefinite article		○
disagreement of determiner and noun phrase	Extra Cond.*	
Relative		
lack	Bug Rule	
word order error	Bug Rule	
case error of relative pronoun	Extra Cond.	
Tense		
habitual adverb in the past tense	Extra Cond.*	
tense error of a verb following an auxiliary verb	Extra Cond.	
future tense in an adverb phrase		○
disagreement of tense	Extra Cond.	○
Progressive		
form error	Bug Rule	
confusion of progressive and simple form		○
stative verb in the progressive form	Extra Cond.*	
Perfect		
confusion of continuous present perfect form and simple present form	Extra Cond.*	
Comparative		
inflection error	Extra Cond.	
Infinitive and Gerund		
conjugation error in infinitive or gerund usage	Extra Cond.	

☆ Both methods using extra condition and bug rule are applicable

* The origin is identified by using semantic marker in a lexicon

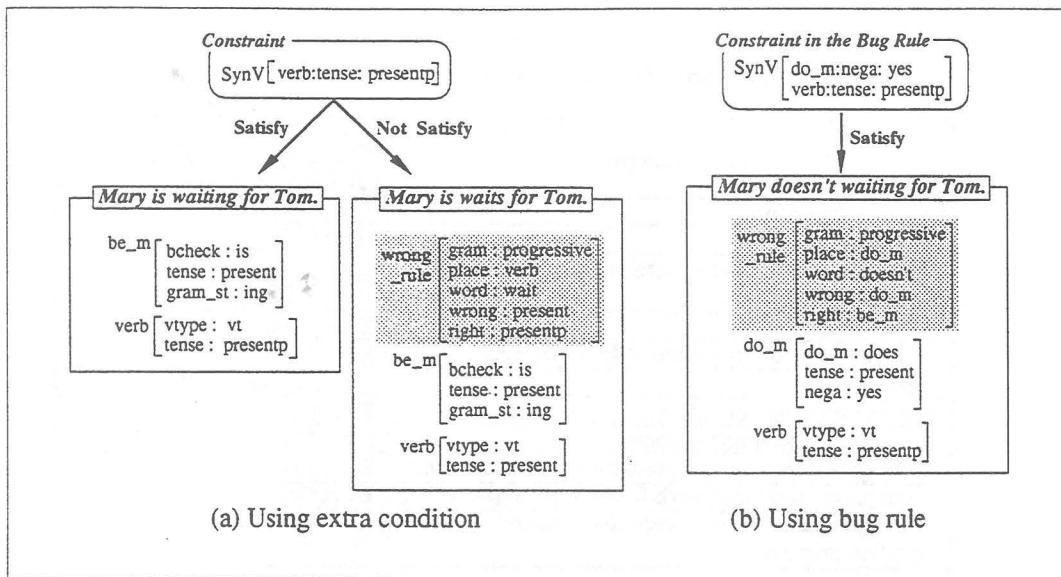


Figure 9. Error identification and feature composition

in the extra condition. Figure 8 (b) is a bug rule, which recognizes errors caused by confusing the progressive form with the simple present form.

Figure 9 shows a part of checking process by the rules given in Figure 8 and a part of the feature structure of an example sentence generated by these rules. The extra condition of the rule for progressive form checks syntactic constraints, i.e. whether tense of the verb is present progressive or not. If an input sentence doesn't satisfy the constraint, the extra condition records location of the error, type of the error and correct form in the feature structure. Figure 9 (a) corresponds to this case. The feature name "wrong_rule" is used to record the contents of the error. The extra condition of the bug rule first checks applicability of the rule, and if it is satisfied, contents of the error are recorded in the feature structure. Figure 9 (b) shows this case.

Semantic Analysis

Purpose of Semantic Analysis

Purposes of semantic analysis in HELEN are as follows;

- (1) To implement the Comprehension Test.

In the Comprehension Test, the NLP module generates questions suitable to each individual learner according to the student model, and it distinguishes semantically between correct and incorrect answers even if surface structures of the input sentences are different from the original sentences. This task requires the module to understand the semantics of the English sentences both in the text and the learner's input.

- (2) To improve performance of syntactic analysis and to reduce the author's burden.

As mentioned earlier, all sentences in a textbook are analyzed by the NLP module during the authoring stage. This process requires the author's intervention to resolve ambiguities. Checking semantic coherence at an intermediate point during the parse, efficiently filters out some of the ambiguities. It contributes to the reduction of the author's burden of creating new lessons.

(3) To divide the textbook into units.

Since the book metaphor was adapted as the external appearance of HELEN, the smallest learning unit corresponds to one page, which appears on a display one at a time. Text should, therefore, be divided into groups which have semantic coherence in order to fit the size one group to a page. This task requires semantic analysis, by which HELEN proposes a candidate of a division to the author.

(4) To answer learner's questions.

The NLP module answers learner's questions about contents of the textbook by referring to the semantic information.

Representation Method of Semantic Information

This method represents semantic information as separate entities of verbs, nouns and adjectives. Figure 10 shows an example of the semantic information, which represents semantics of three sentences given at the top of the figure. Meaning of a sentence is represented by a verb. Relations among verb, noun and adjectives are represented by links between them. Contextual information, such as modification relations and referential relations of pronouns, is also represented by links. For ex-

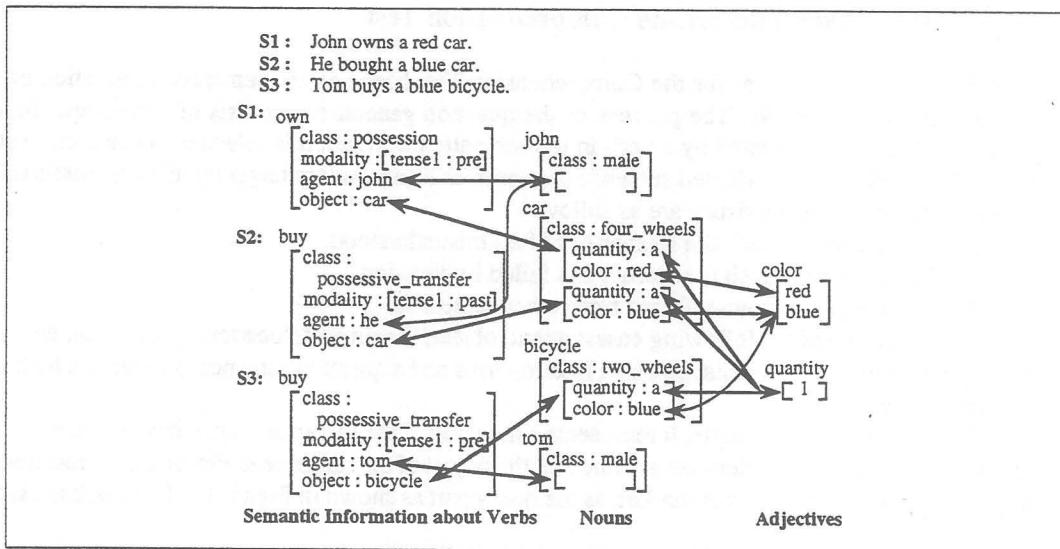


Figure 10. An example of semantic information about verbs, nouns and adjectives

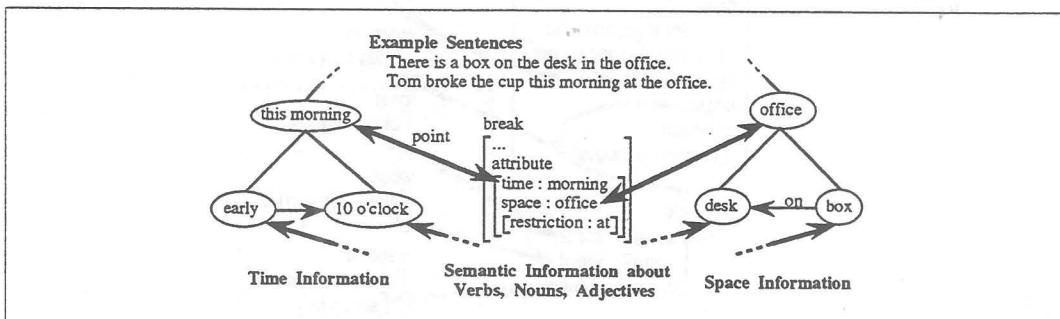


Figure 11. An example of time and space information

ample, "he" which is the agent of the sentence S2 corresponds to "John" which appears in the sentence S1.

Time information such as when an event occurred or ended is represented by a tree structure, and space information such as locations of objects and where an event occurred is also represented by a tree structure. Figure 11 shows an example of time and space information. Hierarchical relations of the trees represent inclusion relations of time and space. Relations between nodes which are children of a node represent partial ordering of time and positional relations between objects in the time and space trees, respectively. For example, the node "early" in Figure 11 represents a time point before "10 o'clock" in "this morning."

Node of the time and space trees and entities of the semantic information about verbs and nouns are linked to show their relations. Links between time nodes and verbs are labeled by "point" or "duration" to distinguish non-continuous events from continuous events.

When a new lesson is created, the semantic information is extracted from the textbook by the NLP module. However, it is difficult to extract a unique meaning automatically because of ambiguities of syntax and semantics. When ambiguity occurs, the NLP module asks the author to resolve the ambiguity by listing all possible interpretations so that the author may select a correct interpretation.

Generation of Questions for the Comprehension Test

HELEN generates questions for the Comprehension Test based on the semantic information of the text and the student model. The process of the question generation consists of three steps; first, a sentence which is represented by a verb in the semantic information is selected. Second, one entity which has a link with the selected sentence is chosen as a questionnaire target by using heuristic rules. Some examples of the heuristics are as follows;

- (1) Choose a word which the learner has often misunderstood.
- (2) Choose a word which the learner has failed in dictation.
- (3) Choose a proper noun referred from other sentences.
- (4) Choose one of the following cases; agent, object, instrument, location, time, cause, etc.

Finally, the chosen part is replaced by an interrogative and a question sentence is generated by transformation rules.

Figure 12 shows an example. It represents a meaning of the sentence "Japan buys meat, wool and minerals from Australia." Here we assume that the object of the sentence is chosen as the questionnaire target. In this case, the object is marked as the query part as shown in Figure 12. This mark is used to

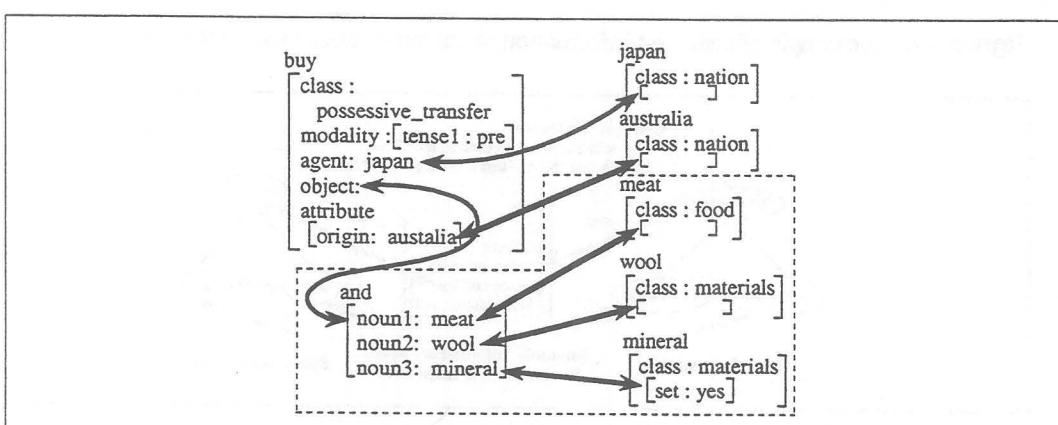


Figure 12. The semantic representation of "Japan buys meat, wool and minerals from Australia."

check the learner's answers. Then the object is replaced by a symbol representing an interrogative pronoun, and the interrogative sentence "What does Japan buy from Australia?" is generated from the semantic information by using transformation rules.

Judgment of Learner's Answers

A learner's answer is translated into the semantic representation by the NLP module in the same way as the textbook. The semantic information of the answer is compared with the semantic information of the textbook. If the answer includes the query part which is marked during the question generation

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HELEN > What does Japan buy from Australia?
Learner > Japan buys meat and wool from Australia.
HELEN > Is there anything else?
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Figure 13. An example of a dialogue

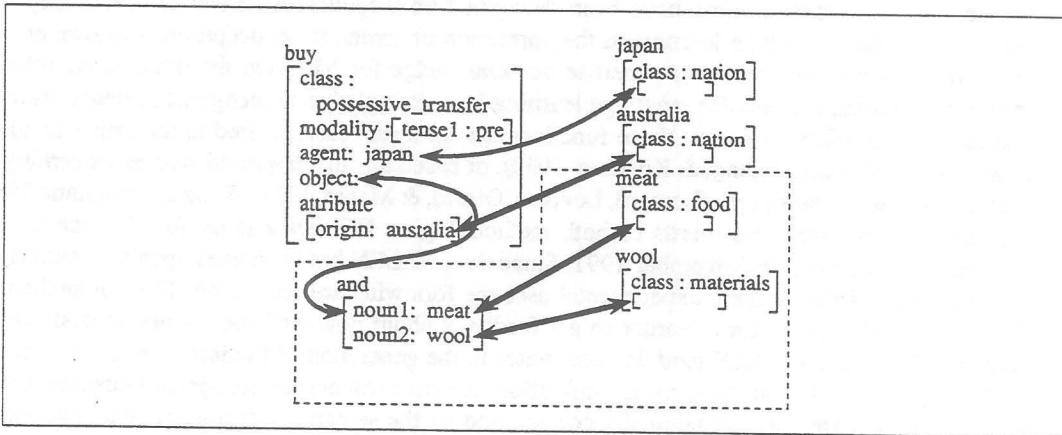


Figure 14. The semantic representation of "Japan buys meat and wool from Australia."

and other part of the answer doesn't contradict with the semantics of the text, the learner's answer is judged as correct.

Figure 13 is an example of a dialogue. The question from HELEN is presented by voice only. The semantic representation of the learner's answer is shown in Figure 14.

Student Modeling and Tutoring

Two methods of student modeling are employed in HELEN; one is a so-called overlay method used for representing the learner's vocabulary as described in (4) of "Learning Functions," and the other is collecting grammatical error rules used by the learner as described in "Syntactical Bug Identification Method." The error rules are classified according to Table 2, which is derived from the analysis of typical errors observed among Japanese students (Matsui 1979; Ono & Miyata, 1989; Ozasa, Fukazawa, & Yorozuya, 1983).

The tutoring strategy is roughly divided into four areas; the first one is for vocabulary, the second one is for failure to recognize words, the third one is for grammatical errors and the last one is for

semantic errors. As described in (4) of "Learning Functions," vocabulary learning is treated within the word-notebook. HELEN warns about failure to recognize words in the dictation and reads repeatedly if the learner wants. Teaching the correct answer is the last measure.

The first warning to the learner about grammatical errors is an indication of the erroneous place and the class in Table 2. If the learner can not correct the errors, a very simple example sentence having the same grammatical structure is displayed. Explicit tutoring about grammar is the last measure.

As to the semantic errors described in "Judgment of Learner's Answers," the following tutoring paradigms are employed; recommending the learner to consult with the text pages, refuting the discrepancy between the text and the answer, noting the missing part in the answer.

Discussions and Conclusions

This paper presents the functions of an English learning environment and methods of intelligent support by the NLP module. The environment which integrates several learning methods using hypermedia plays a significant role in second language education. Recently many hypermedia environments for language learning have been developed on a commercial basis. However they have serious difficulties in aiding learners in the correction of errors, misconceptions, impasse, etc. because they have neither teaching expertise nor knowledge for NLP. On the other hand, although intelligent tutoring systems for language learning have knowledge to recognize sentence structure and identify the learner's errors, these functions are, in most cases, limited to the syntactic advice (Yazdani, 1989; Kudo, Chung, & Koshino, 1990), or based on only empirical studies concerning the first and the second languages (Lessard, Levison, Girard, & Maher, 1992; Wang & Garigliano 1992). Our environment integrates merits of both methodologies. HELEN was exhibited at the Kyushu Advanced Electric Fair in November 1991. Since then HELEN has been used openly by students in our laboratory. Through these experimental uses the following are concluded. The Comprehension Test is especially useful for a learner to get feedback about how well the learner understands the contents of lessons. The NLP module contributes to the generation of flexible response to learners; i.e. by the method of syntactic error identification, the environment can recognize sentences that are syntactically incorrect but semantically correct, and by the semantic information, the environment can recognize semantic coincidence regardless of the difference in surface structure of sentences.

The other characteristic of HELEN is its authoring facilities. Although there is a lot of interesting research which presents deep consideration on language understanding, tutoring methods and student modeling related to intelligent language tutoring systems (Swartz & Yazdani, 1992; Yazdani 1989), very few studies with authoring. Our design goal for authoring is to reduce the author's burden and to make easier for authors to create new lessons. Hence attempts were made to automate authoring processes which relate to technical issues. As a result, with the assistance of the authoring module, authors (teachers) can concentrate on pedagogical issues such as selecting teaching materials, partitioning the material into small lessons and arranging items in the dictionary according to their educational intentions.

At present there are three remaining issues. First, more effective methods than those described in "Student Modeling and Tutoring" are needed to guide a learner who makes syntactic errors. Investigation of a guiding method which reflects both understanding state recorded in the student model and results of error identification is now in progress. Second, further reduction of the author's burden in creating new lessons is needed. A more powerful semantic analysis may reduce ambiguities that occur in the NLP, which the author has to resolve manually at present. Third, in order to enhance the multimodal environment, it is necessary to recognize learner's input in voice, which we are investigating.

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