

# Interpreter for Highly Portable Spoken Dialogue System

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## Abstract

Recently the technology for speech recognition and language processing for spoken dialogue systems has been improved, and speech recognition systems and dialogue systems have been developed to the extent of practical usage. In order to become more practical, not only those fundamental techniques but also the techniques of portability and expansibility should be developed. In our previous research, we demonstrated the portability of the speech recognition module to a developed portal spoken dialogue system. And we constructed a dialogue strategy design tool of dialogue script for controlling the dialogue strategy.

In this paper, we report a highly portable interpreter using a commercial electronic dictionary. We apply this to three domains/tasks and confirm the validity of the interpreter for each domain/task.

**Keywords:** spoken dialogue system, robust interpreter, portability, dialogue script

## 1 Introduction

Recently, much research has been done on the robustness and reliability of spoken dialogue systems. We developed a “Mt.Fuji sightseeing guidance” system which uses touch screen input, speech input/output and graphical output, and have improved the sub-modules of a speech recognizer, nat-

ural language interpreter, response generator and multi-modal interface (Kai and Nakagawa, 1995; Itoh et al., 1995; Denda et al., 1996; Kogure et al., 1999; Nakagawa et al., 2000). General speaking, all of these modules except for the speech recognition module depended on a given task or domain.

As speech recognition systems are increasingly being used in practical applications, spoken dialogue systems will also become more widespread. However, the cost of developing a new spoken dialogue system is enormous. The systems that have been developed so far can not be transferred to other domains easily, and a highly-portable system that can be easily adapted to another domain or task urgently should be developed. There are several examples of researches that focused on high portability and expansibility (Kaspar and Hoffmann, 1998; Brondsted et al., 1998; Sutton et al., 1998; Sasajima et al., 1999; Abella and Gorin, 1999; Levin et al., 2000).

In (Kaspar and Hoffmann, 1998), a prototype could be simply constructed even in a complicated speech dialogue system using the PIA system, which was implemented using Visual Basic. This system placed priority on achieving high robustness of speech recognition and high naturalness of generated dialogue. However, the system limited the task to the domain of knowledge search. E. Levin et al. reported the design and implementation of the AT&T Communicator mixed-initiative spoken dialogue system (Levin et al., 2000). The communicator project sponsored by DARPA launched in 1999.

On the other hand, we have also considered the portability of spoken dialogue system (Kogure and Nakagawa, 2000). We showed from experience that

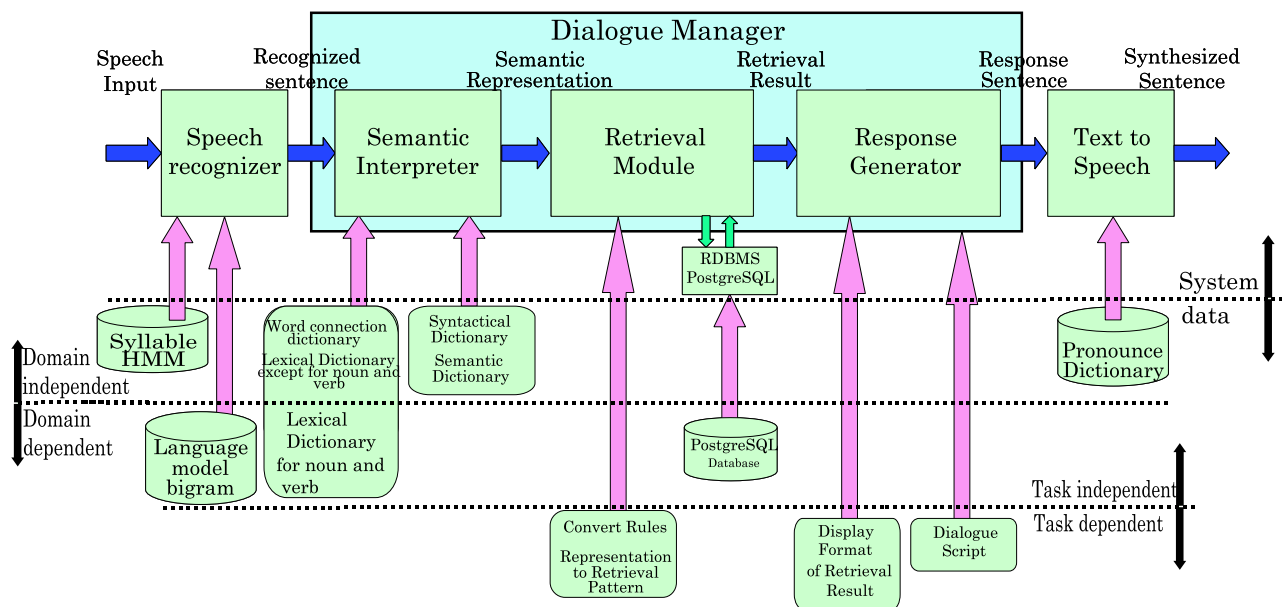


Figure 1: System overview.

it was difficult to transfer from the Mt. Fuji sightseeing guidance existing system to the East Mikawa sightseeing guidance.

Therefore, we built portable spoken dialogue system developing tools based on GUI (Kogure and Nakagawa, 2000). Especially, we focused on the developing tools of spoken dialogue system for database retrieval.

Some spoken language systems focused on robust matching to handle ungrammatical utterances and illegal sentences. The Template Matcher (TM) at the Stanford Research Institute (Moore and Podlozny, 1991) instantiates competing templates, each of which seeks to fill its slots with appropriate words and phrases from the utterance. The template with the highest score yields the semantic representation. R.Kuhn and R.De Mori suggest a method where the system's rules for semantic interpretation are learnt automatically from training data (Kuhn and Mori, 1995). The rules are encoded in forest of specialized decision trees called as Semantic Classification Trees (SCTs). The learned rules are robust to ungrammatical sentences and misrecognition in the input. Minker compared a rule-based case frame grammar analysis and a stochastics based case frame grammar analysis for understanding (Minker, 1998). Globally speaking, the performances of the stochas-

tic and rule-based parsers were comparable for ATIS (Air Travel Information Service). Y. Wang suggests a robust chart parser which is the major Spoken Language Understanding (SLU) engine component behind MiPad (Wang, 2001). The robustness to ungrammaticality and noise can be attributed to its ability of skipping minimum unparsable segments in the input. The robust parsing algorithm is an extension of the bottom-up chart-parsing algorithm.

In (Nakagawa et al., 2000), the dialogue system understands spontaneous speech which has many ambiguous phenomena such as interjections, ellipses, inversions, repairs, unknown words and so on, and responds to the user's utterance. But the system fails to analyze some utterances. "Incompleteness" with the interpreter mainly causes the analysis failure, and leads to domain/task dependent development. Therefore, in this paper we focused on improving the interpreter in order to make it a robust/portable one.

For this purpose, we used the EDR electronic dictionary as a semantic dictionary and improved the interpreter so that it had some new functions. Finally, we applied the system to three domains/tasks; hotel retrieval, Mt.Fuji sightseeing guidance and literature retrieval.

## 2 Highly-portable System for Information Retrieval from Database

The proposed system in the dialogue processing parts consists of semantics interpreter, retrieval module, response generator and dialogue manager which integrates three modules. The system overview is shown in Figure 1.

Each module has the following roles:

- **Speech Recognizer:** This module recognizes a user utterance via speech input and generates a recognized sentence. We used SPOJUS (Kai and Nakagawa, 1995) for this.
- **Semantic Interpreter:** This module understands a user utterance via recognized sentence and generates semantic representation.
- **Retrieval Module:** This module that extracts the word as retrieval key word/phrase from the semantic representation.
- **Response Generator:** This module is activated by a dialogue manager, selects a kind of response strategies and generates a response sentence.
- **Text-to-speech Module:** This module generates a response sentence, synthesizes speech signals and playbacks this audio files to user.

In this paper, we focused on three modules: **Semantic Interpreter**, **Retrieval Module** and **Response Generator**. We believe that the **Speech Recognizer** except for the language models and the **Text-to-speech Module** are domain and task independent. A domain/task adaptation technique of the language models for the speech recognizer was preliminarily evaluated (Kogure and Nakagawa, 2000).

## 3 Improving the Semantic Interpreter

### 3.1 Adding New Functionality

Our purpose is to improve our previous interpreter (Kogure and Nakagawa, 2000) to make it more robust and portable. In this study, we implemented new functions into the interpreter as follows:

- **Processing of Correction Utterance:** The system omits the word sequence as restatement

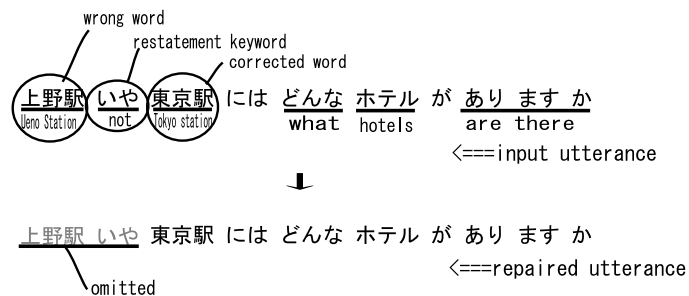


Figure 2: An example of processing of correction utterance.



Figure 3: An example of removing recognition error caused by logging error.

and word preceding this sequence. The omitted word sequence is the word or word sequence which the user uses when he/she tells the system to repair the wrong word or word sequence. Figure 2 shows this process.

- **Removing Recognition Error by Logging Error:** The system ignores non-semantic words at the head or the tail of the sentence caused by detection errors of beginning/ending speech and adopts the grammatically longest candidate from plural candidates as the valid

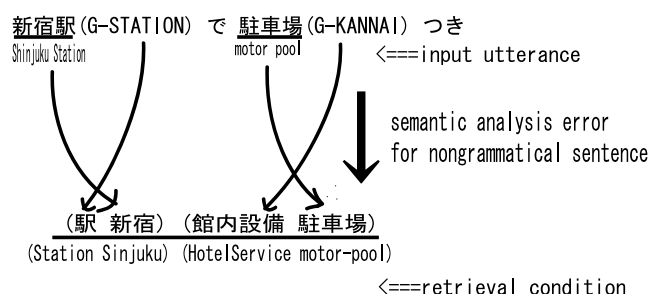


Figure 4: An example of improving keyword retrieval.

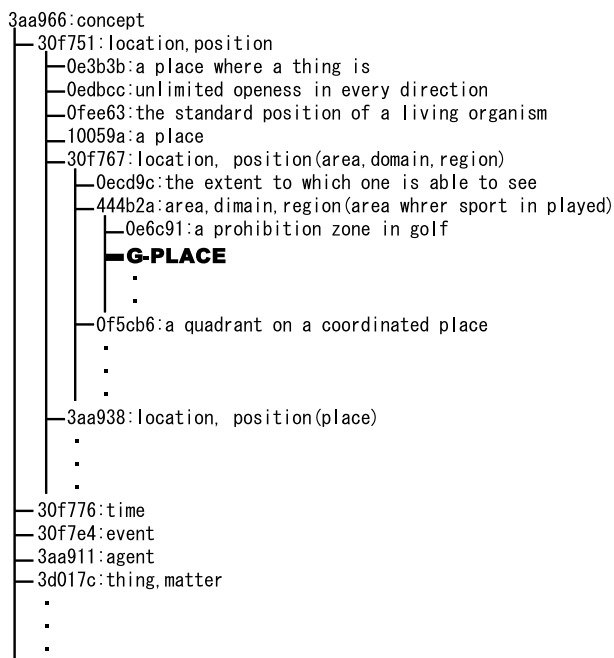


Figure 5: An example of concept classification.

sentence. Speech segmentation errors in background noise environments yield non-semantic words. Figure 3 shows this process.

- **Improving Keyword Retrieval:** If an input sentence is inadequate for parsing, the system creates a retrieval condition from the semantic labels which are attached to the word used as the keyword in a sentence. Figure 4 shows this process.

### 3.2 EDR Electronic Dictionary for Semantic Interpreter

In the study, we clearly separated domain/task independent parts and dependent parts. When an application developer wants to change a domain or task, he/she modifies or prepares only domain/task dependent parts, such as semantic features, proper nouns, and so on. In this section, we describe the domain/task dependent information obtained from the EDR electronic dictionary, which is used to analyze the utterance in the interpreter.

The EDR electronic dictionary<sup>1</sup> has widely been used for research and application development of

<sup>1</sup><http://www.jsa.co.jp/EDR/>

```
search[3cec34] :::
  agent 30f6b0;30f746 =GA,
  object 3f97b1 =WO
```

Figure 6: An example of case frame.

Japanese language processing. We developed a high portable semantic dictionary for the interpreter using the EDR electronic dictionary.

#### 3.2.1 Concept Dictionary

The EDR electronic dictionary is constructed by a hierarchical tree structure with classification records which are composed of 410,000 concepts.

Figure 5 shows a part of concept classification from “location.” “30f751” denotes the concept classification for “location.”

We assign the concept for domain/task dependent words to the existing hierarchical structure. In Figure 5, “G-PLACE” is a keyword which is used for referencing to a place. Since the morphological analysis assigns the concept to the word, the interpreter can use the concept information.

#### 3.2.2 Dictionary of Selectional Restriction for Japanese Verbs

The interpreter analyzes an input sentence using the dictionary of selectional restrictions or case frames for Japanese verbs, which are attached as a co-occurrence dictionary for the EDR electronic dictionary. This dictionary contains information related to the surface case and the deep case about main verbs. The interpreter converts the input sentence to the case frame format information using this dictionary, which is formalized from the information on a deep case and the conceptual classification information for every verb using the technique of a selectional restriction.

Figure 6 shows the case frame of the verb “search”. It shows that “3cec34” is the concept classification of “search.” When the deep case is “agent” and the surface case is “GA”, “30f6b0” or “30f746” is selected, and when the deep case is “object” and the surface case is “WO”, “3f97b1” is selected. Where “GA” and “WO” are particle peculiars (postpositions) in Japanese.

```

山手線 沿線 に どんな ホテル が あり ます か
Yamanote Line along what hotel are there
(In English:What hotels are there along Yamanote Line?)
<===input utterance

(sentence (noun-phrase (noun "山手線/G-LINE, 30f751") (noun "沿線") (particle "に"))
(sentence (noun-phrase (noun-phrase (adnominal-phrase "どんな/AAA15") (noun "ホテル/G-KIND, 30f6ae")) (particle "が"))
(verb-phrase (verb-phrase (verb "あり/0e5a74") (auxiliary verb "ます")) (particle "か"))))
<===parsing result

ある[0e5a74] :::
object 30f6ae-30f6af-30f6e5:30f751-3aa938-3f9658 =が,
goal 30f751-3f9658-3aa938;101260 =に
<===used case frame

(*ある
(object "ホテル"[ "どんな", AAA15], G-KIND, 30f6ae)
(goal "山手線"[ "沿線", 0e6acc], G-LINE, 30f751)
)
<===semantic analyzing result

(沿線 山手線)(種類 ホテル) <===retrieval condition
(Line Yamanote) (Facility-kind Hotel)

```

Figure 7: An example of semantic interpreter.

### 3.3 An Example

Figure 7 shows an example of the interpreter flow.

In Figure 7, the user inputs a *Japanese* utterance that means "What hotels are there along Yamanote Line?" in English. The interpreter executes the processes of a morphological analysis and parsing, and generates a parsing result that is represented by a tree-structure in accordance to the prepared grammar. This sentence's verb is "ARU" (*There are*, in English), and the concept classification of "ARU" is "0e5a74". The interpreter generates a semantic analysis result from the parsing result using this concept classification information, that is, the case frame of "ARU". The system transfers the semantic analysis result into a retrieval condition. This condition is used to generate SQL language for the retrieval.

## 4 Domain/Task Independency and Dependency

### 4.1 Domain/Task Independency/Dependency

In this section, we describe how to realize the high portability which has the benefit of efficiency when application developers design a new dialogue system. That is, while the system performance is kept at a certain level, we will shorten the period of developing the dialogue system as possible. Therefore, we define the *domain/task independency/dependency*.

*Domain independency* means that application developers can use common data for all domains<sup>2</sup>. *Domain dependency* means that applications are not domain independent. *Task independency* means that application developers can use these common data for all tasks<sup>3</sup> in a certain domain. *Task dependency* means that is not task independent. Hereafter, four data types are abbreviated as *DI*, *DD*, *TI*, *TD*, respectively.

We clearly separated semantics, retrieval and response modules into *DI/DI*, *DD/TI*, *TI/TD*, and *TI/TI* parts, respectively. The system core was built whilst keeping it completely domain and task independent (*DI/TI*). We can divide data sets three types<sup>4</sup> as shown in Table 1; *DI/TI*, *DD/TI* and *DD/TD*. *DI/TI* data sets served as information for a morphological analysis except for nouns or verbs with respect to the domain/task and so on. *DD/TI* data sets are used as information for morphological analysis of nouns or verbs with respect to the domain/task, information for semantics analysis and so on. *DD/TD* data sets are used as information for format that the system responds the retrieval results and so on. In the

<sup>2</sup>Domain is a field or area of dialogue object.

<sup>3</sup>Task is the problem or process that the user wants to realize in a particular domain.

<sup>4</sup>Since we define a domain and a task as the above, all domain independent data sets are surely task independent data sets, therefore *DI/TD* data sets are none.

Table 1: Separation of domain/task dependent data sets and domain/task independent data sets.

types	Data
<i>DI/TI</i>	syllable HMMs, morphological dictionary except for noun and verb, syntactic grammar, noun and verb semantic dictionary for dialogue processing ,semantic dictionary, case frame
<i>DD/TI</i>	morphological dictionary for noun and verb field information of database, database
<i>DD/TD</i>	convert rule from semantic representation to retrieval pattern, display format of retrieval result

*DI*: domain independent      *DD*: domain dependent  
*TI*: task independent        *TD*: task dependent

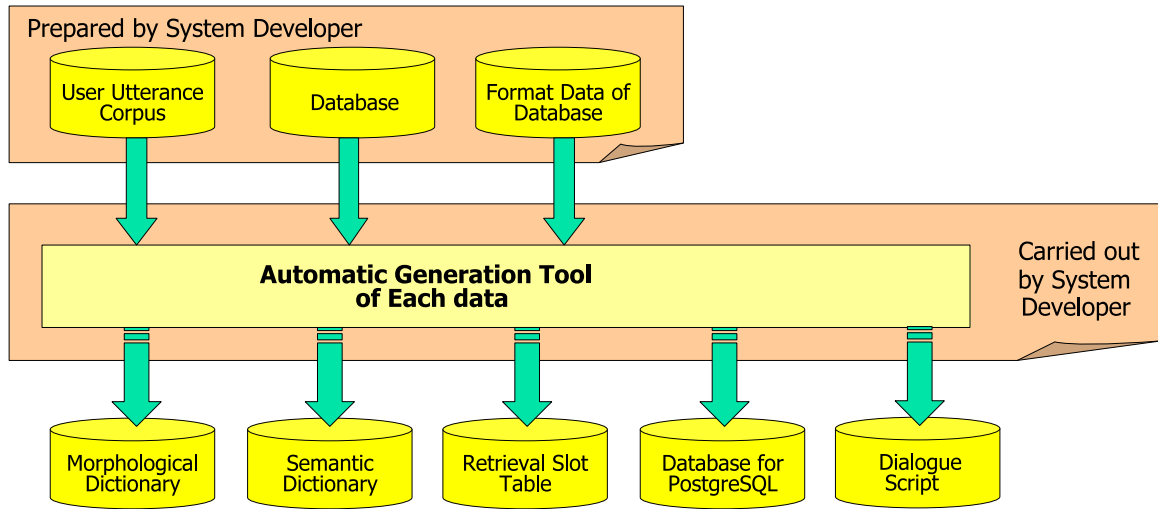


Figure 8: Task adaptation.

next section, we describe how application developers prepare *DD/TI* and *DD/TD* data sets.

## 4.2 System Core

We used Chasen<sup>5</sup> as Japanese morphological analysis and PostgreSQL<sup>6</sup> as a database retrieval management system. We have constructed Semantics Modules based on the Mt. Fuji sightseeing guidance system (Nakagawa et al., 2000) with separating task dependent and independent parts. All parts of the system core are clearly *DI/TI*.

<sup>5</sup><http://chasen.aist-nara.ac.jp/>

<sup>6</sup><http://www.pgsql.com/>

## 4.3 Data Sets

Data sets consist of *DI/TI*, *DD/TI* and *DD/TD* data sets. The separated results are shown in Table 1.

## 5 Task Adaptation -Hotel Retrieval System-

Figure 8 shows the flow chart of the task adaptation.

We consider what kind of data may be prepared as task-dependent knowledge when a new task is applied. In the proposed framework, the application developer prepares the following:

- A generally usable database (machine readable)
- The format information of each field of the database

A generally usable database

```
-----  
<name>GrandCentralHotel</name>  
<address>2-2 Kandatsukasa-machi Chiyoda Tokyo</address>  
<access>On foot-from JR line and subway line Kanda station 3 minutes</access>  
<land>Tokyo Tower,TOKYO DOME</land>  
<single>8900,7120</single>  
:
```

The format information of each field of the database

```
-----  
Database format information  
-----  
S|<name>|</name>|name  
S|<address>|</address>|address  
R|<access>|:|,|</access>|access  
R|<land>|:|,|</land>|land  
R|<single>|:|,|</single>|single  
:  
-----  
Transfer format information  
-----  
DATABASE:::  
hotel:$hotel_id{int},$name{varchar(200)},$address{varchar(200)},  
$checkin{varchar(10)},$checkout{varchar(10)},$scale{varchar(20)},  
$room{varchar(20)},$smoking{varchar(20)}  
acc:$acc_id{int},$hotel_id{int},$access[]{varchar(200)}  
land:$land_id{int},$hotel_id{int},$land[]{varchar(200)}  
single:$single_id{int},$hotel_id{int},$single[]{varchar(200)}  
double:$double_id{int},$hotel_id{int},$double[]{varchar(200)}  
twin:$twin_id{int},$hotel_id{int},$twin[]{varchar(200)}  
inside_hotel:$inside_hotel_id{int},$hotel_id{int},$inside_hotel[]{varchar(200)}  
room:$room_id{int},$hotel_id{int},$room[]{varchar(200)}  
service:$service_id{int},$hotel_id{int},$service[]{varchar(200)}  
card:$card_id{int},$hotel_id{int},$card[]{varchar(200)}  
DATABASE:::
```

Figure 9: An example of hotel information and the definition given by a developer.

- **A corpus of user utterances** (dialogue examples)

The database information retrieval system first requires a database (generally, one that is open to the public) as a retrieval target. The format information of each field in the database should be given in order to access the database. In addition, since the dictionary and language model are adapted to the database information retrieval system in the task, a corpus of the user utterances is required.

For examples, Figure 9 shows **a generally usable database and the format information of each field of the database** in a hotel retrieval system.

We used the hotel data of Hornet<sup>7</sup> of the hotel reference site in Japan. The web page of this site can be automatically translated into a database. The data obtained from the HTML source is translated into a data format like the **generally usable database** in Figure 9.

This is translated according to the rules of Figure 9. In Figure 9, *hotel information* consists of

<sup>7</sup><http://www.inn-info.co.jp/>

the name of the hotel, address of the hotel, access method to the hotel, and so on. *Transfer format information* describes how each item of hotel information is processed.

In Figure 9, the landmarks, 'Tokyo Tower' and 'Tokyo Dome' are substituted into an array variable 'landmark' which represents a landmark.

From the description of this file, the construction of a database and creation of the table for every category can be performed automatically. And word registration to an analysis dictionary can be automatically performed using a morphological-analysis dictionary tool and a semantic dictionary registration tool. In this way, the hotel retrieval system was constructed in about 10 hours.

The sample of a dialogue is shown in Figure 10.

## 6 Other Task Adaptation

### 6.1 Application to Mt. Fuji Sightseeing Guidance System

We applied the portable system to Mt. Fuji sightseeing guidance system as well as the hotel retrieval

```

===== Speech Input =====
Input :What hotels are there around Kanda Station?
                                     <=== input utterance
                                     :What hotels are there near in Kanda Station?
                                     <=== recognized sentence
===== System Output =====
5 facilities were found.

===== Retrieval Result =====
No.1 Olympic in Kanda, single room:11000yen
No.2 Grand Central Hotel,single room:8900yen,double room:12200yen, twin room:142000yen
No.3 Sun Hotel Kanda,single room:8400yen,twin room:13600yen
No.4 Central Hotel,single room:6500yen,double room:9800yen,twin room:9300yen
No.5 New Central Hotel,single room:7000yen,double room:7500yen,twin room:9600yen

===== System Output =====
The retrieval result is the above.

===== Speech Input =====
Input :Please display the data of No.2.
                                     <=== input utterance
                                     :Please display the data of No.2.
                                     <=== recognized sentence
===== System Output =====
The details of the data of No.2 are displayed.

===== Retrieval Result =====
*** Grand Central Hotel ***
2-2 Kandatsukasa-machi Chiyoda Tokyo
On foot-from JR line and subway line Kanda station 3 minutes
Landmark:
Room charge :: single:8900yen double:12200yen twin:14200yen
check in time is 15:00,check out time is 11:00
11 stories,157 rooms
No smoking room is Nothing
Inside-a-hotel equipment:conference room,vending
machine,laundromat,restaurant,banquet hall
indoor equipment:bath,toilet,air conditioning,lighting
desk,refrigerator,Japanese tea,drier,amenity
set,television,video broadcast,satellite broadcasting,telephone
service:Room service,copy,facsimile,word processor loan,iron
loan,trouser press loan,parcel delivery service
receptionist,cleaning receptionist,message,mail servic
Usable credit card:DC,VISA,JCB,Master,UC,AMEX,Million,Dainers,NICOS

```

Figure 10: Dialogue example (hotel retrieval system).

```

===== Speech Input =====
Input :What is there in Kawaguchi Lake?
                                     <=== input utterance-1
===== System Output =====
29 facilities were found.
The reference conditions which can be used by addition are shown below.
action : reading(9) lodging(7) appreciation(2) resting(2) camping(2)
kind   : hotel(4) museum(3) concert hall(2) pension(2) campsite(2)
===== Speech Input =====
Input :Campsite.
                                     <=== input utterance-2
===== System Output =====
(Facility-kind campsite)
                                     <=== retrieval condition
2 facilities were found.

===== Retrieval Result =====
Kitagishi no Myoukosan(campsite), Kawaguchi Lake, 0yen
Tozawa center(campsite), Kawaguchi Lake, 4000yen

===== Speech Input =====
The retrieval result is the above.

```

Figure 11: Dialogue example (Mt. Fuji sightseeing guidance system).



```

===== System Output =====
This is a document retrieval system. Please input retrieval conditions.
===== Speech Input =====
input: Is there a paper on the multi modal?    <=== input utterance
        Yet uh uh.. is there a paper on the multi modal such?
                                                <=== recognized sentence

===== System Output =====
23 papers were found.
Please input additional retrieval conditions.
===== Speech Input =====
input: This is related to Internet.            <=== input utterance
        This is related to Internet.          <=== recognized sentence
===== System Output =====
3 paper were found.
===== Retrieval Result =====
No.1 A. Nakashima, et al.:"Intelligent network for personal move
communication",Institute of Electronics, Information and
Communication Engineers Journal of Japan, 1995)
No.2 K. Ono, et al.:"Development of new generation communication
network",Institute of Electronics, Information and Communication
Engineers Journal of Japan, 1995)
No.3 H. Aiso, et al.:"Future prospects of information highway",
Institute of Electronics, Information and Communication Engineers
Journal of Japan, 1995)
===== System Output =====
The retrieval result is the above.

```

Figure 12: Dialogue example (literature retrieval system).

system. An example of using the system is shown in Figure 11.

The dialogue manager uses the dialogue script in order to decide a dialogue strategy. This scripts have the functions that if retrieval results are too numerous, the system does not display all retrieval results but inquires the user for additional retrieval conditions. Of course, application developers can easily change this dialogue strategy with the GUI tools.

For example, since `input utterance-2` in Figure 11 is not a sentence, the interpreter may fail at the step of the semantic analysis. The interpreter adapts **Improved Keyword Retrieval** described in Section 3. The concept classification of *campsite* is "G-KIND", so the interpreter directly changes this word (see `retrieval condition`) to "G-KIND."

## 6.2 Application to Literature Retrieval System

We also applied the system to a literature retrieval system as well as the hotel retrieval system.

Figure 12 shows an example of using the system. In this example the `recognized sentence` has misrecognition and interjections. So the CFG grammar cannot accept this sentence. Therefore, **Removing Recognition Error by Lodging Error** in Section 3 is used for this sentence. So *yet*,

*uh, uh and such* are omitted in the `recognized utterance`.

If there are some related papers catalogues as retrieved results and the user inputs an utterance "Please display detailed information of the second paper.", the system displays detailed information like the abstract of the second paper in the paper catalogue.

## 6.3 Evaluation of Portability

We evaluated the portability of our dialogue system and robustness of the interpreter through the Mt.Fuji sightseeing system and literature retrieval system, and we confirmed that the developing period was shortened to the time of the hotel's one, which means a reduction to 10 hours from 15 hours in the previous system (Kogure and Nakagawa, 2000).

## 7 Summary

We improved the portable semantic interpreter for spoken dialogue systems. The highly portable semantic interpreter was constructed using the EDR electronic dictionary. By the example of the hotel retrieval system, we explained the structure of a high portable system.

We also constructed the Mt.Fuji sightseeing system and literature retrieval system, and we con-

firmed that the developing effort/period was reduced to the same as the hotel's one, which means a reduction to 10 hours from 15 hours in the previous system.

In the near future, we will construct a system that can change a task during a dialogue.

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