A multimodal restaurant finder for semantic web

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A Multimodal Restaurant Finder for Semantic Web

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***Abstract*— Multimodal dialogue systems provide multiple modalities in the form of speech, mouse clicking, drawing or touch that can enhance human-computer interaction. However, one of the drawbacks of the existing multimodal systems is that they are highly domain-specific and they do not allow information to be shared across different providers. In this paper, we propose a semantic multimodal system, called Semantic Restaurant Finder, for the Semantic Web in which the restaurant information in different city/country/language are constructed as ontologies to allow the information to be sharable. From the Semantic Restaurant Finder, users can make use of the semantic restaurant knowledge distributed from different locations on the Internet to find the desired restaurants.**

***Index Terms*— Multimodal dialogue systems, Semantic Web, Ontology**

I. Introduction

Conversation or dialogue is the most natural way for people to exchange ideas, convey information, and express feelings, etc. Therefore, speech interfaces offer great potential for enhancing human-computer interaction (HCI). In recent years, lots of research work have been done to enhance the speech communication by using complimentary information from gestures. The first known multimodal interface was built in 1980 by Bolt [1] in which shapes could be created, moved, copied, removed, and named using the combination of speech and pointing to resolve deictic references such as *that* and *there*. Cheyer [2] describes a multimodal map-based application for a travel planning domain by combining handwriting, gesture and speech. More recently, Johnston *et al.* [3]–[5] developed a multimodal system called MATCH (Multimodal Access to City Help) which provides a mobile multimodal speech-pen interface to restaurant and subway information for New York City. Pelé *et al.* [6] developed a virtual human called Nesto which is an interactive 3D embodied conversational agent.

One of the drawbacks of the existing multimodal systems is that they are highly domain-specific and they do not allow information to be shared across different providers. In this paper, we propose a semantic multimodal dialogue system, called Semantic Restaurant Finder (SRF), using Semantic Web services in which the restaurant information in different city/country/language are constructed as ontologies to allow the information to be sharable.

The rest of the paper is organized as follows. Section II describes the current development of Semantic Web and Semantic Web services. Section III discusses the system support for the multimodal Semantic Restaurant Finder. Section IV gives the Semantic Web architecture for SRF. The approach for automatic generation of restaurant ontology is then discussed in section V followed by the performance analysis presented in section VI. Finally, section VII concludes the paper.

II. Semantic Web and Services

Vast information are available on the Web. The Semantic Web extends the ability of the World Wide Web by developing standards and tools that allow meaning to be added to the content of web pages.Ontology is a formal, explicit specification of a shared conceptualization. It is the key enabling technology for the Semantic Web which provides a framework for the sharing and reuse of data on the Web.

Web Services [7] have recently become an important feature in the Web community since they provide a new level of interoperability between applications. Web Services are based on agent technology [8]. A Web Service is identified by a URI (Universal Resource Identifier) [9], whose public interfaces and bindings are defined and described using XML-based service description languages. Typical Web Service techniques such as Web Services Description Services (WSDS) [10] or Universal Description, Discovery and Integration (UDDI) [11] provide technical information on service accessibility (including the service address and the service port), but it lacks the description on service capability. In addition, functions offered by typical Web Services are accessible, but not fully understandable by other programs.

This problem can be tackled by the Semantic Web. The Semantic Web uses ontology as a standard for knowledge presentation. Therefore, knowledge can be shared, reused and exchanged on the Semantic Web. Based on OWL (Web Ontology Language) [12], an ontology language description language, OWL-S (former DAML-S) [13] was introduced to describe Web Services in a semantic manner.

III. Multimodal Dialogue Support

Figure 1 depicts the multimodal dialogue support for Semantic Restaurant Finder. Users can interact with the SFR system in natural ways such as speech, typing, or mouse clicking and drawing to enquire restaurant information. For example, users can request a list of restaurants by saying "show me seafood or general restaurants near Orchard Road". An example of restaurant finding result is displayed in Figure 2.

The multimodal Semantic Restaurant Finding system consists of eight main components. The Open Agent Architecture (OAA2) [14], [15] is used to facilitate multiple asynchronous communications among various components. The components are briefly discussed as follows.

- *Speech Recognizer*. Implemented using the ATK toolkit [16], which is the real-time API for HTK [17].
- *Speech Semantic Parser*. Implemented using the Hidden Vector State (HVS) model [18], [19]. This is illustrated in Figure 3 which shows the sequence of HVS stack states corresponding to the given parse tree. The details of how this is done are given in [19].
- *Gesture Recognizer*. The gesture recognizer used is a sample C++ Win32 application called *GestureApp* [20].
- *Gesture Semantic Parser*. The gesture semantic parser can be rather treated as an interpreter to map the recognized raw gesture or symbol into a semantic partial frame.
- *Multimodal Input Fuser*. Multimodal input fusing is done by using the time correlates between speech events (words) and the pointing, drawing or mouse clicking events.
- *Dialogue Manager*. The dialogue manager controls the interaction with the user.
- *Response Generator*. The response generator produces an appropriate response according the the instructions given by the dialogue manager.
- *Speech Synthesizer*. The Festival 2.0 speech synthesizer [21] is used to transform text into speech.

IV. Semantic Web Architecture for Semantic Restaurant Finder

Figure 4 shows the system architecture of SRF using Semantic Web services. There might be several restaurant ontologies available on the Semantic Web. We will discuss the ontology generation process in section V. The Semantic Web architecture consists of three major components: *Web Service Provider*, *Matchmaking Agent* and *Web Service Requester*.

There might be many *Web Service Providers* on the Web. Each *Web Service Provider* accesses the restaurant ontology to retrieve restaurant-related information for a given user request. These *Web Service Providers* must register its services with the *Matchmaking Agent* which serves as a registry and look-up service repository by

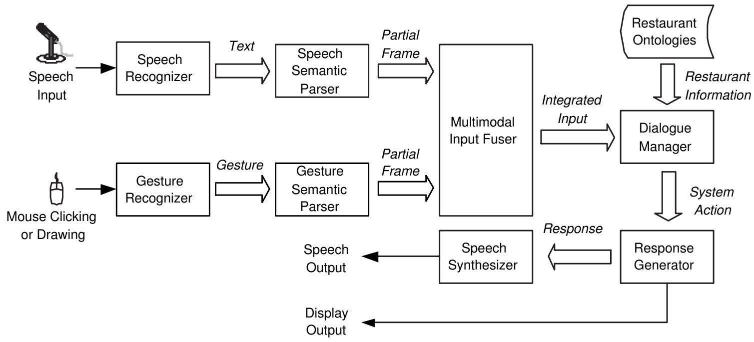
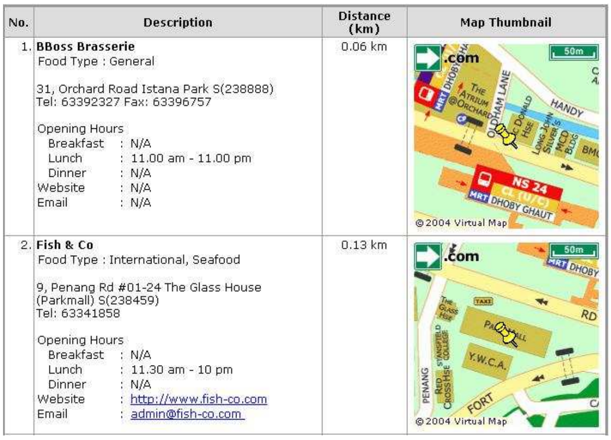


Fig. 1. Multimodal dialogue support for SRF.



No.	Description	Distance (km)	Map Thumbnail
1.	**BBoss Brasserie** Food Type : General 31, Orchard Road Istana Park S(238888) Tel: 63392327 Fax: 63396757 Opening Hours Breakfast : N/A Lunch : 11.00 am - 11.00 pm Dinner : N/A Website : N/A Email : N/A	0.06 km	© 2004 Virtual Map
2.	**Fish & Co** Food Type : International, Seafood 9, Penang Rd #01-24 The Glass House (Parkmall) S(238459) Tel: 63341858 Opening Hours Breakfast : N/A Lunch : 11.30 am - 10 pm Dinner : N/A Website : http://www.fish-co.com Email : admin@fish-co.com	0.13 km	© 2004 Virtual Map

Fig. 2. An example of restaurant finding result.

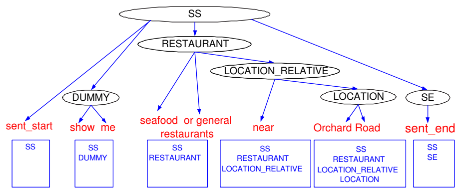


Fig. 3. Example of a parse tree and its vector state equivalent.

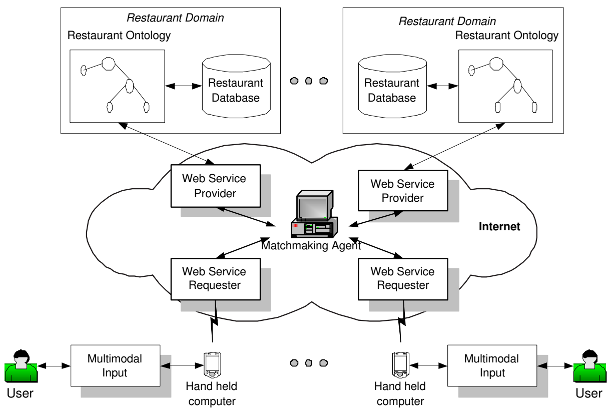


Fig. 4. Semantic Web architecture for Semantic Restaurant Finder.

sending a profile file. The information in the profile is described using the ontology-based service description language OWL-S. The *Web Service Requester* connects the client Web Browser of the Semantic Restaurant Finder system with the restaurant ontology. It creates a profile upon receipt of the user's request. Such a profile is then sent as a request to the *Matchmaking Agent* to locate the appropriate *Web Service Provider* to answer the request.

V. Restaurant Ontology Generation

Restaurant information can be extracted from the Web and stored in a database, known as the Restaurant Database. Then, the information on the Restaurant Database will be converted into ontology formalism. This is shown in Figure 5.

A. Knowledge Discovery

The Knowledge Discovery process discovers hidden knowledge from the Restaurant Database using a clustering technique. In this research, we have applied one of the most effective clustering techniques known as Kohonen Self-Organizing Map (KSOM) Neural Network [22] for knowledge discovery. Figure 6 shows the Knowledge Discovery process.

- *Feature Selection* - Information on restaurants' street addresses, regional locations and cuisine types are extracted as feature factors.
- *Preprocessing* - Information on the extracted features (i.e. the restaurant addresses, locations and cuisine types) is converted into *representative binary strings*.
- *Transformation* - The restaurant records are converted into *restaurant vectors*.
- *KSOM Clustering* - This step clusters the restaurant vectors using the KSOM neural network. The training algorithm for the KSOM network is given in [22]. After training, a set of clusters for restaurants (or restaurant vectors) are generated, and they are referred to as *restaurant clusters*. Information on restaurant clusters is then stored in the Restaurant Cluster Database.

B. Ontology Generation

The Ontology Generation process creates the Restaurant Ontology to represent the knowledge on restaurants, which can be obtained from the Restaurant Database and Restaurant Cluster Database. The Ontology Generation process is shown in Figure 7. Figure 8 shows the generated Restaurant Ontology.

Class Mapping maps the schematic and discovered knowledge into ontology's schematic and discovered classes.

Schematic Relation Generation generates relations between schematic classes.

Composed Relation Generation generates the relations between the schematic classes and discovered classes.

Instances Generation generates instances for the schematic and discovered classes based on the data available on the Restaurant Cluster Database and Restaurant Database.

VI. Performance Analysis

To evaluate the performance of the proposed approach, an experiment has been conducted. In the experiment, a Restaurant Database is constructed. The database contains 2100 restaurants in Singapore, which are located over 66 locations based on MRT (Mass Transit Railway) stations and provides a variety of 76 cuisine types.

As discussed earlier, KSOM neural network is adopted for the proposed system.For comparison purpose, a supervised neural network, Learning Vector Quantization Version 3 (or LVQ3) and the k-nearest neighbor (kNN) technique, are also used in the experiment for evaluation. There are two popular variations of the kNN technique. The first variation, denoted as kNN1, is based on vector's normalized Euclidean distance to find the matches closest to the input string, while the second variation, denoted as kNN2, uses the fuzzy-trigram technique.

Table I gives the retrieval accuracy of different techniques. The accuracy of the two neural networks KSOM and LVQ3 are better than those of the kNN techniques. And LVQ3 has achieved better performance than KSOM. This is expected as supervised learning techniques often perform better than an equivalent unsupervised

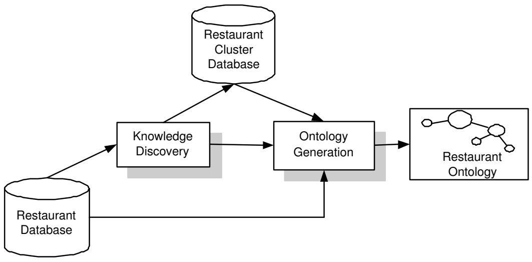


Fig. 5. Restaurant ontology generation.

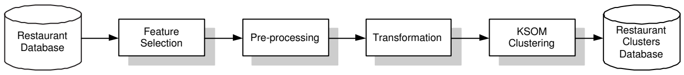


Fig. 6. Knowledge Discovery process.

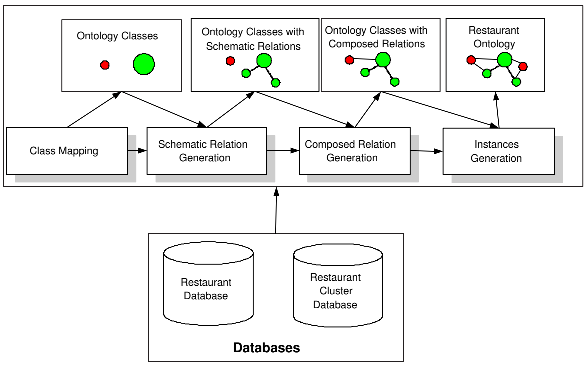


Fig. 7. Ontology Generation process.

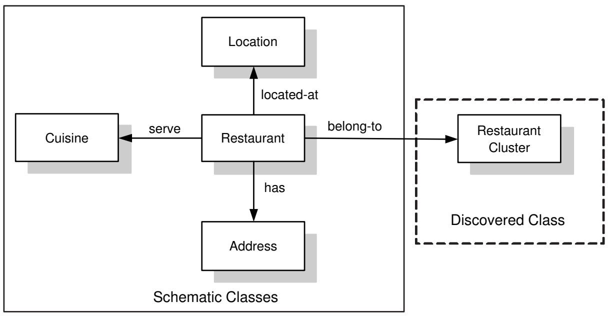


Fig. 8. Restaurant Ontology.

one when applied to the same domain. However, as LVQ3 always require human interpretation in training, it will encounter difficulties when training a large dataset.

Based on the clustering results from KSOM, the Restaurant Ontology is then generated. The generated ontology can be represented using an ontology description language that enables it to be sharable over the Semantic Web by Web-based applications.

VII. Conclusion

In this paper, we have proposed the Semantic Restaurant Finder system, in which restaurant information in different city/country/language are constructed as ontologies for knowledge sharing. As such, users can make use of the semantic restaurant knowledge distributed from differ-

TABLE I
PERFORMANCE ON RETRIEVAL ACCURACY.

Retrieval Technique	Retrieval Accuracy
kNN1	81.4%
kNN1	77.6%
LVQ3	93.2%
KSOM	90.3%

ent locations on the Internet to find the desired restaurants. To achieve this, this paper has presented the multimodal dialogue support and the semantic web architecture for Semantic Restaurant Finder. In the proposed architecture, Web Service Requester, Matchmaking Agent and Web Service Provider are constructed to allow users to access the multiple Restaurant Ontologies available on the Semantic Web environment. A framework for ontology generation using the KSOM neural network has also been discussed. Finally, an experiment has been conducted to evaluate the performance of the proposed system.

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