Mediation in the Knowledgeable Community

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Abstract

The Knowledgeable Community is a framework of knowledge sharing and reuse based on a multi-agent architecture. In this paper, we describe the scope and goal of the Knowledgeable Community project, present the organizational structure that facilitates mediation between those agents requesting for a service and those providing the service, and illustrate a technique of ontology-based mediation by example.

1 Introduction

Large scale knowledge base is indispensable to put AI theories to work in the real world. Previously, two rather separate approaches have been taken to this end. One is to take a rather straightforward approach to building a large scale knowledge base system, such as Cyc [6, 4]. The other end is to develop a framework of knowledge sharing and reuse by developing common languages and ontologies among interacting [8, 11]. Obviously, these two approaches are complementary to each other. It is beneficial to integrate the two and take a step toward large scale knowledge sharing.

The purpose of the Knowledgeable Community project [9, 10] is to develop an artificial community of cooperating agents for large scale knowledge sharing. Currently, we are focusing on (a) development of an organizational structure that helps agents to interact easily, (b) design of knowledge media which is meaningful both to humans and computer softwares.

In what follows, we will give an overview of the Knowledgeable Community project, describe the organizational structure of agents, and present a mechanism for mediating agents based on the ontological structure embedded in the community of agents. We will illustrate how the mechanism for ontology works using an example.

2 The Framework of the Knowledgeable Community

The Knowledgeable Community is an artificial community of cooperating agents (Figure 1). Each agent consists of a communication software and an interface with natural or/and artificial problem solver. Agents communicate with each other using common protocol, language, ontology, and social convention. Social amenities of various kinds help agents to cooperate and maintain coherence of the agent community.

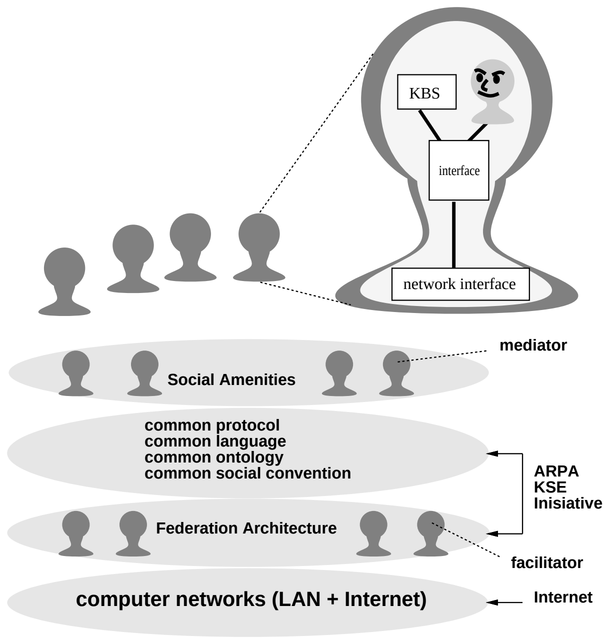

Figure 1: The framework of the Knowledgeable Community

Roughly, agents can be classified into three categories. The first category involves those that provide domain, problem solving, and task knowledge. The second consists of facilities that play functions similar to operating systems. The rest consists of mediators that help agents to find proper information servers.

We are building the Knowledgeable Community on top of the federation architecture proposed by the ARPA knowledge sharing effort. We choose a distributed information system as a testbed. The system, called KC-Kansai, is designed to provide various information about the Kansai area[1] in Japan. Each agent provides information about institutions, transportations, accommodations, shops, restau-

[1] Roughly, it consists of Kyoto, Nara, Osaka, and Kobe.

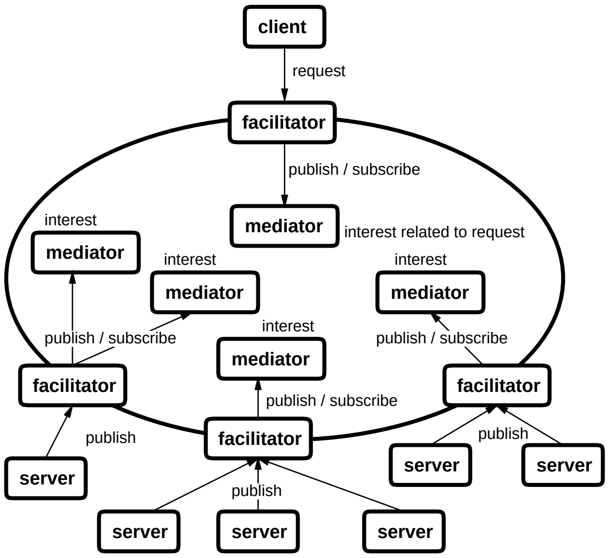

Figure 2: Organization of agents in the Knowledgeable Community

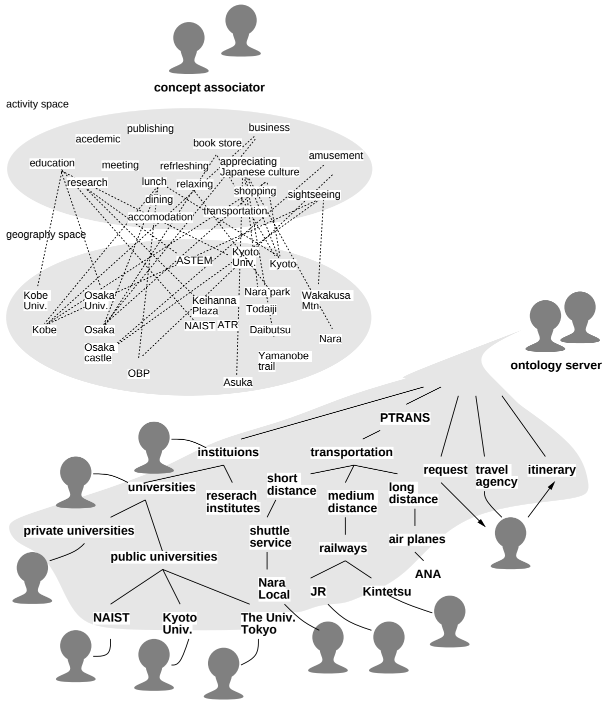

Figure 3: Ontology servers and concept associators for mediation

rants, points of interest, and so on. One of the most typical tasks of KC-Kansai is travel assistance in which agents cooperatively help travellers figure out itinerary or execute the plan.

3 Mediation in the Knowledgeable Community

We would like to incorporate into the Knowledgeable Community as much social amenities as possible, to decrease the overhead imposed at the development and maintenance stages. Suppose one is to write an agent for travel arrangement. Probably, s/he may first try to figure out what information is needed to accomplish the task and what kind of assistance other agents can provide. Once one has found a set of servers, one may try to understand the specification of each server to incorporate offered services. We would like to organize agents in the Knowledgeable Community so that one need not know which agent provides what information service in what form.

Two kinds of agents are introduced for these purposes. Facilitators take care of low level communication issues (Figure 2). For instance, they monitor execution of information servicing agents and solve low-level timing problems. If a message from a client does not specify the recipient, a facilitator will forward it to mediators, which will suggest a set of possible recipients based on its knowledge about agents. Although facilitators are public and do not use heuristics to find a potential recipients, mediators are private in the sense that they are based on rather subjective heuristics. Mediators are like ordinary agents except the difference in the type of information they provide.

Major source of knowledge for mediation is ontology. Ontological information is provided by two kinds of agents (Figure 3). *Ontology servers* provide logical information about concepts based on definitions and mutual relations of concepts represented in description logic. In particular, as agents are associated with conceptual structures kept by ontology servers, it is possible to access agents by following conceptual relations. The other kind of agents are called *concept associators*, which correlate concepts in terms of conceptual distance.[2]

In the rest of this section, we will illustrate how an ontology server works. Suppose an agent sends out an message asking for agents that provide information about going from Tokyo to NAIST. The message will be sent to the physical-transfer agent which in turn will call for an ontology server to figure out what Tokyo means and NAIST means. It will also ask for mediators to propose a means of physical-transfer. The mediator will make use of ontology server to determine the type of physical-transfer and return the names of agents that provide information about primary means of transportation.

Now, let us illustrate a more sophisticated example. Consider Figure 4 which shows a part of the ontology for KC-Kansai. Each box in solid line denotes a class concept and one in a grey line an agent associated with a concept. Suppose the following request is given:

[2] As for more detailed description of concept associators, the reader is referred to [10].

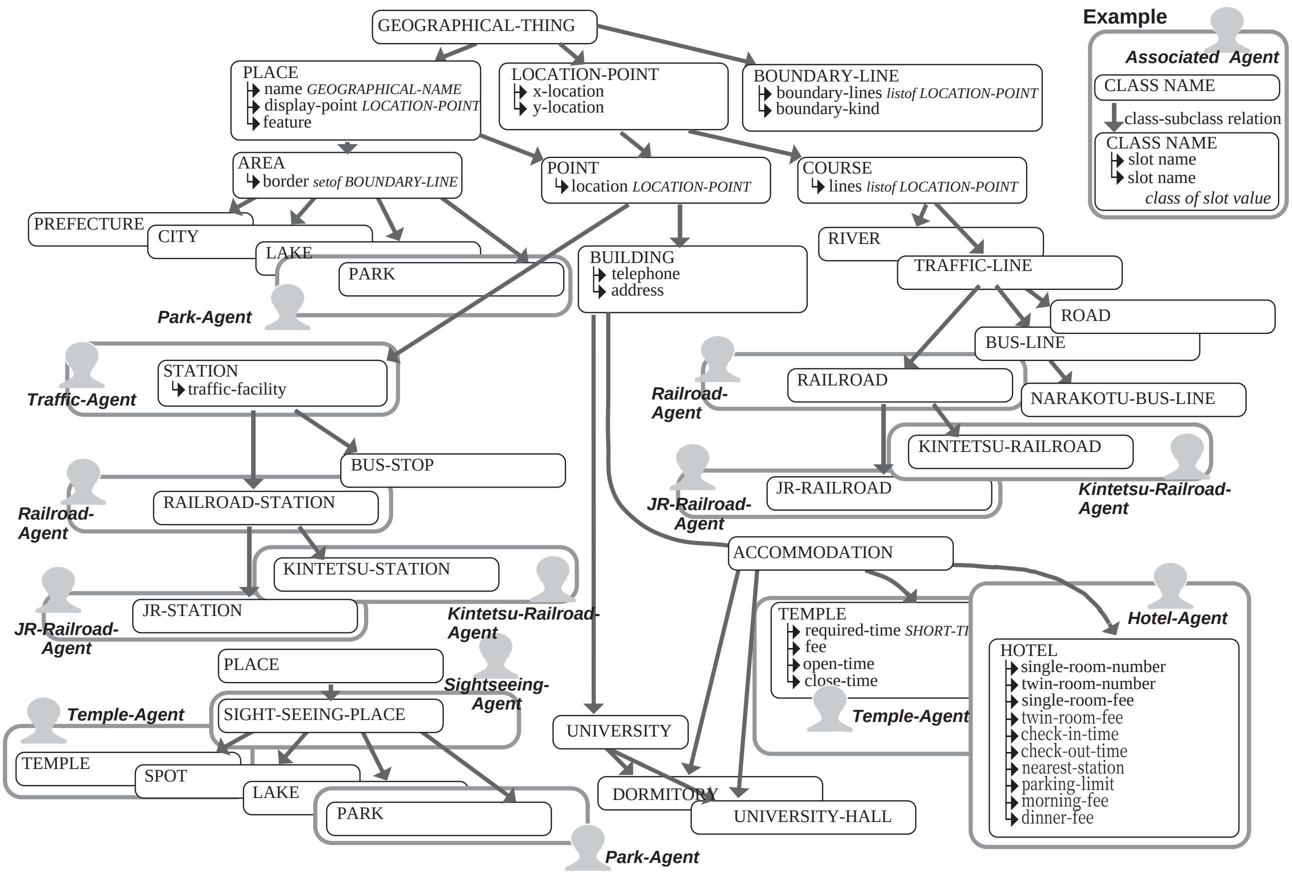

Figure 4: Part of ontology for travel plan

Give me the phone numbers for accommodation near Nara.

The request is represented in KQML and KIF, as shown in Figure 5a. Given the message from a client, a facilitator will forward it to a mediator, which in turn will send a message to an ontology server, as shown in Figure 5b, asking for a list of agents which can answer the specified inquiry. The ontology server analyzes the message it received. It first looks at the concept definition of accommodation and its super- and sub- classes, ending up with a message as shown in Figure 5c.

4 Related Work

The Knowledgeable Community is being built on top of several technologies. Compared with network information resource utilization technology, such as information lens [7] and information resource finding [2, 1], the Knowledgeable Community is distinguished from existing technologies by the degree information and knowledge sources are structured and organized. The current technology for network information resource management and utilization assumes that humans play an essential role in interpreting and manipulating information. Although this approach

(a) Problem representation in KQML and KIF

```
(broker-all :content
  (ask-one :content (and (accommodation ?x)
                         (near ?x nara)
                         (telephone ?x ?tel))
           :aspect ?tel :language KIF)
  :reply-with q1)
```

(b) Message from mediator to an ontology server

```
(recommend-all :content
  (ask-one :content (and (accommodation ?x)
                         (near ?x nara)
                         (telephone ?x ?tel))
           :aspect ?tel :language KIF)
  :reply-with m1)
```

(c) response from the ontology server

```
(reply :content ("temple" "hotel")
       :in-reply-to m1)
```

Figure 5: Messages used for mediation

brings about direct implications to the end users, it does not decrease intellectual information processing loads. In contrast, the Knowledgeable Community aims at knowledge media that are understandable and manipulatable both by humans and computers. AI techniques will be used to structuring and organizing information so that computer software may handle it, decreasing the various load required to make use of potential information. The approach in this direction involves concepts such as softbots [3] and knowbots [5].

The agent-oriented technology is similar to the object-oriented technology. However, there are two differences. First, agents are active in the sense that they understand and react the environments autonomously, while objects are passive entities that only respond incoming messages. Second, instance objects are almost empty in the object-oriented technology; they are just a set of individual values in object-oriented systems, while instance agents are crucial in the agent-oriented technology. In the agent-oriented technology, instance agents are not simply a set of individual values but also individual entities that may persist and evolve over time.

We have chosen the platforms developed by the ARPA knowledge sharing and reuse initiative [8, 11] as a base. The net progress in the Knowledgeable Community is the the use of knowledge media and powerful mediation mechanism.

Problems related to mediating information producers and consumers are surveyed and discussed in detail in [12]. The method presented in this paper is concerned with more conceptual issues and is intended to be a proposal from the AI side.

5 Conclusion

In this paper, we have presented a framework of the Knowledgeable Community. In particular, we have focused on ontology-oriented agents organization and illustrated how it helps mediation.

There are lots of interesting research issues left for further work. A most promising direction may be to incorporate ecological and biological mechanisms to allow Knowledgeable Community to evolve autonomously.

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