Bridging Humans via Agent Networks

Toru Ishida
Department of Information Science, Kyoto University
ishida@kuis.kyoto-u.ac.jp

Abstract

We propose an architecture of agent networks, where each agent learns the preferences (or the utility function) of the owner and acts on behalf of the owner in maintaining his/her organizations. Let us consider the situation in which an agent network is supporting a human organization. The conventional *human interface* is now divided into two parts, *personal* and *social interfaces*. For the personal interface, several research results have been published along this direction. On the other hand, however, the social interface has not been discussed before. This interface should provide protocols for bridging humans.

This talk investigates the functionalities of the social interface in two cases: one is *teleconferencing* and the other is *tele-education*. Both cases assume the existence of B-ISDN, and will be soon extended to a more dynamic domain, such as business meeting scheduling using PHS (Personal Handy System) networks with PDA (Personal Digital Assistant) terminals. The mechanism of *mutual selection protocols (MSPs)* for organizing humans will be discussed based on an analysis of their dynamic properties.

1 Introduction

Recent drastic advances in telecommunication networks have enabled a new class of human organization, the *teleorganization*, which differs from any existing organization in the following points.

- The organization is virtual and remote in the sense that people do not actually shake hands.[1] The organization is easy to create using telecommunication networks.
- People can join multiple organizations at the same time in a time-sliced fashion. Mouse clicking allows people to navigate from one organization to another. As a result, multiple organizations are threaded and proceed simultaneously for each person.
- The organization can involve people who may not know each other. Since no supervisor exists, organizational protocols based on *mutual selection mechanisms* have to be provided for creating and maintaining a satisfying organization.

Suppose humans are required to organize/reorganize the groups by themselves. Since teleorganizations will appear and disappear more dynamically than conventional organizations, the overhead incurred to establish and maintain the organizations is excessive. To enjoy the recent advances in telecommunications, we need an *agent network* to help people organize themselves at runtime.

[1]Teleorganization includes the organization that is composed of the employees who do not necessarily work at the same building, but instead use modems or some other form of communication device to work remotely. This example was suggested by Douglas C. Schmidt. In this paper, however, we will focus on more dynamic teleorganizations.

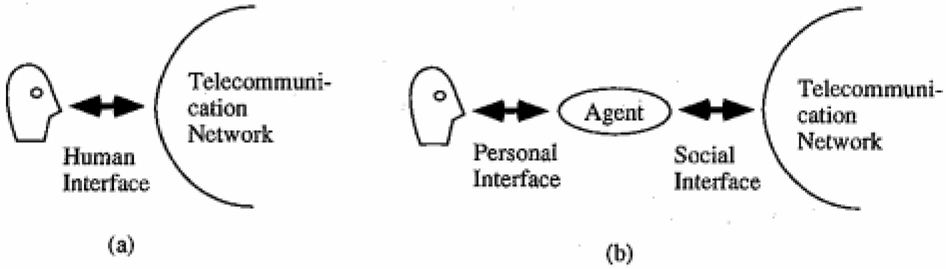

Figure 1: Personal and Social Interfaces in Agent Networks

This paper proposes an architecture of agent networks, where each agent learns the preferences (or the utility function) of the owner and acts on behalf of the owner in maintaining his/her organizations. This architecture is especially useful when the organizing/reorganizing decisions are not critical (suboptimal decisions permitted), but manually laborious.

Let us consider the situation in which an agent network is supporting a human organization. The conventional *human interface*, represented in Figure 1(a), is now divided into two parts, *personal* and *social interfaces* as described in Figure 1(b). For the personal interface, each agent adapts to each person, learns his/her preferences, and behaves as a personal assistant. Several research results have been published along this direction [Maes *et al.*, 1993]. On the other hand, however, the social interface has not been discussed before. This interface should provide protocols for bridging humans.

The rest of the paper investigates the functionalities of the social interface in two cases: one is *teleconferencing* and the other is *tele-education*. Both cases assume the existence of B-ISDN, and will be soon extended to a more dynamic domain, such as business meeting scheduling using PHS (Personal Handy System) networks with PDA (Personal Digital Assistant) terminals.

2 Teleorganization

Teleorganizations can be simulated on workstations connected by local area networks, such as Ethernet or FDDI. When using wide area networks, however, we think that the openness of the networks will force us to face new organizational issues. The following two scenarios describe such situations.

CASE1: Teleconferencing

Two different types of teleconferences are currently available as follows.

- One extreme is the *E-mail conference*, wherein people sit down in front of their own workstations and discuss the same topic by sending/receiving a series of E-mail messages. The participants of the conference are never synchronized: no schedule is required to connect the humans. Usually, for each person, multiple conferences (20 to 30 for busy people) proceed simultaneously. The conferences are slashed into units of 5 or 10 minutes, and accessed in a time-sliced fashion.

  Thus, E-mail conferences have *multiple threads*, and are *asynchronously* operated with *no scheduling*.

Conference Type	E-mail Conference	Workstation Video Conference	Video Room Conference
Environment	Workstation	Workstation	Conference Room
Parallelism	Multiple Threads (Parallel)	Multiple Threads (Parallel)	Single Thread (Sequential)
Synchronization	Asynchronous	Partially Synchronous	Totally Synchronous
Scheduling	No Scheduling	Realtime Scheduling	Offline Scheduling

Figure 2: Three Organizations in Teleconferencing

- The other extreme is the *video room conference*, where people must travel a local site that contains the required video equipment. For a typical example, people in Tokyo use a conference room located in the Tokyo area, and people in Kyoto use a room in Kyoto. The video room conference saves people from moving between Tokyo and Kyoto, but still requires them to gather at particular places. Since the conference room is distributed among different locations, the video room conference requires more careful scheduling than conventional conferences. The conference is usually completed in several hours to at most several days. Since all participants share the same time, the conference occupies their time completely from the beginning to the end.

  Thus, video room conferences have a *single thread*, and the participants are *totally synchronized*. *Offline scheduling* is usually performed, in advance.

Suppose the situation allow people to communicate with sitting at their workstations. Since B-ISDN is available, people can send voice and video. If their schedules match, more than two people can have a conference by interacting between their displays. We call this the *workstation video conference*.

- The workstation video conference lies somewhere between the E-mail and the video room conferences. The participants may not be fully synchronized because not all of them have to meet at once. Obviously, however, at least two participants have to be synchronized. Therefore, the workstation video conference can have *multiple threads* as in the E-mail conference, and participants are *partially synchronized*.

  Unlike the video room conference, because of the dynamic property of the workstation conference, *online scheduling* is appropriate. A *mutual selection mechanism* is thus required to reflect humans' preferences, which dynamically change with the progress of the conference.

Figure 2 summarizes the above scenario. The E-mail conference can easily be combined with the workstation video conference, because both can be realized in the same workstation environment.

CASE2: Tele-Education

B-ISDN will enable people to learn various topics in collaboration with other people. We call the learning process in telecommunication networks *tele-education*. A typical example is learning a foreign language

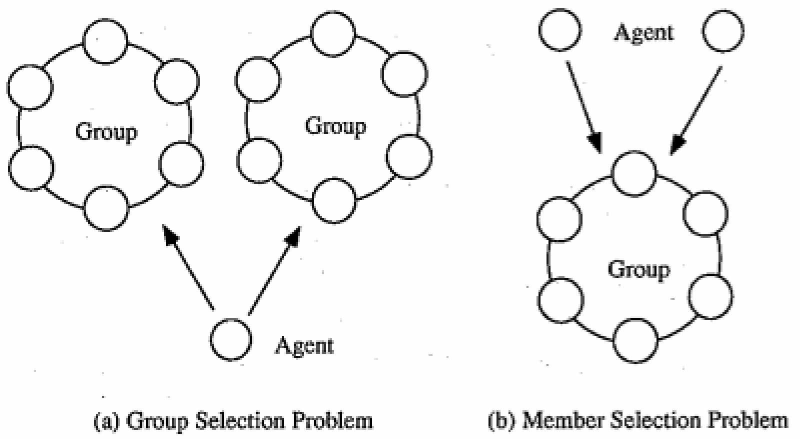

Figure 3: Organizational Problems in Tele-Education

through conversation. Instructors and students hold classes on their workstation displays, enjoying free conversation anytime their schedules match. We think that forming groups in tele-education involves the following new organizational issues.

1. *Group selection problem:*

   The first problem is how to select a particular group to join. Suppose various class groups have already been established. Since the groups are formed dynamically, it is not obvious which group is appropriate for the new comer. Figure 3(a) represents this problem.

2. *Member selection problem:*

   The second problem is how to select a student who tries to join a group. Suppose several people have already organized a group and started a class. The signal tells them that someone wants to join their group. Should the people accept this request? Moreover, should they stop the class and start assessing the new comer? Figure 3(b) illustrates this problem.

We can imagine that the people do not wants to spend too much time an organizational matters. Their purpose is leaning, not organizing a learning group. Furthermore, since teleorganizations are dynamic, reorganization requests will arrive continuously. Again, a mutual selection mechanism is required to automatically select appropriate members. While permitting dynamic reorganization, the mechanism is also expected to maintain the quality of the organization.

If people could establish agents that represented their preferences, the agents could negotiate amongst themselves to resolve the member/group selection problems: the learning group is automatically maintained, while the members of the group can change dynamically.

3 Mutual Selection Protocols (MSPs)

Let us first investigate the applicability of human and computer communication protocols to the social interface protocols.

- *Human protocols* have been analyzed and modeled by using finite state automata. However, it appears that human protocols are too *informal* and unsuited for accepting computational support. Various attempts have been made, but most fail, because the real protocol is far more flexible than that represented by finite state automata.

- *Computer protocols*, on the other hand, are too *formal*, and are not well accepted by humans. Assume that we try to apply the *two phase locking (2PL) protocol* to organize humans. The 2PL protocol employs the two-phase rule, *a transaction locks all accessing data items before unlocking any one of them*, to guarantee the serializability of transactions. Though the application of the 2PL to conference scheduling can guarantee the serializability of threaded conferences, humans cannot accept being locked by other people.

Both formal and informal protocols are not appropriate to agent networks. Therefore, we need *semi-formal* protocols, called *mutual selection protocols (MSPs)*, which are characterized as follows.

- Each agent makes decisions based on the owner's preferences.

- Organizational decisions are made through the mutual selection mechanism of agent networks.

Organizations have been an important research issue in the area of distributed artificial intelligence [Fox, 1981; Gasser *et al.*, 1988; Ishida *et al.*, 1992; Klein, 1991]. Mutual selection protocols have been studied, including the *Contract Net Protocol* [Smith, 1980; Davis *et al.*, 1983], *Multi-Stage Negotiation Protocol* [Conry *et al.*, 1991] and *Unified Negotiation Protocol* [Zlotkin *et al.*, 1991]. These protocols have been evaluated statically [Zlotkin *et al.*, 1991] or for specific domains [Malone *et al.*, 1988; Sandholm, 1993]. The dynamic properties of MSPs have not been studied in detail. However, their dynamic properties should be clearly explained, so that humans can confidently leave organizational tasks to the agent networks.

Let us take the Contract Net Protocol as an example. This protocol has been applied to the system called Enterprise [Malone *et al.*, 1988], which performs task scheduling in distributed computing environments. TRACONET [Sandholm, 1993] allows different vehicle companies to negotiate to complete their tasks. However, there is not yet enough information as to whether people can accept the Contract Net Protocol in different applications, such as scheduling workstation video conferences.

We have analyzed the Contract Net Protocol by utilizing queuing models. Figure 4 shows a part of the results obtained from our analysis. The x-axis represents the mean arrival time of tasks to the agent network, and the y-axis represents the utility rate of managers and contractors. This figure clearly shows that (1) contractors' utility rate increases with load, and (2) managers' utility rate increases as load decreases. We also observed the following. (For detailed results, see [Gu *et al.*, 1994].)

- As the number of managers and contractors increases, the contractors' average utility rate increases. We call this the *large numbers effect* of the Contract Net Protocol. As the number of managers and contractors increases, however, the managers' average utility rate does not increase, because the average number of bids for each manager does not increase.

- As agents become *homogeneous* (that means all agents share the same preferences), the community becomes unfair and thus the average utility rate decreases while its variance increases. We call this the *homogeneous effect* of the Contract Net Protocol.

The above analysis is informative when applying the Contract Net Protocol to human organization design. The results suggest that if the community is homogeneous, the Contract Net Protocol may not be accepted by the members of the community. As in the above discussion, the dynamic properties of MSPs must be analyzed in detail so that humans can accept/reject the protocols in various domains.

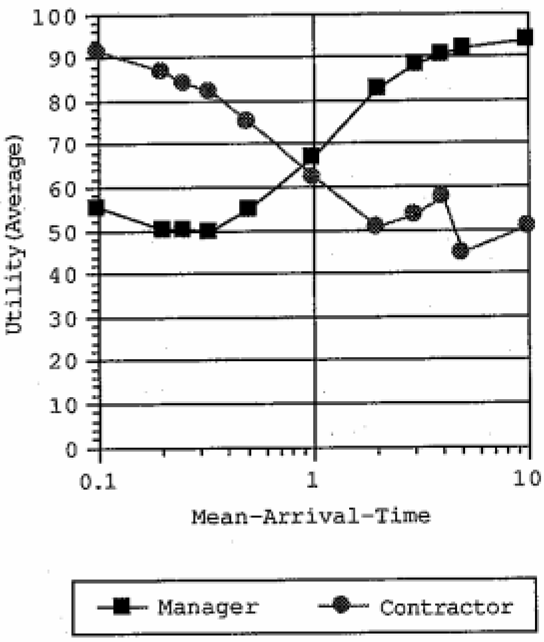

Figure 4: Dynamic Properties of the Contract Net Protocol

4 Conclusion

We addressed the new class of human organizations called the *teleorganization*, which is enabled by recent telecommunication technologies. Two example domains were given and discussed: *teleconferencing* and *tele-education*. Due to the dynamic nature of teleorganizations, *mutual selection protocols (MSPs)* are required to organize/reorganize humans via *agent networks*. MSPs should reflect humans' preferences, and have clear computational dynamics.

Many research issues remain. Some of them are (1) to provide a lineup of MSPs, (2) to analyze the dynamics of these protocols, (3) to implement applications of these protocols using B-ISDN and PHS, and (4) to evaluate the impact of teleorganizations on human societies.

References

[Conry, 1991] S. E. Conry, K. Kuwabara, V. R. Lesser, and R. A. Meyer, "Multistage Negotiation for Distributed Constraint Satisfaction," *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. 21, No. 6, pp. 1462–1477, 1991.

[Davis *et al.*, 1983] R. Davis and R. G. Smith, "Negotiation as a Metaphor for Distributed Problem Solving," *Artificial Intelligence*, Vol. 20, No. 1, pp. 63-109, 1983.

[Fox, 1981] M. S. Fox, "An Organizational View of Distributed Systems," *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. 11, No. 1, pp. 70–80, 1981.

[Gasser *et al.*, 1988] L. Gasser and N. Rouquette, "Representing and Using Organizational Knowledge in Distributed AI Systems," *Distributed Artificial Intelligence Workshop*, 1988.

[Ishida *et al.*, 1992] T. Ishida, L. Gasser and M. Yokoo, "Organization Self-Design of Distributed Production Systems," *IEEE Transactions on Knowledge and Data Engineering*, Vol. 4, No. 2, pp. 123-134, 1992.

[Klein, 1991] M. Klein, "Supporting Conflict Resolution in Cooperative Design Systems," *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. 21, No. 6, pp. 1379–1390, 1991.

[Maes *et al.*, 1993] P. Maes and R. Kozierok, "Learning Interface Agents," *AAAI-93*, 1993.

[Malone *et al.*, 1988] T. W. Malone, R. E. Fikes, K. R. Grant and M. T. Howard, "Enterprise: A Market-like Task Scheduler for Distributed Computing Environments," In B. A. Huberman Editor, *The Ecology of Computation*, North-Holland, pp.177-205, 1988.

[Sandholm, 1993] T. Sandholm, "An Implementation of the Contract Net Protocol Based on Marginal Cost Calculations," *AAAI-93*, pp. 256-262, 1993.

[Smith, 1980] R. G. Smith, "The Contract Net Protocol: High-Level Communication and Control in a Distributed Problem Solver," *IEEE Transactions on Computers*, Vol. 29, No. 12, pp. 1104-1113, 1980.

[Zlotkin *et al.*, 1991] G. Zlotkin and J. S. Rosenschein, "Cooperation and Conflict Resolution via Negotiation Among Autonomous Agents in Noncooperative Domains," *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. 21, No. 6, pp. 1317–1324, 1991.