マルチメディア通信と分散処理 76－19
（1996．5．16）

やわらかいネットワークと人間－エージェント共生空間

菅原研次　木下哲男　白鳥則郎

千葉工業大学 情報工学科
沖電気工業 (株) マルチメディア研究所
東北大学 電気通信研究所

本研究の目的は，固定的かつ画一的な従来の固い情報システムの限界を乗り越え，新鮮で独創的な発想を触発するやわらかい発想支援環境 (サイバースペース) を，ネットワークを基盤とするエージェント指向分散環境上に構築することである．当面の目標としては，分散環境をベースとしたエージェント指向システム構築基盤の開発，それに基づくやわらかいネットワークシステムの開発，及び，前二者をインフラとして実現される発想支援環境基盤の開発を考えている．

Flexible Networks and Human–Agent Symbiotic Space

Kenji Sugawara, Tetsuo Kinoshita, and Norio Shiratori

Dept. of Computer Science, Chiba Institute of Technology
Multimedia Lab., Oki Eloctric Industry Co., Ltd.
Research Institute of Electrical Communication, Tohoku University

The aim of this research is to develop a flexible reasoning support environment (*cyberspace*) that can perceive, reason, and act to achieve multiple goals under dynamic, uncertain, and complex conditions found in information systems. Current information system architectures are too rigid to cope with heterogenity, inaccuracy and inflexibility of the real world requirements. In order to overcome such limitations we propose a distributed multiagent software architecture for flexible intelligent information systems with the following goals: a) Framework for development of agent-oriented systems in distributed environment called ADIPS, as an infrastructure and two classes of systems built on it, b) Flexible networks, and c) Reasoning support environment called *cyber-office*.

1 Introduction

The aim of this research is to develop a flexible reasoning support environment (*cyberspace*) that can perceive, reason, and act to achieve multiple goals under dynamic, uncertain, and complex conditions found in information systems. Current information system architectures are too rigid to cope with heterogenity, inaccuracy and inflexibility of the real world requirements.

In order to overcome such limitations we propose a distributed multiagent software architecture for flexible intelligent information systems with the following goals:

a) Framework for development of agent-oriented systems in distributed environment called ADIPS, as an infrastructure and two classes of systems built on it:

b) Flexible networks, and

c) Reasoning support environment called *cyber-office.*

2 The ADIPS Framework for Agent – oriented System Development

2.1 Overview of the ADIPS Framework

The four important concepts of the ADIPS framework that characterize methodology for developing agent-oriented systems effectively are summarized as follows:

(1) Agentification and cooperative mechanism; ADIPS as a multiagent system is realized by adding a cooperative mechanism to computational processes and subsystems, which comprise Distributed Information Processing System (DIPS). This operation is called *agentification* and an agentified computational process is called a *base process.*

(2) Extended contract-net protocol and organization/reorganization of agents; In the ADIPS, a DIPS is controlled by an organization of ADIPS agents called *Agent-based Management Mechanism (AMM).* Services to the users of the ADIPS are provided by a group of base processes. The AMM is constructed from cooperative behavior of ADIPS agents based on an extended-net protocol. In order to adapt to the changes in the environment AMM is reorganized and the result is fed back to DIPS to initialize appropriate modifications of DIPS functions.

(3) Domain knowledge and design process: Each of ADIPS agents contains agentified base processes and certain domain knowledge on the design specification, operation and maintenance of base subsystems. The agent functions and its performance are determined by the domain knowledge. This knowledge is acquired through designer interaction during DIPS development and operation. Design process of the organization of the ADIPS agents is executed based on the domain knowledge.

(4) Repository and class agents: The ADIPS agents which comprise the AMM of the ADIPS are stored in a shared database as parts of the DIPS. This database is called *repository* and stores prototypes of the ADIPS agents. These prototypes are called *class agents.* If the request for construction of new services or the request for modifications are submitted, ADIPS agents which operate as components of the AMM are implemented from appropriate class agents. These agents are called *instance agents.* The access to class agents and the implementation of instance agents are performed as a cooperation of the ADIPS agents using an extended contract-net protocol.

The ADIPS framework described above is shown in Fig. 1. The ADIPS framework has two subsystems: 1) ADIPS operation environment and 2) ADIPS repository. These subsystems are implemented as a distributed system on networked workstations.

2.2 ADIPS Agents and ADIPS Architecture

The ADIPS consists of*primitive agents* (*pa*) and organizational agents (oa). The architecture of the primitive agent is defined based on the following three components which agentify the base process cp (Fig. 2). That is:

$$pa = \langle CM, TPM, DK, cp \rangle$$

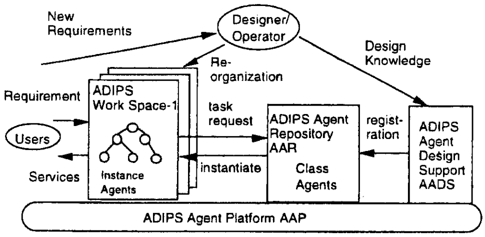

Figure 1: ADIPS framework

where, CM (*cooperation mechanism*),which primitive agents use for organization and reorganization of their associations dynamically. For that purpose CM uses the extended contract-net protocol. TPM (*task processing mechanism*) observes, controls, and executes base processes. DM (*domain knowledge*) is stored in a knowledge base with the management system. It stores and manages particular information on functions and properties of *pa*, e.g. knowledge on design specification of *cp* services provided and the relationship with the other processes, and knowledge on their operation. CM and TPM refer to DK in order to recognize the characteristics of lower subsystems and their role in the organization of agents whenever they organize agents for some task.

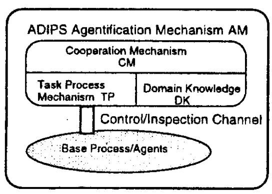

Figure 2: Agent Architecture

The *organizational agent* (*oa*) is defined by:

$$oa = \langle CM, TPM, DK, MA \rangle$$

where CM, TPM, and DK are defined same as in the case of *pa*. MA (*member agents*) is a set of ADIPS agents organized under contract to process a subtask of *oa*. Each of the agents of MA is a primitive agent or an organizational agent. The agents are organized in appropriate layers of subsystems of DIPS. According to the above definitions, *pa* and *oa* have the same components except for *cp* and MA. However, the functions embedded in the TPM of oa are different from the ones embedded in the TPM of *pa*. The TPM of *oa* has the function which observes and controls their member agents. By using this function, *oa* can behave autonomously to various changes in the environment of the ADIPS.

We call the multi-agent system which is constructed from a group of primitive agents *pa* and the organizational agents oa ADIPS. As shown in Fig. 3, the ADIPS has the layered structure of multiagent organization corresponding to the layered structure of subsystems of distributed applications.

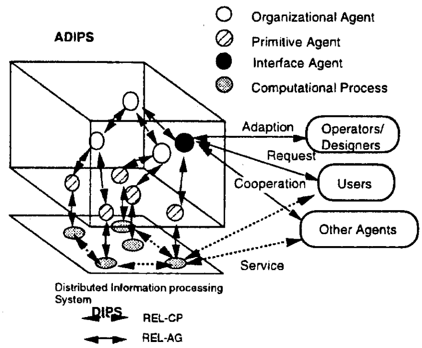

Figure 3: ADIPS architecture

3 Flexible Networks and Agent – oriented Architecture

The present computers and information networks are basically *inflexible systems* such that they cannot work in the presence of the unexpected changes in their environment. Such unexpected events cannot be treated successfully since there are no preprogrammed counter measures. What is the worse these events may trigger inappropriate actions and degrade the performance significantly. We call these networks *inflexible networks.* The inflexible networks cannot meet the needs of users especially when the size of network becomes larger and the user requirements for the quality and performance of network becomes higher. Tackling this matter is the key for the design of the next generation networks.

The *flexible network* has ability to modify its functions/properties corresponding to the changes of their environment flexibly. Here, the changes in their environment mean the changes of the internal state of the network which may happen due to faults and overload, and changes in the network user requirements.

As an approach to implementing the flexible network we proposed an agent-oriented architecture. By using autonomy and cooperation among agents we can realize the network service which recognizes its environment and changes its functions / properties in order to fit to the changes in the environment itself. By using the ADIPS framework described in Section 2, we can realize adaptability of the network service in which the organization of the agents modifies automatically and in accordance to the changes of the CPU load and/or user requirements.

A flexible network system based on the agent-oriented architecture consists of agents which play various roles corresponding to the network services. Conceptual schema of flexible network consists of two layers shown in Fig. 4. The lower layer is the *communication service layer*, which corresponds to the whole four layers under the transport layers of the OSI reference model. The upper layer is the *flexible network service layer*, which has the services of the presentation layer and the session layer of the OSI reference model and the flexible network service for distributed applications based on the cooperation of communication agents.

In the Fig. 5 the multiagent architecture of flexible networks is shown. The components of the upper layer of the flexible network are agentified and the protocol of the lower layer is the TCP/IP. We implemented the ADIPS agent platform, called AAP, on the top of the operating systems of TCP/IP networked workstations and personal computers. A communicating agent class defined in the ADIPS agent repository, called AAR, is referenced by the user agent of the AAP to implement a communication service as an instance agent on the AAP.

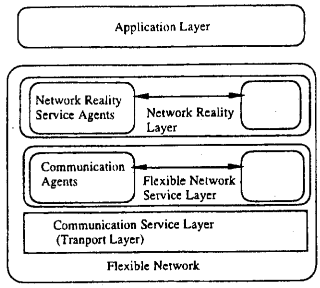

Figure 4: Conceptual Schema of Flexible Network

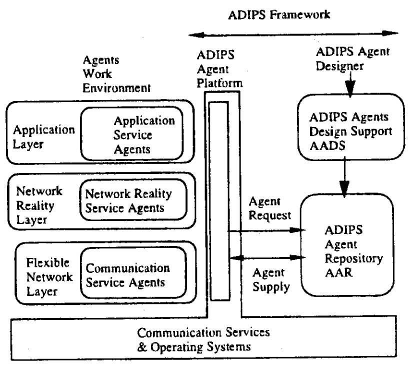

Figure 5: Agent–based Architecture of Flexible Network

In the Fig. 6 the cooperation among agents is shown. The service agent provides communication services, the user agent receives the services, the *organizational agent* manages the services agents, and the *watcher agent* observes the internal states of the system. The change in the user requirements is sent to the organizational agent as the change of the request to the service agent of the user agent. Similarly, the change in internal states related to the service agent is sent to the organizational agent. The organizational agent realizes adjustment / modification of functions / performances of the service agent by using prepared knowledge of design/ operation. A flexible network service is realized based on the cooperation of the agents.

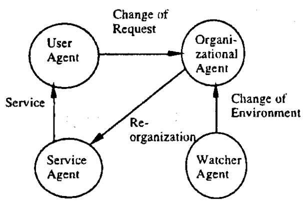

Figure 6: Cooperation among Agents

4 Network Reality and Human – Agent Symbiotic Space

The user of computers and information networks experiences reality of a virtual society (*network society*) on the networks through interactions with other users and information resources. In the virtual society, the user can easily receive various services if the services are provided by using metaphors of the real world. The virtual society is called *cyberspace*. The cyberspace consists of various virtual facilities, e.g. an electronic library, a cyber shopping mall, a cyber office, and a virtual class. The cyberspace provides its user artificial reality through both user's senses and reasoning ability. On the one hand, the artificial reality of user sensitivity has been studied in the field of virtual reality. On the other hand, the artificial reality of user reasoning is derived from the fact that user activities in the network society logically map onto the ones of the real world. For example, if somebody goes to an electronic library, a librarian advises him how to use the library. If somebody attends virtual meeting, a specialist connected on the network, a database in the form of software robot, an expert system, and the person himself cooperate to solve the problems (Fig. 7). Such an artificial reality of the activities in the network society is called *network reality.*

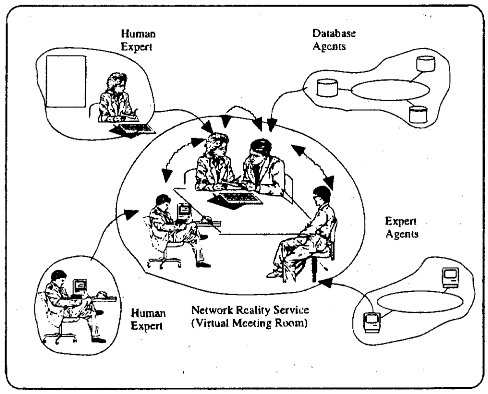

Figure 7: Network Reality and Symbiotic Space of Human and Agents

In order to realize the network reality, we propose agentification (personification) of network services and information resources connected on the network. As shown in the Fig.4, network reality service agents are incorporated in the application layer as a network reality layer and provide functions for realizing network reality of various applications in cyberspace.

The network society based on the layered structure (Fig. 4) constructs artificial space (*cyberspace*) in which humans and agents cooperate with each other for the common purpose. We call the artificial space the *human-agent symbiotic space.*

5 Agent–oriented Approach to Cyber Office

In order to evaluate an agent-based realization method for the network reality we produce a cyber office (a virtual office implemented on the networked computers) as an example of human-agent symbiotic space. The cyber office consists of a secretary agent and facilities, e.g. a desk, which support users activities. For example, in the Fig. 8., a user has to search data of marketing trends and afterwards, hold a planing meeting for a new product. Therefore, the user asks the secretary agent to search data and schedule the meeting as soon as possible. The secretary agent does not have any knowledge of data searching method. So it asks the agent to hand over this task to task management agents. A task management agent which is an expert for searching data accepts the task (this is achieved by extended net protocol), makes a plan for the task, and executes the task according to the plan. The task plan consists of the sequence of actions as follows: access database agent, retrieve data, send a data to a task processing agent execute the statistics of processing, and display the results. In order to complete this plan, the task management agent executes the sequence of actions while moving to appropriate environments.

To enable the cooperation among agents, the language and ontology necessary for sharing knowledge and exchanging information is defined. By using both local and shared domain knowledge agents can process information flexibly. Because of the support receiving from the agents, the human user of the cyber office can concentrate on the essential mental work. In other words, the cyber office provides a reasoning support richer than it is available in the real world.

6 Conclusion

At the present, we have set the goals for developing:

(1) Framework for development of agent-oriented systems in distributed environment called ADIPS, as an infrastructure and two classes of systems built on it:

(2) Flexible networks, and

(3) Reasoning support environment called cyber-office.

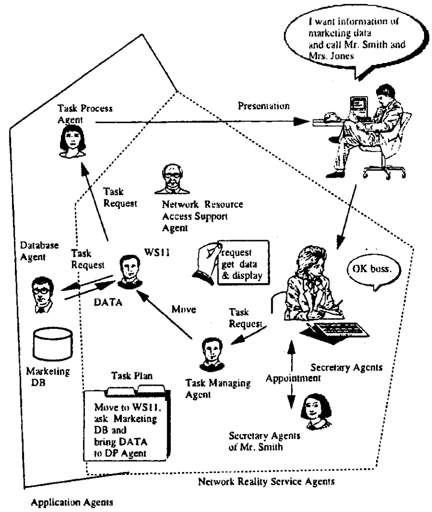

Figure 8: Cyber Office in Symbiotic Space of Agents

(1) is an multiagent distributed software architecture; (2) is an network architecture constructed as an organization of agents based on the ADIPS framework; and (3) will be developed as an application and example of a flexible reasoning support environment.

This research was supported in a part by a grant from the IPA of the Ministry of International Trade and Industry.

References

[1] Norio Shiratori, "Post Modern Distributed Systems," Journal of IPSJ, Vol. 36, No. 9, pp. 811–814, 1995.

[2] Kenji Sugawara, "Flexible Network," Journal of IPSJ, Vol. 36, No. 9, pp. 827–830, 1995.

[3] Tetsuo Kinoshita, "Knowledge–based Design Support Paradigm and Its Evolution," Journal of IPSJ, Vol. 36, No. 9, pp. 846–850, 1995.

[4] Shigeru Fujita, Kenji Sugawara, Tetsuo Kinoshita, and Norio Shiratori, "An Agent–oriented Architecture of Distributed Systems," Transactions of IPSJ, Vol. 37, No. 5, 1996.