Agent–based Information Processing System
Architecture

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Abstract
The fast development of information technology and rapid expansion of information demand have challenged contemporary information systems. This paper presents architecture of an information processing system with intelligence, coordination and adaptability. A prototype of typical news system is then implemented as an example. The principal techniques used in the system are analyzed and investigated in-depth and the architecture proposed is evaluated.

Key Words: agent, information processing system, system analysis and design, workflow

I. Introduction
We are in an information era with the development of technologies such as computer, network and database accelerating greatly the maturation of information techniques. Information has been regarded as one important resource and commodity with inestimable value. Information processing system is just the key element to produce and provide new information. Whereas, due to the existence of various unstructured information, information processing not only need routine manipulations of computer but also need the interaction between human & machine and the cooperation among people, especially on such aspects as contents, quality and responsibility. Many achievements have been acquired on partial techniques of information processing, but the relationship of each part and the whole architecture of information system have not been deeply investigated. Meanwhile, new information systems will face a lot of vital problems and opportunities, such as distribution and diversification of information, coordination and intelligentization of workflow management, diversity and individuality of users’ need, and so forth. Therefore the adjustment and reconstruction of system structure and framework is inevitable.

The development of distributed artificial intelligence has provided us the ideas and methods of agents. In a multi-agent system, the autonomy, social ability, responsibility and pro-activeness of agents make them coordinate to accomplish systemic integrated functions, which is just what a new information processing system needs.

This paper presents architecture and design method of an agent-based information processing system, which consists of five subjects: information entry, information processing, information publication, information resource management and service, system management and decision. A typical news system is designed and analyzed to show agents’ specific functions and communication protocols. Then the operation process and cooperative relation among agents are described and
analyzed. Further investigation and discussion are also made on the difficulties and key problems in system design such as workflow management and control, inheritance and polymorphism of agents, and the cooperation and fusion among agents.

II. Agent-based information system architecture

1. Basic concepts and structure of agent

The internal structure of an agent is first given in figure 1:

Communication unit: This unit receives, sends all kinds of information; accomplishes information intercommunication among agents; provides interface and communicates with outside environment.

Reasoning unit: Based on contents in knowledge or rules base, it makes reasoning on information, examines if it is valid and realizable, and makes corresponding message correspondence.

Planning unit: It schedules undertaken tasks according to capability of each agent and informs execution units.

Execution unit: This unit executes and accomplishes some kind of function based on the plan designed by the planning unit.

Monitor unit: The unit monitors internal states and task executions.

Knowledge updating and discovering unit: It discovers new knowledge and rules from outer messages and former work summary; receives instructions from superior agent to expand knowledge or rule base.

Knowledge or rule base: store contents relevant to agent functions, message grammar, semantic knowledge and rules.

A fairly complete internal structure of agent is already explained. In practical system design and implementation, it is necessary to simplify or strengthen some units.

2. Cooperation and communication mode of agent:

Many methods of cooperation among agents have been investigated, and here we will discuss the method of registration table (figure 2):

Fig.3 Communication mode based on blackboard

Planning unit: Through the cooperation with registration / match agent, it acquires tasks and divides them into some executive small ones.

Registration / match agent: This agent manages and maintains function agents and agent registration table; receives tasks divided by planning agent, matches tasks according to registration table and distributes them to each function agent.

Execution monitoring and control agent: It monitors and controls each function agent executing tasks.

Conflict coordination agent: The agent coordinates and solves problems when diverse function agents’ goals conflict.

Communication among agents in the system will adopt the communication mode of dividing grouping blackboard based on agent subjects (figure 3)

3. Architecture of agent-based information processing system

Since a large-scale information processing system contains a great number of agents, if we create these agents without classifying, it will induce chaos of system management, increase the difficulty of system maintenance and aggravate the load of system operation and communicating. Accordingly, we adopt the idea of grouping (subject dividing) while designing the system framework. According to the logical relations and functions of agents in the system, they are divided into some subjects. Each agent subject maintains its relative independence on logic and function. And they accomplish the information processing cooperatively through the interchange of data information and transmission of control information (figure 4).

General functions of every part of agent-based
information processing system are as follows:

1) Agent subject of information entry: These agents collect original information for the system through various channels and ways, arrange and classify information and provide materials for further processing.

2) Agent subject of information processing: On the basis of certain processing mechanism, such agents process original information and generate information products. Agent subject of information processing is the kernel of the whole system. And the quality of the information products is determined by its functions. However, the design of information processing subject has close relation with the processing mechanism and operation mode of the system, which will be exemplified in detail later.

3) Agent subject of information publication: These agents publish and distribute information products to outside, manage relevant transactions, provide information services for environment and collect feedback information from users.

4) Agent subject of comprehensive information management and service: Such agents manage comprehensively system information resources and intermediate information while processing, provide convenient and efficient services of storage and inquiry for the system.

5) Agent subject of management and decision: The agents administer the whole information processing system in a high level, analyze data synthetically and control the operation tactics of the system.

III. Agent-based news system

I) Background and logical structure of Computer Integrated News System

We have implemented Computer Integrated News System (CINS) for Science & Technology Daily office, a good-sized newspaper office. CINS will enhance the management level, competence and adaptability all-around. It integrates such systems as collecting and editing, manuscript delivery, typesetting, printing and publishing, and distributes news quickly. Moreover, it can obtain feedback information from users and demand information from outside in time, control and adjust system strategies of information collection, processing, distribution and newspaper publication. We will introduce the specific design and structure of agent-based information processing system using this typical news system as an example.
II) Agent-based system structure (5 parts)
1. Agent subject of information entry

- **User agent**: So-called system users include information source provider, information processor, information user and information manager and so on. Therefore, user agents not only possess general functions of information interaction, but different agent subjects have different specific functions. First we will show elementary functions:
  
  a) **User interface**: provide fast and easy operational interface, receive users' inquiry demand and display inquiry results.
  
  b) **Examine validity of users' input and translate vague, incomplete demand to standard communication description of agents**.
  
  c) **Communicate with the agent of comprehensive information management and service**.
  
  d) **Provide functions and communication ways relevant to agent subjects**.

- **Information collection agent**: It collects raw materials for the whole information processing system; receives and processes manuscripts from everywhere, including reports and news from domestic and overseas correspondents, free contributors, national news agencies and government-relating institutions; searches relevant information from Internet.

  Functions:
  
  a) Receive and process regularly or irregularly, routine or mobile transferring manuscripts.
  
  b) Search information on Internet.
  
  c) Submit raw information materials to information classification agent.

- **Information classification agent**: It classifies preliminarily raw information materials on hand and prepares for further processing.

  Functions:
  
  a) Receive raw information materials from information collection agent.
  
  b) Classify raw information according to relevant knowledge and rules.
  
  c) Store information about classification results.
  
  d) Notify information processing agent of new materials.
  
  e) Adjust classification based on control information.

2. Agent subject of information processing

- **Editing agent**: The agent filters out raw materials; edits, pre-signs and reviews selected manuscripts by some rules; completes the processing of information contents.

  Functions:
  
  a) Receive classified manuscripts.
  
  b) Select manuscripts.
  
  c) Edit, preview, review and sign manuscripts following designed procedure.
  
  d) Save edited reports and notify typesetting agent.

- **Typesetting agent**: This agent is responsible for designing layout of edited manuscripts and completing typesetting.

  Functions:
  
  a) Receive signed reports.
  
  b) Typesetting.
  
  c) Modify layout in cooperation with editing agent.
  
  d) Save layout information and inform printing agent.

- **Printing agent**: Functions:

  a) Receive layout information file.
  
  b) Adjust layout, make films and PS2 format file by laser scanning.
  
  c) Printing.
3. **Agent subject of information publication**

- **User agent**: It supports relating operators to do information processing.
- **Publishing management agent**: This agent distributes or publishes final information products (including press publication and electronic publication), manages information and publishing process.
- **User service agent**: It provides publication information and information inquiry service for users.
- **User information collection agent**: The agent collects order information and feedback from users.

4. **Agent subject of comprehensive information management and service**

- **Service management agent**: This agent receives service demands; for those demands it can handle, it divides tasks and does planning, collates results and returns them to demander.
  
  **Functions**:
  
  a) Receive demands from other agents, and examine their validity.
  
  b) Accept reasonable demand.
  
  c) Do reasoning and divide tasks to the other two agents.
  
  d) Optimize return results and send them to demanders according to standard agent communication mode.
  
  e) Manage dynamically data access agent and format conversion agent.

- **Data access agent**: This agent provides services of inquiring and storing data information from different databases.
  
  **Functions**:
  
  a) Receive demands from service management agent; inquire and store data from databases.
  
  b) Transfer relevant data to format conversion agent and ask for unique format.
  
  c) Operate on data results after conversion and send results to service management agent.
  
  d) Monitor changes of data sources dynamically.

- **Format conversion agent**: It takes charge of converting different types of data, including structural data conversion and multimedia data conversion, to standard formats.

5. **Agent subject of management and decision**

- **User agent**: It supports daily management for managers and decision-makers; supports decision discussion.

- **Data analysis and information fusion (DAIF) agent**: This agent arranges and analyzes internal and external information, does information fusion, summarizes and discovers useful rules in or out of systems and provides evidences for management and decision.

- **Cooperative DSS (CDSS) agent**: It organizes management agents to have meetings and discussions, coordinates work at a high level and establishes cooperation strategies.

### IV. Further discussion

**Management of workflow and virtual edit department**

The definition of workflow:

The workflow in information processing system refers to the whole work process from collecting and arranging raw information materials to distributing information products and providing relating services. Since information processing is the kernel part, here we mainly discuss the management and control of workflow in that module.

Usually the workflow of a news information system consists of three stages as collection & editing, typesetting and printing. And each stage can be divided into specific processing procedure (as described before). Since main resources (except hardware) consist of information resources and human resources, the management and control of workflow should pay attention to the following three points:

1. How to customize information-processing flow to guarantee completing tasks efficiently and qualifiedly.
2. How to allocate human resources in the information processing flow to achieve efficient, timesaving and low-cost operation of the system.
3. How to define the responsibilities of personnel in the system, i.e. role definition.

**Virtual edit department**:

- Fig. 8 Subject of information publication
- Fig. 9 Subject of comprehensive information management and service
- Fig. 10 Subject of management and decision
- Fig. 11 Redefinition of workflow
Usually a newspaper office consists of some edit departments, which are responsible for different types of news reporting respectively. But to some sudden, important news incidents, it is necessary to select personnel from relating departments and form a temporary organization. Such organizations are called virtual edit departments because of their high time demand and short lifecycle. And to guarantee completing such tasks as reporting sudden incidents quickly and accurately, there should be some difference on the organizational and operational mode.

Through redefining the role of virtual edit departments and customizing workflow, it is possible to simplify procedures of manuscripts’ processing, reduce processing time and improve the timeliness. A description of virtual edit department workflow is given below:

In virtual edit departments, correspondents’ manuscripts will be delivered directly to editors for selecting and editing without classifying. After they have been modified, the director is responsible for finalizing and signing and then the manuscripts are stored in sample depository for typesetting and publishing. After we simplify procedures of manuscripts’ processing, system efficiency will be improved and distribution time will be shortened. But it is necessary to redefine personnel’s roles and it also means the augmentation of personnel’s rights and responsibilities. For example, since customary procedures of pre-signing and finalizing manuscripts are replaced by once signing, the director should be more capable and take more responsibilities.

- **The cooperation and function fusion between editing agent and typesetting agent while doing typesetting**

Since the agent-based information processing system in this paper is a MAS (Multi-Agent System), the cooperation among agents is very frequent, which is also the basic requirement to accomplish the whole function of system. However, since the goal and evaluation standard of each agent may differ, it is possible to cause conflicts among agents and increase difficulty of cooperation. Quite a few papers have investigated the problem of cooperation among agents on theory. Here we only explain it in a practical system, then present and discuss the method of agent fusion.

In examples before, three steps are necessary for manuscripts processing as collecting and editing•typesetting and printing. Each time manuscripts are signed by the editor, they are delivered to typesetters. Since it is usual to modify manuscripts repeatedly, typesetters will redo their work time after time. However, the evaluation methods of editing and typesetting are different. For editor, less modification times means higher quality of editing. But for typesetters, to achieve better visual effect usually needs more modification times and more work. Editors expect less modification but typesetters want more. Therefore goal conflict appears between editing and typesetting on manuscript modification.

We present agent fusion to solve goal conflict discussed above. Usually after the first time manuscripts are read and edited, the contents and size of articles will not change much. That is to say, the modification of manuscripts is only local adjustments on layout. Therefore, we combine the work of re-editing and re-typesetting and let it done by only one person, not two as usual. In system architecture, the work done by two agents are accomplished by single agent, which will produce agent fusion. Since the contents of reports are significant and local adjustments of layout are comparatively easy, the work of re-editing and re-typesetting can be assigned to collecting and editing agent. And typesetting agent will confirm the modification. The problem of cooperation under goal conflict can thus be solved. It should be noticed that agents’ functions and rules are adjusted too. Another advantage of agent fusion is reduction of workload and number of typesetters.

- **Base class and polymorphism of agent**

In a MAS, a group of agents may have identical functions, but to other similar functions their focuses differ. In order to construct, maintain MAS conveniently and decrease cost, we can borrow the concepts in Object Orientation (OO) technology and introduce the mechanism of inheritance and polymorphism for agent class.

**Inheritance:**

- CDSS agent
- DAIF agent
Among the agents in a MAS, part of the functions or knowledge in some agents may be identical. It is reasonable to create a base class with the common part and other agents can inherit those functions or knowledge from the base class. An inheritance tree forms after some levels of inheritance.

In the example above, all the user agents, such as correspondent agent, collecting and editing (C&E) agent, reader agent, share many common functions, such as basic interface support and information inquiry and so on. These functions and relevant knowledge can be sum up and form a base user class. The user class in each subject can be created through inheriting base user class. The agent inheritance tree of the example above is shown below.

Polymorphism:

Inheritance solves the problem of using same functions and knowledge among agents. But some kind of agents often have similar but not identical functions, which can not be solved by inheritance but need the assistance of polymorphism. Based on the mechanism of polymorphism, those offspring agents created by inheritance can modify and enhance functions, knowledge or rules of father agent according to practical need, which make individual offspring agent have different functions (or reasoning, planning etc.) under the same interface.

In the above example of news information system, as to the function of information inquiry, correspondent agent will get the information of all the relevant manuscripts, editor agent will receive those manuscripts being modified and be able to store results after each modification, and reader agent can acquire information of printing or electronic publication which is convenient to be browsed. These behaviors exhibit the polymorphism of information inquiry. To meet practical need, polymorphism is also introduced to the mechanism of reasoning, knowledge and so forth.

Inheritance and polymorphism are important features of OO technology. The introduction of these two mechanisms will help to simplify the concepts and structures of systems, make them easy to understand, and facilitate systems’ building and maintaining. Inheritance in OO technology is limited within properties and functions, and polymorphism is mainly used in functions. However, inheritance and polymorphism in agent-based system has been expanded to include knowledge base and reasoning rules, which is a significant problem in the application of agent technology.

V. Summary

This paper presents the architecture of agent-based information processing system. It not only analyzes the functions of all the subjects and structural relationships among them in the view of the whole system, but also provides the agent technique to facilitate the realization of intelligence and adaptability. The entities of agents bring the object-oriented characteristics, which make the system more flexible and easier to build and rebuild. In the analysis and implementation of the news system, we describe basic analyzing approaches and communication protocols of agent-based systems. The investigation of workflow management provides the system with more flexibility, adaptability and better ability to deal with sudden affairs. The technique of agent fusion plus workflow management realizes the cooperation under goal conflicts and improves the efficiency and quality of the system. And the discussion of inheritance and polymorphism will facilitate the management and decrease the workload of developing and maintaining a system.

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References: