Agent Oriented Business Forecasting

Zhiqi Shen and Robert Gay

Information Communication Institute, School of Electrical and Electronic Engineering
Nanyang Technological University, Block S2, Nanyang Avenue, Singapore 639798
Email: zq_shen@yahoo.com, eklgay@ntu.edu.sg

Abstract

Business forecasting is vital to the success of business. There has been an increasing demand for building business forecasting software system to assist human being to do forecasting. However, the uncertain and complex nature makes it a challenging work to analyze, design and implement software solutions for business forecasting. Traditional forecasting systems in which their models are trained based on small collection of historical data could not meet such challenges as the information explosion over the Internet. This paper presents an agent oriented business forecasting approach for building intelligent business forecasting software systems with high reusability. Although agents have been applied successfully to many application domains, little work has been reported to use the emerging agent oriented technology for business forecasting purpose. The main contribution of this paper is that it explores how agents can be used to help human to manage various business forecasting processes in the whole business forecasting life cycle.

Keywords: Business forecasting; Multi-agent system; Agent-oriented technology

1. Introduction

Business forecasting plays an important role in the economic world. It is vital to the success of business. Business forecasting is concerned with the process to predict the unknown future[1]. There has been an increasing demand for building business forecasting software system to assist human being managing the forecasting processes. However, the uncertain and complex nature makes it a challenging work to analyze, design and implement software solutions for business forecasting. Most of the current efforts on development of business forecasting software systems are focused on implementation of a specific forecasting method i.e. the algorithms of the forecasting methods by computing languages. Some processes, for example data collection and data preparation, are still carried out by manual work in traditional business forecasting system [2].

The rapid growth of Internet and World Wide Web has already produced significant impacts on business forecasting. The Internet has evolved from an information space to a market space with millions of electronic storefronts, auctions and stock markets etc. Nowadays, E-Commerce enables small businesses to sell products to the market all over the world. WWW has already become a part of our daily life, where we read newspapers, check banking account, buy stocks, and make investments etc. As a result, huge amounts of business data are published on the web for the forecasting. But they are updated frequently. Traditional forecasting systems in which their models are trained based on small collection of historical data could not meet such challenges of the information explosion over the Internet. Further more, collecting the most recent data for related variables/factors is very important to the business forecasting. The publishing of a new banking interest may have an immediate affect to

stock markets. Obviously, traditional business forecasting systems are not able to satisfy the above new requirements of business forecasting.

Building on the combination of artificial intelligence, distributed computing and software engineering, agent-oriented technology represents an exciting new means of analyzing, designing and building complex software systems [3-6]. From 1990s, especially from 1994, agents have become one of the most important research areas in the soft computing. Now days, agents have been used successfully to help people in many areas such as information collection/filtering, personal assistants, network management, electronic commerce, intelligent manufacturing, health care, and entertainment etc. [7].

An agent presents the characters such as *autonomy* – acts without human intervention and has some kind of control over its actions and internal states; *social* – collaborates with other agents via structured messages; reactivity – responds to environment changes; and *proactive* – acts to achieve goals [8]. An intelligent agent merges the knowledge representation, learning and reasoning as its intelligence. A mobile agent has the ability of migrating itself from one place to another. These characters make agent-based system the most promising software solution for managing the business forecasting processes on behalf of human beings.

In this paper, we propose an agent-oriented business forecasting (AOBF) model for design of various business forecasting agents. We start from the discussion on where agent can be used in the business forecasting life cycle. Thereafter, we further explore how agents can be used to help people to do business forecasting. Finally, the agent-oriented design methodology is given for constructing an intelligent business forecasting system as a multi-agent system.

Following is the outline of this paper: Section 1 gives the brief introduction of this paper. Section 2 addresses where agent can be used in business forecasting life cycle. Section 3 describes the agent-oriented approach in business forecasting system development. Section 4 illustrates how to construct the intelligent business forecasting agents based on given agent-oriented approach. Finally the conclusion is reached in section 5.

2. Where can agents be used in the business forecasting life cycle?

In traditional business forecasting system, human beings have to be involved in each process and use different tools or manual work to manage forecasting processes in the life cycle as shown in Figure 1.

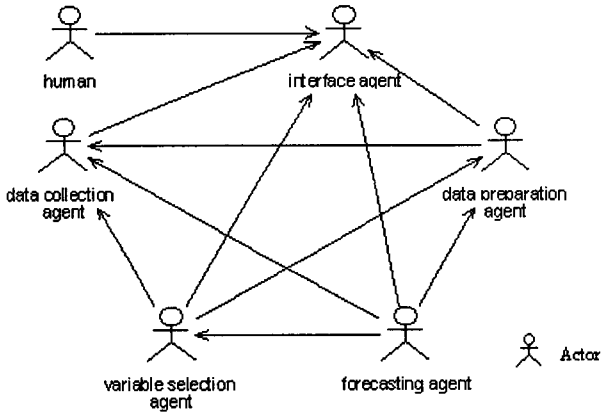


Figure 1 Traditional Business Forecasting Use Cases

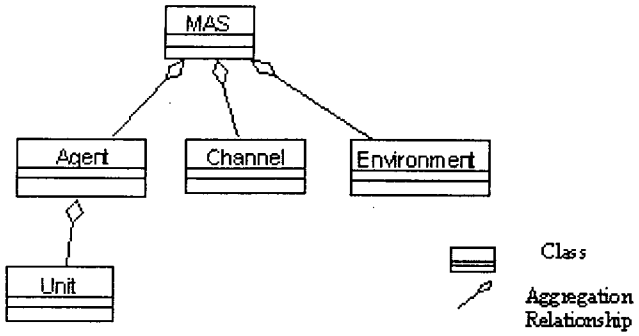
In fact, agents can be used for managing many processes on behalf of human beings in the business forecasting life cycle. The characteristics of agent such as communication ability, autonomy and reactivity enable agents to assist people in many ways:

- Agent can help to collect most recent data (Data Collection Agent)
- Agent can help to prepare data (Data Preparation Agent)
- Agent can help to select variables (Variable Selection Agent)
- Agent can help to do business forecasting (Intelligent Forecasting Agent)

Figure 2 Agent-Oriented Business Forecasting Use Cases

Unlike traditional business forecasting Figure 2 shows the agent-oriented business forecasting paradigm. Agents act as dynamic processes of data collection, data preparation, variable selection and business forecasting. They corporate with each other during the business forecasting life cycle. The interface agent is responsible for interaction with human beings. Human beings can interfere and take appropriate

actions during the business forecasting life cycle through the interface agent.

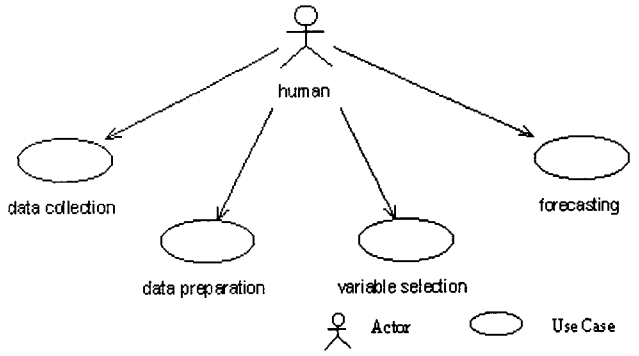


3. Agent-Oriented Business Forecasting

In our previous research work, we have proposed an intelligent forecasting agent [9], and an intelligent agent architecture for designing business forecasting agents [10]. In this section, we further propose an systematic agent approach to model, design and construct a business forecasting system as a multi-agent systems (MAS). Each agent inside MAS manages a process in the business forecasting life cycle, and the entirety of MAS provides a complete software solution for assisting people to do business forecasting.

3.1 Agent-Oriented Business Forecasting Model

The agent-oriented business forecasting (AOBF) model is proposed for modeling the processes of business forecasting



life cycle and construct agents for managing business forecasting processes in a multi-agent system environment. The model consists of *Unit, Agent, Channel and Environment*. Units are components for construction of Agent. Channels are protocols through which agents can communicate with each other. Environment is the common area where agents are working in. Figure 3 shows the relationship between MAS, Agent, Unit, Channel and Environment.

Figure 3 The Business Forecasting Agent Model

3.1.1 Business Forecasting Agent Model

Business forecasting (BF) agent is composed of units. There are eight types of units defined in the business forecasting agent (BFA) model.

Figure 4 Business Forecasting Agent Model

The process unit is an abstraction of real process in business forecasting life cycle. It defines the objective and tasks of business forecasting agent. The perception unit is used to sense the environment so that agent detects changes of the environment. The action unit implements the actions that the BF agent performs. The communication unit specifies how the BF agent communicates with other agents. The knowledge unit maintains the knowledge of the agent. It also implements the reasoning and learning algorithms of the forecasting model. The data unit is used to manage and access data. The control unit is used to coordinate the other units. It makes execution plan and make decision to take actions. The mobile unit enables the agent to travel from one place to another. An agent defined in business forecasting agent model consists of at least a process unit, a control unit, a perception unit, a action unit and a communication unit, which are essential to define the basic characters of agents.

With BFA model, various types of agents can be composed. The basic units and a mobile unit can compose a mobile agent, who can travel from one place to another in the network. An intelligent agent, who has the abilities of knowledge representation, reasoning and learning, can be constructed with the basic units and a knowledge unit. Similarly, a mobile intelligent agent can be designed with basic units, together with both mobile and knowledge units. Figure 4 shows the BFA model.

Agents defined by the BFA model present the following characteristics:

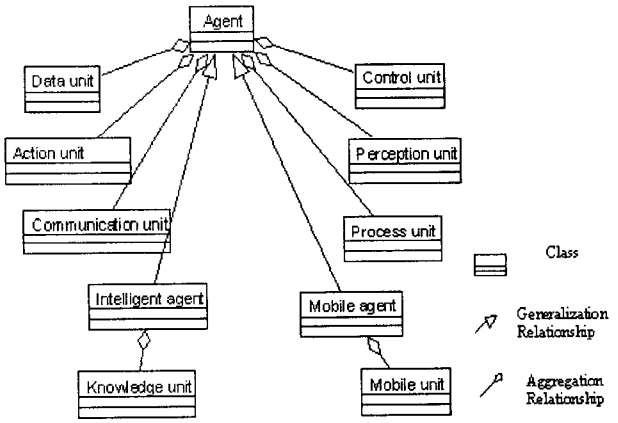
- Autonomous

Once an agent starts running, the control unit,

perception unit and communication unit start to work. They make decisions, take actions to reach the goal, react to the environment changes and communicate with other agents or humans by themselves. The agent runs forever after it is started.

- Pro-active

They are goal-oriented, and have their own purposes. The control unit acts as a coordinator and planner of the agent. It first enables the process unit and gets the goal. Then it sets the goal of agent and makes the execution plan. It selects the actions from action unit proactively based on the execution plan and performs the actions to reach the goal. If the environment changes, the control unit will select actions from action unit to react the change. The control unit is also able to manage to exchange information with other agents through communication unit.



- Re-active

They respond timely while the environment changes. The perception unit is sensing the environment. Once the environment changes, perception unit will notify the control unit. Control unit will then react to the changes through actions in the action unit.

- Mobile

An agent has the ability to move itself to the new hosts in the network if the mobile unit is defined and implemented.

- Intelligent

An agent has knowledge and has the abilities of reasoning and learning if the knowledge unit is defined and implemented.

- Process-centric

An agent acts as a dynamic process in a business forecasting life cycle. The goal defined in the process unit is business forecasting process related. The tasks needed to reach the goal are also defined in the process unit.

3.1.2 MAS Design

- **Agents**

The AOBF model is proposed to model, design and construct a business forecasting system as a multi-agent system. As the goals and tasks of an agent defined by AOBF model are specified by its process unit, different agents can be designed to manage different business forecasting processes.

Figure 5 Business Forecasting Agents

For example, a data collection agent can be designed by specifying the agent's process unit with the goal and task list abstracted from real business process of data collection. The actions in the task lists are designed in the action unit. Figure 5 shows the design of different agents for managing different processes in the business forecasting life cycle.

Among these agents, the business forecasting agent is the core agent in the MAS. It determines how to do reasoning and forecasting based on the forecasting model represented by its knowledge unit. The forecasting results can be obtained by the intelligent forecasting agent through the reasoning algorithms of the forecasting model.

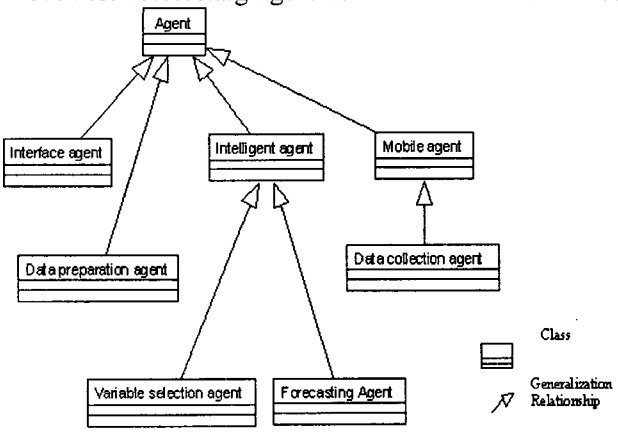
- **Channel**

Channel defines protocols through which agents can communicate with each other. The channel consists of message transportation protocol, message protocol and message language.

Message transportation protocol defines how messages are transferred between agents. It includes message package format, message exchange method and message management, etc. Currently, many mature

communication products are available, such as CORBA event channels, Java message queues. One of them will be adopted to be the transportation protocol based on specific project requirement.

Message protocol defines message types and message formats. The message types and formats used in business forecasting agent communication are defined



using knowledge query and manipulation language (KQML) which is popularly used in the agent domain recently. A sub set of the performatives are implemented.

Message language defines the contents of the messages that agents can understand with each other.

- **Environment**

Environment defines states in each of the business forecasting processes and the agent working environment. They are the indicators to reflect status changes in the working environment. The agents will sense the environment to detect the changes by monitoring the states defined here.

4 Construction of an AOBF System

4.1 The Business Forecasting Agent Framework

An Java-based agent framework for construction of various forecasting agent has been developed based on the proposed agent model. The framework contains reusable Java components and interfaces including the agent class and all the units defined in AOBF model with basic functionality. An agent can be built by implementing the interfaces, customizing the reusable components.

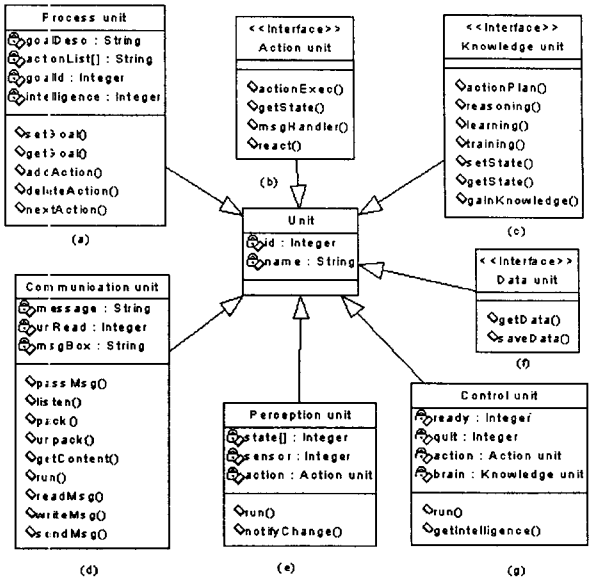


Figure 6 The Agent Framework

Figure 6 describes the agent framework. Process unit defines the goal of the agent. It also specifies the actions that need to be performed to reach the goal. The contents of the goal and the action list will be defined during agent construction in real application. The actions in the action list can also be changed dynamically by function *addAction()* and *deleteAction()*.

Perception unit defines the activities the agent senses the environment. It contains a list of states to indicate the status of the environment. If the environment changes, the perception unit will notify the control unit to take actions against the change. Once the agent starts work, the perception unit will keep running in a separate thread. The activities of perception unit are specified in the function *run()*, which is the execution body of the thread.

Communication unit defines the communication mechanism between agents. The agents communicate asynchronously through message queues. The function *pack()* and *unpack()* are used to pack messages and unpack messages respectively based on the message transformation protocol. The function *listen()* is to check the message queue for any new message. Once it finds a new message, the control unit will be notified. The control unit will then take actions to handle the messages. The function *readMsg()* and *writeMsg()* are used to read message from the message queue and to write message to the queue, respectively. Similarly, the

communication unit keeps running in a separate thread when the agent is working. The function *run()* of the communication unit calls the function *listen()* to monitor the message queues.

Control unit makes decisions on agent activities. If the perception unit of an agent detects an environment change, the control unit calls function *react()* to react on the change. If the communication unit finds a new message in the message queue, the control unit calls function *messageHandler()* to process the message. In the normal case, the control unit executes the functions defined in action list of the process unit sequentially to pursue the goal of the agent. The control unit runs in a separate thread too. The function *run()* of control unit defines the execution mechanism of the agent. If a knowledge unit is defined, the control unit calls the function *actionPlan()* defined in the knowledge unit regularly to make new execution plan.

Action unit contains all the action functions used by other units. It is an interface and defines the mandatory functions that must be implemented in the real agent construction. For example, the function *react()* and *messageHandler()* that are used by the control unit are essential to the agent. The other actions, such as the functions defined in the action list of the process unit, are also needed to be implemented in real agent construction.

Data unit is an interface for data access. They are used to access data source, such as database or data files. The functions defined in the action unit use the functions defined in this interface to manipulate data. They need to be implemented to control the real data operation during the agent construction.

Knowledge unit, which is an interface class, defines the functions of intelligent activities such as reasoning, learning, training and action planing. During the intelligent agent construction, the reasoning and learning algorithms of a knowledge model need to be implemented.

An agent class and an intelligent agent class are also defined in the framework. The agent class consists of a process unit, a control unit, a perception unit, an action unit and a communication unit. The function *initAgent()* initialize the agent. The function *doWork()* starts the three threads in the control unit, the communication unit and the perception unit respectively and drives the agent to work. The intelligent agent class extends the agent class with a knowledge unit. Figure 7 gives the definition of agent class and intelligent class.

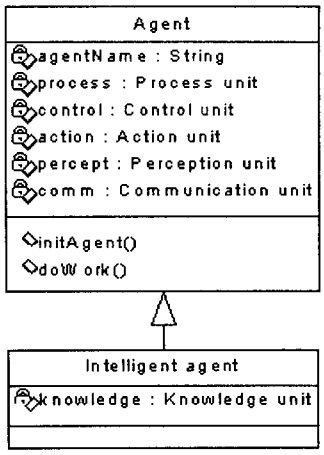


Figure 7 The Agent Classes

With the agent framework, an BF agent can be built by the following steps:

- Set agent goal and task list in process unit based on the business forecasting process. If it is an intelligent agent, set intelligence to true;
- Implement interface functions defined in action unit including sensing function, message handler and functions identified in task list. Other agent specific functions are also implemented here;
- If it is an intelligent agent, define the knowledge representation structure and implement the interface functions that include reasoning mechanism, learning algorithm, training monitor and action planning; The function *gainKnowledge()* binds the implementation of the knowledge representation into the knowledge unit.
- Define the agent by extending the agent class and initialize the agent using function *initAgent()* and call the function *doWork()* to start the agent. If it is an intelligent agent, define the agent by extending the intelligent class in the framework instead.

4.2 The Multi-Agent System Architecture

Figure 8 shows the architecture of the multi-agent business forecasting (MABF) system based on AOBF model. The agents are constructed using the agent framework we developed. The data and the knowledge are stored in the Oracle database system. Currently the data collection agent is developed as a basic agent. It collects the data through

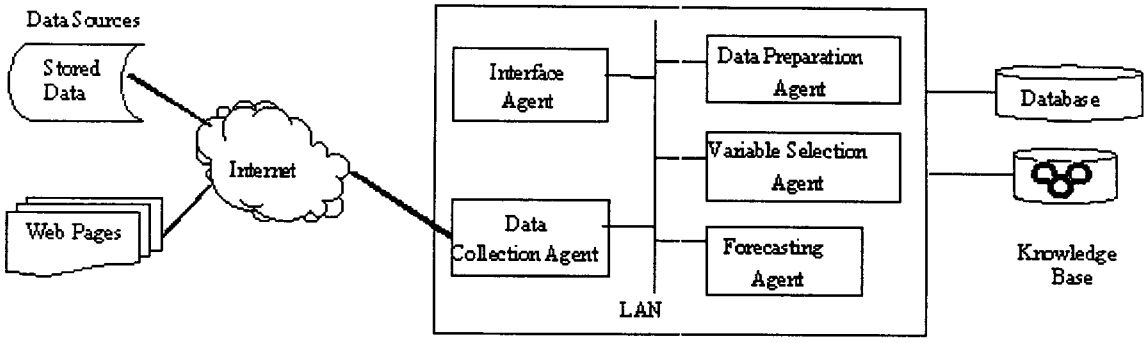


Figure 8 System Architecture

network connection autonomously. It collects data from remote data sources and web pages via Internet. We are enriching the framework with the mobile unit so as to make the data collection agent mobile. The data preparation agent converts the collected data when the new data arrives.

The variable selection agent automatically selects significant variable using the collected data. If it found new variable, it will send message to forecasting agent to update its knowledge. It is still under developing now.

The business forecasting agent transforms a fuzzy neural network model as its knowledge, and implements the reasoning algorithms of forecasting model to do forecasting. It generates the forecasting results based on the new collected data. For example, the intelligent forecasting agent senses the environment through three boolean variables: *message_arrival*, *data_arrival* and *data_ready*. If *data_ready* is true, business forecasting agent retrieves the data from the data source, inferences based on computation and sends the forecasting results to the interface agent. Then the *data_ready* is set to false. If *data_arrival* is true, *data_ready* is still false after a time threshold value, business forecasting agent sends a warning message to interface agent to get help from humans. If *message_arrival* is true, the agent reads message from the message queue.

The agents are working in a local network. They communicate with each other through the message queues.

5 Conclusion

In this paper, we have presented an agent-oriented approach for business forecasting to construct a business forecasting system as a multi-agent system. The motivation of this paper is to explore how agents can help in the whole business forecasting life cycle. Based on the AOBF model proposed in this paper, various types of agent can be constructed. These agents are able to play many important roles in doing business forecasting, which include variable selection, data collection/preparation and forecasting. We argue that AOBF model provides a generic software solution for assisting people to model the business forecasting problems and make forecasting. Compared with the traditional forecasting system, the AOBF presents a practical new approach for designing and construction of intelligent forecasting systems.

References

[1] Allen, P. G., and Fildes, R. 2000. Econometric Forecasting. *Principles of Forecasting: A Handbook for Researchers and Practitioners*. Norwell, MA: Kluwer Academic Publishers.

[2] Armstrong, J. S. 2000. Standards and Practices for Forecasting. *Principles of Forecasting: A Handbook for Researchers and Practitioners*. Norwell, MA: Kluwer Academic Publishers.

[3] Nwana, H., and Ndumu, D. 1999. A Perspective on Software Agents Research. *Knowledge Engineering Review* 14(2): 1-18.

[4] Kendall, E. A., and Murali, K. 1998. Patterns of Intelligent and Mobile Agents. In Proceedings of Autonomous Agents, 92-99.

[5] Kendall, E. A. 1998. Agent Roles and Role Models. In Proceedings of Intelligent Agents for Information and Process Management.

[6] Wooldridge, M., Jennings, N. R., and Kinny, D. 1999. A Methodology for Agent-Oriented Analysis and Design. In Proceedings of Agent'99.

[7] Miao, C. Y., Goh, A., Miao, Y., and Yang, Z. H. 1999. Computational Intelligent Agent. In Proceedings of 1st Asia Pasific Conference on Intelligent Agent Technology.

[8] Wooldridge, M., and Jennings, N. R. 1995. Intelligent Agents: Theory and Practice. *The Knowledge Engineering Review* 10(2): 115-152.

[9] Shen, Z. Q., Gay, R., and Miao, Y. 2000. Intelligent Forecasting Agent. In Proceedings of the 20th International Symposium on Forecasting.

[10] Shen, Z. Q., Li, X., Gay, R., Miao, Y., and Yang, Z. H. 2000. An Intelligent Agent Architecture for Business Forecasting. In Proceedings of the International Symposium on Multi-Agents and Mobile Agents in Virtual Organizations and E-Commerce (MAMA'2000).