Agent-Based Stock Trader

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ABSTRACT

In this paper, we introduce a unique implementation scheme of the Belief-Desire-Intention (BDI) model to be used in an agent-based application using Java. The example prototype system is the Agent-based Stock Trader (AST) that is a stock-trading expert based on intelligent agents. Agents in AST are based on the Belief-Desire-Intention (BDI) model in artificial intelligence.

This paper proposes how to program the BDI-based agents using the Java programming language, and how to make an agent-based application more intelligent and flexible. This paper contributes new implementation scheme of the BDI agents in the Java programming language useful on many applications. This work also shows how to implement the BDI agents with Java while manipulating BDIs intelligently and dynamically at runtime. Using our concepts and implementation scheme, the Internet-based application like stock trading can be more intelligent and flexible.

Keywords

Agent-Based Programming, Intelligent Agents, BDI model, Stock Trading Application

1. INTRODUCTION

An agent is a software entity that has some degree of intelligence and autonomy. It is a high-level system component, which is capable of having goals that it needs to be accomplished. From the traditional definitions, agents have the following properties: autonomous, perceptive, pro-active and cooperative [5]. Agents may have their autonomy and are not controlled directly by the others. The perception of agents allows the communication between the agents and their environments. Agents can cooperate with other agents to achieve the same goal. Intelligent agents have learning ability, so that those agents can learn and adapt to new environment to achieve their goals in the better way while learning. Agent computing is a new and active research area today [6] [9].

To realize the intelligent agent computing effectively, a model based on Belief, Desire, and Intention (BDI) has been proved as a powerful technique [2]. The "Belief" in BDI of an agent represents the knowledge about itself and the world (outside environment) of the BDI agent. The "Desire" in BDI represents a goal that the agent likes to achieve. The "Intention" describes a set of plans to achieve the predefined goal or to react to a specific situation.

In this work, we build BDI-based agents for an example stocking trading application using the Java programming language. Since Java does not support agent programming, there was no proper language constructs to program BDI agents. Therefore, we show here how to program agents, belief, desire and intention by using the Java class constructs. Stock trading agents create objects for belief, desire and intention from the corresponding classes implemented already. The desire object finds appropriate an intention object to achieve its goal based on the information of the belief object. One of the merits of this paper is to show how to use the Java programming language effectively to build the BDI-agent application. This paper shows not only how to build agents using Java, but also how to manipulate runtime knowledge dynamically to make agents intelligent.

There have been several research and experimental works based on the BDI model extending the Java programming language. BDIM Agent Toolkit is implemented as a Java package to provide a prototype of runtime architecture [3, 4]. JAM Agents are composed of five primary components such as a world model, a plan library, an interpreter, an intention structure, and an observer [7]. JACK offers Class, Interface, Method, Syntactic and Semantic extensions of Java implemented as Java plug-ins to support an agent-oriented development environment [1].

These works are based on Java. Jack uses DB nicely for belief, however, it does not support dynamic manipulation of desire and intention, while our work does. Even though JAM provides a way to manipulate BDIs, neither JAM or BDIM supports well dynamic manipulation of BDIs not like ours. Once above agents are built by users, then they are fixed during runtime. In other words, users cannot modify them dynamically at runtime. Users have to redefine and recompile them if a modification is needed. In our work, we can build a BDI agent directly in Java with the help of database that a user can handle the BDI agent dynamically by manipulating the relations among the agent's belief, desire, and intention defined in the BDI knowledge-base at runtime.

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2. OVERVIEW OF AST

2.1 The BDI Concepts in AST

Agent-based Stock Trader (AST) is a stock-trading expert based on intelligent agents, which uses BDI model in artificial intelligence. Beliefs in AST specify all kind of stock information that agents know. Agents have explicit goals to achieve or events (desires) to handle. The stock names to get recommendation from expert agents in AST can be goals. A set of plans (Intentions) is applied to describe how agents achieve their goals based on certain beliefs. Each plan elucidates how to achieve a goal under varying environments. According to the technical analysis of the history and current information of some stocks, a plan will give its suggestion to help people to invest. However, another plan may be used if the history, information, or stock is different. Agent itself can autonomously decide which plan will be executed according its current situation.

2.2 The Architecture of AST

The following figure shows the conceptual overview of the AST system. Three-tiered design is considered to make the AST system components portable and flexible [Figure 1].

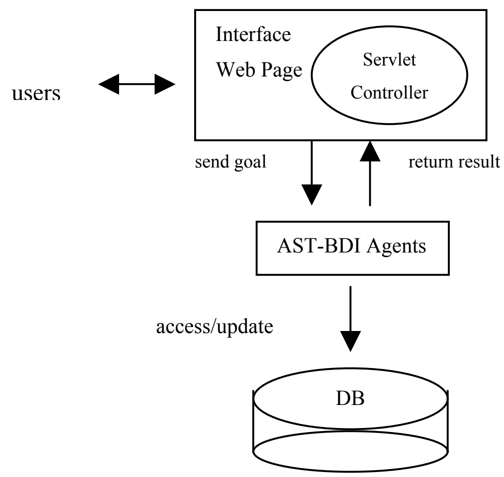


Figure 1. The Architecture of AST

The whole system consists three parts. The first level is the Servlet Controller, which is a link between users and BDI agents. It provides user interface and dynamically generates corresponding web pages. The second level consists of the BDI agents, which are the core part of AST. The third level is a data access layer where all information about the AST system such as the BDI agent's beliefs and the knowledge base are stored. In AST, we use relational database to represent the beliefs and the knowledge base.

When a user asks to find the recommendation of a specific stock, the interface agent will send this goal to the agent through the servlet program. Then the corresponding agent will check whether it can fulfill this goal. If so, it will choose proper plans to achieve the goal through its control structure and return the result. If not, it may directly ask other agents for help, or send a fail message back. Finally the interface agent generates the web page from which the user can get the result from the agent.

3. HOW TO IMPLEMENT BDI-AGENTS?

Agent-based programming is a new programming paradigm that has been arisen from research in distributed artificial intelligence. Unfortunately we have no proper agent-based programming language to implement the BDI agent concept well. We have decided to use the Java programming language to implement encapsulation of agents. However, Java does not support the BDI agent concept. Therefore, we have to devise some mechanism to support the BDI concept on Java. We discuss here how to implement the BDI agents using Java. This is an important merit of this paper.

3.1 How To Implement BDI-Agents

In AST, we use a relational database to represent an agent's belief, including the agent's knowledge base and the environment states.

We have thought a BDI mapping table that includes current states of belief, desires to achieve, and its corresponding intentions. By using this BDI mapping table, we can manipulate dynamically belief, desire, and intention at runtime. We can also show mapping among them, and we can change their mapping dynamically at runtime.

The AST application starts by initiating a certain goal defined in the desire definition. Based on specific belief an intention is chosen to achieve the goal based on current states of belief. There may be several sophisticated plans for each intention. Each plan triggers the event handler to achieve the goal based on behavioral description in each plan. An intention consists of a combination of one or more plans. In our current implementation, we use only one plan for each intention. To implement the concept of the BDI mapping table, we use several database tables with Java classes like the following. The related Java codes are shown in the next section. The following table [Table 1] shows the AST database contents.

AST Database	
Table Name	**Content**
Client	Clients' personal information and account balance.
Holding	What kinds and how many stocks clients own.
Orders	All orders clients posted and the agent processed.
Knowledge	Agent's knowledge. Desire, belief values and a synthesis value of belief values.
BPmap	Shows what plan will be chosen according the certain condition.

Table 1. AST Database Contents

It is good to be able to manipulate BDIs dynamically for the BDI-based agent system. Belief can be dynamically changed to represent current environment. Desires can be set and changed to new ones at run time based on current situations such as belief. Intentions can be changed, updated, or newly added to achieve a current desire. However, it is hard to manipulate BDIs directly and dynamically well using Java. To solve this, the belief values can be stored in a file or database table, and can be manipulated dynamically at run time. For this AST application, belief was stored in a database table with which stock agents can consult and update dynamically. In the AST, the desire is also stored and manipulated dynamically in a database table. Both desire and belief are stored at the “Knowledge” table in the AST database. To map the corresponding plans in the intention dynamically based on both the current goal defined in the desire and the current environment based on the belief, another table “BPmap” has been used in the AST system. Among contents in the AST database, the table “Knowledge” is the most important table to manipulate the BDI information dynamically. The following table “Knowledge” shows an example of the knowledge base for desire and belief [Table 2].

AST BDI Knowledge		
Field Name	**Data Type**	**Description**
Symbol	Text	Stock name
A	Number	World economy
B	Number	US economy
C	Number	Financial markets and institutions
E	Number	Others
F	Number	Buy or sell market
Belief	Number	The result of analysis of A~F

Table2. AST Database Knowledge Table Definition

The stock name “Symbol” is a kind of desire to get any recommendation on its stocks through the stock market for stock exchange (either selling or buying). The knowledge A through F represents its belief that represents the current environment surrounding its stock. The final field “Belief” holds the value that we can get from the analysis of the belief factors, A~F, by applying certain mathematical and stochastic equations.

The following table shows the table “BPmap” that describes the mapping to the corresponding plans defined in the intention, from the information based on the current environment defined in the belief [Table 3]. Therefore, it is a kind of mapping table from belief to intention. The “Plan” may have recommendation values for stock exchange such as “Strongly Sell”, “Moderate Sell”, “Hold”, “Moderate Buy”, or “Strongly Buy”. The “PlanChoice” holds the identification number for each plan defined in the AST intention definition. Theoretically, we may have one or a combination of plans. However, to make this example simple, we use only one plan as a recommendation value.

BPmap		
Field Name	**Data Type**	**Description**
LowLimit	Number	Lower limit of belief
UpLimit	Number	Upper limit of belief
Plan	Text	Corresponding plan
PlanChoice	Text	Choice of a plan

Table 3. BPmap Table Definition

3.2 How To Program BDI-Agents

The stock export agent can be created by defining its own Belief, Desire, and Intention classes. The agent has its own main controller whose control structure is shown in Figure 2.

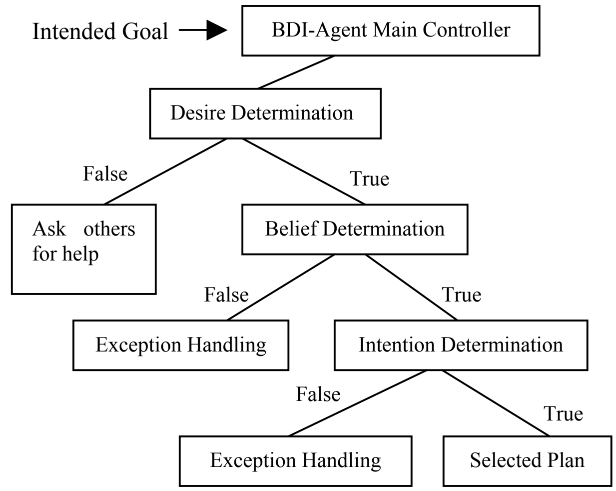


Figure 2: BDI-Agent Runtime Control

With the definitions of necessary belief, desire and intention using Java classes, we can create an agent class by declaring its own belief, desire, and intention from their definitions. When a goal is sent to an agent through the desire, the agent will check whether it can handle. If so, its corresponding desire will be achieved by executing proper plans defined in its intention. If not, it may delegate it to other agents for help. It can be implemented by message exchange among multi-cooperative agents, even though our current system is not implemented in this way. The following code shows the Agent class for the AST application.

```
// Agent.java
package agent;  import java.util.*;  import java.sql.*;
public class Agent {
   public Belief B;   public Desire D;   public Intention I;
   public Agent (Connection x) {  //constructor
       D = new Desire(x);
       B = new Belief(x);
       I = new Intention(x);
   }
    // agent controller
   public String perform(String goal)
   {
       if ( D.achievable(goal) ) {
          int b = B.getBelief(goal);
          if (b==11111)      // 1111 = False flag
             return "Belief sensor error";
          else {
             String p = I.selectPlan(b);
             return p;
          }
       }
       else
          return "Unachievable goal";
   }
}
```

An agent always starts from the behavioral description named “perform” in this application (“perform(String goal)”). A desire is passed to the application through the string “goal”. The desire class checks whether the current goal is achievable or not (by “D.achievable(goal)”). If it is achievable, the system gets the current environment through the belief (by “B.getBelief(goal)”). Unless the current belief is not available, its plan is chosen to achieve the given goal using the information of belief (“I.selectPlan(b)”).

4. EXAMPLE SESSIONS

The AST system is working based on the principles described in the previous sections. Here we just explain an example session with a snap shot of the application.

The AST system starts with the entry form of user login. The registered users may login with their user Ids and passwords. The new user may register into the system. This session is related to the table “Client” in the database [Table 1]. After successful login, a list of services regarding online stock trading that AST can provide appears. Currently the prototype system provides six services such as getting quotes, recommendation for stock trading, deposit/withdraw, order placement, account details, and trading history.

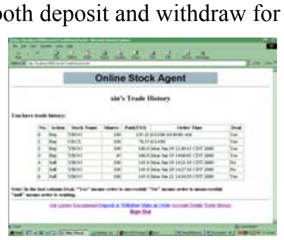
The selection of the stock quote option brings the user to the stock quotation menu. We borrow the Stock Quotes from Yahoo [10], due to the limitation of accessing to a real stock market database.

The recommendation service provides a recommendation to buy, hold, or sell for a certain stock. Actually the expert agent does the back-ground work. Once a user selects a stock and clicks on the “Recommend” button, this stock name will be sent to the expert BDI-Agent as a goal through the servlet program. Then the expert BDI-Agent achieves the goal just as we described in the previous sections. It checks its desire and current belief to select and execute a suitable plan. Finally the expert BDI-Agent sends back its result, the recommendation of the stock, to the interface through the servlet program. Both “Knowledge” and “BPmap” tables [Table 1] are related to this session.

Once the agent performs a certain function needed to get an appropriate recommendation, the system shows the result. This is the corresponding answer from the export agent. For example, the AST system recommends the user to hold the ORCL stock continuously.

User can post his stock order, and the order management agent will process it for the user. The order will be either successful or fail based on the several reasons such as the availability of the stock in the market to buy, and the availability of the funds to buy the stock, and etc. The related table in the database is “Orders” [Table 1].

The account detail option in the main menu can be selected to see the user’s account in detail. It shows what stocks and how much money the user owns. The tables “Client” and “Holding” [Table 1] relate to this session. The user may select the trading history option to see the user’s trade history in the current past. The fund manager handles both deposit and withdraw for the user.



5. CONCLUSIONS

Agent-based computing is emerged as a future-computing paradigm. The BDI model is one of the powerful techniques to describe autonomous intelligent agents. In this paper we have presented a stock trading application based on intelligent agents using the BDI model.

One of the merits of this work is to show how effectively to use an object-oriented language such as Java can be used to implement the BDI-agent-based application. The Java programming language does not support any construct for the BDI-agent concepts. However, in our work, the agent and its desire, and intention are programmed as Java classes. Its information of desire, belief, and intention are stored in a database and updated dynamically at runtime as the environment changes. Therefore, in our work, we show how effectively to use the Java programming language to program the BDI-agent-based application by using a database to implement the knowledge base for BDIs.

We also show how we can manipulate BDIs dynamically at runtime without having any trouble while Java does not support any runtime knowledge management. Our work also shows how we can implement a real world application like stock trading using the BDI-agent model to represent real world problems more naturally in a better way.

One of the future works may implement this system in a real agent-based programming language like APL [8] which we have developed as a concurrent research work. It may prove how the BDI agent model well match the real world solution and solve the complex system more intelligently.

The Java/Servlet programming technique on the Internet has been used to implement our prototype system.

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