Using Multiagent Based on Fuzzy Reasoning Approach to Solve Project Team Work Allocation Problems

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ABSTRACT: *When a new project starts, the right selection of people integrates into a work team in order to carry on the project is of very importance. The success of a project is greatly due to the personal responsibility of each team member, and to an adequate communication, collaboration and co-operation among the team members. Nowadays, the project team formation process is typically performed by a manager based on past experience and available information (though frequently uncertain and dynamic) about the cognitive characteristics of the potential team members. The dynamic and continuously changing nature of construction project team justifies the need for decision support tools with high adaptability and handling of uncertainty which is featured by multi-agent techniques for human resource allocation. An Agent-based Project Management System (AbPMS) is proposed to simulate the interaction of a team member with other team members and with the tasks of a project. Meanwhile, the system is based on the software (Belief, Desire, Intention [BDI]) agents which are used for modeling social human behavior at work, where human characteristics are represented by a set of fuzzy values, model the interaction between the agents to generate the possible performance of a work team are modeled by fuzzy rules. This paper presents the project team agents and techniques in AbPMS and discusses a sample case applying these techniques for the project allocation initialization and human resource management in the urgent state. We use AbPMS platform to perform scenarios of stimulus/response agents in order to solve specific problems, such as project durations, task quality and adaptive allocation emergency response.*

KEYWORDS: *Multiagent systems, BDI, Fuzzy, Project Management.*

1. Introduction

1.1 Research motives

Any project is in need of participation by members within a group and successfully executing jobs to finish one project is of very importance. Making a well-organized team is no easy, because many factors need consideration and evaluation. Factors that are necessarily considered during project running are given as follows:

1. Personal characteristics: Knowing about professional degree and education experience of each person is essential. These characteristics define the patterns of jobs this person is qualified for. Selecting person having relevant experience to finish time-pressing jobs need to consider personal characteristics from objective and subjective views. Thus, how to choose suitable person to join in project team is virtually a key for execution proficiency of project.

2. Social characteristics: Communication and coordination among group members are valued highly concerning whether project team runs smoothly or not, thus social characteristics among team members is one important indicator for selecting staff.

3. Duration and task quality: Project leader often wishes his working team can finish project by using pre-planned schedule. Generally speaking, difficulty and easiness of task executed by each member combines with resources, leading to a possibility that duration is often advanced or delayed. Due to influence of its relation with task quality, selection of project in middle phase is also an important and influential factor.

Thus, before starting project plan, selection of staff and even dispatch and allocation of staff during plan execution are important issues for human resource allocation in project management. Effective integration and utilization of various resources inside company comes to a key determining success and failure of project; additionally, human resource takes priority over all other essential resources. Human resource management is divided into four parts: selection, utilization, cultivation and retention, interrelated with each other. As a new product project launches and forms, project host (manager) pays deliberate attention to selection and utilization of talents. At the start of project, professional talents will join into the project, thus allocating them into tasks which they are most suitable and push project forward smoothly becomes the most important issue. In addition, it must allow for monitoring progress of project at any time in order to solve problems at the first time upon occurrence of emergencies or progress lagging.

In Figure 1, initial allocation of project management is the most important issue in undertaking any project. During project running, the problem of emergent allocation often takes place (Belout and Gauvreau, 2004), thus this study conducts deeper discussion and empirical analysis on two important issues described below:

1. Human resource problem in initial allocation of project management: In order to make project run smoothly during project management, human resource must be configured properly in its initial allocation, otherwise, it affects duration and task quality of project execution.
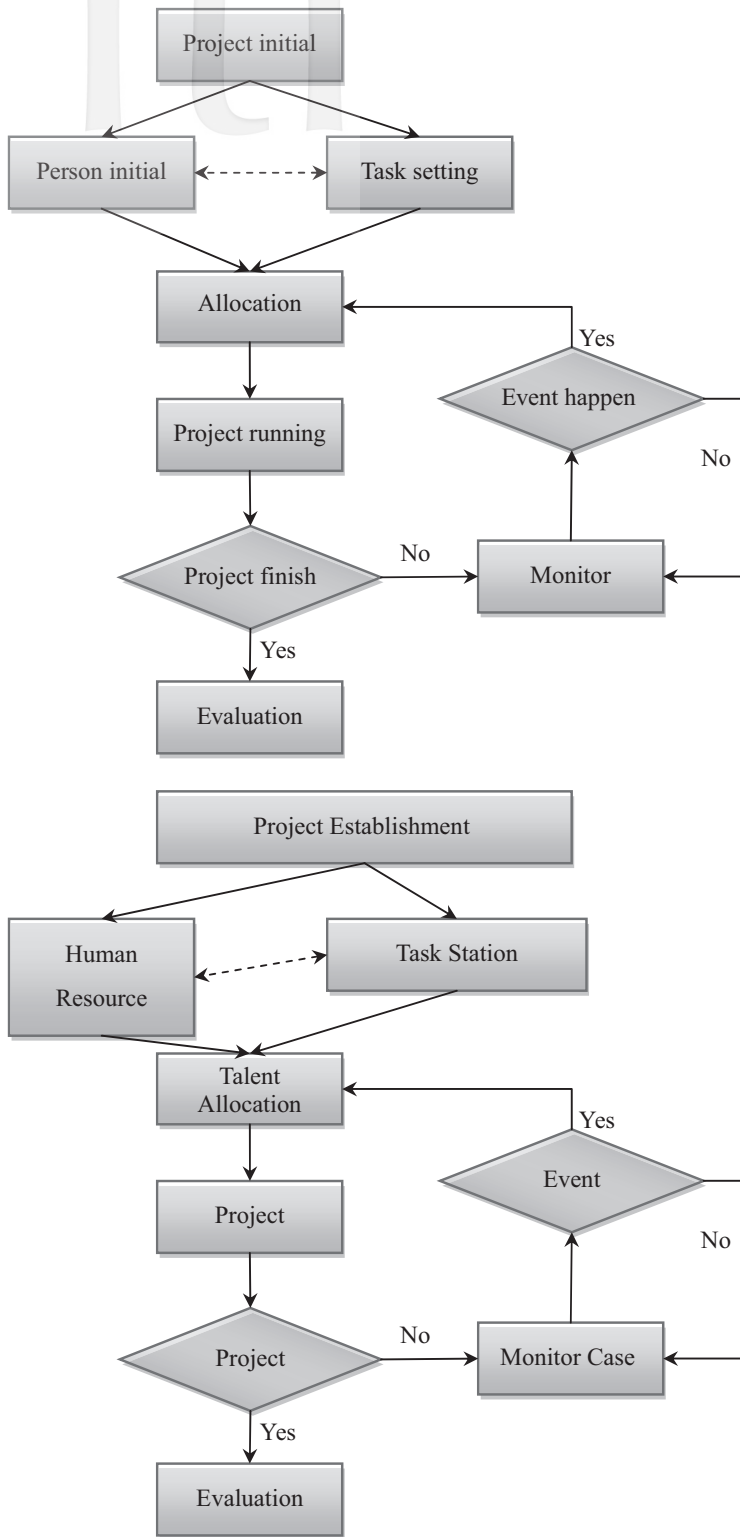
Figure 1 Project Flow Chart

2. Urgent human allocation problem: This essay proposes one function of monitoring project with the aim of monitoring various changes in execution environment at any time and taking responsive actions. Thus, it is supposed that as project management is under way, if sudden event happens to one executor, the task must stop execution. At this time, monitor project will start and select appropriate substitutes who continue executing subsequent tasks.

1.2 Research purpose

In recent years, multiagent system (MAS; Iglesias et al., 1998) helps completion of many complex and routine jobs. To simplify its repeatability, multiagent system doesn't truly represent unique behavior properties of individual decision members but also has its own behavior decision mode, thus it is very suitable to treat human resource allocation problem in project management, handles with many complex and routine jobs, leading to talents problem in human resource of project management are properly configured and solved instead of always considering allocation optimization as the only factor. Much emphasis is paid to agent who owns his unique characteristics and speciality and develops his autonomy to undertake project management. Agent roles established in multiagent system include:

1. Project manager agent: Such agent role must have the capability of managing project and fully understanding and mastering tasks.

2. Engineer agent: Such agent role has expertise and knowledge in particular task.

3. Technician agent: Such agent role has professional knowledge about task in certain field.

4. Assistant agent: Such agent role is good at handling with routine affairs in tasks.

Because agents can't handle with project during project management alone and must interact with each task station (T_i, $i = 1, 2, \ldots\ldots, n$), with respect to description of task station, its definition will be given in combination with agent parameters. T1 parameters include: number of participating people, duration, difficulty and easiness, task pattern and task quality. Agents of all kinds will join in the calculus of properties of task station, configuring each agent to task station properly to execute tasks. Allocation of talent selection is a process that involves autonomous coordination and communication from multiple aspects, with the purpose of realizing suitability of human resource allocation in project management. The purposes of this study are described as follows: (1) regarding talent utilization, an agent-based project management system will be designed by using individual behavior model of agents and timeliness and role analysis and interactive model in GAIA methodology (Wooldridge, Jennings and Kinny, 2000). (2) Agents are introduced into BDI model, and established with their BDI models according to fuzzy

integration of social characteristics, emotion attribution and task characteristics of member roles in project, and configured to determine its duration and quality in project task by means of fuzzy allocation system (FAS).

2. Literature review

2.1 BDI agent theory

2.1.1 Introduction of BDI agent

Philosopher Michael Bratman firstly proposes BDI theory on the basis of actual reasoning inference process of human beings in 1987 (Bratman, 1987). This model describes logically three mental properties and their relations with each other including belief, desire and intention (shortly named as BDI hereunder) based on philosophy and logic theory.

BDI framework is an empirical inference framework that means inference process is similar to decision process in daily lives. The concepts of this framework are seen in Figure 2 and detailed as follows:

1. Belief of revision function: This function is in charge of sensing input from outer cycle and current belief of agents, in this case, produces and integrates new belief in belief database to indicate information sensed by agents under current environment.

2. Option of generation function: This function is used to decide whether agents make proper judgment. The choice judgment is decided by current belief and intention.

3. Filter function: This function represents the deliberation process agent goes through, determines intention of agent and represents what is currently highlighted by agent. It is also the goal that agent tries to realize and finish.

4. Action of selection function: This function is used to decide which action is taken to achieve goal with current intention.

2.1.2 BDI agent framework -- Procedural reasoning system (PRS)

There are two famous frameworks in BDI framework -- IRMA (Intelligent Resource-Bounded Machine Architecture) and PRS. IRMA is mainly proposed by Bratman, Israel and Pollack, including four abstract data structures: plan library, beliefs, desires and intentions. Also, reasoner, means-ends analyzer, opportunity analyzer, filtering process and deliberation process are also used to construct IRMA.
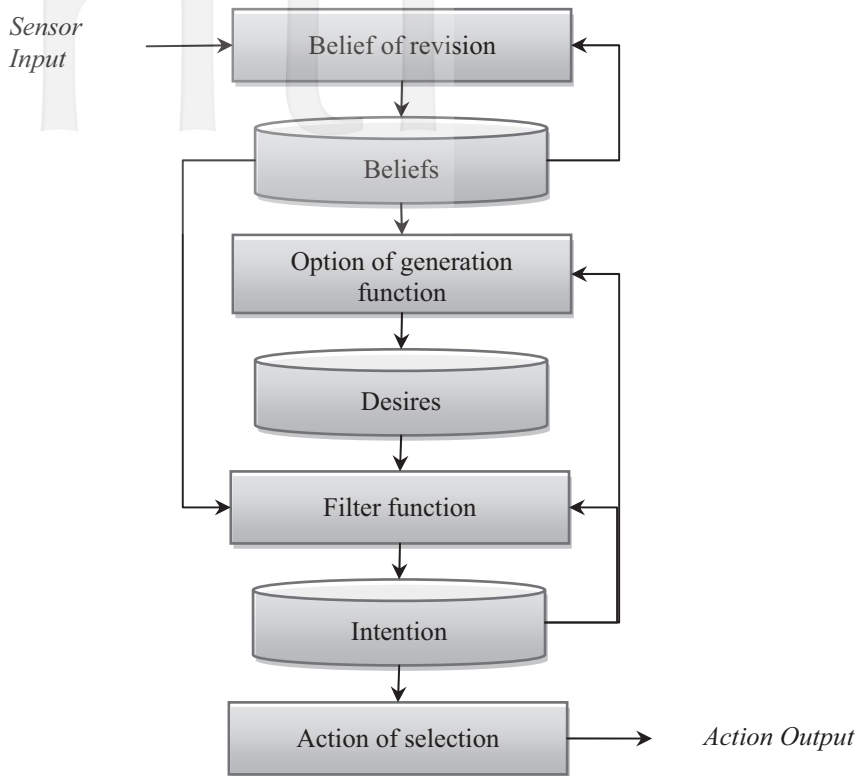
Figure 2   BDI Framework Chart (Wooldridge and Jennings, 1995)

PRS is an agent framework created by practicing BDI agent theory by scholars Georgeff and Lansky (1987), its framework seen in Figure 3. It includes database, knowledge library, goals and intention structure and interpreter. Description is given as follows:

1. Database: It represents information owned by one agent in the world he lives in. It provides agent with beliefs related to current status of the area agent stays.

2. Goals: It arises from environment stimulus or self-monitoring after agent understands demands by him and stipulates goals.

3. Knowledge library: Once the agent stipulates goals, the goal will be developed into the plan of realizing such goals that are expressed by rule forms and produce intention action by linking with database.

4. Intention structure: It represents the request of agent who promises to finish. The task accepted by agent upon his decision is intention of agent, including goal, motivation and evaluation.
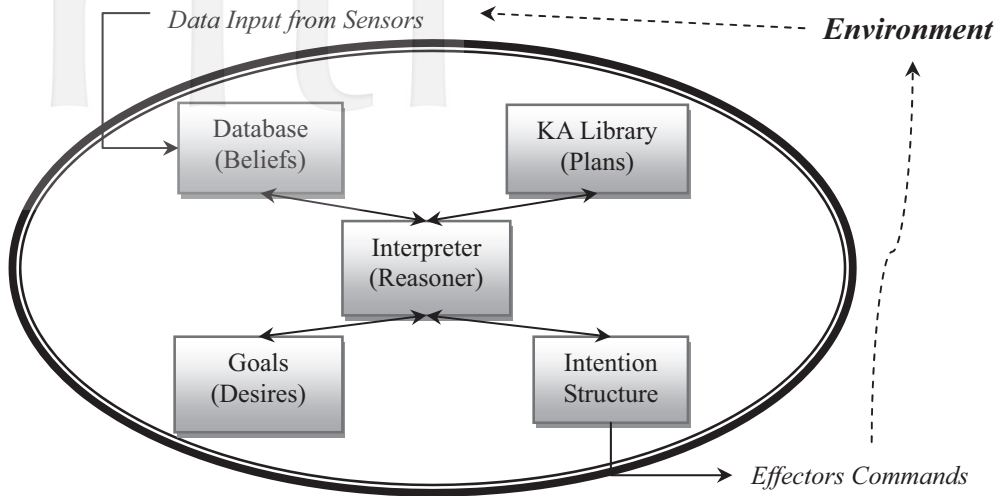
Figure 3 PRS of agent framework chart (Georgeff and Lansky, 1987)

5. Interpreter: As an important factor in BDI agent, interpreter is used to correct beliefs by environmental observation, produce new desires based on new beliefs to choose an acceptable plan, and then forms intention in combination with selected plans and goals. After continually periodical running and environment interaction, finally, the goal is realized.

2.1.3 Realization of BDI agent

In 1995, scholars Rao and Georgeff take the initiative to apply this BDI framework into intelligent agent field. Later on, BDI develops into one of models widely used for reasoning agent. Realization model Map of BDI agent is seen in Figure 4 (Rao and Georgeff, 1995).

Each execution made by interpreter will decide which each goal or event takes place. Therefore, it will select and add one plan from planned candidate list into intention framework to execute; after intention is executed every time, it will be classified into inner event and change inner information or goal and intention. The whole steps are composed of deliberate calculus mechanism based on PRS framework established at initial period and makes BDI theory evolve into an empirical framework and applied into practice.

2.2 GAIA methodology

Wooldridge, Jennings and Kinny (1999) propose a methodology of agent-based analysis and design in 1999 -- GAIA, that regards construction of agent system as one design process of organization to display system framework by means of multi-layer technology conforming to popularization in terms of maintenance and understandability.
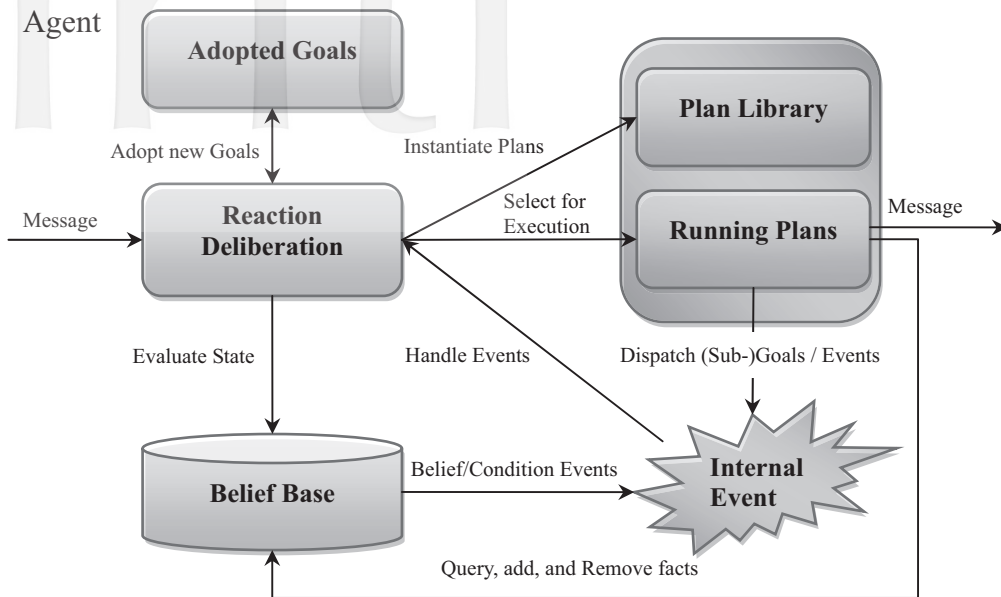
Agent

Figure 4   BDI Model Chart (Rao and Georgeff, 1995)

This system model to be analyzed and designed will develop into one framework Map. To develop research framework, this study summarizes model relation map of GAIA methodology into Figure 5. After demands are submitted, what is required by system will be analyzed in role model and interaction model, and relevant role properties are defined as: responsibilities, permissions, activities and protocols. Based on definition and properties of role demands, the object-oriented concept is converted into agent model; service model is defined and designed by protocol, activity and liveness in role model and interactive model; acquaintance model is designed by activity in role model and interactive model.

Concepts to be analyzed and designed are divided into two types: abstract and concrete, seen in Table 1. Abstract entity is to conceptualize the system during analysis without directly involving realization of system; concrete entity is related to running and execution of system during design.

Social model patterns are used into analysis in view of agent-based analysis. In 1999, Wooldridge, Jennings and Kinny refer to roles as functional classification of agents in society, each role having its unique functional property and responsibility. Roles have four properties in concept of agent-based analysis, including responsibility, permissions, activities and protocols. Responsibility property defines the function of the role that must be done. Responsibility has two properties: safety property and liveness property. Safety property is described as "something good happens" meaning a status of thing carried by agent in given environment condition. Liveness property is described as "nothing
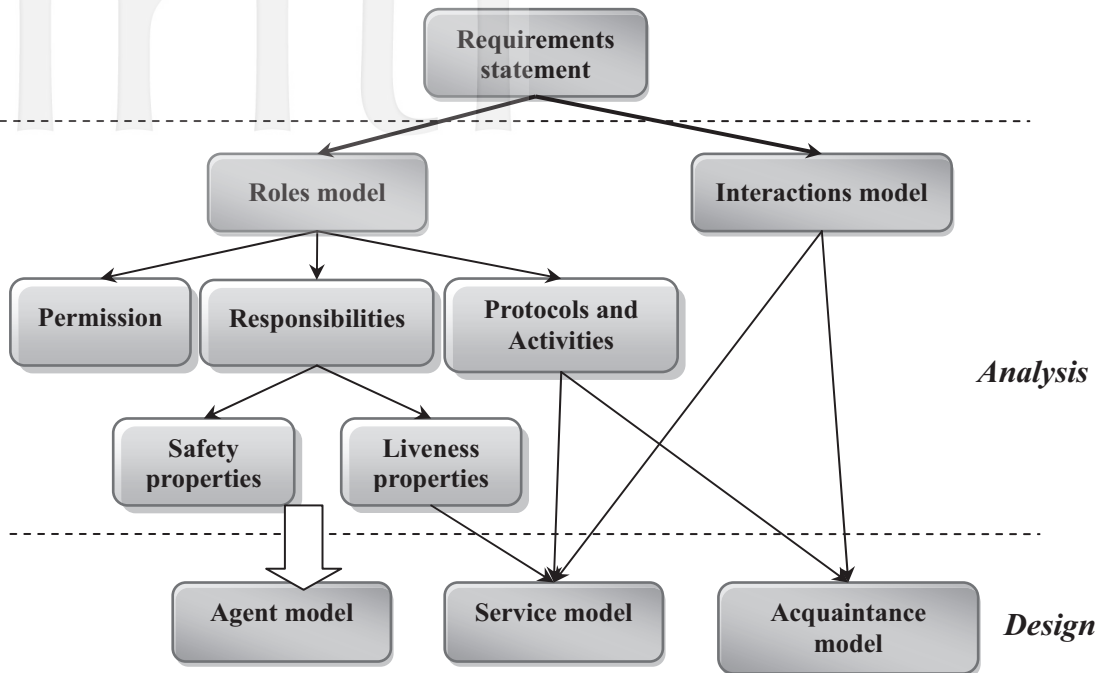
Figure 5 Method Relation Chart

Table 1 Abstract and Concrete Concepts

Abstract concepts	Concrete concepts
Roles	Agent Types
Permissions	Services
Responsibilities	Acquaintances
Protocols	
Activities	
Liveness properties	
Safety properties	

bad happens," meaning a status of acceptable thing is maintained during execution. Permission property is right limit of roles, defines information resources that are stored, corrected or produced by roles. Activity property represents execution force of role itself. Protocol property defines interaction approach among roles.

Role model is composed of a group of role outlines. Each role in system has its role outline. In this outline, role name, role description, protocol and activity property, permission property and responsibility property (incorporating liveness property and safety property) are included. Role models are seen in Figure 6.

Role Schema	Name of Role
Description	short English description of the role
Protocols and Activities	protocols and activities in which the role plays a part
Permissions	"rights" associated with the role
Responsibilities	
Liveness	liveness responsibilities
Safety	safety responsibilities

Figure 6   Role Model

Interactions Model defines interactive relation amid roles and consists of a group of protocols. Interaction for each role is endowed with one protocol. This protocol has the following properties:

1.   Purpose: Brief description of the nature of interaction.

2.   Initiator: Which role is responsible for initiating interaction.

3.   Responder: Role object which interacts with initiator.

4.   Inputs: Information applied by initiator when protocol is adopted.

5.   Outputs: Information delivered by responder during interaction.

6.   Processing: Brief description of the procedures of interaction made by initiator.

Agent-based design program produces three models in view of agent-based design, including agent model, service model and acquaintances model. Agent model confirms agent pattern constituting the system and agent instance of realizing such agent pattern during execution period. Service model confirms major service in each agent pattern, namely, confirms agent function. In view of object-oriented terms, service is similar with method. One object method is called by other objects, whereas agent service is one kind of service uniquely owned and participated in by single agent, not able to be called by other agents. Acquaintances model defines communication and linkage among agents of all kinds. By means of graph indication, this model neither defines message delivered by each communication and linkage nor when such message is delivered, instead, simply indicates communication routes among agents of all kinds.

2.3 Fuzzy allocation system (FAS)

This paper proposes basic framework of FAS consisting of control rule database and fuzzy decision logic, with its basic framework map seen in Figure 7. In principle, design steps of this framework are described as follows:
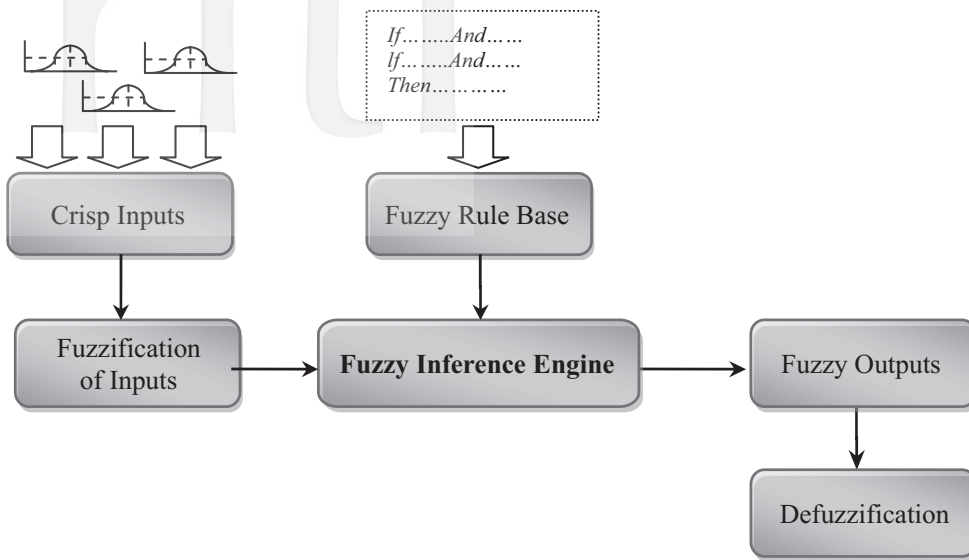
Figure 7 FAS Flow Chart

Agents are introduced into BDI model, and established with their BDI models according to fuzzy integration of social characteristics, emotion attribution and task characteristics of member roles in project, and configured to determine its duration and quality in project task by means of fuzzy allocation system (FAS).

1. Factor input: Firstly, social characteristic, emotion attribution and task property related to agent in BDI model and membership function categories are determined.

2. Fuzzy input: In order to decide universe of discourse for each variable, measurement and operation scope of output and input variables are decided on actual status. And then language presentation matters and corresponding membership function of each variable are arranged.

3. Fuzzy engine and fuzzy rule: enerally, convert it into fuzzy rule base explained by language with experience of operator and expert knowledge. Conditional rules narrating linguistic meanings like If-Then are usually used.

Fuzzy inference engine conducts inference when concepts narrated in judgment sentence are not clear to make composition calculus in fuzzy theory under existing logic rules (Mamdami and Assilina, 1975). Generally use max-min product composition, max-product composition, max-bounded product composition, max-drastic product composition, etc. This essay utilizes Mamdani inference method (namely, max-min composition).

4. Fuzzification output and defuzzification: Defuzzification means to convert duration and task quality in fuzzy output of project task inferred into real crisp values, adopting three methods, e.g. center of gravity, center of maximum and mean of maximum. In this essay, use center of gravity to make defuzzification. Because it is suitable to continual output value, its principle is the same as acquiring center of gravity location of objects, namely, acquiring center value of fuzzy integration to represent the whole fuzzy integration. It is supposed that membership function of fuzzy integration is u_i, when inferred value y_i (refer to duration and task quality) is continual under I rule, center of gravity method is shown in formula(1) as:

$$y'_{COG} = \frac{\int y_i u_i(y_i) dy_i}{\int u_i(y_i) dy_i} \tag{1}$$

3. Agent-based project management system (AbPMS)

This essay studies analysis and design of the core parts in this framework by means of milt-level technique (Nwana and Woddridge, 1996), analyzing roles modules to analyze demands of project management layers for role analysis and defining role characteristics. It further extends to agent module to design communication and interaction of roles and actions in agent-based system (Wood and DeLoach, 2001), and establishes inner actions in agent model by using object modules and add group organization and calculus of fuzzy allocation system to develop agent-based project management system (AbPMS). Finally, it designs exemplars by using UML object-oriented to practice exemplars and simulate results by JAVA language and medium software platform (JadeX, 2007). Figure 8 shows the study framework map in this essay.

3.1 Project management of group organization

This essay advances the allocation principle of applying group organization concept in the human resource allocation, which makes trans-department manpower selection, not depending on the experience or technology, but more widely considering social characteristic and emotion attribution to select the task executor, and reflecting such two characteristics in the system as variables. Group organization will show an interaction between the organization and the group during the process of human resource allocation; at this time, the project management leader will make negotiation and coordination with leaders of different departments, thus to produce an harmonious effect among the project management leader, department leader, and candidate, and improve the system flexibility and feasibility. The group organization concept map is shown as Figure 9. It is supposed
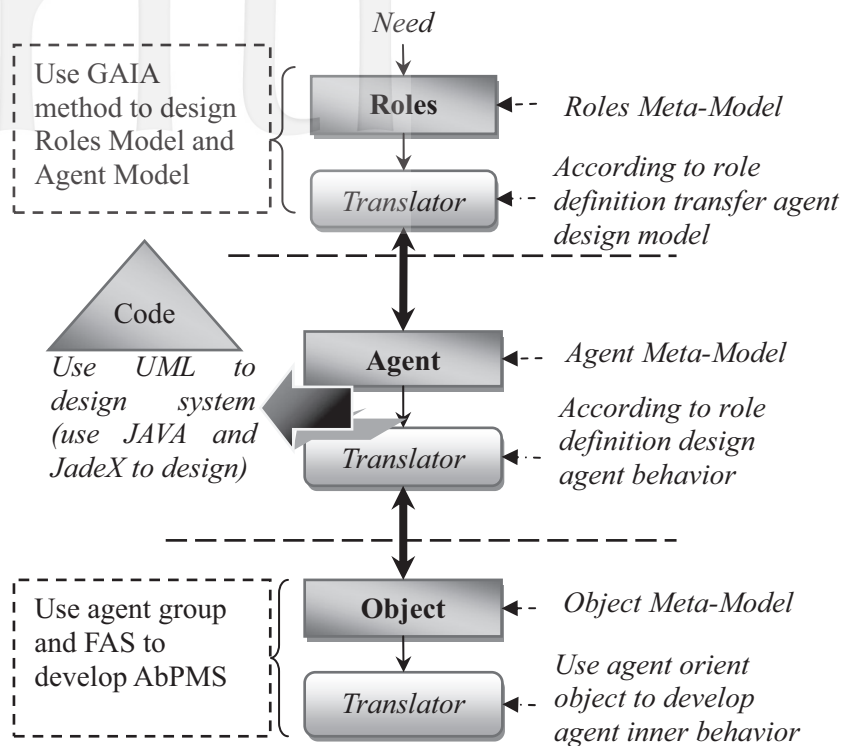
Figure 8 Research Framework Chart

that there are three members in Department_1: PA11, PA12, and PA13 and three members in Department_2: PA21, PA22, and PA23. Based on the group organization concept, use the BDI mode of the candidates to present their autonomy and use FAS to allocate the attributive group; the result shows that they are divided into three groups: Group 1, Group 2, and Group 3. Therefore, the department leader, project management leader, and the candidate will form an interactive relationship involving mutual communication and influence. Through such communication and coordination, there can arrange allocation processes for different requirements.

3.2 Analysis of GAIA methodology

Known from literature review, GAIA method is divided into two parts: analysis and design. Analysis has two phases including role analysis and interaction analysis. They are used in role analysis to define role characteristics and communication and interaction of roles and actions respectively.

As requirements of founded project generate, proposal person (PP) will receive project requirements and analyze resources required by project, including number of task station required, relevant task information, and delivery of talent recruitment message.
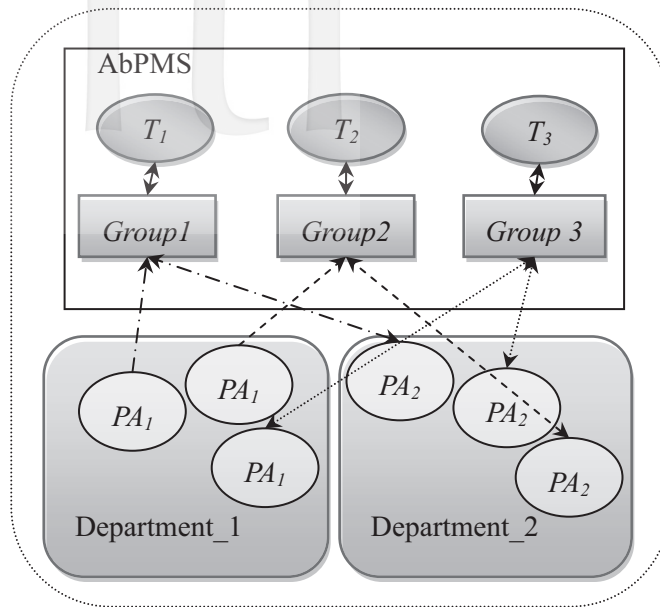
Figure 9   Group Concept Chart

For example: as one project is founded, PP will propose how many task stations should be produced on the basis of project requirements; meanwhile, deliver messages to relevant selected talents and inform them such requirements. Therefore, from above description, it is known that PP has two protocol properties and one activity property: Get Project Requirements is to receive and analyze project requirements; Produce Analysis is to analyze resources required by project; Send Project Requirement Messages is to deliver requirement messages to relevant roles. PP is the only role who has the right of reading required resources and producing talent recruitment messages in permission properties. As to responsibility property, when requirements exist, he will continuously undertake tasks in protocol property and activity properties and deliver requirement messages to other roles. Role model map of proposal person is seen in Figure 10. Furthermore, this essay proposes six role models to construct role analysis process, including task generator (TG), project person (ProP), fuzzy allocation system (FAS), task manager (TM), project leader (PL) and monitor inspector (MI).

In GAIA methodology, interaction analysis narrates protocol property relations among roles. Thus, protocol property during role analysis is considered as important point in interaction analysis. In project management, interaction protocol is divided into four parts: PP gets project requirement notice and generates project requirements, task generator gets project requirement message, task manager gets task details, proposal person gets task target, all of which finish human resource allocation procedures in fuzzy allocation system; as task station manager (TM) gets allocation result delivered
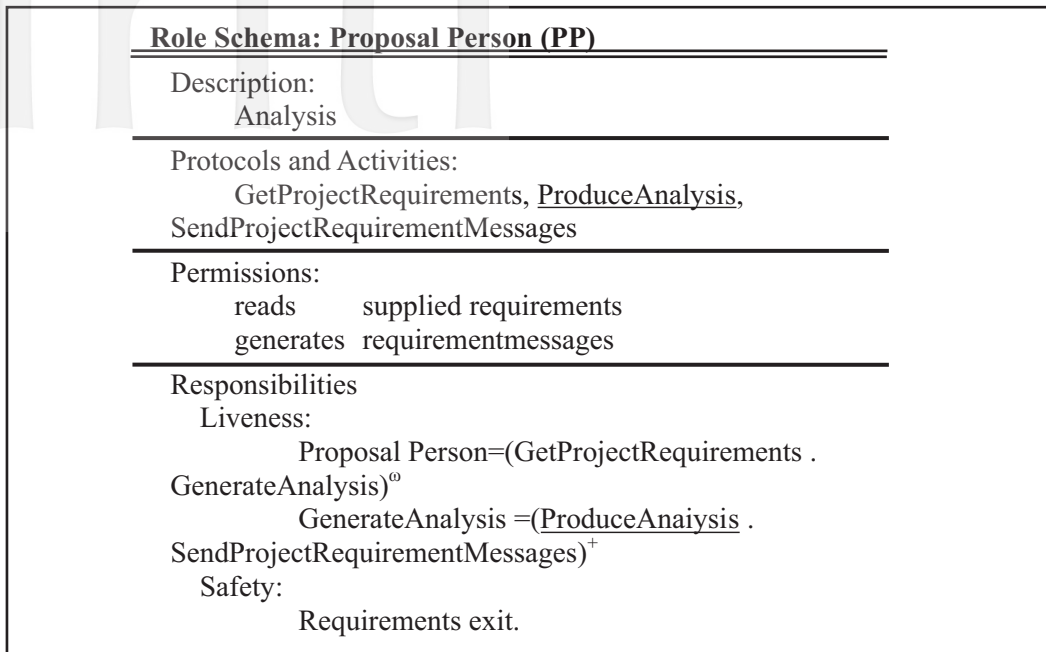
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__Role Schema: Proposal Person (PP)__

Description:
    Analysis

Protocols and Activities:
    GetProjectRequirements, <u>ProduceAnalysis</u>,
SendProjectRequirementMessages

Permissions:
    reads   supplied requirements
    generates requirementmessages

Responsibilities
  Liveness:
       Proposal Person=(GetProjectRequirements .
GenerateAnalysis)$^{\omega}$
       GenerateAnalysis =(<u>ProduceAnaiysis</u> .
SendProjectRequirementMessages)$^{+}$
  Safety:
       Requirements exit.

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Figure 10 Proposal Person (PP) Model

by proposal person, three different exemplars will occur (send task executor, send task progress and send negotiation message). Therefore, four protocol exemplars will take place, including human resource allocation protocol process, project monitor protocol process, protocol process negotiated between task manger and proposal person and selection protocol of project leader. Project monitor protocol process is seen as in Figure 11.

3.3 Design of GAIA methodology

In this section, three models in design of GAIA methodology include: agent model, service model and acquaintance model. They are used to design inner action of agent module.

Agent module confirms agent patterns constituting system, agent instance of realizing such agent patterns during execution period, and put such instances into practice into system. Generally speaking, each agent is usually one substantiated role in role analysis, designed and practiced in system. Thus, this essay regards roles with different patterns as agent model to construct one system. List of role converting into agent is seen in Table 2. Figure 12 is agent model.

Service module confirms major service of each agent pattern, namely, function of agent. In view of object-oriented terms, service is similar with method. One object method is called by other objects, whereas agent service is one kind of service uniquely
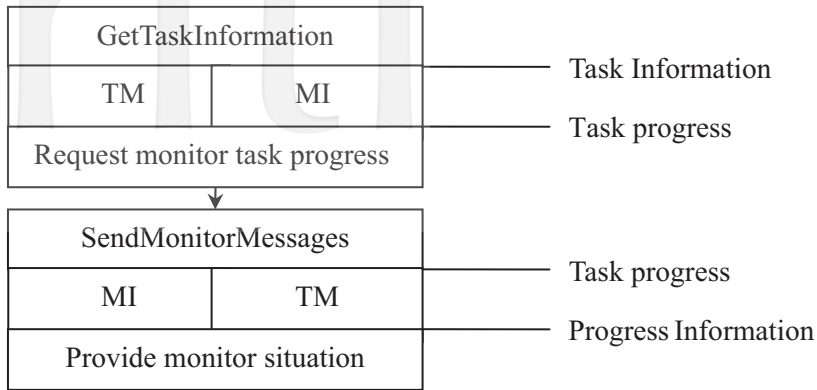
Figure 11 Project Monitor Process

Table 2 Role-Agent Transformation

Role	Agent
Proposal Person (PP)	Proposal Agent (ProA)
Task Generator (TG)	Task Generator Agent (TGA)
Task Manager (TM)	Task (T_i)
Project person (ProP)	Project Agent (PA_j; j = 1, 2,......, m)
Fuzzy Allocation System (FAS)	Fuzzy Allocation System (FAS)
Project Leader (PL)	Project Manager Agent (PMA)
Monitor Inspector (MI)	Graphics Agent (GraA)

owned and participated in by single agent, not able to be called by other agents. In GAIA methodology, service model can get designed module from analyzed activity and liveness of responsibility property in GAIA methodology. Service module consists of inputs, outputs, pre-condition and post-condition. Inputs and outputs can be designed in interaction analysis; pre-condition and post-condition are designed in security property in responsibility property. Service item establishment list of service model is seen in Table 3.

Acquaintances model defines communication and linkage amid various agents. By means of graph indication, this model neither defines message delivered by each communication and linkage nor when such message is delivered, instead, simply indicates communication routes among agents of all kinds. Acquaintance model map is seen in Figure 13.
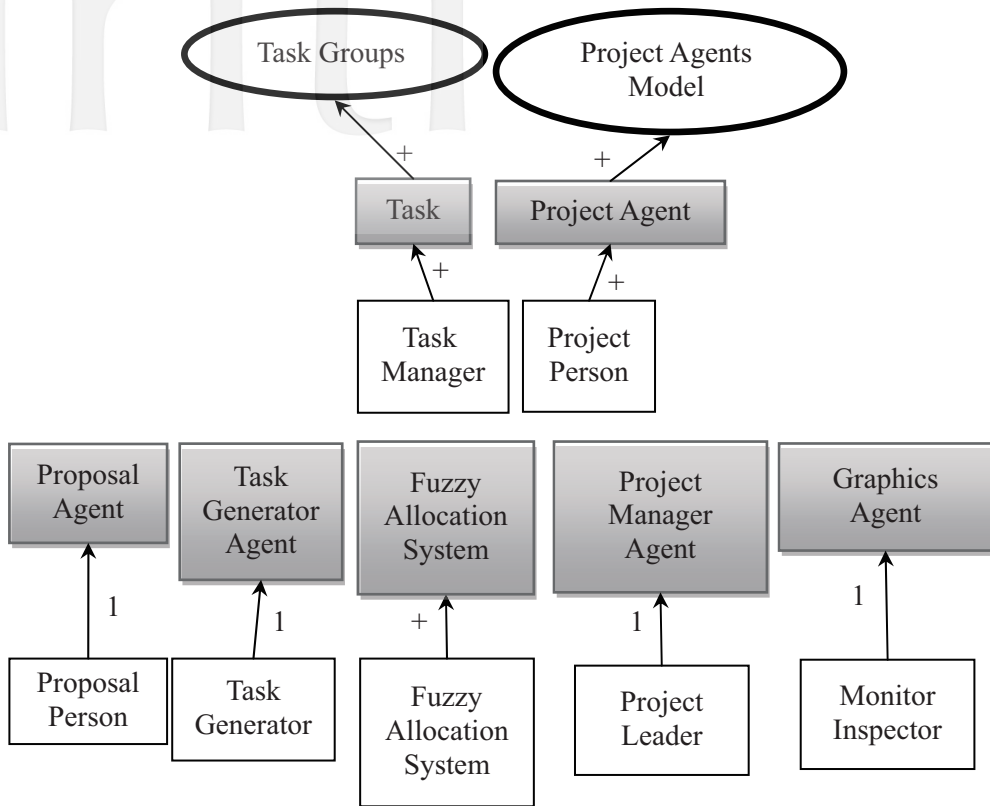
Figure 12 Agent Model

Table 3 Service Model

| Service	Inputs	Outputs	Pre-condition	Post-condition
Get Project Requirements	Requirements	Requirements details	True	True
Produce Analysis	Requirements details	Requirement messages	True	True
Produce Tasks	Requirement messages	Task details	True	True
Alter Tasks	Requirement messages	Task details	True	True
Compare Fuzzy Allocation	Fuzzy allocation outputs	Allocation information	True	True
Send Messages	Allocation information	Allocation information messages	True	True
Computer Fuzzy Allocation	Fuzzy allocation inputs	Fuzzy allocation outputs	True	True
Update Task Data	Task details	Task information	True	True
Find Task Executor	Allocation result	Task executor	True	True
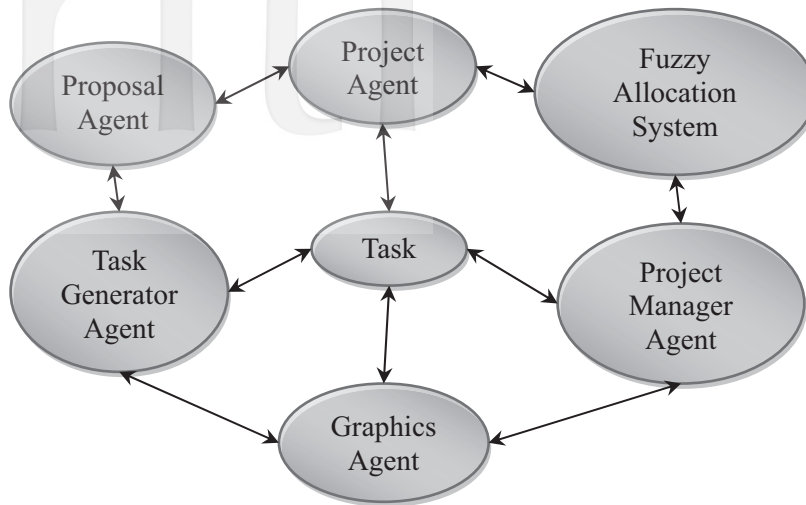
Figure 13   Association Model

After analyzing and designing overall requirements by using GAIA methodology, this essay proposes an agent-based project management system (AbPMS) framework according to relevant analysis to understand what role each agent plays during the whole project management and their tasks. This agent-based project management system framework is seen as Figure 14. Task station is shortly named as T_i (i = 1, 2,……, n); project agent is shortly named as PA_j (j = 1, 2,……, m); i, j, k refers *to* task station, project agent and department number respectively.

3.4 Process of human resource allocation

This essay proposes human resource allocation process involving group organization concept, BDI module of project agent and fuzzy allocation system (FAS). Therefore, project agent will actively configure task station. As requirements generate, project management will initiate structures. ProA in system framework who participate in this process will receive requirements and send proposal to TGA to set up relevant task station, which is called as initiation; as initiation finishes, project agent (PA_j) notified will make inner BDI module calculus, conduct fuzzy inference and calculus on each inner parameter and variable in FAS, interact with task station groups and conduct proper allocation. After allocation, verify whether repeated executor exists during allocation of task station. At this time, each T_i is put into verification. In case repeated executor exists, a new allocation principle will be sent to project agent to conduct partial fuzzy inference calculation and allocation in FAS until task station is configured; finally, *GraA* is in charge of monitoring project and urgent treatment. ProA continues to receive changes of tasks from outside. Human resource allocation process of project agent is seen as Figure 15.
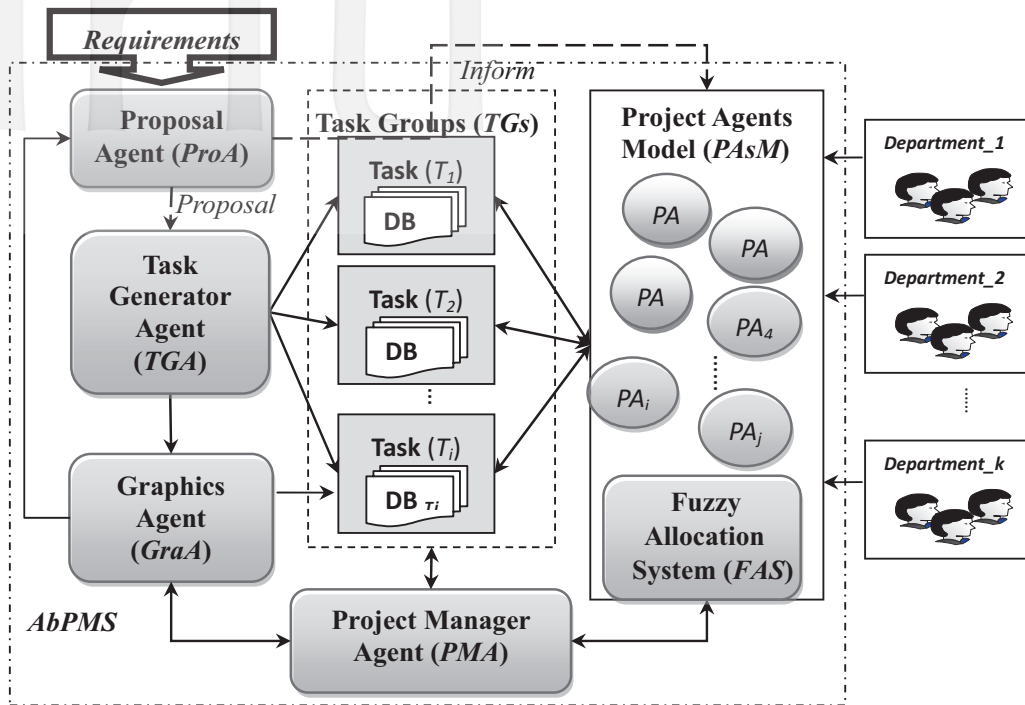
Figure 14 AbPMS

i: Numbers of Task
j: Numbers of project agent
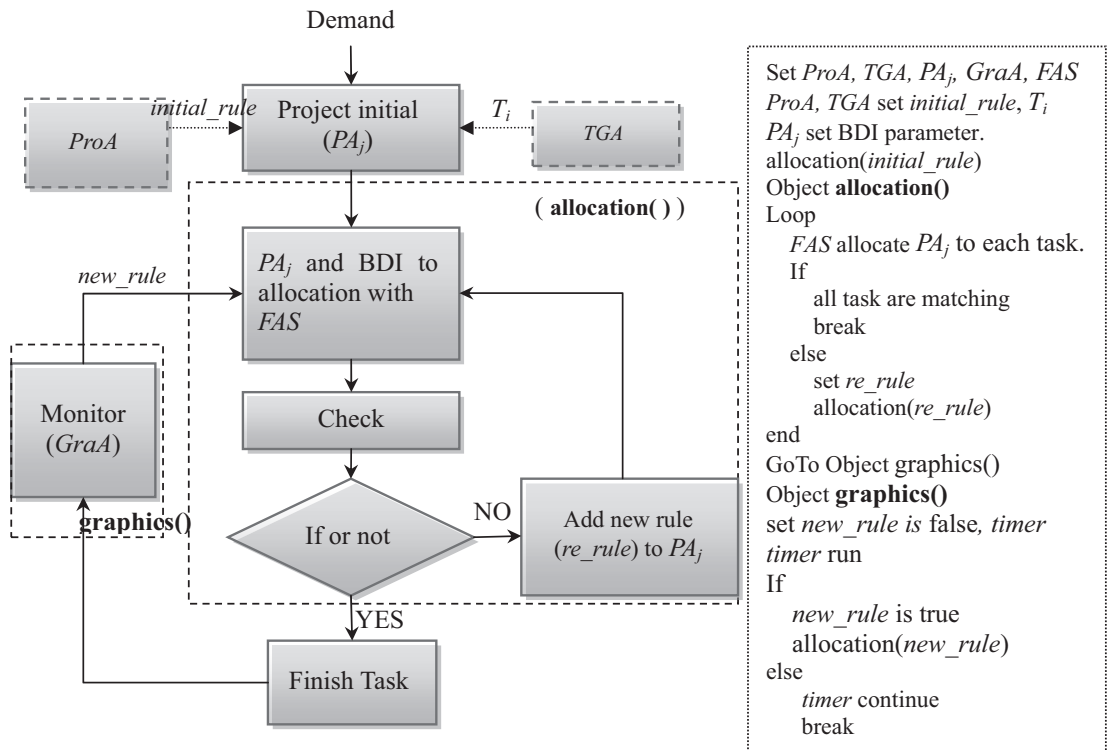*k: Number of departments*

Figure 15 Project Allocation Process

4. Performance of agent-based project management system

This essay puts two questions mentioned in foreword into practice in system, constructs FAS and performs project agent (PA_j) by using project agent model in AbPMS. Use JadeX medium platform, make agent communicate with other agents through ACL message, and construct task groups (TGs) in AbPMS by using GUI interface developed by JAVA. Finally, in simulation tests, two exemplars including human resource allocation and urgent human allocation are supposed to conduct simulation process for validating feasibility and applicability of this system in terms of performance.

4.1 FAS performance

FAS plays an important role in exemplars mentioned by this essay, utilizes fuzzy inference to conduct calculus of different parameters and also combines results with project monitor. Its performance process is described as follows:

4.1.1 Step 1 -- define its variables

This essay makes calculus on variables selected from exemplars. Variables include: *Creativity*, *Experience*, *Desire*, *Interest*, *Stress*, *Difficulty*, *Type*, *duration* and *quality*. Variables are defined by fuzzification. Stress is defined to include three linguistic variables: *Low* (0~25), *Medium* (20~80) and *High* (65~100). *Duration* is defined as five linguistic variables: *Excellent* (-30~-10), *High* (-15~0), *Acceptable* (-5~5), *Regular* (0~15) and *Low* (10~30). *Quality* is defined as five linguistic variables: *Very Low* (0~30), *Low* (25~65), *Minimum* (45~75), *Acceptable* (65~95) and *Satisfactory* (90~100). Other variables are defined as three linguistic variables: *Low* (0~35), *Medium* (25~75) and *High* (65~100).

4.1.2 Step 2 -- decide its fuzzy sets

Each fuzzy sets is presented by each membership function graph. This essay uses Gaussian-type membership function to show membership function of each variable, make each variable value in linguistics overlap and interact with each other and meet the requirements of continual calculus.

4.1.3 Step 3 -- construct fuzzy rules

This essay constructs fuzzy rules for different variables, setting up 180 rules through linguistic matching, and conducts inference. Finally, parameters are acquired in defuzzification. Exemplar rules are described as follows:

RULE: IF (Difficulty IS low) AND (Experience IS low) AND (Interest IS low) AND (Stress IS low) THEN (duration IS regular).

4.1.4 Step 4 -- de-fuzzificate output variables of duration and task quality in project task

Finally, calculus is made. This essay will use UML in JAVA language and jFuzzyLogic to develop FAS.

4.2 Project agent performance

After FAS is constructed, this essay will continue to perform project agent (PA_j, description is made by taking PA_j as example hereunder). This essay will use XML to generate single PA_j, conforming to object provided by JadeX, allow agent to inherit category provided by JadeX during practice undertaking. These categories include beliefs, goals, plans, events and properties. Practicing is described as follows:

1. Beliefs: Receive events given from outer environment and deliver them to inner properties to generate new goals, record agent properties in map gathering, allow agent to make calculus on T_i property value according to property value contained in map.

2. Goals: Mainly record results acquired from calculating FAS and execution goals each time, allow agent to find suitable goals from selecting goals to execute such goals. Variables contained are seen in Table 4.

Table 4   FAS Goals

Variable	Type	Define
Difficulty	String	Record T_i parameter: *Difficulty*
Type	String	Record T_i parameter: *Type*
Result	String	Record FAS result: (duration, quality)

3. Plans: Mainly execute methods. In this practicing, there are three methods established: agent execution procedure, allocation procedure and message delivery procedure. In agent execution procedure, agent will judge pattern generated by new beliefs to judge which method is adopted, and respond to outer environment by executing such method; allocation procedure will make calculus on inner properties and parameter values delivered by T_i in FAS system and receive results; message delivery procedure is to communicate received results with project leader and T_i.

4. Events: Mainly define format setting delivered by message, communicate and deliver messages by following ACL Message standard (FIPA, 2007). In this practicing, ACLMessage.REQUEST and ACLMessage.INFORM are incorporated to receive

request and parameter of T_i respectively.   INFORM has two functions: notify results by using messages delivered back after allocation; as T_i selects a certain agent to execute task, deliver a message related to whether participate in or not.

5. Properties: Mainly record all activities of agents undertaking in JadeX platform, for the convenience of record and request in the future.

5. Application examples

This essay uses situational description to construct simulated environment to describe AbPMS proposed by this essay, including role description of agent, description of task station and description of simulation conditions, and then describes the procedures by means of two supposed examples. The involved party configures PA_j by using property values given by different T_i and configures PA_j into proper task station for executing task and solving human resource allocation problem in project management.   Furthermore, when project management is under way, if urgency occurs when PA_j is executing task, he must stop executing task. At this time, AbPMS monitor system will send messages and inform other PA_j and configure new executors to implement unfinished tasks.

Supposed conditions are described as follows: (1) Suppose that task station in human resource allocation has single task and single executor, however, human resource takes priority over other resources in allocation. Suppose if urgency occurs, other relevant human resources will be given preference to execute tasks. (2) Suppose when urgency occurs, schedules arrangement amid task stations will be not affected and cost limitation and calculation are not considered.

5.1 Human resource problem in initial allocation of project management

Suppose there are 12 T_i and 10 PA_j in project management, including 1 project management agent, 3 engineer agents, 3 technician agents and 3 assistant agents, to participate in allocation process. Each parameter is produced by using normal distribution method, to render uncertain change of variables, with simulation executed for 30 times. This essay develops agent allocation interface (see Figure 16) and task station allocation interface (see Figure 17) allowing users to access parameters setting.

It is known that menu of agent allocation interface includes agent allocation, task allocation and monitor interface. In agent allocation, agent sets up its parameters on interface. As setting finishes, press "Show" to check in lower window. If errorless, press "Create Agent" to generate ADF file in XML and agent appears in right side of "Created Agent" window. If setting is wrong, press "Clear" to set up parameters again.
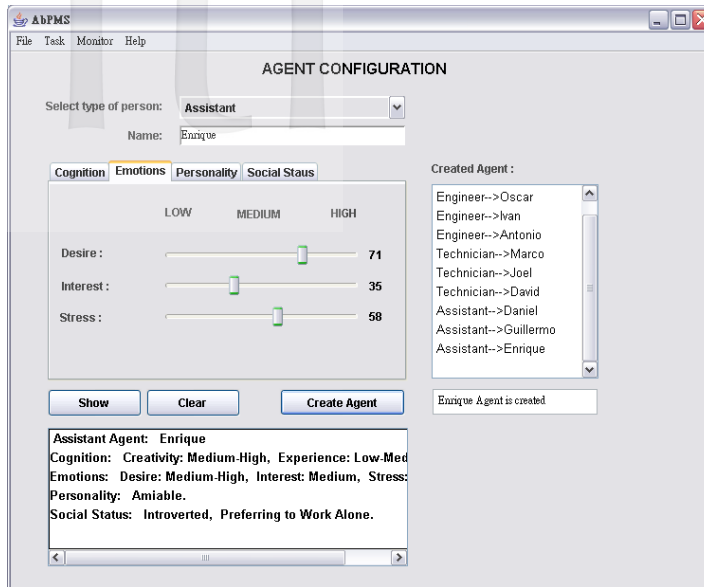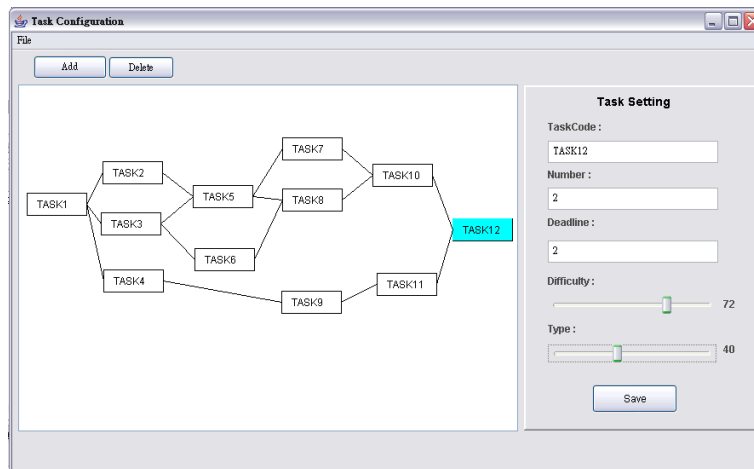
Figure 16 Agent Configuration

Figure 17 Task Configuration

Task station allocation user interface is seen in Figure 17. On this interface, it can add task station, set up the order of priority of task station. If clicking task station, parameters can be set up on "Task Setting" window in right side, including: number of participated people, duration, task difficulty and task pattern. Finally, press "Save" to store information of task station and enter into monitor state.

Finally, after PA_j and T_i complete setting, with JadeX platform combined and used, status and allocation result of each PA_j are understood. During allocation, PMA will participate in coordination of repeated use problem of human resource, meanwhile,

evaluate composites with higher benefits. Simulated results of duration and task quality outputs in this essay are seen in Figure 18 and Figure 19 respectively. Known from results, in task stations of T_1, T_2, T_3, T_9 and T_{10}, their agents will complete tasks as scheduled, other agents are under delay state; Regarding performance of task quality, agents in task stations of T_1 and T_2 will provide tasks with higher quality. These two statistics maps are demonstrated to make users and project leaders clearly acquire relevant utility messages and analysis results.

5.2 Urgent human resource allocation problem

This essay also proposes a function of monitoring project with the aim of monitoring changes of environment at any time for giving responses. Therefore, suppose when project management is under way and one PA_j is executing task, if urgency occurs, he must stop
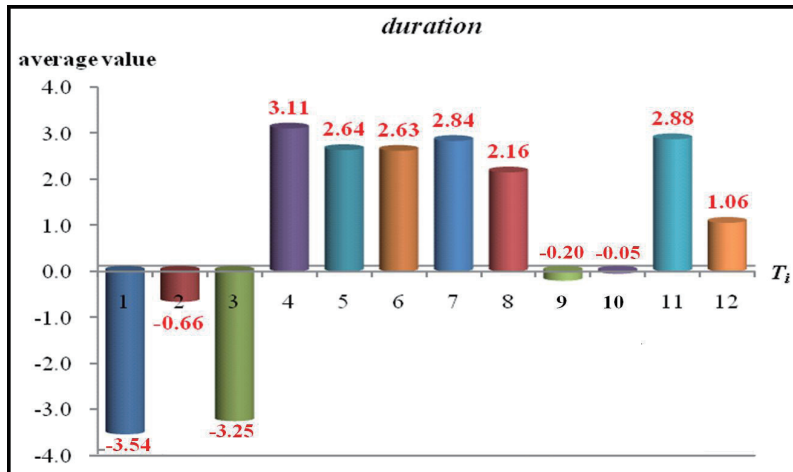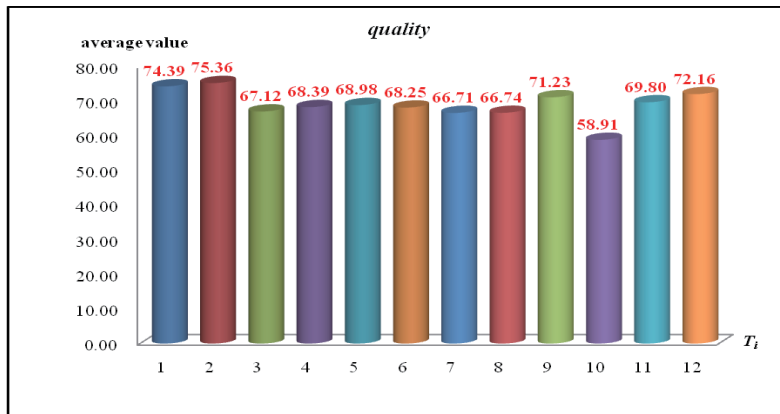

Figure 18   Duration Output

Figure 19   Quality Output

executing task. At this time, AbPMS monitor system will send messages to inform other PA_j to configure new executor for executing subsequent tasks. Its monitor interface is seen in Figure 20.

Simulated results are described as follows: Suppose during project monitoring, monitor interface moves until T_5, Graphics Agent (GraA) will know about lagging events and send messages to Project Manager Agent (PMA) to execute the task of picking up substitutes: PMA will enter into project and execute tasks through FAS allocation calculus and send request concerning whether working with allocation calculus. Sending request will not stop until new project agent is found. Message delivery process is seen in Figure 21. It is known from communication messages that agent Joel will take over task 5.
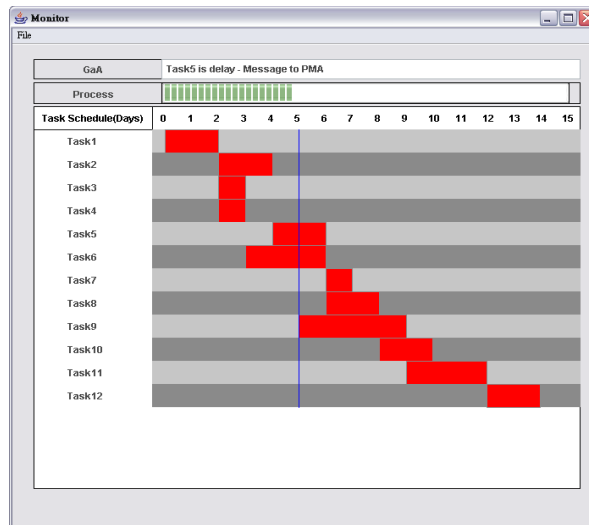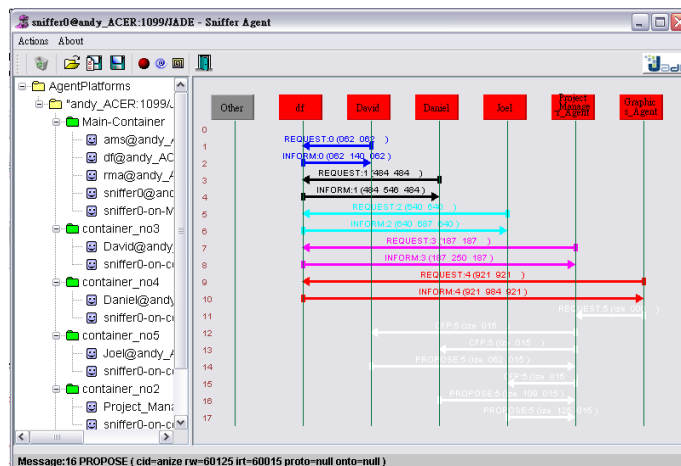

Figure 20 Progress Monitor

Figure 21 Rush Allocation Message Transfer Each Other

6. Conclusion and subsequent research direction

This essay mainly discusses and practices human resource allocation and urgent human allocation in project management. In the process of study, it is able to rapidly understand, perform and construct AbPMS by means of GAIA methodology and a whole set of system framework theory, allowing project management to finish project plan based on this system. Agent technique is applied into project management through application of PA_j and T_i allocation constructed by this essay and monitor interface. Meanwhile, construction of BDI agent permits agent roles to allocate themselves in task stations in combination with FAS system according to methods and parameters used during participating in project, and adjust change of inner parameters depending on beliefs provided in different environment, which truly demonstrates characteristics of agents and function of real-time project monitor.

Because project management involves wide issues for discussion, subsequently, it can be extended from existing AbPMS model to other discussion topics as follows:

1. Resource conflict problem: When a project is undertaken, task delay problem often occurs, causing project in need of great change, and even progress of overall project to be affected, thus, how to control human resource and adjust project progress to solve resource conflict in project needs further discussion.

2. Multi-project problem: In enterprises, projects are undertaken in multiple ways. Only undertaking single project never happens. Thus, how to allocate human resource and develop function of monitoring multiple projects to allocate project with suitable human resources for the goal of completing tasks will become another issue worthy of investigation.

In conclusion, this essay focuses on practicing human resource allocation problem and urgent human resource allocation problem, constructs AbPMS to develop BDI multi-agent system function on the basis of GAIA methodology. This system has an opened framework, thus to incorporate different project management issues and provide for project managers in terms of practice application.

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