A Controllable Reputation BDI Model

Jun Hu
School of Information Science & Technology, Hunan University, Changsha, China
Email: hujun_111@hnu.cn

Yang Yu
School of Information Science & Technology, Hunan University, Changsha, China
Email: yuyang@hnu.edu.cn

***Abstract*—The architecture and reasoning mechanisms of traditional BDI (Beliefs-Desires-Intentions) agent have some vital shortcomings such as the inability to provide a clear and simple decision-making mechanism, and the difficulty to predict and control Agent's behavior as a result of its autonomy and the lack of conflict management mechanisms, and lack of reliability evaluation of Agent behaviors. These shortcomings fundamentally restrict and hamper BDI based agents applying to some new areas. In this paper, by taking advantage of the non-monotonic knowledge representation and reasoning mechanisms of defeasible logic, a reputation-oriented Agent model is proposed, which is capable of accepting policy guidance, the real-time rule modifications, and handling the run-time rule conflicts. This agent is both autonomous and controllable, and is able to cooperate with other Agents via contracts in an open and dynamic environment.**

***Index Terms*—Controllable, BDI Agent, Policy-oriented, Defeasible logic, Reputation.**

I. INTRODUCTION

The increasing demand of shared resource and coordinated services under distributed environment requires that software system be developed, deployed, operated and maintained in the increasingly open, dynamic network environment. Previous non-self coordinated service cannot effectively, flexibly, fully, timely respond to the dynamic, transitional network environment. In this context, Agent becomes increasingly hot research. Because it has characteristics of reactivity, autonomy and sociality, Agent has been generally considered to be a key technology which is support for large-scale, open and distributed information systems to achieve dynamic service integration and collaboration [1]. But the traditional BDI logic-based Agent still has some shortcomings in architecture and logical reasoning process:

1. The unpredictable and uncontrollable Agent behaviors: When the increasingly intelligent Agent and strange Agent form cooperative system, individuals pursue the maximization of their own interests. Moreover, Agent autonomy and collaboration opacity cause that the Agent behaviors cannot be reliably predicted and controlled by the system [2]. As a result, it's questionable whether Agent can complete the overall goal collaboratively, seriously affecting the self-service collaborative practicability.

2. Lack of reliability evaluation of Agent behaviors: There are complicated factors resulting from uncertainty and incompletion in the multi-Agents' social collaborative environment. Traditional BDI logical models haven't evaluated the reliability of Agent behaviors and referred to the impact of social other Agents. So Agent's collaborative cooperation might fail.

3. Lack of conflict management mechanism in traditional model: Because traditional Agents don't consider the sources of multiple motivations, they lack conflict management mechanism of multiple motivations.

Under the background for the application of virtual organizations, this paper, against the shortcoming of lack of controllability in Agent models and based on the policy-based multi-agent coordination theory, innovates the mental models of traditional Agents. Against the second shortcoming, this paper adds reputation model to traditional BDI models, so that Agent can consider the reliability evaluation of other Agents in the process of logical reasoning and the effects from other social Agents when making decisions. The use of defeasible logic Agent modeling proposed by Governatori [3] and Dastani it articulates a kind of Agent model which can dynamically accept the rule changes, flexibly deal with real-time rule conflicts and effectively undertake non-monotonic process in this paper. We call this model PR-BDI model, which can, under the guidance of the policy, fully consider the reliability evaluation of other Agents to carry out regular dynamic changes and has effective mechanism flexibly adapting to these changes.

First, this paper will briefly introduce the background of the model, defeasible logic and conception related to policies. Then, it wills analysis architecture, formal specification, reasoning mechanism and working principle of the model and gives an example of the application of e-commerce systems.

II. PRELIMINARIES

Supported by the National Natural Science Foundation of China under Grant No.60773208; the Specialized Research Fund for the Doctoral Program of Higher Education under Grant No.20070532075; Hunan Province Young Core teacher training project.

doi:10.4304/jsw.7.1.110-117

A. Policy

Policy specification is a concept family, including norms, obligations, convention, rules, etc. Usually it refers to the external constraints abided by each agent considering the target in the MAS, decision making and behavior [2]. From the Virtual Organization Individual Agent perspective, each agent are subject to two different sources of policy-oriented, that is, different parties according to policy formulation will be further subdivided into two policies: organizational-level policies and individual-level policies ,which are issued and implemented by the corresponding policy framework , as shown in Fig. 1:

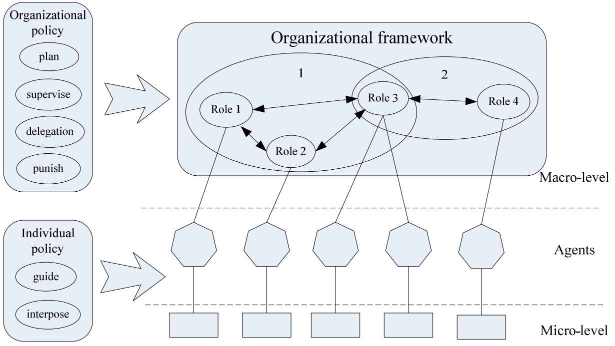

Fig. 1 Schematic diagram of two-tier policy

Organizational-level policy is seen as the agreement between the various business entities of virtual organization,, or the accepted norms of the industry's formalization, including organizational planning and system supervising, the delegation of responsibilities, punish, etc. It is a means of the synergy between the virtual organization and agent. Generally speaking, it is a division of responsibilities focusing on roles. Responsibilities embodied in the collection of various rules, such as the specific rights, obligations and prohibition. Organization-level policy is likely to come from the organization's accepted norms. It may be formed after the consultation of all the corporate entity in the whole organization as well. It is also probably established by some large corporate enterprises or by a virtual business intelligence platform. Organization-level policy ensures a harmonious organization, which reflects the collective interests of the virtual organization. Individual-level policy is seen as a foreign strategy of an individual legal entity or individual preferences for the realization of the restraint and control of agent behavior by individual companies. Individual-level policy is established by the individual legal institution which the agent belongs to, reflecting the individual interests of individual firms.

B. Overview Of Defeasible Logic

Defeasible Logic is a simple, efficient but flexible non-monotonic formalism which has been proven able to deal with many different intuitions of non-monotonic reasoning [11], has been applied in many fields in the last few years. Here we propose a non-monotonic logic of agency based on the framework for Defeasible Logic developed in [3, 4].

Accordingly a defeasible theory D is a structure (F,R, $>$) where F is a finite set of facts, R a finite set of rules (either strict, defeasible, or defeater), and $>$ a binary relation (superiority relation) over R. Facts are indisputable statements. Strict rules are rules in the classical sense: whenever the premises are indisputable so is the conclusion; defeasible rules are rules that can be defeated by contrary evidence; and defeaters are rules that cannot be used to draw any conclusions. Their only use is to prevent some conclusions. In other words, they are used to defeat some defeasible rules by producing evidence to the contrary. The superiority relation among rules is used to define priorities among rules, that is, where one rule may override the conclusion of another rule.

A rule r consists of its antecedent (or body) A(r) (A(r) may be omitted if it is the empty set) which is a finite set of literals, an arrow, and its consequent (or head) C(r) which is a literal. Given a set R of rules, we denote the set of all strict rules in R by R_s, the set of strict and defeasible rules in R by R_{sd}, the set of defeasible rules in R by R_d, and the set of defeaters in R by R_{dft}. R[q] denotes the set of rules in R with consequent q. If q is a literal, ~q denotes the complementary literal (if q is a positive literal p then ~q is ¬p; and if q is ¬p, then ~q is p).

A conclusion of D is a tagged literal and can have one of the following four forms:

$+\Delta q$ meaning that q is definitely provable in D (i.e., using only facts and strict rules).

$-\Delta q$ meaning that we have proved that q is not definitely provable in D.

$+\partial q$ meaning that q is defeasibly provable in D.

$-\partial q$ meaning that we have proved that q is not defeasibly provable in D.

Provability is based on the concept of a derivation (or proof) in D. A derivation is a finite sequence P = (P(1), . . . , P(n)) of tagged literals satisfying four conditions (which correspond to inference rules for each of the four kinds of conclusion). P(1..n) denotes the initial part of the sequence P of length n

$+\Delta$: If $P(n + 1) = +\Delta q$ then
  (1)$q \in F$ or
  (2)$\exists r \in Rs[q]\ \forall a \in A(r): +\Delta a \in P(1...i)$

$-\Delta$: If $P(n + 1) = -\Delta q$ then
  (1)$q \in F$ and
  (2)$\forall r \in Rs[q]\ \exists a \in A(r): -\Delta a \in P(1...i)$

The definition of Δ describes just forward chaining of strict rules. For a literal q to be definitely provable we need to find a strict rule with head q, of which all antecedents have already been definitely proved. And to establish that q cannot be proven definitely we must establish that for every strict rule with head q there is at least one antecedent which has been shown to be non-provable.

$+\partial$: If $P(i+1)=+\partial q$ then either
  (1) $+\Delta q \in P(1...i)$ or
  (2)(2.1) $\exists r \in R_{sd}[q]\ \forall a \in A(r): +\partial a \in P(1...i)$ and
    (2.2) $-\Delta \sim q \in P(1...i)$ and
    (2.3) $\forall s \in R[\sim q]$ either
      (2.3.1) $\exists a \in A(s): -\partial a \in P(1...i)$ or

(2.3.2) $\exists t \in R_{sd}[q] \forall a \in A(t): +\partial a \in P(1...i)$
and $t \succ s$

$-\partial$: If $P(i+1) = -\partial q$ then
(1) $-\Delta q \in P(1...i)$ and
(2) (2.1) $\forall r \in R_{sd}[q]\ \exists a \in A(r): -\partial a \in P(1...i)$ or
(2.2) $+\Delta{\sim}q \in P(1...i)$ or
(2.3) $\exists s \in R[{\sim}q]$ such that
(2.3.1) $\forall a \in A(s): +\partial a \in P(1...i)$ and
(2.3.2) $\forall t \in R_{sd}[q]$ either
$\exists a \in A(t): -\partial a \in P(1...i)$ or $t \not\succ s$

Let us work through this condition. To show that q is defeasibly provable we have two choices: (1) We show that q is already definitely provable; or (2) we need to argue using the defeasible part of D as well. In particular, we require that there must be either a strict or a defeasible rule with head q which can be applied (2.1). But now we need to consider possible “attacks”, i.e., reasoning chains in support of ~q. To be more specific: to prove q defeasibly we must show that ~q is not definitely provable (2.2). Also (2.3) we must consider the set of all rules which are not known to be inapplicable and which have head ~q (note that here we consider defeaters, too, whereas they could not be used to support the conclusion q; this is in line with the motivation of defeaters given earlier). Essentially each such rule s attacks the conclusion q. For q to be provable, each such rule s must be counterattacked by a rule t with head q with the following properties: (i) t must be applicable at this point, and (ii) t must be stronger than s. Thus each attack on the conclusion q must be counterattacked.

The purpose of the $-\partial$ inference conditions is to establish that it is not possible to prove $+\partial$. This rule is defined in such a way that all the possibilities for proving $+\partial q$ (for example) are explored and shown to fail before $-\partial q$ can be concluded. Thus conclusions tagged with $-\partial$ are the outcome of a constructive proof that the corresponding positive conclusion cannot be obtained [3, 4, 7].

III. POLICY-ORIENTED REPUTATION MODEL IN BDI AGENT

A. PR-BDI System Architecture

The PR-BDI Agent Model discussed in this article is quite different from the traditional BDI Agent Model. It not only integrates the possibility of the cognitive reputation model into the cognitive BDI Agent, but also introduces the idea the regulation and control policy. Let the agent complete the expected task of the organizations and individuals under the influence of the dual model of the policy and reputation [5, 6]. The architecture of PR-BDI model is shown in Fig 2.

It contains three main function modules: belief generation, desire generation, and intended to produce. 1) The function module of belief generation not only considers the expansion, amendment, or contraction of conviction results from environmental information, but also takes direct trust and reputation in credibility system into account. Direct trust refers to the credibility of the evaluation of target agent by their own while reputation refers to the evaluation of target agent by other members in the organization; 2) Desire to produce results from three motives: desire to rule, goal rules, and obligations of the rules. The previous mentioned rules of organizational policy embodied by the obligations, goal rules embody the individual policy rules; 3) intended to produce modules based on the current beliefs and aspirations, and a desired corresponding planning with the intent [1]. This three modules are expressed as rules of logical reasoning, from the following rule set: belief in rule set (R^B), trust in rule set (R^T), the reputation of rule sets (R^R), desire to rule set (R^D), goal rules set (R^G), obligations set of rules (R^O) and intentions set of rules (R^I). R^T, R^R, R^G and R^O can be dynamically changed. The maintenance of the credibility of evaluation is responsible for the amendment of credibility of the agent according to the environment and cooperation process. The different systems uses different correction algorithm to make the system run optimally. The credibility of the correction adopts numerical calculation and makes their decisions for the appropriate correction function g (x).

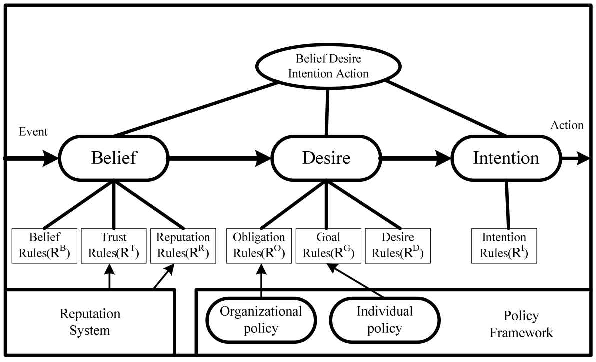

Fig2: PR-BDI Agent System Architecture

B. Logic Framework

In this paper we use extend defeasible logic, which contains three elements: Literals, Rules and superiority relation. We gave the definition of the Language as follow.

Definition 1 (Language) Let Prop={p, q,…} be a set of propositional atoms, $£=\{t|0<t\leq 1\}$ is the set of credible value, if t2>t1 stand for credibility t2 is larger than t1, Mod={BEL, TRU, REP, DES, GOL, OBL, INT} be the set of modal operators, and Lab=$\{r_1, r_2, \ldots\}$ be a set of labels. The sets below are the smallest sets closed under the following rules:

Literals

Lit = Prop $\cup$ $\{\neg p | p \in \text{Prop}\}$, we use ψ, $\psi_1, \psi_2, \ldots, \psi_n$ or a, b, c, g, e...donate literals; If ψ is a literal, $\sim\psi$ denotes the complementary literal (if ψ is a positive literal p then $\sim\psi$ is $\neg p$; and if ψ is $\neg p$, then $\sim\psi$ is p);

Credible Literals

TruLit=$\{l{:}t|\ l \in \text{Lit},\ t \in £\}$

If l is literal, and $t \in £$ is credible value, then l:t is credible literal

Modal literals

ModLit = $\{X\psi, \neg X\psi \mid \psi \in \text{TruLit},\ X \in \text{Mod}\}$ we use φ, $\varphi_1, \ldots, \varphi_n$ to donate literals;

Rules

Rule = $\{r : \varphi_1{:}t_1, \ldots, \varphi_n{:}tn \Rightarrow X\ \psi{:}t \mid r \in \mathrm{Lab}, \{\varphi_1{:}t_1, \ldots, \varphi_n{:}t_n\} \subseteq \mathrm{ModLit}, \psi \in \mathrm{Lit}, X \in \mathrm{Mod} \cup \{\Theta\}\}$

$R^X[\psi{:}t] = \{\varphi_1{:}t_1, \ldots, \varphi_n{:}t_n \rightarrow X\ \psi{:}t` \mid \{\varphi 1{:}t1, \ldots, \varphi n{:}tn\} \subseteq \mathrm{Lit} \cup \mathrm{ModLit}, \psi{:}t` \in \mathrm{Lit}, X \in \mathrm{Mod} \cup \{\Theta\}\}$

$R^X[\sim\psi{:}t] = \{\varphi_1{:}t_1, \ldots, \varphi_n{:}t_n \rightarrow X \sim\psi{:}t` \mid \{\varphi_1{:}t_1, \ldots, \varphi_n{:}t_n\} \subseteq \mathrm{Lit} \cup \mathrm{ModLit}, \sim\psi{:}t` \in \mathrm{Lit}, X \in \mathrm{Mod} \cup \{\Theta\}\}$

Superiority relation

$S \subseteq R^X \times R^X$

S is a binary relation over R, superiority relations are asymmetrical, non-cyclic, and we use the symbol > to indicate the superiority relations between the two rules.

Definition 2 (Framework)A PR-BDI Model in Agent Organization can be defined as the following tuples: $M=<£, F, \Theta, R^B, R^T, R^R, R^D, R^G, R^O, R^I, S>$, in which:

- £=($t|0<t\leq 1$) the set of credible value
- F denotes the set of fact
- $\Theta=\{B,T,R,D,G,O,I\}$ denotes the set of the internal state properties of a model, be made up of modal literals
- R^B denotes the rules of agent belief, cognitive theory of agent about the world
- R^T denotes the rules of agent trust; trust of the target agent or its behavior
- R^R denotes the rules of agent reputation; the reputation of target agent;
- R^O denotes the rules of agent obligation; Obligation is stand for organization policy;
- R^G denotes the rules of agent goal; Goal is stand for individual policy
- R^D denotes the rules of agent desire,
- R^I denotes the rules of agent intention;
- S denotes the superiority relations; deal with conflict between the rules

We will introduce the generation of belief, desire and intention detail. and if one of the prove process is the literals sequence P=(P(1),…,P(n)),we use P(1...i) to express initialization the length of i of sequence p.

C. Belief Generation

Definition 3

PR-BDI model $M=<£, F, \Theta, R^B, R^T, R^R, R^D, R^G, R^O, R^I, S>$ The belief formula q is true, if and only if $I \vdash +\Delta q$, or $I \vdash +\partial q$. they means respectively that q is definitely provable and defeasibly provable. Because of adding credible literals, the strict rules were definition to defeasible rules which credible values is 1. Then beliefs generated unify by defeasible method. Belidef geaeration rules $R^{BEL}= R^B \cup R^T \cup R^R$, and we think that $S(R^B)>S(R^T)>S(R^R)$, $R^T<1$and $R^R<1$.

Definition 4

The reasoning rules of belief generation by defeasible way. $R^{BEL}= R^B \cup R^T \cup R^R$

The reasoning rules of $\pm\partial^{BEL} q{:}t$

(1) $\exists r \in R^{BEL}[q{:}t]$,

(1.1)$\forall a{:}t_1 \in A(r){:}+\partial^{BEL} a{:}t_1 \in P(1...i)$,

$\forall b{:}t_2 \in A(r){:}-\partial^{BEL} b{:}t_2 \in P(1...i)$ or

(1.2) $\forall a{:}t_1 \in A(r){:}+\partial^{BEL} a{:}t_1 \in P(1...i)$,

$\exists b{:}t_2 \in A(r){:}+\partial^{BEL} b{:}t_2 \in P(1...i)$ and $t_1>t_2$

(2) $\forall s \in R^{BEL}[\sim q{:}t]$

(2.1)$\exists a{:}t_3 \in A(s) : -\partial^{BEL} a{:}t_3 \in P(1...i)$

(2.2)$\exists u \in R^{BEL}[q{:}t_1]$, $\forall a{:}t_1 \in A(u)$:

$+\partial^{BEL} a{:}t_1 \in P(1...i)$ and $u>s$

$-\partial^{BEL}$: if $P(i+1) = -\partial^{BEL} q : t_1$ then either

(1) $\forall r \in R^{BEL}[q{:}t]$:

$\exists a{:}t_1 \in A(r){:} -\partial^{BEL} a{:}t_1 \in P(1...i)$ or

$\forall a{:}t_1 \in A(r){:}+\partial^{BEL} a{:}t_1 \in P(1...i)$,

$\forall b{:}t_2 \in A(r){:}+\partial^{BEL} b{:}t_2 \in P(1...i)$,

$t_2>t_1$

(2) $\exists s \in R^{BEL}[\sim q{:}t]$:

(2.1)$\forall a{:}t_1 \in A(s){:} +\partial^{BEL} a{:}t_1 \in P(1...i)$ and

(2.2)$\forall u \in R^{BEL}[q{:}t]$

$\exists a{:}t_1 \in A(u){:}-\partial^{BEL} a{:}t_1 \in P(1...i)$ or

$\exists a{:}t_1 \in A(u){:}+\partial^{BEL} a{:}t_1 \in P(1...i)$,

$\forall b{:}t_2 \in A(u){:}+\partial^{BEL} b{:}t_2 \in P(1...i)$,

$t_2>t_1$ or

$u<=s$

To show that BEL q is defeasibly provable we need to consider possible “attacks”, i.e., reasoning chains in support of ~q. To be more specific: to prove q defeasibly we must show that ~q is not definitely provable. It is that all the rules which have head of ~q either cannot be satisfied (2.1) or were defeated by rules that have higher priority (2.2). The reasoning rules of $-\partial$ are complement of $+\partial$. Detail of explain was omitted. The process of defeasibly provable embody the way of conflict resolution which the rules with higher priority can defeat rules which is conflict with them.

D. Desire Generation

Definition 5

PR-BDI model $M=<£, F, \Theta, R^B, R^T, R^R, R^D, R^G, R^O, R^I, S>$ The desire formula q is true, if and only if $I \vdash +\partial q$. They mean respectively that q is definitely provable and defeasibly provable. Desire geaeration rules $R^{DES}= R^O \cup R^G \cup R^D \cup R^B$ Generally speaking, the priority of organization policy is higher than individual policy and the priority of individual policy is higher than their desire. we think that $S(R^O)>S(R^G)>S(R^D)$

Definition 6

The reasoning rules of Desire generation by defeasible way, $R^{DES}= R^O \cup R^G \cup R^D \cup R^B$

The reasoning rules of $\pm\partial^{EDS} q$,

$+\partial^{DES}$: if $P(i+1) = +\partial^{DES} q : t_1$ then

(1) $\exists r \in R^{DES}[q{:}t]$,

$\forall a{:}t_1 \in A(r){:}+\partial^{BEL} a{:}t_1 \in P(1...i)$,

$\forall b{:}t_2 \in A(r){:}-\partial^{BEL} b{:}t_2 \in P(1...i)$ or

$\forall a{:}t_1 \in A(r){:}+\partial^{BEL} a{:}t_1 \in P(1...i)$,

$\exists b{:}t_2 \in A(r){:}+\partial^{BEL} b{:}t_2 \in P(1...i)$ and $t_1>t_2$

(2) $\forall s \in R^{DES}[\sim q{:}t\ ]$

(2.1)$\exists a{:}t_3 \in A(s){:}\ -\partial^{BEL} a{:}t_3 \in P(1...i)$

(2.2)$\exists u \in R^{DES}[q{:}t],\ \forall a{:}t_1 \in A(u){:}$

$+\partial^{BEL} a{:}t_1 \in P(1...i)$ and $u>s$

$-\partial^{DES}$: if $P(i+1) = -\partial^{DES} q : t_1$ then either

(1) $\forall r \in R^{DES}[q{:}t]$:

$\exists a{:}t_1 \in A(r){:}\ -\partial^{BEL} a{:}t_1 \in P(1...i)$ or

$\forall a{:}t_1 \in A(r){:}+\partial^{BEL} a{:}t_1 \in P(1...i)$,

$\forall b{:}t_2 \in A(r){:}+\partial^{BEL} b{:}t_2 \in P(1...i)$,

$t_2>t_1$

(2) $\exists s \in R^{DES}[\sim q{:}t]$:

(2.1)$\forall a{:}t_1 \in A(s){:}\ +\partial^{BEL} a{:}t_1 \in P(1...i)$ and

(2.2)$\forall u \in R^{BEL}[q{:}t]$

$\exists a{:}t_1 \in A(u){:}-\partial^{BEL} a{:}t_1 \in P(1...i)$ or

$\exists a{:}t_1 \in A(u){:}+\partial^{BEL} a{:}t_1 \in P(1...i)$,

$\forall b{:}t_2 \in A(u){:}+\partial^{BEL} b{:}t_2 \in P(1...i)$,

$t_2>t_1$ or

$u<=s$

The reasoning rules of the generation of desire and belief are similar; we do not explain it in detail here.

E. Intention Generation

Definition 7

PR-BDI model $M=<£,F,\Theta,R^B,R^T,R^R,R^D,R^G,R^O,R^I,S>$ The intention formula q is true, if and only if $I \vdash +\partial q$. they means respectively that q is definitely provable and defeasibly provable. Desire generation rules $R^{INT}= R^I \cup R^D$

Definition 8

The reasoning rules of intention generation by defeasible way, $R^{INT}= R^I \cup R^D$

The reasoning rules of $\pm\partial^{INT} q$:

$+\partial^{INT}$: if $P(i+1) = +\partial^{INT}\ q : t_1$ then

(1) $\exists r \in R^{DES}[q{:}t]$,

$\forall a{:}t_1 \in A(r){:}+\partial^{DES} a{:}t_1 \in P(1...i)$,

$\forall b{:}t_2 \in A(r){:}-\partial^{DES} b{:}t_2 \in P(1...i)$ or

$\forall a{:}t_1 \in A(r){:}+\partial^{DES} a{:}t_1 \in P(1...i)$,

$\exists b{:}t_2 \in A(r){:}+\partial^{DES} b{:}t_2 \in P(1...i)$ and $t_1>t_2$

(2) $\forall s \in R^{INT}[\sim q{:}t\ ]$

(2.1)$\exists a{:}t_3 \in A(s){:}\ -\partial^{DES} a{:}t_3 \in P(1...i)$

(2.2)$\exists u \in R^{INT}[q{:}t_1],\ \forall a{:}t_1 \in A(u){:}$

$+\partial^{DES} a{:}t_1 \in P(1...i)$ and $u>s$

$-\partial^{INT}$: if $P(i+1) = -\partial^{INT} q : t_1$ then either

(1) $\forall r \in R^{INT}[q{:}t]$:

$\exists a{:}t_1 \in A(r){:}\ -\partial^{DES} a{:}t_1 \in P(1...i)$ or

$\forall a{:}t_1 \in A(r){:}+\partial^{DES} a{:}t_1 \in P(1...i)$,

$\forall b{:}t_2 \in A(r){:}+\partial^{DES} b{:}t_2 \in P(1...i)$, $t_2>t_1$

(2) $\exists s \in R^{INT}[\sim q{:}t]$:

(2.1)$\forall a{:}t_1 \in A(s){:}\ +\partial^{DES} a{:}t_1 \in P(1...i)$ and

(2.2)$\forall u \in R^{INT}[q{:}t]$

$\exists a{:}t_1 \in A(u){:}-\partial^{DES} a{:}t_1 \in P(1...i)$ or

$\exists a{:}t_1 \in A(u){:}+\partial^{DES} a{:}t_1 \in P(1...i)$,

$\forall b{:}t_2 \in A(u){:}+\partial^{DES} b{:}t_2 \in P(1...i)$,

$t_2>t_1$ or

$u<=s$

The reasoning rules of the generation of intention and belief are similar. We do not explain it in detail here.

F. Consistency Theorem

We have defined the generation of belief, desire and intention in detail before, and we demand that the belief, desire and intention which produced by the definition above must be uniform, that is to say, there is not q:t which made $M \vdash +\partial_X\ q{:}t$ and $M \vdash -\partial_X\ q{:}t$ come into existence at the same time when $X \in \{BEL, DES, INT\}$. And we have the theorem about it as below.

Theorem 1:

As for the PR-BDI theory, the generation of the belief, desire and intention has uniformity.

Demonstration: Take the generation of intention for example, and we use reduction to absurdity. If there is p:t which made $M \vdash +\partial_X\ q{:}t$ and $M \vdash -\partial_X\ q{:}t$ come into existence at the same time, and we divided it into two situation[2]:

Firstly, if $M \vdash +\partial_{INT}\ q{:}t$ was true because the first condition in the definition is satisfied, that is to say, there is a intention regulation r whose intention conclusion is q:t and it made the follow condition were true: all the premise of r are true and the conclusion of r cannot be defeated by the opposite rules. But judging by $M \vdash -\partial_{INT}\ q{:}t$, as for all the intention regulation r whose intention conclusion is p:t, there is one condition above not true at least, that is to say, it is contradict.

Secondly, if $M \vdash +\partial_{INT}\, q{:}t$ was true because the second condition in the definition is satisfied, we can get the contradiction by the same rule. So the generation of intention meets uniformity.

And we can prove the generation of belief and desire has uniformity by the same rule. (omit)

Ⅳ. PUTTING THE MODEL TO WORK

In this section we analyze the reasoning processes performed of model by an example of buy and sell wine. For simplicity, we only analyzed mental reasoning process between one shopper and three suppliers. The three suppliers are supplier *a*, supplier *b* and supplier *c*.

TABLE 1.
RELATED WITH SYMBOLS AND THEIR SIGNIFICANCE

SYMBOLS	SIGNIFICANCE
LowTime(d_i:t_j)	supplier d_i has limit deliver time, probability t_j
WellQua(d_i:q_j)	supplier d_i has well quality, probability q_j
LowPrice(d_i:p_j)	supplier d_i has Low price, probability p_j
Trust(d_i:u_j)	Agent direct trust for supplier d_i, Trust worthiness u_j
Reputation(d_i:r_j)	reputation worthiness of supplier d_i is r_j
Choice(d_i:p_j)	choose supplier d_i probability p_j
Event(d_i:p_j)	Event happened on supplier d_i, probability p_j
Refuse(d_i:p_j)	Refuse supplier d_i, probability p_j
Punish(d_i:p_j)	Punish supplier di, probability p_j
Use(d_i:p_i)	Use supplier d_i probability p_j
Update(d_i:p_i)	Update direct trust value of supplier d_i
Avg(p1,p2…)	Average of credibility value p1, p2…
LessThan(pi,pj)	Average of credibility value pi, pj less than 0.5

Shopper Agent model: M=<£, F, Θ, R^B, R^T, R^R, R^D, R^G, R^O, R^I, S> all part of M as follow:

- £={p|0<p<=1}
- F={
  LowTime(a:0.8), WellQua(a:0.6),
  LowPrice(a:0.7), Trust(a:0.5),
  Reputaion(a:0.4), LowTime(b:0.7),
  WellQua(b:0.8), LowPrice(b:0.6), Trust(b:0.5) ,
  Reputaion(b:0.7), Event(b:1), LowTime(c:0.5),
  WellQua(c:0.7), LowPrice(c:0.7) ,
  Trust(c:0.5) , Reputaion(c:0.7)
  }
- Θ is Agent internal state , as shown in Table 2;
  R^{BEL}= $R^B \cup R^T \cup R^R$
  ={
  b1:Event(di:1) $\Rightarrow$BEL Punish(di:1);
  b2:Trust(di:uj), Reputaion(di:rj),
  LessThan(uj, rj) $\Rightarrow_{BEL}$ Refuse(di:1)
  }
- R^{DES}= $R^D \cup R^O \cup R^G$
  ={
  d1: Punish(d_i:p_j) $\Rightarrow_{DES}$ ¬ Choice(d_i:p_j);
  d2: Refuse(d_i:1) $\Rightarrow_{DES}$ ¬Choice(d_i:1);
  d3:LowTime(d_i:tj), WellQua(d_i:qj),
  LowPrice(d_i:pj)$\Rightarrow_{DES}$Choice(d_i:g(x);

  g(x) is denotes credibility value calculation， in this paper we use Avg(tj,qj,pj)
  d4: Punish(d_i:p_j) $\Rightarrow_{DES}$Update(d_i:-0.2);
  d5: Refuse(d_i:1) $\Rightarrow_{DES}$ Update(d_i:-0.1);
  }
- R^{INT}={
  i1: Choice(d_i:p_j) $\Rightarrow_{INT}$ Use(d_i:p_j),
  Update(d_i:+0.1)
  }
- S={d1>d2>d3>d4>d5}

The generation process of desire is not only reflects the traditional reasoning but also take the influence of direct trust and reputation. In the generation process of desire, we have considered the influence which made by organizational and individual policy, and it deal well with the conflict between organizational benefits and individual benefits. According to individual benefits, or considering profits, Agent should have chose supplier *b*, but because *b* is being punished by organization and organization stipulate that other corporation can not choose supplier *b*, Agent will give up *b* because its reasoning mechanism can follow the organizational policy. In the end, because chose supplier *c*, we need to revise the direct trust and it also tally with actual situation.

TABLE 2
AGENT MODEL REASONING RESULT

BEL	DES	INT
M $\vdash +\partial_{BEL}$LowTime(a:0.8) M $\vdash +\partial_{BEL}$WellQua(a:0.6) M $\vdash +\partial_{BEL}$LowPrice(a:0.7) M $\vdash +\partial_{BEL}$LowTime(b:0.7) M $\vdash +\partial_{BEL}$WellQua(b:0.8) M $\vdash +\partial_{BEL}$ LowPrice(b:0.6) M $\vdash +\partial_{BEL}$LowTime(c:0.5) M $\vdash +\partial_{BEL}$ WellQua(c:0.7) M $\vdash +\partial_{BEL}$ LowPrice(c:0.7) M $\vdash +\partial_{OBL}$ ¬Choice(d_3) M $\vdash +\partial_{BEL}$ Punish(b:1) M $\vdash +\partial_{OBL}$ Refuse(a:1)	M $\vdash +\partial_{DES}$ Choice(c:0.7); M $\vdash +\partial_{DES}$ ¬Choice(a:1); M $\vdash +\partial_{DES}$¬ Choice(b:1); M $\vdash +\partial_{DES}$Update(a :0.1); M $\vdash +\partial_{DES}$Update(b:0.2);	M $\vdash +\partial_{INT}$ Use(c:0.7); M $\vdash +\partial_{DES}$Update(c:0.1)

Ⅴ. RELATED RESEARCH

Recently, the policy as a new MAS metaphorical concept was introduced in the field, policy-oriented Agent model has been paid more attention to [1, 7, 8, 9], the research is divided into two areas: the distributed system applications and the theoretical modeling based on Agent.

A. Distributed System Applications

Policy applications in the distributed system can be divided into two main areas, one is as a software engineering development paradigm, and the other is the policy-based management of large-scale distributed systems which is to reduce the complexity of the system configuration.

In the areas of software engineering, Literature [12] proposed a software engineering methodology Gaia, Gaia is used for medium to large, highly decentralized information systems, especially in open and dynamic environment, software system, the concepts of organization and policy are introduced to MAS. The Organizational Rules（OR） is one of the important design modules, to describe all the constraints satisfied by the roles and the interaction protocols. The article insists that OR for the open system is important: for example the designer should decide whether allow new member to join system when it is running. If allowed to join, what behavior is lawful? Through the organization rules, overall restriction policy can be defined, and easier to solve the reflection of the business requirements.

In the area of policy management for large-scale distributed systems, especially in safety-critical systems, policy-based management has got research and development.

Literature [9] proposed a policy-based management framework for large distributed systems, it first proposes a model of software system security and policy management, given the definition of policy, and designed a policy description language. By keeping the simplicity, the language can be integrated in the management framework and are effectively used to manage the behavior of large distributed systems. It is similar with the concept of policy proposed by us, but the policy in POCM model is the perspective from the MAS system modeling, it is understood as a representation of external demand, and can be refined into the set of logical rules.

B. Theoretical Modeling Based On Agent

In the area of theoretical modeling, most of the current Agent model taking modal logic as formal description tool. Modal logic is beautiful in theory and is an excellent tool for Agent theory, but modal logic has many problems in the realization which mentioned in the introduction of [14].

For the shortcomings of modal logic, Governatori and Dastani put forward the use of Agent defeasible logic modeling idea [7]. Based on defeasible logic, they proposed Agent BIO logical model. They follow the BOID (Belief, Obligation, Intention, Desire) architecture to describe agents and agent types in Defeasible Logic. By introducing modal logic operators and the relationship of transformation and confliction to the Defeasible Logic, the Logical Framework can derivate the Agent internal beliefs, obligations and intent with non-monotonic modal logic systems, they argue, in particular, that the introduction of obligations can provide a new reading of the concepts of intention and intentionality. Then they examine the notion of social agent (i.e., an agent where obligations prevail over intentions) and discuss some computational and philosophical issues related to it. We show that the notion of social agent either requires more complex computations or has some philosophical drawbacks.

Literature [8] provides a computational framework, based on defeasible logic, to capture some aspects of institutional agency. Their work focuses in particular on the notions of counts-as link and on those of attempt and of personal and direct action to realize states of affairs. We show how standard defeasible logic (DL) can be extended to represent these concepts: the resulting system preserves some basic properties commonly attributed to them. Although the model clearly mentions the concept of the organization, and taking into account the interaction between Agent on the impact of Agent decision-making, but its focus is still on the individual Agent's internal derivation, it is a Single Agent internal reasoning model in the organization.

Literature [10] proposed a framework for institutional agency framework for dynamic workflow resource allocation based on the framework proposed in Literature [8]. Although the article focused on the work of workflow system, But the article concludes that this approach can also be used for other social organizations based MAS system modeling, and for the realization of uncertainty and unpredictability of environmental information, it indicate the potential of Agent revocation logic used in software system application.

Based on the defeasible logic framework, under the context of autonomic computing research, a flexible Agent model is proposed In Literature [1], which is capable of accepting the real-time rule modifications, flexibly handling the run-time rule conflicts, and providing efficient non-monotonic reasoning abilities. The flexible agent is both autonomous and controllable, and is able to cooperate with other Agents via contracts in the open and dynamic environment.

As can be seen from the above reach, it has attracted the attention of researchers that use the logic of defeasible logic to model the rational Agent and MAS. It is also a trend that social norm or Policy is introduced to MAS model to give the macro-guidance and external control, to reflect the controllable needs outside the system, to enhance the credibility of Agent System, and to achieve the balance of Agent internal autonomy and external control. These are necessary requirements to make Agent technology to adapt to the open, distributed information systems.

Ⅵ. CONCLUSIONS

In the open complex software system modeling，the traditional collaborative model of MAS will be faced with many problems, such as individual behavior is difficult to control, without considering the impact of reputation on the decision making, and conflict resolution and so on. For example, LIAO Bei-Shui is proposed a flexible Agent with defeasible logic [1, 13], but reputation effects are not considered. Isaac Pinyol has presented a cognitive reputation model, Repage, in BDI agent architecture [5], but it cannot accept the policy guidance. Hu Jun proposed a Policy-oriented autonomic, controllable Agent model [2]. In our paper, we have presented a possible integration of a cognitive reputation model in BDI agent architecture. We use organizational and individual policy to constraints on and guide the Agent's behavior. This method can make Agent have autonomy and keep Agent to be controlled and predictable. We give the belief of agent probabilistic semantics by using extensionally defeasible logic.

In conclusion, there are still many theoretical studies need to be improved in spite of the valuable or useful part in the paper. For example collaboration in MAS, reputation evaluation and computational complexity need intensive study.

ACKNOWLEDGMENT

This work was supported by the National Natural Science Foundation of China under Grant No.60773208; the Specialized Research Fund for the Doctoral Program of Higher Education under Grant No.20070532075”; Hunan Province Young Core teacher training project. Also, we would like to give special thanks to Zhi-Ang Li for the useful comments on the manuscript.

REFERENCES

[1] LIAO Bei-Shui, HUANG Hua-Xin, GAO Ji, A Defeasible Logic-Based Flexible Agent for Autonomic Computing. Journal of Software, Vol.19, No.3, March 2008, pp.605−620

[2] Hu Jun, Li Zhi-ang. A Policy-Oriented Autonomic, Controllable Agent Model for Virtual Organization. Journal of Hunan University. 2010, 37(6):71-76.

[3] Guido Governatori, Vineet Padmanabhan, Antonino Rotolo, Abdul Sattar. A Defeasible Logic for Modeling Policy-based Intentions and Motivational Attitudes. Logic Journal of the IGLP(Accepted 2009)Vol. 17 No. 3, © The Author 2009.

[4] Nute D. Defeasible logic. In: Bartenstein O, et al, eds. Proc. of the INAP 2001. LNAI 2543, Berlin, Herdelberg: Springer-Verlag, 2003. 151−169..

[5] Isaac Pinyol Jordi Sabater-Mir :Pragmatic-Strategic Reputation-Based Decisions in BDI Agents, Proc. of 8th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2009),Decker, Sichman, Sierra and Castelfranchi (eds.), May, 10–15, 2009, Budapest,Hungary,pp.1001-1008

[6] He Lijian, Huang Houkuan, Zhang wei: A survey of Trust and Reputation Systems in Multi-Agent Systems, Journal of Computer Research and Development, Vol.7, 2008, pp.1151～1160.

[7] Guido Governatori · Antonino Rotolo. BIO logical agents: Norms, beliefs, intentions in defeasible logic. Autonomous Agent and Multi-Agent System, Volume 17, Number 1, 2008.8.pp. 36-69.

[8] Guido Governatori, Antonino Rotolo. A computational framework for institutional agency. Artif Intell Law (2008) 16:25–52

[9] N. C. Damianou, A Policy Framework for Management of Distributed Systems , Ph.D. thesis, Imperial College, London, 2002.

[10] Guido Governatori, Antonino Rotolo, Shazia Sadiq1. A Model of Dynamic Resource Allocation in Workflow Systems. ACM International Conference Proceeding Series,Vol. 52 Proceedings of the 15th Australasian database conference - Volume 27 Dunedin, New Zealand Pages: 197 - 206 Year of Publication:2004.

[11] G. Antoniou, D. Billington, G.Governatori, and M.J.Maher. A flexible framework for defeasible logics. In Proc. 17th American National Conference on Artificial Intelligence (AAAI-2000),405-410.

[12] Zambonelli, Jennings, Wooldridge. Multi-Agent Systems as Computational Organizations: The Gaia Methodology. Agent-oriented methodologies p136-177 Idea Group Inc (IGI), 2005

[13] Liao, B, Huang, H. ANGLE: an autonomous, normative and guidable agent with changing knowledge. Information Sciences, 2010, 180(17):225-237

[14] Faiza S, Mohamed B.A multi-agents system approach for designing complex systems. Information Technology Journal, 2010, 5(6):435-443

Jun Hu born in 1971 and received M.Sc. in Computer Application from Kunming University of Science and Technology, Kunming, China, and Ph.D. in Computer Science and Technology from Zhejiang University, Hangzhou, China. In 2010, he was an academic visitor at University of Southampton working on multi-agent system. Currently, he is an associate professor of Hunan University, Changsha, China. His research interests are in multi-agent system, distributed artificial intelligence and software engineering.

Yang Yu born in 1985 and received M.Sc. in Computer Application from Hunan University, Changsha, China. His main research interests include distributed artificial intelligence, multi-agent systems, and machine learning.