

Role-Based Social Mental States of Agents

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Abstract

Roles are fundamental artifacts for understanding and describing agent's actions and interactions. An agent by performing certain social role participates in a multi-agent society, and then interacts with others in the society based on the mental states of the role. Two roles interact with each other in different manners because of different relationships between them. Several usual relationships between roles are analyzed based on the generalized correlativity from the farthest mutual promotion to the farthest mutual restraint. We also present the role-based mental states and capture how the mental states of an agent are affected differently by others who have different relationships with him.

Keywords: generalized correlativity, relationship, role-based mental state, social mental states

1 Introduction

The recent years have witnessed a large interest in MAS due to the limited knowledge and simplified reasoning of each agent. The problem is no longer to analyze how an individual can achieve a task but how a group composed of individuals can solve complex problems and plan their actions collectively. Many methodologies and technologies are contributed to this field [3, 4, 6, 10]. However, the social ability of the individual in a group is crucial to the capability of the group of whole. Accordingly, a major challenge is to develop the sociality of agents for ensuring that agents can effectively interact with each other in MAS.

Chainbi[2] drew its inspiration from the widely recognized fact that interaction is the most important single characteristic of complex systems, so stressed the interaction aspect to deduce the intentional structure of an agent. For this reason, he presents a theory for multi-belief-goal-role agents, which consisted of beliefs and goals as communication concepts and roles as concepts related to organization. Cavedon and Sonenberg[1] use roles as an abstraction to enable the agent designer to scope the sphere of influence of one agent with respect to another. Roles then provide a way to specify how the agent should balance competing obligations from different relationships, and from tensions between personal preferences and social obligations. Cavedon and Sonenberg's theory is developed in [7, 8], roles can provide agents not only with goals but also with beliefs, desires, and intentions, as well as the mental attitudes are provided not only by roles but also by social relationships. Drew this inspiration a framework presented captures how the social nature of agents that are situated in a multi-agent environment impacts upon their individual mental states. Roles and social relationships provide an abstraction to allow extending the standard BDI model to social mental shaping.

This paper bases on these contributions just mentioned and further develops them. We learn that an agent implements his functions usually by performing roles, once an agent holds a role he must completely adopt role-based mental states to interact with others relating to him as the role-holder. Therefore, it is shown that the concept of roles implies social relationships and interactions, and should be put in the mental states of an agent to develop sociality of the agent.

Drawing these ideas, we begin, in the following sub-section, by analyzing the sociality of an agent. Section 3 describes primary relationships between roles based on the generalized correlativity from the farthest mutual promotion to the farthest mutual restraint. We introduce role-based mental attitudes and capture how the mental states of an agent are influenced differently by others who have different relationships with him in section 4. Finally, some conclusions and future works are deduced in section 5.

2 Sociality of Agents

A multi-agent society is composed of some agents, who are linked by various social relationships and interact with each other. For example, a university is made up of administrators, teachers and students that connect by diverse relationships. Apparently, the relationship actually exists between roles but not between certain persons, and interactions happen between roles but not between certain persons. From another point of view, an agent implements his functions usually by performing roles, and while he performs a role he must completely exist in the social relationships of the role and interacts with others on the position of the role. Accordingly, roles are fundamental artifacts for understanding and describing agent's acting and interacting.

Hence, as Figure 1 shows, an agent by performing certain social role participates in a multi-agent society, and then interacts with other role-players of the

society on the position of the role. During this process, the agent (role-player) perceives its environment and acts upon its environment. Accordingly, it is shown that the sociality of an agent is the embodiment of the course of performing roles.

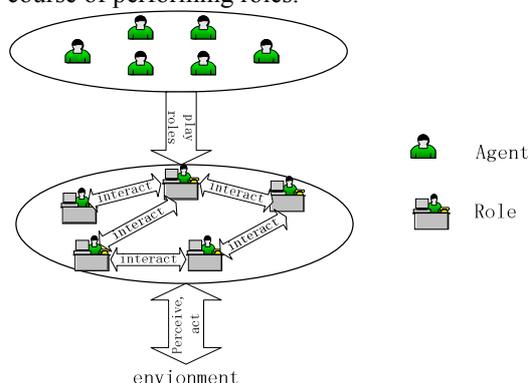


Figure 1: The Sociality of Agents

3 Various Relationships between Roles

The role is an abstract representation of an agent function, service or identification within a society, Such as managers, intermedias, auctioneers, and so on. All roles in the society that can be played by agents constitute a finite set RO .

An agent implements his functions and interacts with others by playing a role in a society, so in fact it is the relationship between roles (not agents) that reflects the relation of interaction. Moreover, two role-players must interact with each other in different manner because of different relationships between them. $RE \subseteq RO \times RO$, is a finite set of the binary relation between roles.

It is considered that things of the world are to be related mutually in Chinese classical philosophy, and they are correlative from mutual promotion to mutual restraint. Based on this point of view, the generalized correlativity including all kinds of relationships in series from the farthest mutual promotion to the farthest mutual restraint is proposed in universal logics principle [5].

It is no exception to the multi-agent society, in which the roles also have the generalized correlativity leading to interact between them. There are also all kinds of relationships between roles in series from the farthest mutual promotion to the farthest mutual restraint in the multi-agent society no less than those in human society. But only several specific relationships of the generalized correlativity are considered during the present period.

The two roles are not excluding mutually but are the farthest promotive mutually, and one belongs to another, such as a manager and his underling. The manager controls his underling viz. the latter belongs to the former. The relationship between them are said to be the farthest promotion of the generalized

correlativity. Here, we define this type of relations between the two roles to be *implication relationship* (IM for short). Role r_1 implicates role r_2 , denoted by $(r_1, r_2) \square IM$, which means r_1 reigns over r_2 and r_2 belongs to r_1 . Apparently any implication relationship $IM \subseteq RO \times RO$, must satisfy the following properties:

- Reflexive: $(r, r) \square IM$, for all $r \square RO$.
- Transitive: if $(r_1, r_2) \square IM$ and $(r_2, r_3) \square IM$ then $(r_1, r_3) \square IM$.
- Anti-symmetric: if $(r_1, r_2) \square IM$, then $(r_2, r_1) \notin IM$.

When two roles interact due to the necessary of helps for a common goal or for their respective goals, they are related but neither reigning nor belonging. The relationship between the two roles are said to be on their own related of the generalized correlativity. We define this type of relations as *dependence relationship* (DE for short). The dependence relationship exists between roles primarily due to resource or capability restrictions of one of them. For example, the role r_2 can access to a piece of information, and the role r_1 can not access the information but he has to gain this information from r_2 to satisfy one of his goals, then r_1 is dependent on r_2 , denoted by $(r_1, r_2) \square DE$. In addition, r_1 and r_2 may be mutually dependent on each other, which can be described formally by $(r_1, r_2) \square DE$ and $(r_2, r_1) \square DE$, so the dependence relationship does not satisfy symmetric nor anti-symmetric. The dependence relationship may not always be transitive because roles could depend on each other for different things. So any dependence relationship $DE \subseteq RO \times RO$, only is reflexive.

- Reflexive: $(r, r) \square DE$, for all $r \square RO$.

There exists a situation that two roles represent the farthest exclusive mutually but without restraint of the generalized correlativity. For instance, two buyers who all want certain limited goods supplied by a seller are the farthest exclusive each other for their respective interests, but have no intentions to restrain each other. We call such relationship between roles r_1 and r_2 as *competition relationships* (CO for short), formally as $(r_1, r_2) \square CO$. Apparently any competition relationship $CO \subseteq RO \times RO$, must satisfy the following properties:

- Anti-reflexive: $(r, r) \notin CO$, for all $r \square RO$.
- Symmetric: if $(r_1, r_2) \square CO$, then $(r_2, r_1) \square CO$.

It presents the farthest mutual restraint of the generalized correlativity between two roles, if they must antagonize and restrain each other for achieving their own goals. We call such relationship between roles r_1 and r_2 as *restraint relationships* (RS for short), denoted by $(r_1, r_2) \square RS$. The restraint relationship is different from the competition relationship, because one tries to achieve his goal and at the same time must

prevent another from coming true goals. For instance, it is the restraint relationship between two teams in soccer game. In evidence any restraint relationship $RS \subseteq RO \times RO$, must satisfy the following properties:

- Anti-reflexive: $(r, r) \notin RS$, for all $r \in RO$.
- Symmetric: if $(r_1, r_2) \in RS$, then $(r_2, r_1) \in RS$.

4 Role-Based Social Mental States

Since interactions happen between roles but not between certain agents, role-based mental states are apt to understand and describe the social mental states of an agent.

A role is an abstract representation of an agent function, so a role cannot think nor act but the role-player think or act. However, for linguistic simpleness, we name the mental states of agents performing roles as role-based mental states. The actions or mental states of a role mentioned in this paper actually indicate role-based act or role-based mental states.

The role-based mental states include the role-based belief, the role-based goal and the role-based intention, and we express the role-based belief, the role-based goal and the role-based intention respectively by the modal operator *RoleBel*, *RoleGoal* and *RoleInt*. Role-based mental states is denoted by the modal operator *RoleAtt*($r, \&$), where *RoleAtt*($r, \&$) represents either a *RoleBel*, a *RoleGoal* or a *RoleInt* that role r holds towards $\&$.

Role-based mental states means the mental states of the role-player, so role-based mental states is similarly with agents' mental states including their formulae and semantics of the modal operators. We base upon a collection of modal operators of Rao and Georgeff's theory [9] in this paper.

The belief set attached to a role includes beliefs concerning the world and beliefs concerning the mental states attached to oneself and others.

To express role-based beliefs, we introduce the modal operator *RoleBel*($r, \&$) means attached to role r there is a belief that holds $\&$.

It is a very important social intelligent action that a role keeps in mind the mental states of others related to him in order to react (such as help or hinder) to them. In another word, a role should have the beliefs about the mental states of others.

RoleBel($r, RoleAtt(r', \&)$), which means roles r believes that roles r' has a belief, or goal, or intention to hold $\&$. If $r = r'$, that means roles r has beliefs about role-based mental states of himself.

Additionally, a role should have the belief about the relationships with others. *RoleBel*($r, (r, r')$), means that roles r believes that certain relationship exists between role r and r' .

Role-based goals reflect the set of behaviors that might be expected of a role by the other related to him. Role-based goals are optional mental states that the role may decide whether or not to adopt. They provide guidelines for certain patterns of behavior, although not specified in detail.

To express Role-based goals, we introduce the modal operator *RoleGoal*($r, \&$), which means that attached to role r there is a goal towards $\&$.

Role-based intentions provide a role with a self-commitment to act. That is, a role commits himself to act accordingly. Thus, role-based intentions are mandatory mental attitudes that the role-player is compelled to adopt. Role-based intentions can be action-directed intentions involving the performance of some action by the role and be state-directed intentions reflecting some state of affairs that a role will commit himself to bring about.

The modal operator *RoleInt*($r, \&$) is used to represent role r has an intention to hold $\&$. In other words, role r promises to bring about $\&$.

As a member of a society, a role must be affected by others related to him. The influence is embodiment of the change of his role-based mental states. We can capture it with the following formula:

$$RoleBel(r, (r, r')) \wedge RoleBel(r, RoleAtt(r', \&)) \supset RoleAtt(r, \&)$$

Crudely, if a role r believes he has certain relationship with another role r' , and believes r' has a mental state to bring about $\&$, and then he produces his mental state to bring about $\&$ '.

However, the mental states of a role are affected differently by others who have different relationships with him. For example, to a child, his father and his partner must affect him in different manner.

When it represents *implication relationship* between two roles, such as boss and his secretary, the role-based mental states of the latter must be influenced by those of the former. In evidence, it is said more concrete that the latter should keep consistent with the former, especially in the aspect of beliefs. The influence is described by the following formula:

$$RoleBel(r, (r', r)) \wedge RoleBel(r, RoleBel(r', \&)) \supset RoleBel(r, \&), (r', r) \in IMr \neq r'$$

The formula denotes that if role r believes the relation between role r' and him is implication relationship and r believes role r' has the belief to hold $\&$, then he has the belief to hold $\&$.

When it represents *dependence relationship* between role r' and role r , role r' wants to achieve a goal that he can not, so he has to refer himself to role r to achieve it. Role r accepts the goal as his goal. We can formulize the situation as:

$$RoleBel(r, r', j) \wedge RoleBel(r, RoleAtt(r', \&)) \supset RoleAtt(r, \&), (r', j) \in DEr \neq r'$$

The formula denotes that if role r believes the relation between role r' and him is dependence relationship and r believes role r' has the goal to hold $\&$, then he has the goal to hold $\&$.

Two roles have the conflict in interests, so they must compete mutually for their respective interests. For example, two buyers all want to buy gas from a seller in low price as soon as possible, one buyer also has to raise the price when another raises the price to gain the limited goods. Apparently, two roles competing mutually must follow each other in the aspect of intentions. It can be captured with the following formula:

$$RoleBel(r, r', j) \wedge RoleBel(r, RoleInt(r', \&)) \supset RoleInt(r, \&), (r', j) \in CRr \neq r'$$

The formula denotes that if role r believes the relation between role r' and him is competition relationships and r believes role r' has the intention to hold $\&$, then he has the intention to hold $\&$.

To two roles antagonizing each other, such as two teams in soccer game, each side has to prevent another's action from achieve goals. So the intentions inducing actions of one side must be blocked by another side, viz. one side must has reverse intention of another side, which can be formulized as:

$$RoleBel(r, r', j) \wedge RoleBel(r, RoleInt(r', \&)) \supset RoleInt(r, \neg \&), (r', j) \in RSr \neq r'$$

The formula denotes that if role r believes the relation between role r' and him is restraint relationships and r believes role r' has the intention to hold $\&$, then he has the intention to hold $\neg \&$.

An agent acts or interacts by playing certain role. The 2-place predicate $Play(a, r)$ is introduced to express the fact that agent a is playing role r . For example, if a is Lina and r is a role of teacher, $Play(a, r)$ means that Lina is taking on a teacher.

Once an agent plays a role, he will completely hold the role-based mental states and act as the role. For instance, Lina is playing a teacher, and a teacher has the role-based mental states to hold $\&$, so Lina has the mental states to hold $\&$. That is denoted formally by the following formula:

$$Play(a, r) \wedge RoleAtt(r, \&) \supset Att(a, \&)$$

Crudely, if an agent a plays a role r and the role r has a role-based mental states to bring about $\&$, then simply for this reason the agent a has the mental states to bring about $\&$.

5 Conclusions and Future Work

Up to now we have described primary relationships between roles based on the generalized correlativity

from the farthest mutual promotion to the farthest mutual restraint and the role-based social mental states of agents in this paper. It is shown that the social concepts and role-based mental states can be held in the concept of the role. Once an agent holds a role he must completely adopt role-based mental states of it and act completely as the role. This paper also has captured how the mental states of an agent are influenced differently by others who have different relationships with him.

In the future, we will explore the mental states of an agent who can play multi-roles, and an agent how to reason and apperceive the mental states of others related to him.

6 References

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