A Hybrid Negotiation Mechanism among Agent Strategies

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Abstract

Agents will adopt different strategies in the multiagent systems. However, the strategies of agents may produce conflicts. While agents coordinate with each other in the operations, they will negotiate about their strategies to reduce conflicts. This paper models the agent strategy negotiation mechanism in three kinds of agent coordination forms: order, cooperation and non-cooperation. In the order form, an agent can order another agent to do something, so the junior agent will follow the strategy of the superior agent; in the cooperation form, two agents may cooperate to behave, so they will negotiate about their social strategies in the operations; in the non-cooperation form, the agents may behave without considering other agents' behaviors, so the agents will adopt their own respective favorite strategy. With the presented framework, the strategy negotiation among different agents can be modeled well.

1. Introduction

Social strategy is the action that agent adopts to behave in the multi-agent systems. While multiagents operate, they should select their respective strategies at first. For example, in the Prisoner's Dilemma game, the agent can select the strategy of cooperation or defect [1-5][11-12]. The multiagent technology can be used in many fields, such as the grid [13]. The selection of strategies for agent will influence the performance of the system. However, agents are always selfish; each agent will select its own social strategy for its benefit, and the strategies among different agents may produce conflict [6-7]. The conflicts among the strategies of different agents will affect the operation of system. Therefore, to receive the harmony among different strategies, we need to endow a set of negotiation mechanisms on the strategies selection of all agents, which should minimize the conflicts among agents. Only if the agents can negotiate their strategies well, then the multiagent coordination may be realized. Therefore, this paper provides a framework for the hybrid negotiation mechanism among agent strategies. In the framework presented by this paper, agents have their individual strategies and can negotiate their strategies with each other in the operations of multi-agent system. With the time goes, the harmonization of strategies among agents will be achieved.

Coordination computing is a key factor in the multi-agent system where many agents inhabit a shared environment [9-10][14-15]. With coordination, an agent can profit from the actions of other agents, as well as benefit to other agents. Coordination computing cannot only make individual agent try its best but also combine agents to improve the ability of the overall system. Coordination may improve the performance of the individual agents or the overall behavior of the system they form; according to different system environments, such as the level of agents' cooperation, agents' regulation and protocols, the number and type of agents, and the communication cost, we can explore different coordination strategies in multi-agent systems [9-10]. In this paper, we will address the hybrid coordination forms, i.e. there are different coordination forms in the system.

In real multi-agent systems, there are always 3 kinds of coordination forms which are order, cooperation and non-cooperation.

- In the order form, an agent can order another agent to do something;
- In the cooperation form, two agents may cooperate to behave;
- In the non-cooperation form, the agents may behave without considering other agents' behaviors.

Obviously, when two agents coordinate with each other, their social strategies may also negotiate with each other; the negotiation of social strategy between two agents will consider the coordination form between them. In the presented framework of this paper, the agents will negotiate about their strategies according to their coordination forms.

In coordination of multiagent, the shapes of pair agents and triple agents are always seen and which are the basic coordination forms in agent system. Therefore, at first we will address the pair and triple agents' interactions. According to [15][19], we know that the numbers of all possible connected graphs with the node number of 2 and 3 are shown as Figure 1. Therefore, in this paper, we will present our hybrid negotiation mechanism of agent strategies for pair agents, triple agents, and more agents.

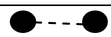
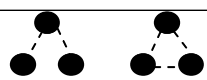
N	Number of Connected graphs	Possible realizations
1	1	
2	1	
3	2	

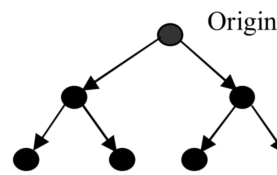
Figure 1. All possible connected graphs of single, pair and triple agents.

The rest of this paper is organized as follows. At first, we present the agent strategy negotiation mechanism in the coordination with order form in Section 2; then we address the strategy negotiation in the cooperation and non-cooperation forms for different agent interaction shapes in Section 3. In Section 4, we give an example to demonstrate the model; then the paper concludes in Section 5.

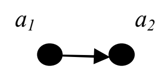
2. Strategy negotiation in the order form

There are many forms for diffusion of social phenomena, among them is the hierarchical diffusion [16-18]. Hierarchical immediate diffusion refers to the spread from more socially dominant actors to junior ones. The hierarchical diffusion is popular in the diffusion of knowledge, culture, and so on in the society. Another known example of this can be seen in physics, where the diffusion often takes place from the high potential energy to the low potential energy. In the hierarchical diffusion of social phenomena, there are a small number of agents are 'experts' and are endowed with a high level of knowledge in at least one value of the vector. All individuals interact among themselves, exchanging information via a simple process of barter exchange. Barter can only take place if the first individual has superior knowledge of one type and the other individual has junior knowledge of another type [20].

From the hierarchical diffusion structure, we can see that the basic diffusion mainly take place from the superior actor to the junior one, which adopts the shape of order diffusion, shown as Figure 2. Certainly, there are still many other complex diffusion forms in the society, but such immediate order diffusion from superior actor to junior one is one of basic hierarchical forms.



(a) The hierarchical diffusion structure



(b) The order form in the hierarchical diffusion

Figure 2. Hierarchical diffusion and order form

Obviously, in the hierarchical order form, the junior agents will follow the strategy of the superior agents.

Let l_1 be the social strategy of agent a_1 before negotiation, l_2 be the social strategy of agent a_2 before negotiation. Obviously, after the order coordination, the social strategy of a_1 after negotiation, $l_1^{'}$, will only imitate its locally most authoritative social strategy, and the social strategy of a_2 , $l_2^{'}$, will have to imitate the one of a_1.

$$l_1^{'} = L_1^*; l_2^{'} = L_1^*. \quad (1)$$

Where L_i^* is the locally most authoritative social strategy of agent a_i.

3. Strategy negotiation in the cooperation and non-cooperation forms

3.1. Negotiation between pair agents

We can represent the state of the population by simply keeping track of what proportion follow the strategies cooperation and non-cooperation. When two agents only coordinate with each other, i.e., the diffusion form is pair-wise, the basic forms are shown as Figure 3, where (a) is the cooperation and (b) is the non-cooperation. We should make different negotiation mechanisms for agent strategies according to the different coordination forms.

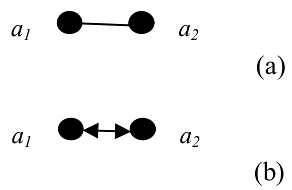


Figure 3. Cooperation and non-cooperation between pair agents

Obviously, if a_1 cooperates with a_2, then they will negotiate about their social strategies in the coordination. If a_1 doesn't cooperate with a_2, then they will imitate their own respective locally most authoritative strategy.

If two agents negotiate about their strategies in the coordination, then how they will decide their new strategies? Now we will have the concept of average strategy.

Definition 1. Let L be a set of social strategies, m be the number of social strategies, $L=\{l_1, \ldots, l_m\}$, the average of L is defined as:

$$average(l_1,\cdots,l_m) \approx \frac{\sum_{1\le i\le m} Rank(l_i)*l_i}{\sum_{1\le i\le m} Rank(l_i)} \qquad (2)$$

Where $Rank\ (l_i)$ is the authority of the strategy l_i. If a strategy is accepted by more agents, then its rank will be high. From the above definition, we can see that the average strategy of a set of strategies will incline to the one with high rank.

We think that the average strategy will minimize the conflicts between two agents. Therefore, in this paper, if two agents cooperate with each other, they will incline to follow their average strategy.

Let L_i^* be the locally most authoritative strategy of agent i, $l_i^{'}$ be the social strategy of agent i after negotiation, then the negotiation rule between pair agents is:

1). If a_1 cooperates with a_2, then we have:

$$l_1^{'} = l_2^{'} = average(L_1^*, L_2^*) \ ;$$

2). If a_1 doesn't cooperate with a_2, then we have:

$$l_1^{'} = L_1^*, l_2^{'} = L_2^* .$$

3.2. Negotiation among triple agents

If three agents coordinate with each other, they will form a triple shape. Now we deal with the cooperation and non-cooperation negotiation of strategies among triple agents.

When triple agents coordinate with each other, there are two kinds of types which are serial and circle-like. In the serial type, the coordination relations among the three agents will like a line; in the circle-like type, the coordination relations among the three agents will like a circle, i.e. the three agents make fully coordination each other. The two types are seen as Figure 4.

Obviously, we should devise different negotiation rules for those types.

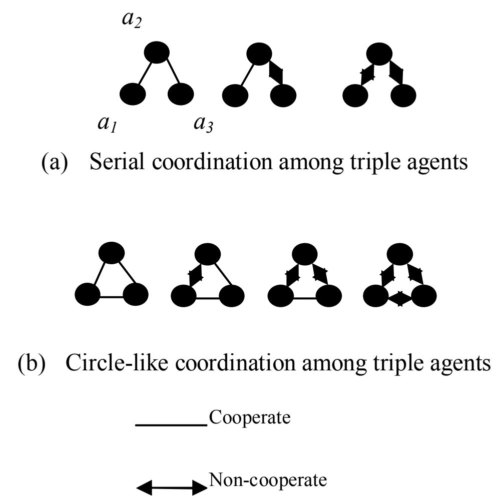


Figure 4. Cooperation and non-cooperation among triple agents

Now we will devise the negotiation rules for the serial and circle-like coordinations with cooperation and non-cooperation. In the following parts of this paper, the notation '$\Leftrightarrow$'denotes 'cooperate', '$\leftrightarrow$' denotes 'non-cooperate'.

About the serial-like type, we have the following negotiation rules:

1). If $a_1 \Leftrightarrow a_2 \Leftrightarrow a_3$, then:

$$l_1^{'} = average(L_1^*, L_2^*)$$
$$l_2^{'} = average(L_1^*, L_2^*, L_3^*)$$
$$l_3^{'} = average(L_2^*, L_3^*)$$

2). If $a_1 \Leftrightarrow a_2 \leftrightarrow a_3$, then:

$$l_1^{'} = l_2^{'} = average(L_1^*, L_2^*)$$
$$l_3^{'} = L_3^*$$

3). If $a_1 \leftrightarrow a_2 \leftrightarrow a_3$, then:

$l_1' = L_1^*$

$l_2' = L_2^*$,

$l_3' = L_3^*$

About the circle-like type, we have the following strategy negotiation rules:

1). If $a_1 \Leftrightarrow a_2 \Leftrightarrow a_3 \Leftrightarrow a_1$, then:

$$l_1' = l_2' = l_3' = average(L_1^*, L_2^*, L_3^*)$$

2). If $a_1 \leftrightarrow a_2 \Leftrightarrow a_3 \Leftrightarrow a_1$, then:

$$l_1' = average(L_1^*, L_3^*)$$

$$l_2' = average(L_2^*, L_3^*)$$

$$l_3' = average(L_1^*, L_2^*, L_3^*)$$

3). If $a_1 \leftrightarrow a_2 \leftrightarrow a_3 \Leftrightarrow a_1$, then:

$$l_1' = average(L_1^*, L_3^*)$$

$$l_2' = L_2^*$$

$$l_3' = average(L_1^*, L_3^*)$$

4). If $a_1 \leftrightarrow a_2 \leftrightarrow a_3 \leftrightarrow a_1$, then:

$$l_1' = L_1^*$$

$$l_2' = L_2^* \quad .$$

$$l_3' = L_3^*$$

3.3. Negotiation among more agents

In the above sections, we deal with the strategy negotiation of pair agents and triple agents. Then, if many agents coordinate with each other, how will they negotiate about their strategies? Now we deal with the strategy negotiation mechanism in the cooperation and non-cooperation forms among more agents.

If some agents coordinate with each other, then those agents will form a group. So we have the following definition.

Definition 2. *Coordination group (CG)*. In the framework considered here, a coordination group of agent *i*, CG_i, consists of all members of the population that play coordination with agent *i*.

In the coordination group of an agent, some agents may cooperate, and some agents may non-cooperate. Therefore, coordination group of agent *i*, CG_i, contains two sub-groups, one is the CCG_i which is the set of the agents that have cooperative coordination with i in the agent system, the other is NCG_i which is the set of agents that have non-cooperative coordination with i in the agent system. We have:

$$CG_i = CCG_i \cup NCG_i$$

Obviously, when such coordination takes place, agent *i* will only negotiate about its social strategy with its cooperation group, but ignore the non-cooperation group. Therefore, we have the negotiation rule for the coordination among mangy agents:

$$l_i' = average(CG_i) \qquad (3)$$

From the above negotiation rule, we can see that the agent will incline to follow the average strategy of its cooperation group.

4. Examples

Now we can make some examples to demonstrate our model for the negotiation mechanism of agent strategies.

agent	strategy (L_i^*)	rank
a_1	l_1	7
a_2	l_4	3
a_n	l_3	2

Figure 5. An example for demonstration

Figure 5 is an example for some agents and their strategies. Now we use it to demonstrate different negotiation mechanisms of their strategies.

If agent a_1 orders a_2, then the social strategy of a_1 after negotiation will be its locally most authoritative strategy, *i.e.* $l_1' = L_1^* = l_1$; the social strategy of a_2 after negotiation will be the one of a_1, $l_2' = l_1' = l_1$.

If agent a_1 cooperates with a_2, then the social strategies of a_1 and a_2 after negotiation are: $l_1' = l_2' = average(L_1^*, L_2^*) = l_2$;

If agent a_1 non-cooperates with a_2, then $l_1' = L_1^* = l_1, l_2' = L_2^* = l_4$.

Now we add an agent a_n which can make coordination with a_1 and a_2. Let the locally most authoritative law of a_n is l_3, the authority of l_3 is 2. We will have:

1).If $a_1 \Leftrightarrow a_2 \Leftrightarrow a_n$, *then:*

$$l_1' = average(L_1^*, L_2^*) = l_2$$

$$l_2' = average(L_1^*, L_2^*, L_n^*) = l_2$$

$$l_n' = average(L_2^*, L_n^*) = l_4$$

2).If $a_1 \Leftrightarrow a_2 \leftrightarrow a_n$, *then:*

$$l_1' = l_2' = average(L_1^*, L_2^*) = l_2$$

$$l_n' = L_n^* = l_2$$

3). *If* $a_1 \leftrightarrow a_2 \leftrightarrow a_n$ *,then:*

$$l_1^{'} = L_1^{*} = l_1$$

$$l_2^{'} = L_2^{*} = l_4$$

$$l_n^{'} = L_n^{*} = l_3$$

4). *If* $a_1 \Leftrightarrow a_2 \Leftrightarrow a_n \Leftrightarrow a_1$, *then:*

$$l_1^{'} = l_2^{'} = l_n^{'} = average(L_1^{*}, L_2^{*}, L_n^{*}) = l_2$$

5). *If* $a_1 \leftrightarrow a_2 \Leftrightarrow a_n \Leftrightarrow a_1$, *then:*

$$l_1^{'} = average(L_1^{*}, L_n^{*}) = l_1$$

$$l_2^{'} = average(L_2^{*}, L_n^{*}) = l_4$$

$$l_n^{'} = average(L_1^{*}, L_2^{*}, L_n^{*}) = l_2$$

6). *If* $a_1 \leftrightarrow a_2 \leftrightarrow a_n \Leftrightarrow a_1$, *then:*

$$l_1^{'} = l_n^{'} = average(L_1^{*}, L_n^{*}) = l_1$$

$$l_2^{'} = L_2^{*} = l_4$$

7). *If* $a_1 \leftrightarrow a_2 \leftrightarrow a_n \leftrightarrow a_1$, *then:*

$$l_1^{'} = L_1^{*} = l_1$$

$$l_2^{'} = L_2^{*} = l_4$$

$$l_n^{'} = L_n^{*} = l_3$$

5. Conclusion

We deal with the three kinds of forms in the agent social strategy negotiation, which are the order form, cooperation form, and non-cooperation form. Those three coordination forms may take different impacts to the agent social strategy negotiation; therefore, it is necessary to make tradeoff between them. To solve such problem, this paper presents a hybrid negotiation mechanism for agent strategies. After the agent strategy negotiation, the conflicts among agents will be reduced.

Our presented framework is as follws.

1). If an agent coordinates with other agents, they will negotiate about their inclined social strategies to reduce the conflicts;

2) .There are always 3 kinds of forms in multiagent coordination which are order, cooperation and non-cooperation. The agents will adopt different negotiation method about their strategies according to the coordination form.

The presented model is demonstrated by an example. However, now our work is still mainly theoretical and elementary. Our future task will focus on the further application of the agent strategy negotiation model in real large-scale social agent systems.

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