Multi-Agent Coordination: A Fuzzy Logic Based Approach

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ABSTRACT

In the past decade, the multiagent systems have appeared as a new promising software paradigm. However, its successful application is subject to the adoption of effective agent coordination techniques. In this paper, we consider a fuzzy logic based approach to agent coordination. Specifically, a bidding based coordination strategy has been proposed to manage the inter-relations among agents. The strategy is developed under the fuzzy logic based task structure model (FSTS) we proposed. Through using the strategy, agents can effectively coordinate their behaviors without consuming so much communication and computation resources.

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I.2.11 [Distributed Artificial Intelligence]: Multiagent systems

General Terms
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Multi-agent System, Coordination, Fuzzy Logic

1. INTRODUCTION

In the past decade, the multiagent systems have appeared as a new promising software paradigm. However, its successful application is subject to the adoption of effective agent coordination techniques. In this paper, we consider a fuzzy logic based approach to agent coordination. Specifically, a bidding based coordination strategy has been proposed to manage the inter-relations among agents. The strategy is developed under the fuzzy logic based task structure model (FSTS) we proposed. Through using the strategy, agents can effectively coordinate their behaviors without consuming so much communication and computation resources.

Due to the space limitation, we will only discuss our bid selection algorithm developed for this strategy to manage the usage of shared resources. The use of bidding as an agent coordination mechanism often appears in the settings where individual agents are self-interested. The agents may have different goals, and each agent is trying to maximize its own utility without concerning for global good. Recently, bidding mechanisms have also been utilized among cooperative agents, such as Decker and Li’s work [2]. However, they consider only one unshareable resource, which can lead to resource conflicts. Differed from their work, our research acknowledges the fact that several resources are often required by the agent at the same time, and all of those resources may lead to resource conflicts. The simple mechanism adopted by [2] seems ineffective in this case. For this reason, a new bid selection algorithm has been introduced in this paper.

2. THE BIDDING BASED COORDINATION STRATEGY

The bidding based coordination strategy serves as means for managing the inter-relations among agents. One important aspect of it is to ensure the coordinated use of resources among the agents. Specifically, under the consideration of the efficiency of the overall multi-agent system, the coordination strategy should ensure that only the most competent agents are eligible for using specific resources in order to fulfill their missions.

Bidding seems to be the mechanism that can meet this requirement, as the agents must compete with each other in order to get the right of using certain resources. In our coordination strategy, each bid stands for an application for performing certain tasks. The competence of performing a task by an agent, as has been described in FSTS, is modeled in terms of the corresponding utility gain, which can be obtained by the agent. Let $Utility_T$ denote the utility gain of performing the task $T$. The price of $T$, $Price_T$, can be determined through adopting a Takagi-Sugeno like fuzzy system. Suppose that the degree of satisfaction of the premise of rule $i$ in the rule base can be denoted as $\tau_i$, $Price_T$ can be then
evaluated using the following formula:

\[ Price = \frac{\sum \tau_i \cdot Price_b}{\sum \tau_i} \]  

(1)

Where \( Price_b \) is the output of rule \( i \) in the rule base. After the agents have made their bids, the bids that have resources conflicts will form a conflict group \( G_{bids} \). A conflict group \( G_{bids} \) is a set of bids that have mutual resources conflicts with each other. A bid can belong to several conflict groups simultaneously. To choose the set of winning bids, one mechanism would be to select one bid, which is not belong to the same conflict group of any chosen bids, for each agent. And the summation of the prices of all the selected bids is maximized. This is an optimization problem, which may consume so much computation resources of the agents.

Compared with this optimal solution, our bid selection algorithm can only find sub-optimal solutions. But it is simple and has polynomial complexity in the worst case. To decide the set of winning bids, the algorithm first sets \( B_w \) (the set of potential winning bids) to \( B \) (the set of all bids made by the agents), and identifies the set of conflict groups of \( B \). It then changes the price of each bid that belongs to \( k \) conflict groups to price/k. This is because if a is a winning bid and has been taken by the agent who made it, all the other bids belong to the \( k \) conflict groups cannot be taken by other agents anymore. Therefore, the price of a must be high enough in order to become a winning bid. In fact, the price should be greater than the summation of the prices of \( k \) bids with each belongs to a separate conflict group \( a \) belongs to. We hence set the price of a to price/k in order to take this into consideration.

After that, the algorithm begins to find the bid \( a \), which belongs to only one conflict group and has the highest price of that group. All the other bids belong to the same conflict group will therefore be eliminated from \( B_w \). The algorithm then calculates the support factor of each bid, which still exists in \( B_w \). The support factor of a bid that belongs to multiple conflict groups is a measure of the importance of the bid. It calculates the number of times that the bid has the highest price among the different conflict groups. The intuitive heuristic behind this is that a good bid should have the highest price among more conflict groups. Therefore the higher the factor, the more probable the bid is a winning bid. Any bid, whose support factor is lower than that of another bid, which has resource conflicts with it, is then eliminated from \( B_w \). The remaining bids, which belong to multiple conflict groups, are winning bids.

Upon identifying the set of potential winning bids, each agent must choose one of the bids he has won and abandon all the other bids. Let \( B_i \) denote the set of currently considered bids, and \( B^C \) denote the set of bids the agents have committed to take. The overall procedure of deciding \( B^C \) is as follow.

**Step1**

set \( B_c = B \) and \( \delta^C = \emptyset \)

**Step2**

find the set of potentially winning bids \( B_p \) of \( B_c \) by following the procedure described above.

**Step3**

If \( B_p = \emptyset \)

Goto Step4

End If

For each agent Agent, that has at least one bid belongs to \( B_p \). Agent, chooses one bid bid, he has made

\[ B^C = B^C \cup \{ bid \} \]

Remove from \( B_c \) any bid Agent, has made

Remove from \( B_c \) all the bids that belong to the same confliction groups as bid,

End For

Goto Step2

**Step4**

\( B^C \) is now the set of bids the agents have committed to take.

The process begins with \( B_c \) equals to \( B \). It uses the previously described algorithm to find the set of winning bids of \( B_c \). If there are no winning bids, \( B^C \) is the final set of bids the agents have committed to take. Otherwise, each agent must choose one of his winning bids, put the chosen bid into \( B^C \), and eliminates from \( B_c \) any bids he has made. The bids contained in \( B_c \), which have resource conflicts with the bids belong to \( B^C \), will also be eliminated from \( B_c \). After all the agents have made their choices, the process returns to Step2 to find the set of winning bids of the current \( B_c \). It can be shown that the complexity of this algorithm is \( O(n^2) \) and \( O(n^2) \), where \( n \) denotes the number of bids, and \( n \) refers to the number of types of resources, which can raise conflicts. This can also be demonstrated through our simulation results given below.

![Simulation results](image)

Figure 1: Simulation results

3. CONCLUSION

In this paper, we have focused on discussing our new bid selection algorithm, which is designed for our bidding-based coordination strategy. We have also shown that the algorithm has polynomial complexity. Besides the coordination strategy, the algorithm can also be applied in other fields as a typical decision making mechanism. However, its effectiveness in those fields are subject to further investigations.

4. REFERENCES
