A Game-Theoretic Solution of Conflicts Among Competitive Agents

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Abstract. Recently the control of multi-agent behavior using two-player non-zero sum games, such as prisoner’s dilemma, has been studied. In this paper we propose a two player game that includes a dilemmatic structure and extend it to the study of two teams consisting of many players. Iterative versions of dilemma games have been investigated extensively and many strategies for the games have been proposed. For multi-agent applications we extend our dilemma game to a multi-player version. Several decision strategies are studied with this model. The multi-player model is used to decide actions of agents in the burden carriage problem, which includes a typical situation of agents in competition. We show that the behavior of agents in the problem matches the results of team contests of the dilemma game.

1 Introduction and the Prisoner’s Dilemma

Using cooperative work by many agents to treat complex problems is a topic of distributed artificial intelligence. This approach is attractive because multi-agent systems are expected to be robust. For this purpose, agents must be simple but autonomous and well-behaved for many situations. One approach to give the complex behavior for agents is to learn from the collective behavior of natural creatures. This approach includes simulation of natural lives [5] and also genetic algorithms [10], which are a kind of global search algorithm modeled on natural selection.

The game-theoretic approach is another way to study autonomous multi-agent models. This approach assumes agents to be simple but reasonable entities based on a fixed rule or a game. By formalizing situations around agents to an appropriate game we can hope to find a good strategy for agents’ behavior.

The game-theoretic approach is appropriate for systems in which agents cannot negotiate with each other. Autonomous agents must decide their actions by themselves, sometimes without any communication with other agents. In some cases, an agent’s benefit from an action depends on the action of another agent and agents are faced with a dilemma. Prisoner’s Dilemma, a two-player non-zero sum game, is a very well known example that formalizes such cases [2, 8, 4].
Table 1. Payoff matrix for the Prisoner's Dilemma game

<table>
<thead>
<tr>
<th>A/B</th>
<th>cooperate</th>
<th>defect</th>
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<tbody>
<tr>
<td>cooperate</td>
<td>R=2\ R=2</td>
<td>S=0\ T=3</td>
</tr>
<tr>
<td>defect</td>
<td>T=3\ S=0</td>
<td>P=1\ P=1</td>
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</table>

Fig. 1 is the payoff matrix for the Prisoner's Dilemma game. Each of two players can take cooperate or defect actions. If player A takes cooperate his/her payoff is 2 (=R) as a reward for mutual cooperation or 0 (=S) as a sucker, depending on the choice of player B. Similarly, if player A takes defect his/her payoff is 3 (=T) as a winner of tactics i.e. temptation to defect or 1 (=P) as punishment for mutual defection.

A player achieves a high payoff by taking defect whether or not the other player takes cooperate or defect and so defect should be taken if he/she would like to win against the opponent. However, players can achieve more payoff [2] by cooperating with others than the average of the two defect cases, the average of which is (0 + 3)/2 = 1.5. That is, the payoff matrix satisfies T > R > P > S and R > (T + S)/2, and this defines the structure of Prisoner's Dilemma.

In this paper we study a game-theoretic approach to control agents that work in competitive situations. Multi-agents have been studied as a way of solving problems by cooperative work. Agents sometimes face competitive situations during such cooperative work. For example, two agents may each try to take some resource at the same time to accomplish their objectives. In this case their alternative options are to take the resource or to give it to the other agent. To formalize this situation we propose a new dilemma game, Compromise Dilemma (CD) game, in Section 2. We study several strategies for this dilemma game.

In Section 3 an iterative version of the Compromise Dilemma game is studied. Iterative versions of Prisoner's Dilemma have been extensively investigated. Iterative Compromise Dilemma is not sufficient to analyze multi-agent problems. However, we study it to introduce strategies for dilemma games and to compare it with the models introduced in the later sections.

We extend the CD model to a multi-player model, Team Match of Compromise Dilemma (TMCD), in Section 4. We then apply this model to an example of cooperative work in a multi-agent system called the Burden Carriage Problem. In this problem, agents carry pieces of a burden from place to place. An agent will sometimes meet other agents on their own ways. To avoid a collision, agents need to play the Compromise Dilemma game. We apply strategies for Compromise Dilemma to resolve collisions in Section 5.

2 Compromise Dilemma

As we discussed in the previous section, Prisoner's Dilemma is not always suitable to formalize dilemmas in practical situations. Other dilemma games