A Conflict Classification and Resolution Modeling in Multi-Agent Systems

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INTRODUCTION

Multi-agent systems are moving towards large-scale, distributed, and open structure. In this type of environment, the occurrence of conflicts introduces many problems through agents' interactions. Such conflicts must be resolved in the best possible manner so that the performance of conflicting agents does not degrade arising from the conflicts. It is therefore important to ensure selection of appropriate conflict resolution strategies in a way to minimize agents' performance degradation.

Conflict has long been defined as a topic of importance in multi-agent environments and it occurs when two agents have dissenting opinions on the same subject (Nguyen et al., 2002). Specifically, classification of conflicts provides a form of control in an environment in which agents are in conflicts with other agents in unknown conflict ratio and disagreement degree. Classification can be utilized to select the most appropriate resolution strategies to resolve conflicts rather than using one strategy for all conflict situations. In this article, we adapt a conflict model in which we define conflict strength to be a particular measure of conflict between unknown number of agents about undefined dissenting issues.

We propose a classification model of conflict based on three factors: agent's confidence level (which is assumed to be available in the system), conflict ratio, and disagreement degree. We use the conflict ratio and disagreement degree for modelling the conflict strength that is used with the confidence level to choose suitable conflict resolution strategies for the corresponding conflicting situations.

BACKGROUND

Conflict Resolution in Agents and Multi-agent Systems

A multi-agent system is considered as a collection of entities communicating and interacting with each other to achieve individual or collective goals (Liu et al., 1998). Through coordinating operation, agents work jointly to guarantee coherent processes. However, agents occasionally overlook the total view of the overall problem, which causes conflicts among them (Moraïtis, 2013). Clearly, if such a system provides communication between agents, then such communication may include conflicts.

A conflict is any situation of disagreement between two or more agents or two or more groups of agents. This disagreement can be in plans, desires, or belief. The conflict state can happen during the design time or run time. Conflict resolution is a fundamental process for coordinated agent actions. Solving conflicts that arise in multi-agent environments depend on the conflicts' types and dimensions. The essential part of understanding the nature of conflicts is conflict classification. Knowing the nature of a conflict reduces the search space of possible resolution strategies and/or modification mechanisms and helps agents to select the most appropriate behaviors that are most effective to resolve the conflict (Barber et al., 2000).

LIMITATION OF EXISTING APPROACH

The works that we reviewed consider a specific criteria for selecting strategies that resolve conflicts. These works do not exploit other information such as the number of conflicting agents, confidence level of these agents and conflict strength.

To provide a near-perfect method of a conflict resolution strategy selecting operation, the strength of conflict and the confidence level of agents need to be analyzed. Our argument for such proposition is that we should not ignore the influence of the confidence levels of conflicting agents that control the direction of conflict resolution processing. The agents' confidence levels are important since a high confidence level may lead to selecting a forcing or any strategies. Without having the information about an agent's confidence level, it is hard to select an appropriate strategy (Thomas, 1992).

A PROPOSED CONFLICT RESOLUTION STRATEGY

Given the importance of conflict classification as a form of conflict resolution control, several researchers have developed models for this goal. In developing our model, we define the following requirements:

- The model must provide a measure of confidence or confidence level of conflicting agents for each conflict situation, which allows comparison between conflicting agents, so that one agent (or group of agents) can be specified as having higher confidence level than the others.
- The model must provide a ratio of conflict (RC), which detects the number of conflicting agents in both conflicting sides.
- The model must provide a disagreement degree (DD) by detecting the number of dissenting issues in each conflict situation.

Definition

We define the variables which are used in the article as follows:

- **O (opinion):** is an agent's assertion of an idea arising from its belief.
- **C (conflict):** is a state of disagreement between two agents' opinions.
- **CR (conflict ratio):** is a ratio of conflicting agents to a total number of agents.
- **DI (dissenting issue):** is an issue that causes conflict between agents.
- **CS (conflict strength):** If two agents, a_i and a_j conflicts on a dissenting issue, then CS_{ij} represents the conflict strength between a_i and a_j.
- **DD (disagreement degree):** is a ratio of dissenting issues to a total number of issues in one conflicting state.
- **CAS (conflicting agent set):** is a set of pairs of conflicting agents (or groups of agents). For example, if a_i conflicts with a_j, then $CAS = \{(a_i, a_j)\}$.
- **CST (conflicting states):** is a finite set of all conflict states, $\{(c_{ai}, c_{aj}), (c_{am}, c_{an}), \dots\}$. A conflict between c_{ai} and c_{aj} occurs when the agent c_{ai} selects an issue that is different from that selected by c_{aj}.
- **SS (selected strategy):** is the strategy that is selected to resolve the conflict.
- **ACT (agent confidence table):** contains the confidence value for each agent in the system.

CONFLICT CLASSIFICATION

Conflicts classification in MAS increases the conflict resolution process. If we assume there is a single conflict resolution strategy available in the system, classifying the conflict state direct agents on the objectives for using the strategy (Nguyen et al., 2002). Conflict representation, classification, and detection are the basic building blocks for an entire conflict resolution (CR) process. Proper classified conflicts not only help in the search for solutions, but also the selection of CR strategies themselves" (Nguyen et al., 2002).

Few researchers discussed classification of conflicts in multi-agent systems (Barber et al., 1999; Tessier et al., 2000). Barber et al. (1999) classified conflicts in agents' society into three types: goal conflict, belief conflict and plan conflict. Tessier et al., (2000) clas-

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