MASTER'S THESIS

The relationship between local behavior and global characteristics in multi-agent systems

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The Relationship between Local Behavior and Global Characteristics in Multi-Agent Systems

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Abstract

In a multi-agent system (MAS), there usually exist several system-level goals that agents need to attain. In most cases, we can only directly control and engineer individual agents rather than an MAS. For example, in RoboCup, two teams of players play a soccer game. We need to design and implement autonomous players that understand how to organize effective attack and defense maneuvers with their teammates to win the game. In order to attain the system-level goals, understanding the relationship between the local behavior of players and the global characteristics of the team is crucial. Generally speaking, agent local behavior refers to the behavior of an agent that has only local influences on the global characteristics of an MAS. Global characteristics include global performance and global patterns. Global performance corresponds to the overall performance of a team. Global patterns refer to the fashion in which an agent team attempts to execute its actions to fulfill its goals.

Usually the local-global relationship is not very obvious nor straightforward. In some way, the global characteristics of an MAS emerge from the local behavior of agents. Nonetheless, there is no general means to figure out such a relationship.

At present, there are some specific studies devoted to the local-global relationship, e.g., concerning cellular automata computation, multi-agent negotiation, collective robots behavior, Self-Organized Criticality (SOC), and phase transitions. In our present work, we attempt to study the local-global relationship in two distinct yet interrelated types of MAS: RoboNBA and Self-Organizing Multi-Agent System (SOMAS).

For RoboNBA, we have designed, implemented, and tested a RoboNBA platform. Two different sources of local behavior have been introduced: decision-making mechanisms and agent strategies. Two decision-making mechanisms have been proposed for RoboNBA. One adopts a top-down design while another uses a bottom-up design. We have compared the two decision-making mechanisms with respect to global characteristics and have obtained some interesting observations. We have also defined some strategies for players, such as how to pass and defend. Besides, we have addressed the problem of how to quantitatively measure the global performance and global patterns in RoboNBA. For global patterns, we have focused on the diversity of attack patterns of a team. In addition, we have gained some understanding on how the global patterns of a team emerge from the decision-making mechanisms of agents. Furthermore, we have investigated how global characteristics and global performance correlate in different scenarios. Particularly, we have found that the diversity of attack patterns in a team increases as its opponent team becomes weaker.

Our research work on RoboNBA can be beneficial to some research problems, such as RoboCup and multi-agent pursuit and evasion game. However, it is not applicable to a generalized scenario. In order to address this issue, we have developed SOMAS to study the local-global relationship in a more generalized scenario.

For SOMAS, to study the local-global relationship, we need to understand two issues. The first is how to quantitatively define and measure the global characteristics of an MAS. The global characteristics include many attributes, such as the performance of an MAS, the global functioning patterns of an MAS, and most importantly, the complex behavior of an MAS . The second is how to produce different global characteristics from the local behavior of individual agents in an MAS.

In our present work of SOMAS, we have achieved the following objectives to address the aforementioned issues. We have provided SOMAS to describe more general competitive scenarios in MAS applications, such as RobNBA and RoboCup matches. Based

on the model, we have carried out some experiments. By comparing and analyzing the experimental results, we have gained some understanding on the Self-Organized Criticality (SOC) phenomena that occur in SOMAS. The avalanches of player performance and team morale follow a power-law distribution under a particular setting. More importantly SOC phenomena in the team morale avalanche are robust against all k values while the player performance avalanche may demonstrate exponential characteristics for some k values. In addition, we have adopted a probability based mechanism in the opponent selection process and have discovered that it can outperform a greedy algorithm when the information of players is limited. Furthermore, we have explained the SOC phenomena by demonstrating that the SOC occurrence in team patterns is positively correlated to the good performance of a team under different experimental settings. Finally, we have identified that a parameter k in $Y(\alpha_1, \alpha_2)$ can have a great impact on the scaling structures of player performance and team morale as well as maximum size of avalanches. Based on Shannon's entropy theory, we have provided a conjecture that gives some insights into the phase transitions produced by the critical parameter k.

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