Multiagent Behaviors in Neural Network

Jimmy Lin
Barry Feigenbaum

Prof. Risto Miikkulainen

Department of Computer Science
The University of Texas At Austin

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Recap

What we currently have?

- Commitee Machine
- Reinforcement Learning
- Neuro-evolution
- High-level Behaviors

Motivation

- Most of works so far has focused exclusively on single agents we can extend reinforcement learning straightforwardly to multiple agents if they are all independent.
- Intuitive idea: Multiple agents together will outperform any single agent due to the fact that they have more resources and a better chance of receiving rewards.
- Today, we will touch a really broad area

"Multiagent System" (M.A.S.).

Introduction

What is multiple agent system?

- Unfortunately, it is not formally defined by M.A.S. community.
- Employment of multiple agents (10 to thousands).
- Intelligent mechanisms to address interactions between agents.

When is it proposed?

- a relatively new sub-field of computer science
- has only been studied since about 1980
- only gained widespread recognition since about the mid-1990s

M.A.S. Environments

The agents in a multi-agent system have several important characteristics:

- Autonomy: the agents are at least partially independent, self-aware, autonomous.
- Local views: no agent has a full global view of the system, or the system is too complex for an agent to make practical use of such knowledge.
- Decentralization: there is no designated controlling agent (or the system is effectively reduced to a monolithic system).

Applications/Simulations

- Pacman
- Crowd Simulation / Crowd Collision Avoidance
- ClearPath: Highly Parallel Collision Avoidance for Multi-agent Simulation
- MATISSE: A Multi-Agent based Traffic Simulation System

Independent v.s. Cooperative Agents

Tang Ming (1993) [**1**] studied the performance of cooperative agents, using independent agents as a benchmark. Here are the discoveries:

- Additional sensation from another agent is beneficial if it can be used efficiently.
- Sharing learned policies or episodes among agents speeds up learning at the cost of communication.
- For joint tasks, agents engaging in partnership can significantly outperform independent agents although they may learn slowly in the beginning.

Active Research Areas

Currently active research areas of M.A.S. are advanced Multiagent Behaviors, as follows:

- Communication
- Cooperation and Coordination
- Negotiation
- Distributed Problem Solving
- Multi-agent Learning
- Fault Tolerance

Communication

Communication is defined as altering the state of the environment such that other agents can perceive the modification and decode information from it.

- Direct Communication
- Indirect Communication

Cooperation and Coordination

Negotiation

Distributed Problem Solving

The state space of a large, joint multi-agent task can be overwhelming. An obvious way to tackle this is to use domain knowledge to simplify the state space, often by providing a smaller set of more powerful actions customized for the problem domain.
An alternative has been to reduce complexity by heuristically decomposing the problem, and hence the joint behavior, into separate, simpler behaviors for the agents to learn. Such decomposition may be done at various levels (decomposing team behaviors into sub-behaviors for each agent; decomposing an agents behavior into sub-behaviors; etc.), and the behaviors may be learned independently, iteratively (each depending on the earlier one), or in a bottom-up fashion (learning simple behaviors, then grouping into complex behaviors).

Multi-agent Learning

Fault Tolerance

Reinforcement learning

- Barry, here u go.

Questions, Suggestions or Some Other Ideas?

Our Research Project

- Motivations
- Mechanisms
- Suggestions

Further Readings: Books

- W. Michael. *An introduction to multiagent systems*. John Wiley & Sons, 2009.
- S. Yoav, and K. L. Brown. *Multiagent systems: Algorithmic, game-theoretic, and logical foundations*. Cambridge University Press, 2008.
- W, Gerhard, ed. *Multiagent systems: a modern approach to distributed artificial intelligence*. MIT press, 1999.

Further Readings: Courses and Labs

- Stanford CS224M: Multi Agent Systems (Spring 2013-14). HERE
- MIT CPSC689: Special Topics in Multi-Agent Systems (Spring 2006). HERE
- Stanford Multiagent Research Group. HERE
- CMU Advanced Agent-Robotics Technology Lab. HERE
- MIT Robust Open Multi-Agent Systems (ROMA) Research Group. HERE

References

[1] Tan, Ming. "Multi-agent reinforcement learning: Independent vs. cooperative agents." *Proceedings of the Tenth International Conference on Machine Learning*. Vol. 337. 1993.