Multi-Agent Applications with Evolutionary Computation and Biologically Inspired Technologies:

Intelligent Techniques for Ubiquity and Optimization

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Successful decision-making by home-owners, lending institutions, and real estate developers among others is dependent on obtaining reasonable forecasts of residential home prices. For decades, home-price forecasts were produced by agents utilizing academically well-established statistical models. In this chapter, several modeling agents will compete and cooperate to produce a single forecast. A cooperative multi-agent system (MAS) is developed and used to obtain monthly forecasts (April 2008 through March 2010) of the S&P/Case-Shiller home price index for Los Angeles, CA (LXXR). Monthly housing market demand and supply variables including conventional 30-year fixed real mortgage rate, real personal income, cash out loans, homes for sale, change in housing inventory, and construction material price index are used to find different independent models that explain percentage change in LXXR. An agent then combines the forecasts obtained from the different models to obtain a final prediction.

Portfolio optimization is the determination of the weights of assets to be included in a portfolio in order to achieve the investment objective. It can be viewed as a tight combinatorial optimization problem that has many solutions near the optimal solution in a narrow solution space. In order to solve such a tight problem, this chapter introduces an Agent-based Model. The authors employ the Information Ratio, a well-known measure of the performance of actively managed portfolios, as an objective function. This agent has one portfolio, the Information Ratio and its character as a set of properties. The evolution of agent properties splits the search space into a lot of small spaces. In a population of one small space, there is one leader agent and several follower agents. As the processing of the populations progresses, the agent properties change by the interaction between the leader and the follower, and when the iteration is over, the authors obtain one leader who has the highest Information Ratio.

Section 2
Neuro-Inspired Agents

Recently, the relation between neuroeconomics and agent-based computational economics (ACE) has become an issue concerning the agent-based economics community. Neuroeconomics can interest agent-based economists when they are inquiring for the foundation or the principle of the software-agent design, normally known as agent engineering. It has been shown in many studies that the design of software agents is non-trivial and can determine what will emerge from the bottom. Therefore, it has been quested for rather a period regarding whether we can sensibly design these software agents, including both the choice of software agent models, such as reinforcement learning, and the parameter setting associated with the chosen model, such as risk attitude. This chapter starts a formal inquiry by focusing on examining the models and parameters used to build software agents.

This chapter models quantum and neural uncertainty using a concept of the Agent–based Uncertainty Theory (AUT). The AUT is based on complex fusion of crisp (non-fuzzy) conflicting judgments of agents. It provides a uniform representation and an operational empirical interpretation for several uncertainty theories such as rough set theory, fuzzy sets theory, evidence theory, and probability theory. The AUT models conflicting evaluations that are fused in the same evaluation context. This agent approach gives also a novel definition of the quantum uncertainty and quantum computations for quantum gates that are realized by unitary transformations of the state. In the AUT approach, unitary matrices are interpreted as logic operations in logic computations. The authors show that by using permutation operators any type of complex classical logic expression can be generated. With the quantum gate, the authors introduce classical logic into the quantum domain. This chapter connects the intrinsic irrationality of the quantum system and the non-classical quantum logic with the agents. The authors argue

Section 4
Multi-Agent Robotics

Artificial evolution has been considered as a promising approach for coordinating the controller of an autonomous mobile robot. However, it is not yet established whether artificial evolution is also effective in generating collective behaviour in a multi-robot system (MRS). In this study, two types of evolving artificial neural networks are utilized in an MRS. The first is the evolving continuous time recurrent neural network, which is used in the most conventional method, and the second is the topology and weight evolving artificial neural networks, which is used in the noble method. Several computer simulations are conducted in order to examine how the artificial evolution can be used to coordinate the collective behaviour in an MRS.

This chapter presents a framework using novel methods for controlling mobile multiple robots directed by mobile agents on a communication networks. Instead of physical movement of multiple robots, mobile software agents migrate from one robot to another so that the robots more efficiently complete their task. In some applications, it is desirable that multiple robots draw themselves together automatically. In order to avoid excessive energy consumption, the authors employ mobile software agents to locate robots scattered in a field, and cause them to autonomously determine their moving behaviors by using a clustering algorithm based on the Ant Colony Optimization (ACO) method. ACO is the swarm-intelligence-based method that exploits artificial stigmergy for the solution of combinatorial optimization problems. Preliminary experiments have provided a favorable result. Even though there is much room to improve the collaboration of multiple agents and ACO, the current results suggest a promising direction for the design of control mechanisms for multi-robot systems. This chapter focuses on the implementation of the controlling mechanism of the multi-robot system using mobile agents.

Section 6
Multi-Agent Learning

The multiagent reinforcement learnig approach is now widely applied to cause agents to behave rationally in a multiagent system. However, due to the complex interactions in a multiagent domain, it is difficult to decide the each agent's fair share of the reward for contributing to the goal achievement. This chapter reviews a reward shaping problem that defines when and what amount of reward should be given to agents. The author employs keepaway soccer as a typical multiagent continuing task that requires skilled collaboration between the agents. Shaping the reward structure for this domain is difficult for the following reasons: i) a continuing task such as keepaway soccer has no explicit goal, and so it is hard to determine when a reward should be given to the agents, ii) in such a multiagent cooperative task, it is difficult to fairly share the reward for each agent's contribution. Through experiments, this chapter finds that reward shaping has a major effect on an agent's behavior.

In open multiagent systems, individual components act in an autonomous and uncertain manner, thus making it difficult for the participating agents to interact with one another in a reliable environment. Trust models have been devised that can create level of certainty for the interacting agents. However, trust requires reputation information that basically incorporates an agent's former behaviour. There are two aspects of a reputation model i.e. reputation creation and its distribution. Dissemination of this reputation information in highly dynamic environment is an issue and needs attention for a better approach. The authors have proposed a swarm intelligence based mechanism whose self-organizing behaviour not only provides an efficient way of reputation distribution but also involves various sources of information to compute the reputation value of the participating agents. They have evaluated their system with the help of a simulation showing utility gain of agents utilizing swarm based reputation system.

Exploitation-oriented Learning XoL is a new framework of reinforcement learning. XoL aims to learn a rational policy whose expected reward per an action is larger than zero, and does not require a sophisticated design of the value of a reward signal. In this chapter, as examples of learning systems that belongs in XoL, the authors introduce the rationality theorem of profit Sharing (PS), the rationality theorem of reward sharing in multi-agent PS, and PS-r*. XoL has several features. (1) Though traditional RL systems require appropriate reward and penalty values, XoL only requires an order of importance among them. (2) XoL can learn more quickly since it traces successful experiences very strongly. (3) XoL may be unsuitable for pursuing an optimal policy. The optimal policy can be acquired by the multi-start method that needs to reset all memories to get a better policy. (4) XoL is effective on the classes beyond MDPs, since it is a Bellman-free method that does not depend on DP. The authors show several numerical examples to confirm these features.

Pheromones are the important chemical substances for social insects to realize cooperative collective behavior. The most famous example of pheromone-based behavior is foraging. Real ants use pheromone trail to inform each other where food source exists and they effectively reach and forage the food. This sophisticated but simple communication method is useful to design artificial multiagent systems. In this chapter, the evolutionary pheromone communication is proposed on a competitive ant environment model, and the authors show two patterns of pheromone communication emerged through co-evolutionary process by genetic algorithm. In addition, such communication patterns are investigated with Shannon's entropy.

Cellular Automata (CAs) have been investigated extensively as abstract models of the decentralized systems composed of autonomous entities characterized by local interactions. However, it is poorly understood how CAs can interact with their external environment, which would be useful for implementing decentralized pervasive systems that consist of billions of components (nodes, sensors, etc.) distributed in our everyday environments. This chapter focuses on the emergent properties of CAs induced by external perturbations toward controlling decentralized pervasive systems. The authors assumed a minimum task in which a CA has to change its global state drastically after every occurrence of a perturbation period. In the perturbation period, each cell state is modified by using an external rule with a small probability. By conducting evolutionary searches for rules of CAs, the uathors obtained interesting behaviors of CAs in which their global state cyclically transited among different stable states in either ascending or descending order. The self-organizing behaviors are due to the clusters of cell states that dynamically grow through occurrences of perturbation periods. These results imply that the global behaviors of decentralized systems can be dynamically controlled by states of randomly selected components only.