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Abstract

MODELING SWARM INTELLIGENCE AND ITS APPLICATIONS IN ROBOTICS AND OPTIMIZATION

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There are many creatures living in manner of social behavior, such as ants, bees, and fish, where many individuals cooperate with each other to accomplish their jobs for living. Such a social behavior has some special characters, including homogeneous individual, local interaction, implicit communication, etc.. Hence this social behavior results in a novel artificial intelligent technique, named swarm intelligence. Comparing with traditional artificial intelligent techniques, swarm intelligence seems more robust, higher performance, and easier to realize. Hence swarm intelligence has become an attractive research topic in artificial intelligence community, and has been applied in many fields, such as robotics, computation, etc..

When swarm paradigm is used in engineering, because it is a kind of bottom-up architecture, normally the individual behavior of every member is very simple. Hence it is easy to design individual behaviors for members of swarm for engineering tasks. However such a "simple" individual behavior also results in another problem that how to explain the complex behavior of the whole swarm which emerges from individuals "simple" behaviors. In other words, how to model swarm behavior in order to reveal the relationship between complex group behavior and simple individual behaviors.

This dissertation concentrates upon studing on models of swarm intelligence to illustrate how to analyze model and use it to figure out properties of swarm systems, and how to generate practical swarm systems in engineering. Up to now two modeling methods are developed to describe cooperation behavior in swarm systems: macroscopic model and microscopic model. Because the models describe swarm behaviors in two different layers, each of them is built based on some simplifications which ignore some factors that are the key components to build another model. Hence in this dissertation, a hybrid modeling method is generated which combines the both modeling methods, so that this hybrid model can be used to describe individual movements in a complex swarm system with role changes, that is hardly to be described by macro- or microscopic model alone. From the model not only temporal dynamics of roles of robots, but also the expectant trajectories of robots can be figured out. By using Lyapunov theory for smooth and nonsoomth dynamics, some important properties are obtained which depict the spatial distributions of objects in collecting process and temporal distribution of robots in different roles.

Since the both models focus on description of cooperation among individuals, normally the physical properties of individuals are ignored in both models. Hence only by these

models one can not design the practical swarm systems with real robots. To illustrate the applications of swarm intelligence in robotics, the dissertation introduces a practical multi-robot system using some principles of swarm paradigm to realize formation task, where inner relationship of formation is described by graph theory, so that a decentralized control method can be derived to make robots move together. In individual controller, an adaptive neural network with robust terms is applied so that even with parameter uncertainty of mobile robots, the controller is still able to drive robot follow its reference points. Moreover it is proved that using this control strategy, no matter the dynamics of the formation is continuous or noncontinuous, robots will form a formation according to a predetermined pattern. This conclusion is very useful to realize variant formation pattern and obstacle avoidance.

Another application of modeling swarm behavior involved in this dissertation is optimization technique using swarm intelligence. From the view of model, the updating principle of particle swarm optimization (PSO) is indeed a microscopic model. Hence the dissertation analyzes the updating principle of PSO and introduces a kind of random search behavior into this model in order to enhance PSO performance. This modified model is named PSO with controllable random exploration velocity (PSO-CREV). By theoretical analysis on the modified model, some interesting properties are figured out from PSO-CREV. These properties imply that PSO-CREV has higher exploration ability than the conventional PSO. That is also verified by a series of benchmarks. Finally to illustrate the convergent performance of PSO-CREV and its high computational efficiency, two examples of applications of PSO-CREV in engineering, including NN training and real-time predictive control of mobile robots are proposed.