Research on learning of cooperative actions among autonomous mobile robots

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By using many robots, difficult tasks(for example large box pushing) for a robot can be done efficiently. Moreover, the flexibility of system is acquired such as other robots support task when one of robots breaks. When designing such a robot group, the number in the state where a robot should correspond increases that the robots increases. And it is difficult for man to design the robot which performs more advanced cooperation action. Therefore, a robot needs to learn so that it may be adapted for environment. Moreover, the simple internal structure and the learning method of robot is desirable. Our research aims to learn of the cooperation action by the simple internal structure and learning method. And we consider a formation task as cooperation action.

In our research, learning cooperative action among autonomous mobile robots uses the simple method of an Artificial Neural Network(ANN) to internal structure and Genetic Algorithm(GA) to learning method. It is so-called evolutionary robotics that a robot learn to apply to environment using evolutionary techniques. The GA+ANN is popular approach in evolutionary robotics.

A formation by robots is an important task in robot group control and artificial life. In Balch research, three different techniques for achieving and maintaining a given formation within a group of robots are identified:

unit-center-referenced, leader-referenced, and *neighbor-referenced control*. Each robot determines other robot positions by GPS, and its coordinates in the gloabal coordinate system are broadcast to all robots. It is unrealistic that all robots know the positions and orientations of the other robots by problem such as increase of communication cost. Therefor, robots must be controalled by local sensing. In our research, formation task is characterized: *Using local sensing, All robots are equal(There is no leader)* and *There is no communication of each other*. Under such conditions, robot learns column formation used by GA+ANN. And it clarifies the suitable design technique to creating a formation. The dependancy on the initial states at creating a formation is also considered.

Although the structure of various networks is used by GA+ANN, The best structure of the network is not decided. Our research uses the ANN structure of 3-layer feedforward, simple recurrent network(SRN), 2-layer recurrent network and feedforward with past input before one step. And the ANN weight matrix are learned by GA. As the result, it is clear that the feedforward type network is mast suitable.

Fitness function of GA which we designed consists of two kinds about a)individual behavior and b)social behavior. The fitness function a) consists of Wandering, Find and Approach. The fitness function b) is a formation form. We designs three fitness function of social behavior. 1) *The fitness is so high that The time located in a line with the straight line is long.* 2) *Using No.1. Furthermore, a high fitness will be obtained if it becomes in the same direction.* 3)*High fitness are given for every stage which create formation.* Total fitness function consists of fitness function of a) and b). A result, it is clear that it can learn also by fitness function No.2 which is a simple design.

In the result of learning formation by the simulation, the robots was able to get column formation. However, the individual which can be adapted for all initial states did not appear. When we examined by five robots using the learning result, five robots succeeded in createing a column formation.

A result, when a robot learn a column formation, it is clear that a simple feedforward is better. And the result which carried out comparison examination about the fitness function,it is clear that it can learn formation task, even if it describes only a formation in fitness function.