# Multi-agent Cooperation Using Genetic Network Programming with Automatically Defined Groups

Tadahiko Murata and Takashi Nakamura

Department of Informatics, Kansai University, Takatsuki, 569-1095, Osaka, Japan
murata@res.kutc.kansai-u.ac.jp,
http://www.res.kutc.kansai-u.ac.jp/~murata/

**Abstract.** In this paper, we propose a genetic network programming (GNP) architecture using a coevolution model called automatically defined groups (ADG). The GNP evolves networks for describing condition-action relations for agents. By applying ADG to GNP, we evolve different networks in order to realize the cooperation of multiple agents with different abilities. Computational experiments on a load transportation problem show that appropriate networks are obtained with taking account of the ability of agents.

## 1 GNP with ADG

Genetic Network Programming (GNP) has been proposed [1] for describing successions of processing. It is inspired from GP, however it does not have a tree architecture, but has a network architecture. Fig. 1 shows an example of networks obtained by the GNP. There are three types of nodes in a network: a start node, judgment nodes (diamonds), and processing nodes (circles). Agents make decisions on their behaviors according to the obtained network. For example, an agent examines whether it carries a load or not in the first judgment node “Carry?” If it is carrying a load, it moves to a goal according to the processing node “Move to goal.” Otherwise, it will go to a place with heavy loads. Using network architecture GNP can obtain a succession of actions as shown in Fig. 1 while GP realizes a succession of actions by returning to a root node from a terminal node in which an agent can take an action.

When each agent has a different ability, a different network should be obtained according to the ability of the agent. We employ a coevolution model called automatically defined groups (ADG) [2]. While the model was originally proposed for GP, we apply it to GNP in order to develop different networks according to the ability of agents. We show the effectiveness of the GNP with ADG by computational experiments on a load transportation problem [2].

## 2 Simulations on Load Transportation Problem

We applied a GP, a GNP, a GNP with a heterogeneous model (GNP-H) and the proposed method, that is a GNP with ADG (GNP-A) to a load transportation problem.

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In the GNP-H, each agent has its own network while the original GNP has only a network for all agents. In the load transportation problem, there are light and heavy loads in a two-dimensional grid world. The number of agents is 20. Among them only five agents can bring a heavy or light load. The other 15 agents can carry only a light load at a time. When an agent brings a heavy load, five points are obtained. Bringing a light load results in one point. The task of the problem is to maximize the total point within a time limit. Since we set a time limit for each agent to bring a load to the goal three times, the best total point becomes 120. Appropriate action rules for each of the 20 agents should be obtained according to their carrying ability. We employ the total point as a fitness value to be maximized in the evolutionary process.

Table 1 shows average results of computational experiments over 100 times. From Table 1, we can see that the GNP and the GNP-A can attain the best fitness value while the other two methods can not do. Fig. 1 shows the best network obtained by the GNP. The fitness value becomes 120 when each of the 20 agents acts according to this network. Fig. 2 depicts the maximum fitness values over generations obtained by the four methods. The GP could find a tree which enables the five agents to carry a heavy load three times. Since every network should be optimized in the GNP-H, it can not converge during 500 generations. Table 1 and Fig. 2 show that the proposed method (GNP-A) could obtain networks with the best fitness over all 100 trials and converge faster than the GNP. The proposed method shows better performance on the load transportation problem because it obtained two simpler networks for the agents.

**Table 1.** Average fitness values.

| Fitness | GP | GNP | GNP-H | GNP-A |
|---|---|---|---|---|
| Max | 75 | 120 | 118 | 120 |
| Average | 75.0 | 105.8 | 110.9 | 120.0 |
| Min | 75 | 75 | 99 | 120 |

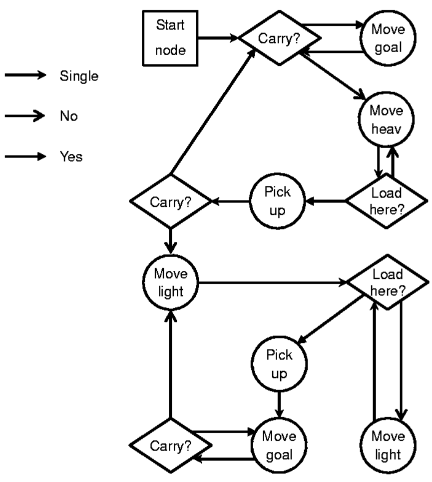


**Fig. 1.** The best network obtained by GNP.

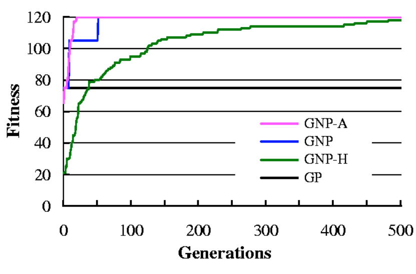


**Fig. 2.** Average results over generations.

## References

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