A Search Method for Route Planning Task with Multiple Goals Based on Genetic Algorithm

Hiroshi Wakuya, Sayuri Kawahara, and Hideaki Itoh
Graduate School of Science and Engineering, Saga University , Japan
E-mail : wakuya@cc.saga-u.ac.jp, {kawahara, hideaki}@ace.ec.saga-u.ac.jp

1. Introduction

A combinatorial optimization problem is a task to find out the best solution under the given constraints. According to the preceding studies, several search methods have been proposed by a lot of researchers so far. For example, a classic computational technique based on round robin, a Hopfield network [1], a genetic algorithm (GA), and so on. Among them, the GA-based technique is adopted in this study to investigate its parallel search performance.

By the way, we have a lot of large-scale natural disasters these years. This fact reminds us that planning out an evacuation procedure in case of emergency is quite important. Then, as an application of the GA-based technique [2], how to find out any pathways suitable for evacuation is tried here.

2. Genetic algorithm

A genetic algorithm (GA) is an application of the evolutionary theory, which is proposed by Charles Darwin in the 19th century, to the search method for combinatorial optimization problems. Its distinct nature is a parallel search performance based on the evolutionary manner. An individual is one of the candidate solutions, and it is represented by various kinds of genes, each of which defines a single feature of the applied task. Their population is provided at first, and it is evolved iteratively to improve a pre-defined cost function by means of i) selection, ii) crossover, and iii) mutation from generation to generation.

One of its difficulties is how to represent the applied task in the form of gene expression effectively. Also, a large number of individuals are required to demonstrate the performance as mentioned above. Moreover, the other parameters, including the rates of selection, crossover, and mutation, might affect the performance.

3. Route planning task with multiple goals

In this study, multiple goals are provided in advance. In order to find out a pathway to reach one of them, selecting an arbitrary goal as an actual destination is required. A primal objective is to find out the shortest pathway to the nearest goal, but to find out alternative shortest pathways to the other goals is also considered.

In order to solve this kind of task successfully, a gene expression is provided based on the graph theory as follows:

i) Each node is an intermediate point between the start and the goals.
ii) Each link is a partial pathway between the two nodes.
iii) Each gene corresponds to a single node, so the number of genes is the same as that of nodes.

A cost function is defined mainly based on the length between the start and the goal. If non-realistic movements are selected unfortunately, additional huge value is applied as a penalty. Even though a primitive situation is considered here, some kinds of hazards will be also taken into account in the future.

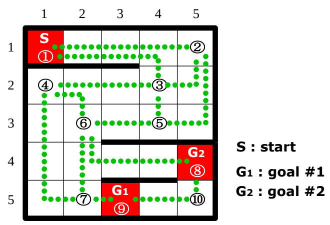

Figure 1. An overview of the route planning task adopted in this study.

4. Computer simulations

4.1. Methods

First of all, an overview of the route planning task adopted in this study is shown in Figure 1. It is a 5x5-wide area, and it contains a single start (S) and two separate goals (G_1, G_2). In addition, another seven nodes are provided as intermediate points, and 14 links between these 10 nodes are prepared as shown in Figure 2. A pathway from the start to the goal is represented by 10 genes, each of which represents the intermediate point one by

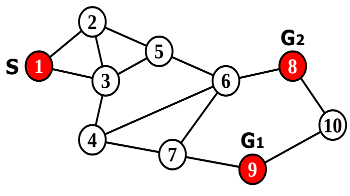

Figure 2. Graph-based representation.

one serially. In order not to generate some kinds of non-realistic solutions, which contain the same genes simultaneously, *a cyclic crossover* proposed by Oliver et al. is employed.

In this study, 1000 individuals (parents) are prepared based on the uniform distribution initially, and the above-mentioned evolutionary procedure is repeated to generate succeeding individuals (offsprings) for 90 generations to minimize the cost function. Although not shown here for brevity, if two nodes without any links between them are selected side by side, a severe penalty is applied to its individual's cost function. And, it will lead to the elimination in the upcoming *selection* cycle.

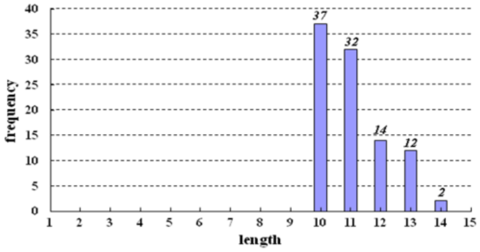

Figure 3. Results of computer simulations [I]
---Distribution of acquired pathways---

4.2. Results

After the evolutionary procedure for 90 generations, 96 individuals reach the goal successfully. Among them, the shortest pathway is 10 steps long, and 37 individuals can find out this solution. Also, the other individuals can find out alternative pathways as shown in Figure 3. All of them can reach either of the two goals provided in advance.

Its detailed information is summarized in Table 1, where the start (1) and the actual goal (8 or 9) are accentuated by the inverted color coordination. Once an individual reaches one of the two goals, the rest of gene sequence is ignored as *don't-care* regions. It clearly says that there are some different pathways whose total lengths are exactly the same.

Thus, it is clear that the GA-based technique can find out several solutions successfully in parallel, and therefore it is concluded that the proposed method is effective.

[Table 1] Results of computer simulations [II]
---Candidates of acquired pathways ---

prioity order	length	gene representation										goal	number of individuals
		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10		
1	10	①	③	⑤	⑥	⑦	⑨	②	⑧	④	⑩	G_1	37
2	11	①	③	⑤	⑥	⑧	⑨	②	⑦	④	⑩	G_2	32
3	12	①	③	④	⑦	⑨	⑥	②	⑧	⑤	⑩	G_1	1
–	12	①	③	④	⑥	⑦	⑨	⑧	②	⑤	⑩	G_1	4
–	12	①	②	⑤	⑥	⑦	⑨	④	⑧	⑩	③	G_1	9
6	13	①	②	⑤	⑥	⑧	⑨	⑦	④	③	⑩	G_2	5
–	13	①	③	④	⑥	⑧	⑨	⑦	②	⑤	⑩	G_2	7
8	14	①	②	③	④	⑦	⑨	⑧	⑤	⑥	⑩	G_1	2

(note) All gray areas show the *don't-care* regions, because each individual has been reached one of the two goals successfully.

5. Discussion

As mentioned above, the GA-based technique adopted in this study shows the good performance. It is summarized as follows:

i) The best sub-group can find out the shortest pathway.
ii) Moreover, the sub-optimal sub-groups can also find out the second and third best pathways simultaneously.

This is just an example where the evolutionary procedure is repeated for only 90 generations. Since a primal objective of the GA-based technique is to find out the best solution under the given constraints, if the evolutionary procedure is repeated furthermore, it is expected that the best sub-group will become bigger than before. This consideration suggests that providing a proper generation is a key aspect to develop a various kinds of sub-groups corresponding to the best and sub-optimal solutions.

6. Conclusions

In this article, a route planning task is adopted in order to investigate the effectiveness of the GA-based search method. As a result of computer simulations, it is clear that the GA-based technique can find out several solutions successfully in parallel, and therefore it is concluded that the proposed method is effective.

7. References

[1] J.J. Hopfield and D.W. Tank, " 'Neural' computation of decisions in optimization problems", Biological Cybernetics, Vol.52, pp.141-152, 1985
[2] Lien T.H. Bui, A. Kashiwazaki, Y. Takahashi, and H. Kanoh, "Real-time route selection using genetic algorithms for car navigation systems", Transactions of the Society of Instrument and Control Engineers, Vol.36, pp.789-796, 2000 (in Japanese)