Evaluation of Genetic Algorithms Incorporating Social Behavior of Naked Mole Rat

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***Abstract*—Genetic algorithm (GA) is a typical meta-heuristic that mimics the evolutionary process of living organisms and is used for various types of optimization, including the quadratic assignment problem (QAP). However, the Metaheuristics Algorithm (MA), which incorporates local search into GA, provides high-quality solutions but also has the problem of increasing computational cost and execution time. To overcome this problem, we propose a GA extension method inspired by the queen-driven reproductive behavior of naked mole rat, and evaluate it using the QAPLIB benchmark.**

***Index Terms*—genetic algorithm (GA), quadratic assignment problem (QAP), naked mole rat**

I. Introduction

The GA is a representative metaheuristic that mimics biological evolution and has been applied to a wide variety of combinatorial optimization problems. MA is an advanced form of GA, incorporating local search into GA to improve solution accuracy. And it has shown to be particularly well suited for QAP caused by facility allocation problems.

On the other hand, MA increases computational cost and execution time due to local search for each individual, which reduces its practicality for large-scale instances and real-time applications. In this study, we propose a hierarchical GA (Queen-Guided Colony GA, Q-CGA) inspired by the queen-guided reproductive behavior of naked mole rats to reduce the computational load while maintaining solution quality equivalent to or better than that of MA. Multiple colonies are formed within a population, and information is shared around the queen to achieve both diversity and convergence.

II. Genetic Algorithm

This section explains the search process when the GA is adapted to the facility placement problem. The flowchart diagram is shown in Fig. 1 below.

In the following subsections, we show the actions taken in each of the phases.

A. Generate initial solution

As shown in (a) and (b) below in Fig. 2, we randomly generate as many matrices as there are populations. In the following, we consider the case of 9 facilities.

B. Evaluation of solution

Calculate the cost.

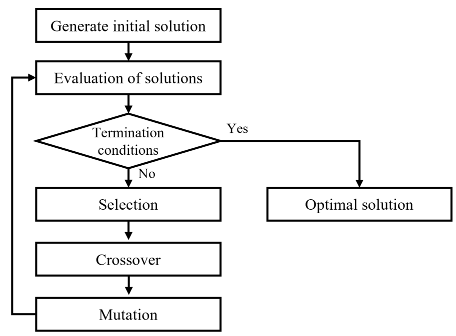

Fig. 1. GA Flowchart.

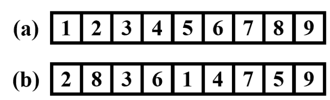

Fig. 2. Matrix Example.

C. Termination conditions

Set the end condition. Generally, it is often set to the number of iterations or the value of the output. In this study, the number of iterations was set. If the output condition is met, the solution is output.

D. Selection (Elite Conservation and Tournament Selection)

Elite conservation is a mechanism that unconditionally copies the top individuals obtained in each generation to the next generation. This prevents the best solutions found in the search process from being lost due to crossover or mutation.

Tournament selection is a method in which individuals are randomly selected from the population and the best individual (or the top few individuals) are adopted as the parent. It is mainly used for crossovers.

E. Crossover

In this study, the general Order Crossover (OX) is used. The matrix transformation is shown in Fig. 3 below. In OX, a new matrix is created with the value with the better evaluation value as the parent. (a) and (b) as parents. A new matrix (c) is created by copying the elements from 3 to 5 of the matrix (a), and the remaining frame is filled with the unexplained elements of (b) in order. The parent in this case is chosen using tournament selection.

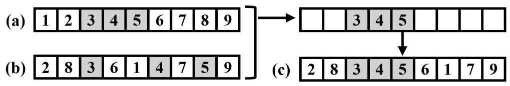

Fig. 4. Order Crossover.

F. Mutation

Since permutations were used to represent the order of facilities in this study, a "two-point swap" was used for mutation. The procedure is simple: two positions are randomly selected from among the offspring, and the facilities there are swapped.

G. Optimal solution

As the saying goes. Solution output.

III. Queen-Guided Colony GA

In this method, the GA incorporates the social behavior of the naked mole rat, in which only one queen in a group is responsible for reproduction. First, the population is divided into five colonies, and the individual with the highest fitness in each colony is selected as the queen. Subsequent mating and mutation will be conducted only within the same colony, including the queen, to enhance local search while maintaining the diversity of the entire population through independence among the colonies. By doing so, we aim to achieve both early detection of high-quality solutions and broadening of solution search. A flowchart of how the Q-CGA is done is shown in Fig. 5.

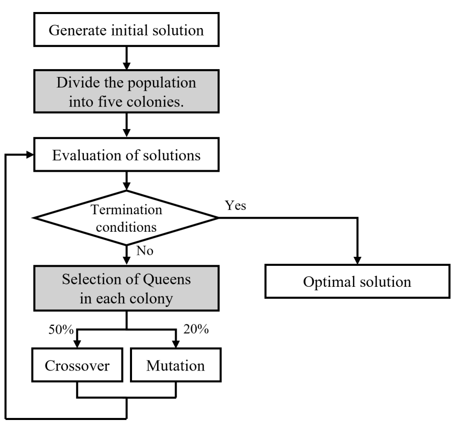

Fig. 3. Q-CGA Flowchart.

IV. Quadratic Assignment Problem (QAP)

To objectively verify the performance of the algorithms, we used QAPLIB, a standard collection of benchmarks for QAP research. QAPLIB contains a large number of instances and known optimal values, including instances obtained from real problems and randomly generated instances, to facilitate comparison among algorithms. We select Tai35a and report the solution quality and computation time of the proposed method.

V. Simulation Result

In this experiment, the population is set to 100, the iteration 10,000, the rate of crossover 0.5, and the rate of mutation 0.2 in the GA and the proposed method; to set the elite selection in the GA to 5, the queen in the proposed method is set to 5, so that there is one queen per colony.

In Fig. 6, the solutions obtained are normalized, and the closer to 1, the better the solution. It can be seen that the proposed method does not fall into the local solution and obtains a better solution than the conventional GA. Table I shows the time until the number of iterations reaches 10,000. The proposed method is able to simulate in a short time.

TABLE I
Simulation Time.

	Simulation time
GA	2h26m23s
Q-CGA	7m51s

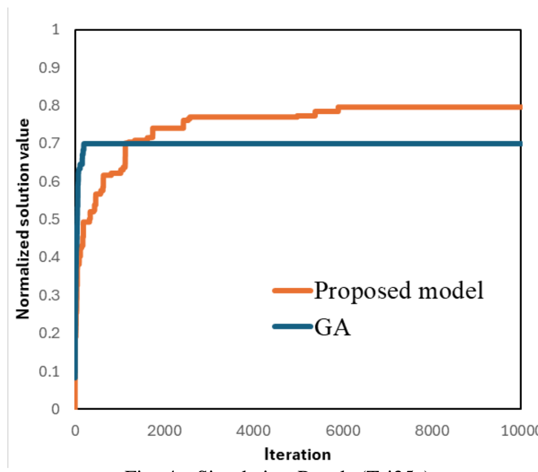

Fig. 4. Simulation Result (Tai35a).

VI. Conclusion

In this study, we proposed a genetic algorithm that incorporates the social nature of the Hadaka shrew. The population was divided into five colonies and crossed around the queen. As a result, we were able to search without falling into local solutions and improved the computational speed.

In the future, we would like to observe how diversity is maintained by varying the number of colonies. In addition, we would like to investigate the act of separating colonies, as it is considered to be highly versatile in many optimization algorithms.

Acknowledgment

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