Avoiding Genetic Algorithm Permutation Convergence Using Baker's Map

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Abstract:

Non-linear optimization problems are one of the most widespread in the world many which needed to solve. There are several algorithms found to solve such problems one of these is Genetic Algorithm (GA). This algorithm is mainly based on randomness in its process to determine the optimal solution, but it has drawbacks one of these is increasing the number of iterations for reaching the global optimum which is called (permuting convergence). The Baker's Map (BM) is used in this paper to overcome the drawback of GA and to increase their performance. The experimental results of the proposed method show their ability to reach optimal solutions with fewer iterations and significantly improve the basic GA's solution quality.

1. Introduction

In computational theory the problem of nonlinear optimization is currently among the most significant problems, since many real-world applications must be optimized [1]. Using fast computers and appropriate algorithms is the simplest and fastest way to address the optimization problem. Furthermore, in some circumstances, discovering the correct solution can take an inordinate amount of time. To solve such challenges, heuristic search methods such as "Evolution Algorithms (DEA), Genetic Algorithms (GA), Particle Swarm Optimizations (PSO), and Ant Colony Optimizations (ACO)" have been created [2]. Since its inception by Holland in 1975, GA has been the most widely used population-based heuristic algorithm [3-4].

GA utilize benchmarks and evaluation functions for evaluating the optimization strategies, and they are used by researchers for evaluating their strategies and techniques. Although GA offers many benefits in optimisation problems, it also has certain drawbacks, one of which is "premature convergence" which requires a significant number of iterations to find the global optimal solution [4-5].

This study employs the Baker's map in the crossover-operator of GA for reducing the iteration numbers required for arriving the best solution. In section 2 we provide an overview of GA. While in section 3 goes over BM. In Section 4 shows the Travel salesman problem. Then in Section 5 describes the proposed algorithm. Section 6 provide the results. Finally Section 7 provide the conclusions.

2. Genetic algorithm (GA)

GA is one of the Evolutionary-Algorithms (EA), it has been developed at the College of Michigan by John Holland in 1970s., which generates solutions to advancement problems by techniques inspired by common development, such as crossover, mutation, selection, and inheritance. GA founds the possible solution by converting the problem to a chromosome -like data structure and uses reproduction operators to keep important information intact [6][7].

The GA is a population of strings (called chromosomes) that convert to candidate solutions (called individuals) in order to find optimal solutions for the optimization problems. The evolution of a population always begins with the individuals who are generated randomly [8].

In each generation, every individual in the population evaluated their fitness value, Then, from the current population, various individuals are chosen randomly depending on their fitness, and the individuals are adjusted by recombination mutations to shape a new population. In the algorithm's second process, the new population is subsequently utilized. Typically, the algorithm will terminate either after reach maximum number of generations or the population has gained a suitable fitness level [7][8][11].

Until date, GA has been utilized to handle complicated nonlinear optimization problems. The key to influencing the performance and the behavior of GA is to choose appropriate GA parameters such as: (the size of population, probability of crossover, and the probability mutation) [1]. When the population size increases in GA, the number of iterations required to attain the objective decreases, so when the population size is very large, the pattern of the genetic will be damaged very easily and each individual with a higher fitness value will be destroyed. However, if a size of population is really small, GA procedure of the search is going to be quite slow. Producing new individual will be more difficult if the mutation probability is very low; nevertheless, if somehow the value of population mutation is very high, the algorithm will become a pure random search method [5].

3. Baker's Map (BM)

The BM is a disorganized map that extends from the unit square inward. Its name refers to a kneading technique used by bakers in which dough is divided in half, piled on top of one another, and compacted. The BM can be thought of as "a bi-infinite, two-state lattice model's bilateral shift operator" [9].

The BM, like many other deterministic dynamical systems, is investigated through its effect on the function's space which defined on the unit square. The map's transfer operator is defined by the BM as an operator on the space of functions. BM is an exactly solvable deterministic chaos model in the sense that the transfer operator's eigenfunctions and eigenvalues may be explicitly calculated [10].

The BM is commonly defined using two different definitions. The first definition is folding or twisting one of the sliced pieces before rejoining it, while the second does not [11].

In the folded BM the equation will be written as follows:

$$S_{baker}(x,y) = \begin{cases} \left(2x\,,\ \frac{y}{2}\right) & for\ 0 < x < \frac{1}{2} \\ \left(2-2x\,, 1-\frac{y}{2}\right) & for\ \frac{1}{2} < x < 1 \end{cases}$$

(1)

The upper section can be written as in equation (2) if it is not folded over $S_{baker}(x,y) = \left(2x - [2x]\,,\ \frac{y+[2x]}{2}\right)$

(2)

4. Traveling salesman problem (TSP): Case Study

The TSP has for many years been used as a key success story in the field of optimization, due of its ease of use and applicability. It has been used as a testing ground for any new methods relating to each of these possibilities. These new methods make the TSP a perfect case - study subject. Furthermore, these new methods incorporate many of the significant developments in the optimization algorithm field. [12-13].

The TSP is a basic combinatorial optimization issue that may be characterized as follows: The salseman wants to determine the shortest route during his visit to many customers in multiple cities. This route starts from his home city, and he has to visit each place specifically once, and then go back to his home city [14-15].

More formally:

“Given a set of n nodes and costs associated with each pair of nodes, find a closed tour of minimal total cost that contains every node exactly once.”

In other words, there are a set of customers ($c_1, c_2, \ldots, c_N$) are given and d(c_i, c_j) represent the distances between each pair of distinct customers. The purpose of it is to discover a city order (Π) that reduces the quantity [6].

$$\sum_{i=1}^{N-1} d\left(c\,\Pi(\mathrm{i}),\ \mathrm{c}\ \Pi(\mathrm{i}+1)\right) + d\left(c\,\Pi(N),\ \mathrm{c}\ \Pi(1)\right)$$

(3)

The above equation known as the tour’s length because it is computing the duration of the trip that a salesman would take if he visited the cities in the sequence indicated by the permutation, returning the end city to the first city [6][9].

5. The Proposed Work

In this paper we improve genetic algorithm by using the Baker's map for solving TSP. The standard GA utilizes a random generator to generate the population, crossover, and mutation, and the testing shows how the suggested technique reduces the iteration number required for finding the optimal solution.

Figure 1 depicts the proposed work's flow chart. Create a random population of 30 individuals, then fitness value of each individual is calculated. The fitness function of TSP is to calculate the lowest cost-path. As a result, an individual's fitness function is the cost of routing that it was represented, and it can be defined as:

$$F_i = \sum_{j=0}^{L_i} c_j \qquad (4)$$

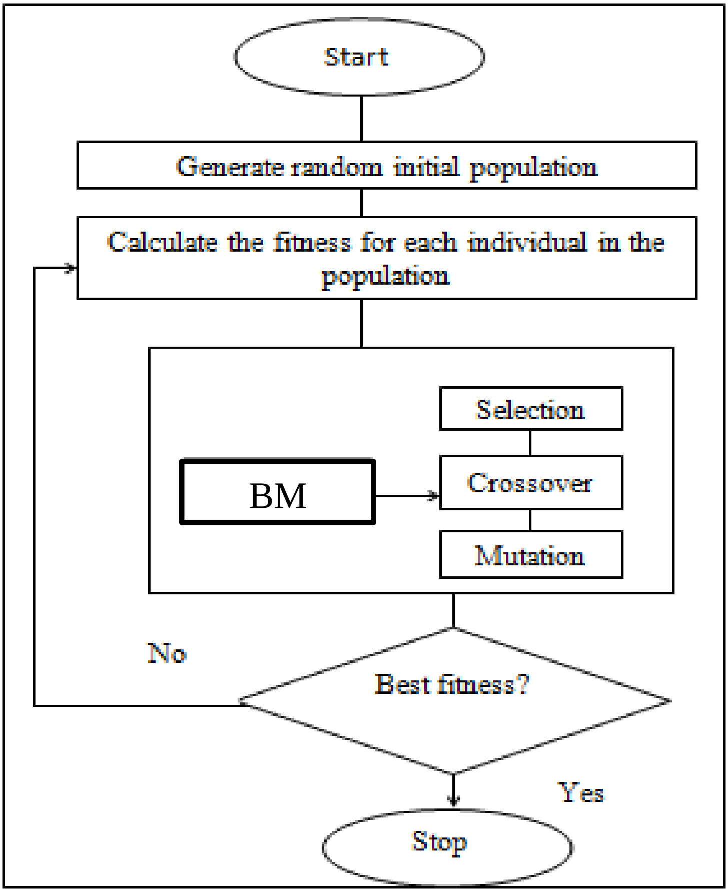

Figure 1: The proposed GA

We proposed in the crossover process BM instead of random number generator, BM can be defined by the following:

$$X_{n+1} = (2X_n - [2X_n]) \quad (5)$$

$$Y_{n+1} = \frac{Y_n + [2X_n]}{2} \quad (6)$$

Where X , $Yn \in (1 , 10)$ and $n = 0,1,2, \dots, m$ where m is the number of cities.

6. Simulation Results

The proposed method was implemented in VB.net and tested on the Windows 10 operating system. It was using (10 cities) and (100 iterations) for evaluating, with Table1 displaying the fitness value and iteration number utilized in the studies.

For performance evaluation of the suggested algorithms, we compared them to the conventional GA. Table 1 shows the fitness function developed and the number of iterations. There is not need to compare time - values because both methods took the same average of 3 milliseconds to run.

Table 1: Comparison Results

	GA		GA-ACM		Optimal Fitness Value
	Fitness Value	Iteration	Fitness Value	Iteration	
1	100	14	90	4	90
2	195	20	160	2	135
3	100	19	95	15	85
4	65	16	60	4	55
5	90	19	90	7	90
6	95	18	90	10	85
7	80	9	65	7	60
8	90	14	70	6	60
9	75	7	65	4	60
10	50	26	50	9	50

7. Conclusions

In this paper, the proposed method used BM to generate chaotic variables instead of the randomness in the standard GA each time a random number is required by the crossover - process to avoid local - convergence. The results in table 1 shows that the proposed technique outperforms the standard GA. The number of iterations that is required to discover the global optimum has been lowered while still achieving a better optimal solution.

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