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Permuting Convergence Overcomingof Genetic Algorithm Using Arnold Cat Map

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Abstract: ***Today the evolutionary algorithms (EA) such as Genetic algorithm (GA) are used to solve nonlinear optimization problems and find optimum solution. The fundamental of GA is the random where many processes used randomness in their operating. However, the most important disadvantages in GA are permuting convergence which is known to increase the number of iteration for reaching a global optimum. This paper use Arnold Cat Map (ACM) to improve the performance of the GA and to overcome this shortcoming. The experimental results show that the proposed method improves the ability of GA for reaching optimal/near optimal solutions with less number of iterationsand significantly improves the solution's quality of the basic GA.***

Keywords: Genetic Algorithm, Arnold Cat Map, Crossover, Optimization

1. Introduction

These days nonlinearoptimization problem are a standout amongst the most critical problem in computational theory. Since a number of many of applications in the real world need to be optimize [1]. The easiest and fastest way to solve the optimization problem is to employ fast computers and proper algorithms. Besides, in some cases, finding the exact solution can introduce unacceptable amount of time. To overcome such difficulties, heuristic search algorithms have been developed such as Genetic Algorithms (GA), Differential Evolution Algorithms (DEA), Particle Swarm Optimizations (PSO), and Ant Colony Optimizations (ACO) [2].GA is the most popular population based heuristic algorithm since it was developed by Holland in 1975 [3]. GA use evaluation functions and benchmarks to evaluate optimization techniques and researchers are using them to evaluate their techniques and methods. GA have many advantages in optimization problem but have a few disadvantages, one of these disadvantages is 'premature convergence' and take a largenumber of iterations to reach the global optimalsolution.

This paper use Arnold cat map in the crossover operator to reduce the number of iteration to reach the optimal solution. Section 2 gives brief basics of GA. Section 3 describes Arnold cat map. Section 4 illustrates TSP problem. Section 5 provides the steps of the proposed System. Section 6 gives the numerical results and comparison. Section 7 concludes the paper.

2. Genetic algorithm (GA)

GAs has been created by John Holland at the College of Michigan in the mid 1970's. GA has a place with the bigger class of Evolutionary Algorithms (EA),which produces answers for advancement issues utilizing procedures motivated by common development,such ascrossover, mutation, selection andinheritance. These algorithms encode a possible answer to a defined problem on a simple chromosome like data structure and apply recombination operators to these structures so as to maintain critical information [1].

In the GA, the population ofstrings (called chromosomes or the genotype of thegenome), which convert to candidate solutions (calledindividuals, creatures, or phenotypes)to anoptimization problem, in order to find better solutions. The evolution always begins from a population their individuals are randomly generated [11].

In each generation, the fitness of each individual in the population is estimated, variousindividual are stochastically chosen from the current population (based on their fitness) and adjusted (recombined and possibly randomly mutated) to shape a new population.The new population is then used in thenext step of the algorithm. Commonly, thealgorithm ends when eithera greatest numberof generations have been delivered or a favorable fitness level has been reached for the population [11].

Till now, GA is good at searching; it is used to solvecomplex nonlinear optimization problems. Selecting thesuitable parameters of GA for example, population size,crossover probability and mutation probability, is thekey to affect the behavior and performance of GA [1].

In GA, when the population size increased it will reduce the number of iteration to reach the goal, so, if the population is very large, the genetic pattern is very easy to damage and the individual which has higher fitness will be destroyed.But, if the population is very small, the search process will be very slow. If the mutation probability is very small, producing the new individual structures will be so difficult; but if the value of population mutationis very large, the GA then becomes a pure random search algorithm [5].

3. Arnold Cat Map (ACM)[10]

Arnold's Cat Map (ACM) is a chaotic map from the torus into itself, named after Vladimir Arnold, who demonstrated its effects in the 1960s using an image of a cat; hence the name. ACM is a special two dimensions chaotic map.

To define the Arnold cat map, we first need to define a torus and phase space. A torus is the surface obtained by revolving a circle in three-dimensional space around a disconnected axis that is coplanar with the circle. A phase space represents all possible states of a system, and each state corresponds to one unique point. The map can be now defined as a discrete system in which the trajectories in phase space are stretched and folded to obtain a torus. The mathematical definition of the Arnold cat map is shown in Equation (1).

Let X $=\begin{bmatrix} x \\ y \end{bmatrix}$. X is an n×n matrix, and the Arnold cat map transformation is as follows:

$$\Gamma : \begin{bmatrix} x \\ y \end{bmatrix} \rightarrow \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \text{mod } n = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \text{mod } n \quad (1)$$

Since this is a chaotic map, made of a discrete system, it expresses the dynamics of chaos. The initial conditions will affect the map, and its outputs will appear to be random.

4. Case Study: Traveling salesman problem (TSP)[6]

TSP is one of the major success stories for optimization because of its simplicity and applicability (or perhaps simply because of its intriguing name), the TSP has for decades served as an initial proving ground for new ideas related to both these alternatives. These new ideas make the TSP an ideal subject for a case study. In addition, the new ideas include many of the important advances in the related area of optimization algorithms.

The origins of the Travelling Salesman Problem (TSP) are somewhat mysterious. It is a classical combinatorial optimization problem and can be described as follows: a salesman, who has to visit clients in different cities, wants to find the shortest path starting from his home city, visiting every city exactly once and ending back at the starting point. 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, a set {c1, c2, . . ., cN} of cities is given and for each pair {ci, cj} of distinct cities has a distance d(ci, cj). The goal is to find an ordering Π of the cities that minimizes the quantity

$$\sum_{i=1}^{N-1} d(c\,\Pi(i), c\,\Pi(i+1)) + d(c\,\Pi(N), c\,\Pi(1)) \quad (2)$$

This quantity is referred to as the *tour length*, since it is the length of the tour a salesman would make when visiting the cities in the order specified by the permutation, returning at the end to the initial city.

The symmetric traveling salesman problem has many applications, from VLSI chip fabrication to X-ray crystallography.

5. The Proposed Work

In this paper we use the Arnold cat map with the genetic algorithm to solve TSP. The basic GA uses random generator in generating population, crossover and mutation., where we use Arnold Cat Map (ACM) in the crossover process and the testshow how the proposed method decrease the number of iterations to reach the optimum solution. The flow chart of the proposed work has been shown in figure 1.First generate random population; where the size of each individual is 30. Then calculate the fitness for each individual, the fitness function for TSP is obvious, because the TSP computation amounts are to find the minimal cost path. Therefore, the fitness function of an individual is the routing cost it represents and it is defined as follows:

$$F_i = \sum_{j=0}^{L_i} C_j \quad (3)$$

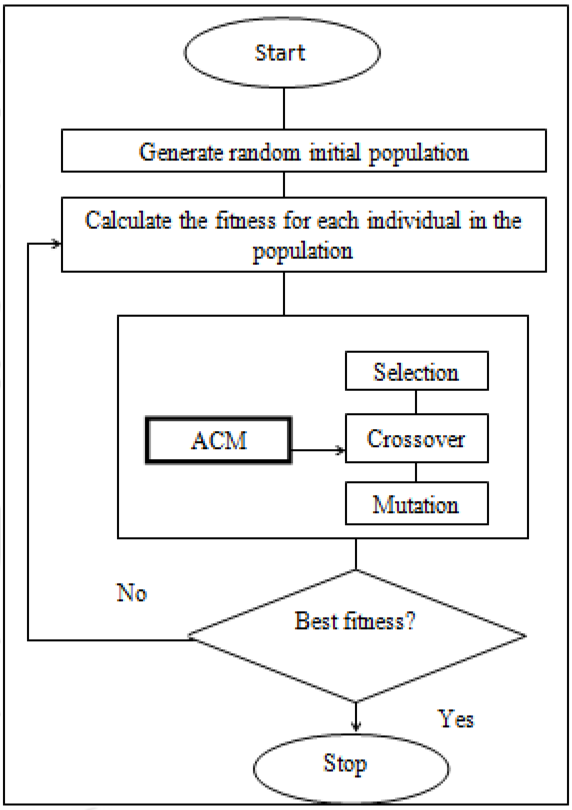

Figure 1: The proposed GA

For crossover process the proposed work Arnold's cat map instead of random generator, ACM is defined by the following equation:

$$X_{n+1} = X_n + Y_n \; mod \; n \quad (4)$$

$$Y_{n+1} = X_n + 2Y_n \; mod \; n \quad (5)$$

Where X_n , $Y_n \in$ (1,10) and n=0, 1, 2, ……. number of cities

6. Numerical Results

The proposed method has been implemented in Visual Basic 6 on Windows 7 Operating System with CPU of Core Due 2 Intel. It has been tested using 10 cities and 100 iterations which Table1 shows the value of fitness and the iteration number used in theexperiments.

To examine the performance of the proposed algorithms, we compared the proposed algorithms with thestandard GA as shown in table 1 with regard to the fitness function produced and number of iterations. No time values need to be comparing since running both algorithms took the same time of average of 3 milliseconds.

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, we have used Arnold Cat Map insteadrandomness in the standard GA to generate chaotic variables each time arandom number is needed by the crossover process in the classical GAalgorithm to avoid local convergence.Results have shown that the proposed method canperform significantly better than the basic GA. Inparticular the number of iterations to find the globaloptimized has been reduced while reaching better optimal solution.

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