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Application of Boundary Value Techniques Based Particle Swarm Optimization Algorithm To Solve Travelling Problem

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Abstract : A novel, enhanced particle swarm optimization algorithm with Boundary Value Analysis technique is introduced. The proposed BVA based PSO algorithm constructs a confined boundary region in the search space for the particles to move around in their searching process. It is applied on the travelling salesman problem and the implementation is carried out in MATLAB. This proposed algorithm is compared with the standard TSPLIB values and also with the existing algorithms and proved that BVA based PSO is better than the general PSO, GA ans ACO. The best solutions are found improved in the minimum number of runs with the proposed algorithm.

Keywords : Particle swarm optimization; travelling salesman problem; component;nature inspired algorithms; boundary value analysis; optimal solution; fitness values

1. INTRODUCTION

Many of the real world problems can be represented as optimization problems that find the best solution among all the possible or feasible solutions. To solve the optimization problems, many researchers had put effort to propose optimization algorithm that has been developed based on heuristic approach to find the optimal or at least near-optimal solutions for the problems.

By the motivation for the increase in the execution performance and the optimized output based on the resources and the input data, many researches has been made to design algorithms that adopt the advantages of other proved techniques. These adaptive algorithms have the benefit of opting either of the involved algorithms and also the techniques to exploit their advantages in solving the problems.

Particle Swarm Optimization (PSO) is a meta-heuristic algorithm which is population based and directs the candidate solutions in an acceptable fitting way rather than guaranteed. PSO is inspired by the intelligence of the flocks of birds or the group of insects in searching their food or finding their shelter. The basic PSO algorithm considers each individual as particle and moves the particle in its own direction and velocity within the boundary known as search space to find a good solution. The communication between the particles about their information/ data leads the swarm towards the satisfactory solution in the search space. The latest update in the history of the particle's position is known as the local-best and the overall update in the history of the subset of the particle gives the Global-best by comparing all the neighbor best (solutions). Basic PSO algorithm was originally developed by Eberhart and Kennedy in 1995 and the working is explained in the Figure 1[1][2][3][4].

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In this paper, the nature inspired Particle Swarm Optimization algorithm is enhanced by adopting the Boundary Value Analysis (BVA) techniques. BVA Techniques is a software testing technique

2. RELATED WORK

Table 1: Existing Works on solving Travelling Salesman Problem

Sl.No	*Author*	*Proposed Work*	*Technique Used*	*Inference*
1.	Suihua Wang, Ailing Zhao	An improved hybrid genetic algorithm incorporates Genetic algorithm for the local search process and the Elite retention strategy is used for the substitution of the individuals [5]	Genetic algorithm,Elite retention strategy	The algorithm improves the performance and the stability of the standard genetic algorithm.
2.	Jun Li, Qirui Sun , MengChu Zhou, Xianz hong Dai	Genetic algorithm encodes cities and salesman into two single chromosomes to solve multiple traveling salesman problem (MTSP). Three modes of crossover and mutation operators are designed SCCM, SSCM, SCM[6]	Genetic Algorithm, Crossover and Mutation operators	The algorithm solves MTSP with rapid convergence with CCM being the best mode of the operators.
3.	Fanggeng Zhao, Jinyan Dong , Sujian Li , Jiangsheng Sun	An improved ant colony optimization algorithm with embedded genetic algorithm is proposed to solve the traveling salesman problem.a) ACO-find solutionsb) genetic algorithm simulate the consulting mechanism- to optimize the solutions found by the ants.[7]	Ant Colony Optimization, Genetic Algorithm	The proposed algorithm could find better solutions of benchmark instances within less iteration than existing ant colony algorithms.
4.	Matheus Rosendo, Aurora Pozo	A hybrid PSO algorithm incorporates the path relinking algorithms. (*a*) PSO - update the velocity of the particle. (b) path relinking algorithms- movement of the particle[4]	Particle Swarm Optimization,Path Relinking Algorithms	Hybrid-PSO algorithm provides good results when dealing with discrete problems.
5.	Wen-hang Zhong, Jun Zhang ; Wei-neng Chen	A novel discrete PSO call C3DPSO for TSP, with modified update formulas and a new parameter c_3 is proposed a) c_3 (mutation factor)- balances between exploitation and exploration b) particle- considered a set of edges [3]	Particle Swarm Optimization,Mutation Operator	The performance of the proposed algorithm is good even with large scale samples.

3. PARTICLE SWARM OPTIMIZATION

In PSO algorithm, behavior of birds is imitated and each individual is referred as "particle" that moves around the multi dimensional space for finding the solution that exist. The position of the particle changes based on the knowledge acquired from the social and psychological or experience in furtherance of finding the best solution. The movement of an individual particle impacts the movement of the other particle as it behaves as the environmental factor. The influence of these social, psychological and environmental factors paves the way for the achievement of reaching the best solution or successful region within the search space[1][4].

In general, the algorithm initializes all the particles and each particle is evaluated by the objective function of the concerned optimization problem. Each particle is associated with the velocity which directs the particle for the further move in the search space. As the algorithm imitates the behavior of birds, it holds feature of following the same direction where the best bird tend to move. In each iteration, the particle adjusts itself with the velocity and the position of the particle gets updated[2][3].

The algorithm runs until it attains maximum iteration or when the criterion is achieved.

At any time t, the position of the particle is calculated as,

$$xi(t) = xi(t-1) + vi(t)$$

The velocity adjustment while moving aroung the search space is calculated by,

$$v_{i,j}(t) = wv_{i,j}(t-1) + c_1 * 1 * [pbest_{i,j} - x_{i,j}(t-1)] + c_2 * 2 * [gbest_j - x_{i,j}(t-1)]$$

$v_{i,j}(t)$ – > velocity of the particle I in dimension j at time t

w – > inertia weight ; controls the momentum of the particle

$c1$, $c2$ – > acceleration constants of cognitive & social components

$c1$, $c2$ – >Random value ranges between [0,1]

t – > time

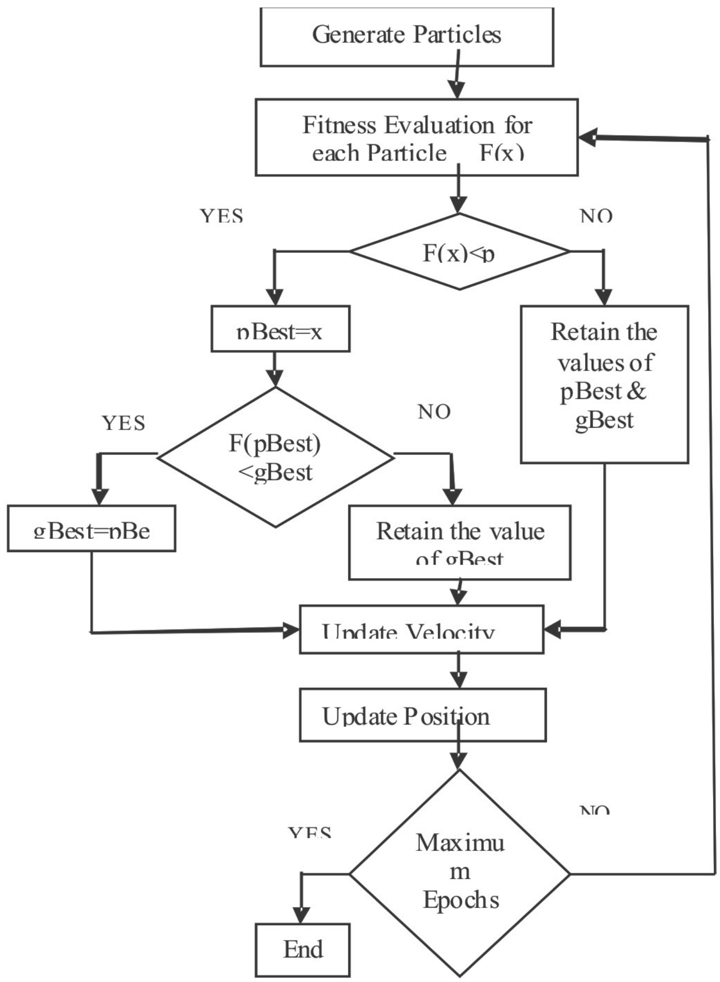

Fig. 1. Working Flow of General Particle Swarm Optimization algorithm

4. PROPOSED WORK

The Particle Swarm Optimization algorithm is enhanced here by adopting the technique of Boundary Value Analysis, which is used to enable the movement of the particle within a confined boundary, instead of, getting deviated from the way of reaching the best solution. From the thorough observation of Boundary Value Analysis, a method Renounce_bc is incorporated in the PSO algorithm and enhances the efficiency of algorithm. In furtherance to achieve best solution faster, the method Renounce_bc is used to confine the search space where the particles move around. This method is used to move the particle from one position to another that resides near the best solution.

A. Implemented Method of BVA based PSO for TSP

The *Traveling Salesman Problem* (*TSP*) is the well known and extensively studied NP-hard combinatorial discrete optimization problem. The problem is under research for three decades and is defined as the shortest possible tour travelled by the salesman has to visit through all the n cities exactly once and return to the starting city. The possible paths for n cities is calculated as (n-1)!/2.The possible solutions increases as the input size(number of cities) grows. Therefore the complexity of finding the good tour increases drastically with the increase in the number of cities. The input size is directly proportional to the computation and time complexity and this makes the bigger sized combinatorial optimization problems a tougher task. Classical algorithms failed to reach near optimal solution for large instances. It has stupendous impact in these types of problems when attaining a near optimal solution in the nominal time. As a result, many heuristic and metaheuristic algorithms have been developed and found better results over TSP[5][6][7][8][9][10].

The proposed algorithm computes the boundary values to form the confined boundary to make the searching process effective. Here, the method Renounce_bc is incorporated from BVA technique which ignores the unwanted portion of the search space. The algorithm starts with generating the particles and evaluating the fitness value of each particle. Then confined boundary region is designed and created by using Renounce_bc. With the knowledge gained by the social, environment and experience factors, the movement of the particle takes place within the boundary by adjusting its velocity by itself in the new position which is near to the best solution

Renounce_bc: In the method Renounce_bc, lower and upper bound values gets reflected and the co-ordinates of x-axis & y-axis assigns their values as the same that of the bound values. Therefore with the available four values a confined boundary is designed and created Boundary based constraint where the particles move around instead of searching the entire search space.

Renounce_bc Method

Renounce

Renounce_*bc*(*x*, *lb*, *ub*)

x = renounce_*bc*(*x*, *lb*, *ub*)

$x = (x >= lb) * (x <= ub) * x + (x < lb) * lb + (x > ub) * ub;$

BVA based PSO algorithm

Input : co-ordinates of cities, distance between cities

Output : Best Tour

Step 1: Initialize Particles

Step 2: Evaluate Fitness Function F(*x*) for each Particle

Step 3: Boundary Fixation

Call **Renounce_bc**

Step 3: If F(*x*)< *p*Best

Assign the value of *x* to pBest (*p*Best = *x*)

If(F(*p*Best) < *g*Best)

Assign the value of *p*Best to *g*Best (g Best = *p*Best)

Else

Retain the values of *g*Best

Update Velocity

Else

Retain the value of *p*Best & gBest

Update Velocity

Step 4: Update Position of the particle

Step 5: Repeat until maximum iterations or minimum criteria is met

5. RESULTS & DISCUSSION

To validate the performance of the proposed algorithm, experimental test is done by executing the algorithm in MATLAB with four examples bayg29, att48, pr144, rd400 of TSP in the range of 29 to 400 number of cities, and the results were studied. The test cases and their proved optimal distance were taken from the standard library of TSP (world-wide acceptable values), TSPLIB website (http://www.iwr.uniheidelberg.de/groups/comopt/software/TSPLIB95). The optimal solution of the test cases is compared with General PSO algorithm and Genetic Algorithm in Table 1. The tabular values prove the performance efficiency of the proposed algorithm.

Table 2. Comparison of Best Solution with the Standard Values from TSPLIB

INSTANCE	*Optimal Value TSPLIB*	*PSO*	*ACO*	*GA*	*BVA-based PSO*
bayg29	1610	1610.1	1610.8	1610.2	1610.3
att48	10628	10628.4	10628.6	10628.5	10628.4
pr144	58537	58537.2	58537.1	58537.1	58537.2
rd400	15281	15281.3	15281.5	15281.2	15281.1

Table 3. Results of the Runs taken to obtain Optimal Fitness

INSTANCE	*PSO*	*ACO*	*GA*	*BVA-based PSO*
bayg29	85	90	92	78
att48	78	83	80	65
pr144	69	60	75	52
rd400	73	85	90	67

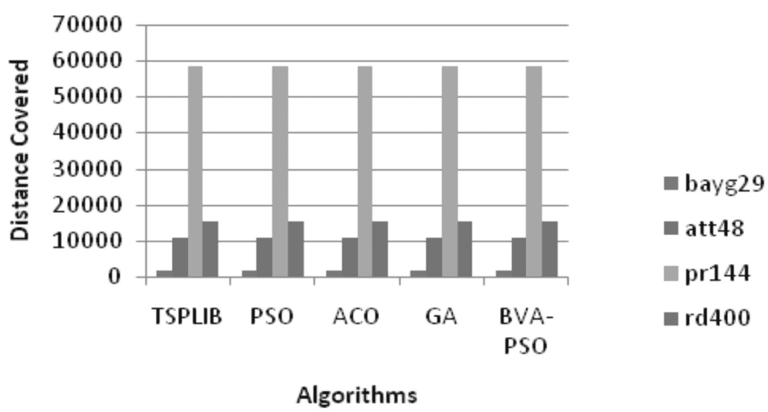

Fig. 2. Comparison Graph of different algorithms with the proposed BVA based PSO algorithm

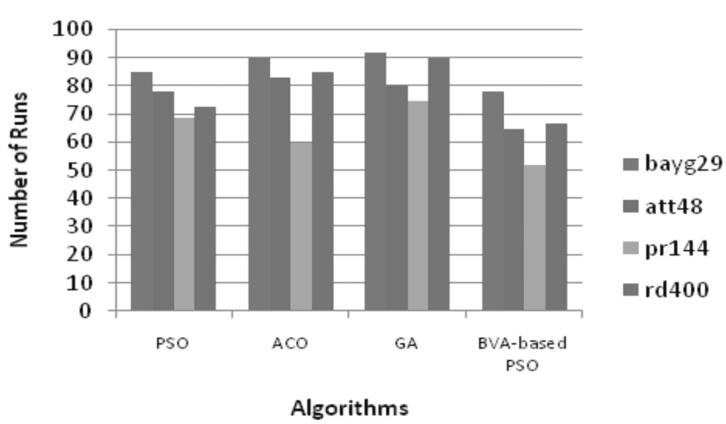

Fig. 3. Number of runs taken to find the Best Solution.

Table 4. Comparison of the values of Best and Worst Fitness of BVA based PSO with the standard values

Instance	*Number of Cities*	*Optimal Fitness*	*Best Fitness*	*Worst Fitness*
bayg29	29	1610	1610.3	1642.9
att48	48	10628	10628.4	10666.9
pr144	144	58537	58537.2	58771.4
rd400	400	15281	15281.1	15539.3

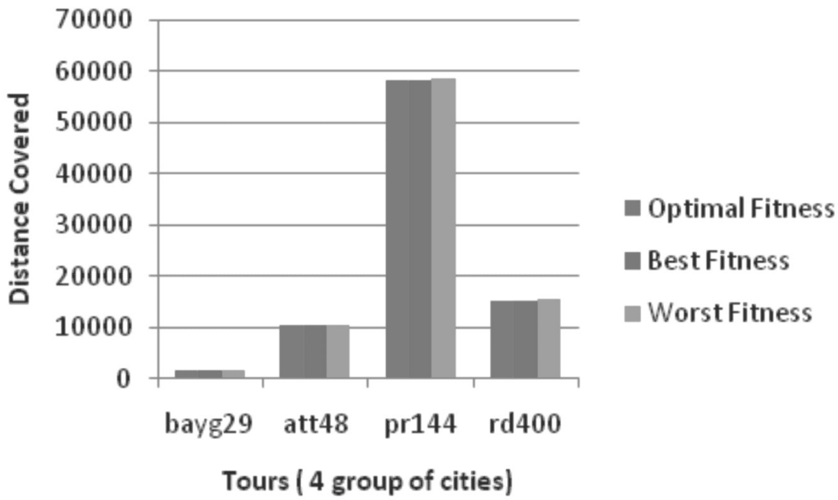

Fig. 4. Fitness(Performance) Graph of the BVA based PSO Algorithm on optimal, best and worst conditions

1. **Comparison of Simulation Results with Existing Algorithms :** From the Figure 2 and Figure 3, it is clearly seen that the proposed algorithm holds the values near to the standard values. The best solution is obtained in the minimum run compared with all the other algorithms and the algorithm results with optimal values in a faster manner. Moreover the Table 2 and Table 3 show the statistics of the experimental results carried out with the existing and proposed algorithms. The results proved that the algorithm finds the best solution (sometimes excellent solution) at early stage (minimum number of runs) efficiently.
2. **Performance Effectiveness of the Proposed Algorithm :** The experiment is carried out with 100 runs and their the values of distance covered as per the type of individual (best, worst, optimal) based on their fitness value is listed in the Table 4. In order to illustrate effectiveness of the proposed algorithm, the simulation carried out in the possible conditions, best and worst and the results were extracted as shown in the Figure 4.

6. CONCLUSION

In this paper, a Boundary Value Analysis technique is imitated as a method Renounce_bc to design and create a confined boundary region which is used for the particles to search the solution within a specific region, thus eliminates the possibility of carrying out any deviation. The proposed method enhances the general particle swarm optimization algorithm with the effective usage of the bound values to find the “Best Solution – Best Tour”. The simulation results of the experiments shows that the proposed algorithm outpaces the working of the existing algorithm such as general PSO, Genetic Algorithm, and Ant Colony Optimization algorithm by considering the parameters such as performance, number of runce, optimal fitness. On contradiction with some of the existing algorithms which are used in solving the Travelling Salesman Problem , the simulation experiments were carried out by the proposed algorithm proves that the algorithm finds the best solution (sometimes excellent solution) at early stage (minimum number of runs) efficiently. By analyzing the testing results, the paper is concluded that the proposed novel algorithm, BVA based PSO is efficient in the optimization speed, optimization fitness, computation time in solving the famous problem TSP.

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