Travelling Salesman Problem using Genetic Algorithm

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ABSTRACT

This paper includes a flexible method for solving the travelling salesman problem using genetic algorithm. In this problem TSP is used as a domain.TSP has long been known to be NP-complete and standard example of such problems. There had been many attempts to address this problem using classical methods such as integer programming and graph theory algorithms with different success. This paper offers a solution which includes a genetic algorithm implementation in order to give a maximal approximation of the problem with the reduction of cost. In genetic algorithm crossover is as a main operator for TSP. There were lot of attempts to discover an appropriate crossover operator. This paper presents a strategy to find the nearly optimized solution to these type of problems, using new crossover technique for genetic algorithm that generates high quality solution to the TSP. The efficiency of the crossover operator is compared as against some existing crossover operators. The work proposed here intends to compare the efficiency of the new crossover operator with some existing crossover operators.

1. INTRODUCTION

The Travelling Salesman problem (TSP)

The Travelling Salesman Problem (TSP) is a classic combinatorial optimization problem, which is simple to state but very difficult t o solve. This problem is known to be NP-hard, and cannot be solved exactly in polynomial time. Many exact and heuristic algorithms have been developed in the field of operations research (OR) to solve this problem. The problem is to find the shortest possible tour through a set of n vertices so that each vertex is visited exactly once.

The traveling salesman first gained fame in a book written by German salesman BF Voigt in 1832 on how to be a successful traveling salesman. He mentions the TSP, although not by that name, by suggesting that to cover as many locations as possible without visiting any location twice is the most important aspect of the scheduling of a tour. The origins of the TSP in mathematics are not really known -all we know for certain is that it happened around 1931.

On the basis of the structure of the cost matrix, the TSPs are classified into two groups – symmetric and asymmetric. The TSP is symmetric if cij = cji, for all i, j and asymmetric otherwise. For an n-city asymmetric TSP, there are (n −)!1 possible solutions, one or more of which gives the minimum cost. For an n-city symmetric TSP, there are (n − 1)!/2 possible solutions along with their reverse cyclic permutations having the same total cost. In either case the number of solutions becomes extremely large for even moderately large n so that an exhaustive search is impracticable.

Genetic algorithm (GA)

Genetic algorithm (GA) as a computational intelligence method is a search technique used in computer science to find approximate solutions to combinatorial optimization problems.

The genetic algorithms are more appropriately said to be an optimization technique based on natural evolution. They include the survival of the fittest idea algorithm. The idea is to first 'guess' the solutions and then combining the fittest solution to create a new generation of solutions which should be better than the previous generation. We also include a random mutation element to account for the occasional mishapThe genetic algorithm process consists of the following:

1. Encoding: A suitable encoding is found for the solution to our problem so that each possible solution has unique encoding and the encoding is some form of a string.

2. Evaluation: The initial population is then selected, usually at random though alternative techniques using heuristics have also been proposed. The fitness of each individual in the population is then computed that is, how well the individual fits the problem and whether it is near the optimum compared to the other individuals in the population.

3. Crossover: The fitness is used to find the individual's probability of crossover. Crossover is where the two individuals are recombined to create new individuals which are copied into the new generation.

4. Mutation: Next mutation occurs. Some individuals are chosen randomly to be mutated and then a mutation point is randomly chosen. The character in the corresponding position of the string is changed.

5. Decoding: Once this is done, a new generation has been formed and the process is repeated until some stopping criteria has been reached. At this point the individuals which is closest to the optimum is decoded and the process is complete.

2. SOLUTION OF TSP USING GENETIC ALGORITHM

A genetic algorithm can be used to find a solution is much less time. Although it might not find the best solution, It can find a near perfect solution for 100 city tour in less than a minute. There are a better than either parent couple of basic steps to solving the TSP using a GA.

First, create a group of many random tours in what is called a population. This algorithm uses a greedy initial population that gives preference to linking cities that are close to each other. Second, pick 2 of the better (shorter) tours parents in the population and combine them to make 2 new child tours. Hopefully, these children tour will be. A small percentage of the time, the child tours is mutated. This is done to prevent all tours in the population from looking identical. The new child tours are inserted into the population replacing two of the longer tours. The size of the population remains the same. New children tours are repeatedly created until the desired goal is reached. The accuracy of solution in TSP will depend upon factors such as : →Speed

→Population Size

After comparing these factors in each solution the best one will be selected and hence will give the new shortest path in each iteration. The task of comparisons and then representing the solution in every iteration become complex with the increment in population size

3. RELATED WORK

In the work proposed by Aybars Uğur in the GENETIC ALGORITHM BASED SOLUTION FOR TSP ON A SPHERE(1) Traveling Salesman Problem (TSP) is one of the extensively studied combinatorial optimization problems. Euclidean TSP which is a NP hard problem is related with determining the shortest tour through a given set of points in d-dimensional Euclidean space. Genetic algorithm (GA) as a computational intelligence method is a search technique used in computer science to find approximate solutions to combinatorial optimization problems. It applies biologically inspired concepts such as crossover and mutation

In the work proposed by FOZIA HANIF KHAN in SOLVING TSP PROBLEM BY USING GENETIC ALGORITHM (2) the main purpose of this study is to propose a new representation method of chromosomes using binary matrix and new fittest criteria to be used as method for finding the optimal solution for TSP. The concept of the proposed method is taken from genetic algorithm of artificial inelegance as a basic ingredient which has been used as search algorithm to find the near-optimal solutions. We introduces additional improvements, providing an algorithm for symmetric as well as Asymmetric TSP, here we are implementing the new fittest criteria as well as new representation of asymmetric matrix and improving our solution by applying the crossover and mutation again and again in order to get the optimal solution.

In the work proposed by Zakir H. Ahmed Genetic Algorithm for the TSP using Sequential Constructive Crossover Operator (3) develops a new crossover operator, Sequential Constructive crossover for a genetic algorithm that generates high quality solutions to the Traveling Salesman Problem (TSP) . Genetic algorithms (GAs) are based essentially on mimicking the survival of the fittest among the Species generated by random changes in the gene-structure of the chromosomes in the evolutionary biology. To apply GA for any optimization problem, one has to think a way for encoding solutions as feasible chromosomes so that the crossovers of feasible chromosomes result in feasible chromosomes. For the TSP, solution is typically represented by chromosome of length as the number of nodes in the problem

In the work proposed by Omar M.Sallabi An Improved Genetic Algorithm to Solve the Traveling Salesman Problem- (4)profound The Genetic Algorithm (GA) is one of the most important methods used to solve many combinatorial optimization problems. Therefore, many researchers have tried to improve the GA by using different methods and operations in order to find the optimal solution within reasonable time. This paper proposes an improved GA (IGA), where the new crossover operation, population reformulates operation, multi mutation operation, partial local optimal mutation operation, and rearrangement operation are used to solve the Traveling Salesman Problem. Crossover is the most important operation of a GA because in this operation, characteristics are exchanged between the individuals of the population.

In the paper proposed by **Eric matel** solving the travelling salesman problem using a genetic algorithm(5) **the basic principles of genetic algorithm: the principles of fitness, crossover, selection and mutation.** Genetic algorithms are loosely based on natural evolution and use a “survival of the fittest” technique, where the best solutions survive and are varied until we get a good result. The GAs is an optimization and search technique, which emerged from a study of biological evolution. GAs operates on “populations” of potential solutions which are usually referred to as “chromosomes.”

In the work proposed by Geetha, R.R., Bouvanasilan, N. Seenuvasan, (6) The travelling salesman problem (TSP) is one of the extensively studied optimization problem. The numerous direct applications of the TSP bring life to the research area and help to direct future work. To solve this problem many techniques have been developed. Genetic algorithm is one among those which solves this problem by using the processes observed in natural evolution to solve various optimizations and search problems. This paper presents a complete survey on genetic algorithm techniques proposed by researchers for solving travelling salesman problem.

In this paper proposed by Angel Goñi Moreno "SOLVING TRAVELLING SALESMAN PROBLEM IN A SIMULATION OF GENETIC ALGORITHMS WITH DNA"(7) it is explained how to solve a fully connected N-City travelling salesman problem (TSP) using a genetic algorithm. A crossover operator to use in the simulation of a genetic algorithm (GA) with DNA is presented. The aim of the paper is to follow the path of creating a new computational model based on DNA molecules and genetic operations. This paper solves the problem of exponentially size algorithms in DNA computing by using biological methods and techniques. After individual encoding and fitness evaluation, a protocol of the next step in a GA, crossover, is needed. This paper also shows how to make the GA faster via different populations of possible solutions. Keywords are DNA Computing, Evolutionary Computing, Genetic Algorithms.

In the work proposed by Kylie Bryant "Genetic Algorithms and the Traveling Salesman Problem"(8) Genetic algorithms are an evolutionary technique that use crossover and mutation operators to solve optimization problems using a survival of the fittest idea. They have been used successfully in a variety of different problems, including the traveling salesman problem.In the traveling salesman problem we wish to find a tour of all nodes in a weighted graph so that the total weight is minimized. The traveling salesman problem is NP-hard but has many real world applications so a good solution would be useful. Many different crossover and mutation operators have been devised for the traveling salesman problem and each give different results. We compare these results and find that operators that use heuristic information or a matrix representation of the graph give the best results.

In the work proposed by Adewole Philip, Akinwale Adio Taofiki, Otunbanowo Kehinde "A Genetic Algorithm for Solving Travelling Salesman Problem" (9) In this paper we present a Genetic Algorithm for solving the Travelling Salesman problem (TSP). Genetic Algorithm which is a very good local search algorithm is employed to solve the TSP by generating a preset number of random tours and then improving the population until a stop condition is satisfied and the best chromosome which is a tour is returned as the solution. Analysis of the algorithmic parameters (Population, Mutation Rate and Cut Length) was done so as to know how to tune the algorithm for various problem instances. In this paper genetic algorithm is used to solve Travelling Salesman Problem. Genetic algorithm is a technique used for estimating computer models based on methods adapted from the field of genetics in biology. To use this technique, one encodes possible model behaviours into "genes". After each generation, the current models are rated and allowed to mate and breed based on their fitness. In the process of mating, the genes are exchanged, crossovers and mutations can occur. The current population is discarded and its offspring forms the next generation.

In the work proposed by It Abdollah Homaifer, Shanguchuan Guan, Guna r E. Li epins "Schema Analysis of the Travelling Salesman Problem Using Genetic Algorithms" (10)provides a substantial proof that genetic algorithms (GAs) work for the travelling salesman problem (T SP) . The method introduced is based on an adjacency matrix representation of the TSP t ha t allows t he GA to manipulate edges while using conventional crossover . This combination, interleaved with inversion (2-opt),allows t e GA to rapidly discover the best known solutions t o seven of the eight TS P test problems frequently studied in t he literature . (The GA solution is within 2% of t he best known solution for t he eighth problem.) These results stand in contrast to earlier tentative conclusions t hat GAs are ill-suited to solving TSP problems, an d suggest that the performance of probabilistic search algorithms (such as GAs)is highly dependent on representation and t he choice of neighbourhood operators.

4. METHODOLOGY

A simple GA works by randomly generating an initial population of strings, which is referred as gene pool and then applying (possibly three) operators to create new, and hopefully, better populations as successive generations. The first operator is reproduction where strings are copied to the next generation with some probability based on their objective function value. The second operator is crossover where randomly selected pairs of strings are mated, creating new strings. The third operator, mutation, is the occasional random alteration of the value at a string position. The crossover operator together with reproduction is the most powerful process in the GA search. Mutation diversifies the search space and protects from loss of genetic material that can be caused by reproduction and crossover. So, the probability of applying mutation is set very low, whereas the probability of crossover is set very high.

Steps Of Algorithms

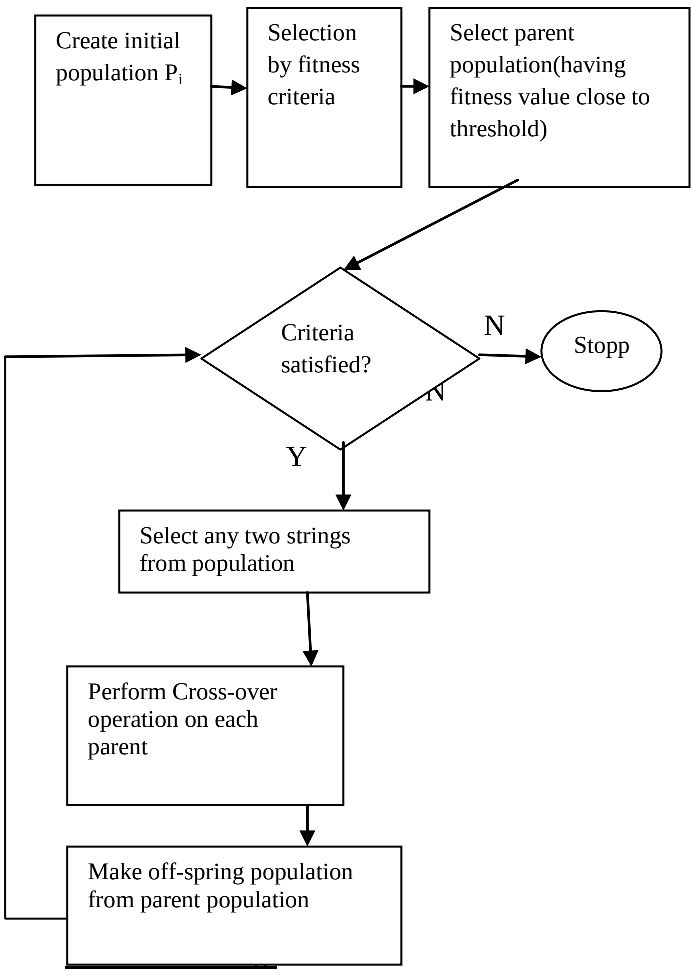
1.Randomly create the initial population of individual string of the given TSP problem and create a matrix representation of the cost of the path between two cities.
2.Assign the fitness to each chromosome in the population using fitness criteria measure.

F(x) = 1/x

where,

x represents the total cost of the string.

The selection criteria depends upon the value of string if it is close to some threshold value.3. Create new off-spring population from two existing chromosomes in the parent population by applying crossover operator.
4.Mutate the resultant off-springs if required.
NOTE: After the crossover off spring population has the fitness value higher than the parents.
5.Repeat step 3 and 4 until we get an optimal solution to the problem.



To apply GA for any optimization problem, one has to think a way for encoding solutions as feasible chromosomes so that the crossovers of feasible chromosomes result in feasible chromosomes. The techniques for encoding solutions vary by problem and, involve a certain amount of art. For the TSP, solution is typically represented by chromosome of length as the number of nodes in the problem. Each gene of a chromosome takes a label of node such that no node can appear twice in the same chromosome. There are mainly two representation methods for representing tour of the TSP – adjacency representation and path representation. W e consider the path representation for a tour, which simply lists the label of nodes. For example, let {1, 2, 3, 4, 5} be the labels of nodes in a 5 node instance, then a tour {1 3 4 2 5 1} may be represented as (1, 3, 4, 2, 5)

Fitness function

The GAs are used for maximization problem. For the maximization problem the fitness function is same as the objective function. But, for minimization problem, one way of defining a 'fitness function'

F (x) = 1/ f (x)

where f (x) is the objective function. Since, TSP is a minimization problem; we consider this fitness function, where f(x) calculates cost (or value) of the tour represented by a chromosome.

Selection Process:

In selection process, chromosomes are copied into next generation with a probability associated with their fitness value. By assigning to next generation a higher portion of the highly fit chromosomes, reproduction mimics the Darwinian survival-of-the-fittest in the natural world. In this paper we are using Elitism method for selection. Elitism is name of method, which first copies the best chromosome (or a few best chromosomes) to new population. The rest is done in classical way. Elitism can very rapidly increase performance of GA, because it prevents losing the best found solution.

Crossover Operator:

The search of the solution space is done by creating new chromosomes from old ones. The most important search process is crossover. Firstly, a pair of parents is randomly selected from the mating pool. Secondly, a point, called crossover site, along their common length is selected, then before crossover point we use method of sequential constructive crossover operator and the information after the crossover site of the two parent strings are swapped, if a gene has already been copied into the off-spring then replace that gene by unvisited gene, thus creating two new children.

The algorithm for this new crossover technique is as follows:

Step 1.Start from the node p(the first node in parents P1 and P2) .

Step 2.Sequentially search both of the parent chromosomes and consider the first legitimate node appeared after the node 1 in both P1 and P2 . Suppose the node x and node y are found in P1 and P2 respectively. Consider the crossover point is selected after 2nd node in both parents P1 and P2 .

Step 3..Now if Cpx < Cpy ,select node x ,otherwise node y as the next node and concatenate it to the partially constructed offspring chromosome.

Step 4.Now if we select node x as the next string in partially constructed offspring chromosome, copy the rest of the genes from parent P2,otherwise copy it from P1.

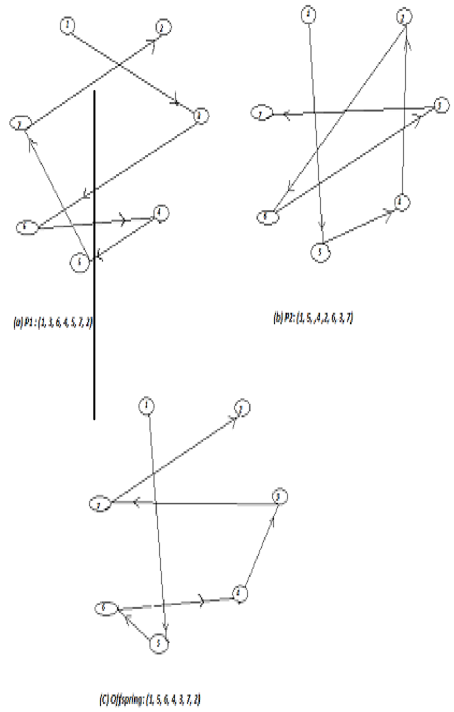
Step 5.Suppose a gene has already been copied into the off-spring then replace that gene by unvisited gene.

Let us illustrate the crossover technique through the example given as cost matrix in Table 1. Let a pair of selected chromosomes be P1 : (1, 3, 6, 4, 5, 7, 2) and P2 : (1, 5, 4, 2, 6, 3, 7) with values 365 and 349 respectively.

Node	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	**100**	**75**	**99**	**9**	**35**	**63**	**8**
2	51	100	86	46	88	29	20
3	50	5	100	16	28	35	28
4	20	45	11	100	59	53	49
5	86	63	33	65	100	76	72
6	36	53	89	31	21	100	52
7	58	31	43	67	52	60	100

The cost matrix

Select first node in parents P_1 and P_2 as node 1.now the legitimate node after node 1 in both the parents p and p are node 3 and node 5 respectively. we consider crossover point after node 3 and node 5 in parents P and P respectively. Now we calculate the value of cost of the path as C_{13}='99' and C_{15}=35.Since $C_{15} < C_{13}$,we accept 'node 5' as the next node in partially constructed chromosome. Node 5 is selected from the parent P_2 so we add the rest of the bits from the parent P_1.Now the partially constructed chromosome is (1,5,6,4,5,7,2).Node 5 has already been copied into off-spring so we replace 'node 5' by unvisited 'node 3'.Thus the complete off-spring will be (1,5,6,4,3,7,2) with value 263 which is less than value of both the parent chromosomes.The crossover is shown in the figure.Parents are shown as (a) and (b) while off-spring is shown as (c).



(a) P1: (1, 3, 6, 4, 5, 7, 2) (b) P2: (1, 5, 4, 2, 6, 3, 7) (c) Offspring: (1, 5, 6, 4, 3, 7, 2)

5. RESULT

Here we have shown an example of 7 cities graph through a matrix representation and on the basis of our calculation we have reached on an experimental result that our new crossover operator is capable of calculating an approximately optimal path for TSP using genetic algorithmin less time . If we look at the sequential constructive crossover(SCX) than our new crossover technique is better in terms of cost and time . In sequential constructive crossover(SCX) there is a sequential search for each gene in a chromosome and hence comparing it with another chromosome parent genes thereby resulting in a child chromosome. This task is time consuming and also a higher cost is occurring . In our crossovermethod,there is only a single search for a crossover point and after that the child chromosome is developed using the single point crossover technique only . This is leading to less time and cost and hence giving a better optimal solution for the given TSP problem .

Algorithm	**Time**	**Complexity**	**Advantage Disadvantage**	**Disadvantage**
GGenetic AlAgorithm	Expon-ential time	O(Kmn)	Best solution Using "fitness criteria" no optimal solution	Approximation of solution is reached but not an optimal solution.
GGreedy AApproach	5 seconds for 15 cities	O(logn)	Fastest no Solution accuracy	No best choices are consideredand hence no accuracy is achieved .
DDynamic PProgramm mi ng	9 seconds for 15 cities	$O(n^2 2^n)$	Global optimal Solution expensive for both memory and time	Expensive for both memory and time

6. CONCLUSION AND FUTURE WORK

Genetic algorithm appear to find good solutions for the Travelling Salesman Problem,however it depends very much on the way the problem is encoded and which crossover and mutation methods are used .We have proposed a new crossover operator named for a genetic algorithm for the Traveling Salesman Problem (TSP). . Among all the operators, experimental results show that our proposed crossover operator (SCX) is better in terms of quality of solutions and cost as well as solution times. That is why, we used a local search technique to improve the solution quality. Also, we set here highest probability of crossover to show the exact nature of crossover operator. Mutation with lowest probability is applied wherever required only.

We presented a comparative study among Greedy approach, Dynamic programming and Genetic Algorithm for solving TSP.It is very difficult to say that what moderate sized instance is unsolvable exactly by our crossover operator. So an incorporation of good local search technique to the algorithm may solve exactly the other instances, which is under our investigation and is categorized under future work .

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