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OPTIMIZATION OF STOCHASTIC TRAVELING SALESMAN PROBLEM USING GENETIC ALGORITHM WITH ROULETTE WHEEL METHOD

LOKESH KUMAR BHURANDA AND DR. MOHAMMAD RIZWANULLAH

Abstract. The present work is based on Stochastic Traveling Salesman Problem (STSP), which is a famous combinatorial optimization problem with NP-hard in nature. In this research, we have taken the path length of each pair of all points in the network as stochastic nature (i.e. random variable) with the application of Genetic Algorithm (GA) for obtaining the optimal route of the Stochastic Traveling Salesman Problem (STSP). GA is a good search algorithm to optimize this type of stochastic problems. The aim of this work is to find the best solution for the STSP by GA with roulette wheel method (RWM). We have also used the advancement ability of hereditary calculation to locate the possible answer for STSP. The scope of this work is further extend to optimize large problems in the field of Industry, Logistics, and other transportation problems.

1. Introduction

1.0.1. *Stochastic Travelling Salesman Problem.* The STSP is an extension form of the TSP. It is the most considered and applied problem which is difficult problem in combinatorial enhancement problems. In this research paper, we have taken the path length of each pair of the given all points as stochastic (random variable). In 1759, the TSP was perceived by Euler, whose interest was in tackling the knight's visit issue. This issue has a salesman and a group of places [11]. The salesman needs to cross the total urban communities starting from a specific vertex and afterward go back to the beginning place. The reason for this issue is to limit the all-out path length went by the sales rep. This kind of the issue is called as NP-hard and can't be settled precisely. Many careful calculations have been created in the scope of tasks examination to obtain the result of this issue [1]. TSP is settled effectively when there is a smaller number of urban communities, yet as the quantity of urban areas expands it is extremely difficult to tackle, as enormous measure of calculation period is needed. Other methodology is to utilize hereditary calculation to tackle TSP due to its power and adaptability. Some run of the mill uses of TSP incorporate vehicle directing, PC wiring, eliminating backdrop and position sequencing. The fundamental use in insights is combinatorial information examination like reordering sections of information networks or

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distinguishing bunches. TSP is formulated in Mathematical form as followed [3]:

$$X = (G, p, s) : G = (K, L) \tag{1.1}$$

which is containing a graph 'G', defined function 'p' from K×K to Z, s € Z, G contains the route length to go alongside the expense which isn't more noteworthy than t, where TSP =X. It is the essential issue in the areas of software engineering, designing, tasks research, discrete science, diagram hypothesis, etc. the issue can be portrayed as the minimization of the absolute distance went by visiting all urban areas precisely once and only once and get back to warehouse point. Hereditary calculations were fruitful to take care of numerous streamlining problems, including Vehicle Routing Problem (VRP), X-Ray crystallography, and PC wiring and so forth [12].

2. Literature Review

C. Archetti et al.[4] have described the dynamic traveling salesman problem. Release dates are described in the paper as stochastic as the distribution happens. The objective of this problem is to minimize the total travel time, including waiting time at the depot, in order to serve all customers. This article has proposed two mathematical models to optimize at each stage. P. M. Hariyadi et al. [9] have provided a brief introduction about the Artificial Intelligence, TSP, GA. They have taken a numerical problem and solved it by GA. S. S. Juneja S. S. et al. [10] have introduced "Travelling Salesman Problem Optimization Using Genetic Algorithm". The authors have proposed a methodology including genetic algorithm. The goal of this article is to obtain an optimal route in among the feasible solutions for the traveling salesman problem in polynomial time. A. Adler and S. Karaman [2] have considered the probabilistic issue for Dynamic, where a certain vehicle is entrusted with traversing 'n' arbitrary objective areas and tackled the longstanding open issue of deciding the route of the briefest direction for a kino dynamic vehicle through a bunch of 'n' haphazardly disseminated focuses in a complex. In this examination, our fundamental commitment is to show how the strategies created in these two separate strands of exploration can be unified to deliver a broader arrangement of observations for the TSP.

S. Gupta and P. Panwar [8] have provided an optimization problem with a bio-inspired technique. He or she starts from a certain city as source place and visits every node of given set of cities and return to the initial point. The main goal of the article is to find the shortest route which cross all edges once and only once. The authors used the genetic algorithm to obtain the optimal solution of the given combinatorial problem. V. Dwivedi [6] have represented TSP using GA. The paper utilized TSP as a space and offered an answer which recalls a computation implementation for appeal to provide an optimal guess of this issue with the decrease of cost. The writing introduced a methodology to discover the almost streamlined answer for these kinds of issues, utilizing new hybrid procedure for hereditary calculation that creates excellent answer for the TSP. E. Filip and M. Otakar [7] have considered the main objective is to search the route which has minimum length that traverses all points exactly once and then go back to the beginning point. This literature provides a computer program to obtain the

exact route for the TSP which is a most studied and helpful problem. L. Zhang and L. Wang [13] have introduced combinatorial problem with ordinal method. In the article, a novel class of hereditary ordinal streamlining has been proposed and ordinal enhancement and ideal registering spending portion are fused sensibly inside the hunt system of GA to propose a novel and viable hereditary ordinal Optimization approach.

3. Formulation of Stochastic Traveling Salesman Problem (STSP)

The STSP is remarkable contrasted with other called NP-troublesome problem which suggests that there is no computation with exact solution to settle it. The irrelevant imagined that period ought to get ideal game plan is exceptional. STSP is portrayed the goal of obtaining the method of the cheapest route. It can be exhibited as an undirected weighted outline, so much that metropolitan networks are all the vertex of this given graph, ways are all the edge of the chart, and the distance of each pair of all given vertices is the length of edge. It is a most famous and helpful minimization issue which is start and finish at a predefined point in the wake of having traversed each other vertex simply a solitary time. Writing gives various varying techniques and approaches as far as the STSP arrangements. From a hypothetical perspective, the STSP is seen by certain creators as a particular issue inside the hypothesis of charts and organizations, on the grounds that visited spots can be seen as specific hubs and the organization edges make transport joins between them. In the event, the hubs are specific spots in a specific topographical region, they can be seen as objections in a guide and a contemporary route innovation can be utilized for the arrangement. From a procedural perspective the undertaking is frequently tackled as an issue of whole number straight programming with explicit situations. There is an observable association with task models utilized in tackling certain issues of creation arranging. Let xij is the variable which is a link of each pair of the vertices 'i' and 'j' and getting two different values:

if the vehicle is traversed on the route (i, j) then xij = 1,
if the vehicle is not traversed on the route (i, j) then xij = 0,
Suppose cij = objective function for the traversed path (i, j).
Then the model of the STSP can be expressed as follows:

$$\text{Minimize } Z = \sum_i \sum_j x_{ij} c_{ij} \tag{3.1}$$

Constraints:

$$\sum_i x_{ij} = 1 \qquad \text{for } i = 1, 2, \ldots, n$$

$$\sum_j x_{ij} = 1 \qquad \text{for } j = 1, 2, \ldots, n$$

$$x_{i_1,j_1} + x_{i_2,j_2} + \ldots + x_{i_n,j_n} = n \qquad \text{for } j_1 = i_2, j_2 = i_3, \ldots, j_n = i_1$$

The last limitation presents a prerequisite of a sequenced course, where each spot is traversed only a single time and all the course makes a shut circuit completing in the beginning stage once more. An essential model can be depicted

additionally as a diagram of hubs and edges among them, and these associations can be placed in a framework of route length of each pair of the given places.

4. Genetic Algorithm (GA)

GA was given by John Holland in 1975. In the field of activities research hereditary calculation is a hunt heuristic that copies the interaction of characteristic development. Hereditary Algorithm has a place with class of developmental calculation. GA start with different problem arrangement which are encoded into populace, a wellness work is applied for assessing the wellness of every person, after that another age is made through the interaction of choice, hybrid and change. After the end of hereditary calculation, an ideal arrangement is gotten. The essential methodology of the GA fundamentally mimics the cycles in and of characteristic frameworks which is significant for development, which mostly follow the standards of Darwin Theory. As we probably are aware in nature, the opposition is there among people for the assets as there is shortage of assets which brings about the mastery of more fragile people by the best fit.

5. Problem description and Mathematical formulation

There are 7 urban cities. The salesman will visit every city just a single time. The fundamental target for the salesman in the paper is to obtain an optimal route which contains all the urban areas just once other than beginning city with least distance. Let the coordinates of any two points are given by (X1, Y1), (X2, Y2) and 'D' is the distance of each pair of all given points. Then we will calculate by help of the equation (A).

$$D = \sqrt{(|X1 - X2|)^2 + (|Y1 - Y2|)^2} \quad \text{(A)} \tag{5.1}$$

The most celebrated reasonable utilization of STSP are standard dispersion of products or assets, obtaining of the briefest of arranging transportation paths and so on including the territories that have nothing to do with movement path.

6. Methodology

The calculation begins with the computation of the minimum distance between the places by Euclidean formula to be traversed by the salesperson. We will start from initial Chromosome (Chrms) which are created to utilizing esteem encoding. At that point we choose two the fittest Chrms by a certain method (roulette wheel determination) which at that point experiences m-point hybrid. Presently we apply exchange change on the off springs created previously. Presently this entire interaction is rehashed until the combination of hereditary calculation [5]. There are a few stages to obtain the optimal solution as route through possible feasible solutions in certain polynomial time follow as:

A. Create the set of the Initial Chrms
B. Fitness Value
C. Select best two fit Chrms
D. Cross-over
E. Mutation

F. Result

6.1. Algorithm.

6.1.1. *Initialization : Create 'N' salesman paths randomly and evaluate value of fitness of every path.*

6.1.2. *Encore these steps:* a) Choose two fittest paths.
b) Reproduce two paths from the two fittest paths.
c) Replace the two worst paths by the best new paths to generate new population.

6.1.3. *Return the best result.*

7. Numerical problem

This example is one of the network problems. It has 7 vertices and 12 edges. The vertices and edges indicate the designation of the urban community and path length between two different places respectively. We have optimized this problem by GA methodology with help of the RWM.

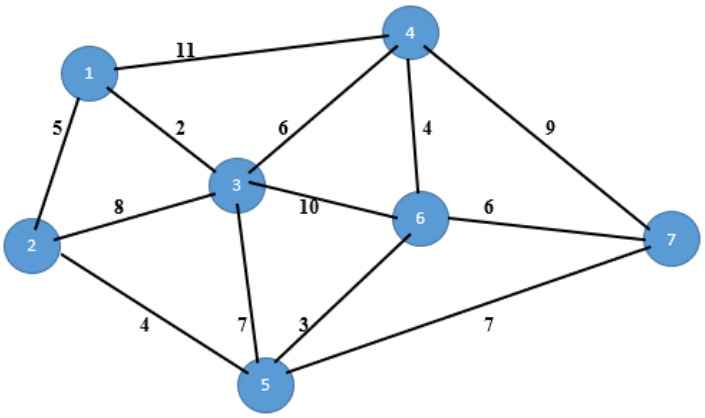

Figure 1. Network of the Stochastic Travelling Salesman Problem (STSP) with edge weights

7.0.1. *Create the set of the Initial Chrms.* Introductory Chrms's populations are made haphazardly by the work of the generate arbitrary number in MATLAB. The underlying population made is appeared in after area. The populace comprises of seven Chrms, where every Chrms signifies the succession wherein urban cities must be crossed and every quality address the number allocated to a city.
Chrms (a): 1 - 2 - 5 - 6 - 7 – 4 - 3 - 1
Chrms (b): 1 - 3 - 2 - 5 - 6 - 7 - 4 - 1
Chrms (c): 1 - 2 - 5 - 3 - 6 - 7 - 4 - 1
Chrms (d): 1 - 2 - 5 - 7 - 6 - 3 - 4 - 1
Chrms (e): 1 - 4 - 3 - 6 - 7 - 5 - 2 - 1

S. No.	Edge	Edge Weights
1.	1 – 2	5
2.	1 – 3	2
3.	1 – 4	11
4.	2 – 3	8
5.	2 – 5	4
6.	3 – 4	6
7.	3 – 5	7
8.	3 – 6	10
9.	4 – 6	4
10.	4 – 7	9
11.	5 – 6	3
12.	5 – 7	7
13.	6 – 7	6

TABLE 1. Edges with their weights

S. No.	Initial Chrms	Costs
a)	1 - 2 - 5 - 6 - 7 – 4 - 3 - 1	35
b)	1 - 3 - 2 - 5 - 6 - 7 - 4 – 1	43
c)	1 - 2 - 5 - 3 - 6 - 7 - 4 – 1	52
d)	1 - 2 - 5 - 7 - 6 - 3 - 4 – 1	49
e)	1 - 4 - 3 - 6 - 7 - 5 - 2 – 1	49
f)	1 - 4 - 7 - 6 - 3 - 5 - 2 – 1	52
g)	1 - 3 - 4 - 7 - 6 - 5 - 2 – 1	35

TABLE 2. Some initial Chromosomes with cost

Chrms (f): 1 - 4 - 7 - 6 - 3 - 5 - 2 - 1
Chrms (g): 1 - 3 - 4 - 7 - 6 - 5 - 2 – 1

7.1. Fitness Value. In the TSP, the models for great Chrms are its length. Computation happens throughout the making of the some Chrmse in equation (B). Every Chrms is made and afterward its wellness work is determined. Then we obtained the Chrms's length of all initial Chrms which are traversed by salesperson.

$$\text{Fitness Chrms} = \sum_{i=1}^{\text{towncount}} t_i \quad \dots(B) \tag{7.1}$$

7.2. Select best two fit Chrms. Choice is utilized to choose the Chrms whose wellness esteem is little. We have utilized the competition determination by utilizing Roulette Wheel Selection Method (RWSM).

7.3. Cross-over. 2-point hybrid is applied on each pair of all Chrms with the goal that new Chrms will be created which may have better wellness esteem. In 2-point hybrid, haphazardly two situations in the set of the Chrms are picked and afterward supplant the quality with one another in the two Chrms.

S. No.	Cost of the initial Chrms	Fitness values [f(xi) = 1/xi]
a)	35	0.028571
b)	43	0.023255
c)	52	0.019230
d)	49	0.020408
e)	49	0.020408
f)	52	0.019230
g)	35	0.028571
	Total	0.159673

TABLE 3. Cost and fitness value of initial Chromosomes

S. No.	Fitness values [f(xi) = 1/xi	Probabilities (Pi) = f(xi) / 0.159673
a)	0.028571	0.178934
b)	0.023255	0.145641
c)	0.019230	0.120433
d)	0.020408	0.127811
e)	0.020408	0.127811
f)	0.019230	0.120433
g)	0.028571	0.178934

TABLE 4. Some initial Chromosomes with cost

S. No.	Probabilities (Pi) = f(xi) / 0.159673	Cumulative Probabilities
a)	0.178934	0.178934
b)	0.145641	0.324575
c)	0.120433	0.445008
d)	0.127811	0.572819
e)	0.127811	0.700630
f)	0.120433	0.821063
g)	0.178934	0.999997 1

TABLE 5. Cumulative Probabilities

Old	New	Chrms
a)	d)	1 - 2 - 5 - 7 - 6 - 3 - 4 – 1
b)	g)	1 - 3 - 4 - 7 - 6 - 5 - 2 – 1
c)	e)	1 - 4 - 3 - 6 - 7 - 5 - 2 – 1
d)	a)	1 - 2 - 5 - 6 - 7 – 4 - 3 - 1
e)	c)	1 - 2 - 5 - 3 - 6 - 7 - 4 – 1
f)	f)	1 - 4 - 7 - 6 - 3 - 5 - 2 – 1
g)	b)	1 - 3 - 2 - 5 - 6 - 7 - 4 – 1

TABLE 6. New Chromosomes

Old	New	Chrms
a)	1 - 2 - 5 - 7 - 6 - 3 - 4 – 1	
b)	1 - 3 - 4 - 7 - 6 - 5 - 2 – 1	
c)	1 - 4 - 3 - 6 - 7 - 5 - 2 – 1	
d)	1 - 2 - 5 - 6 - 7 – 4 - 3 - 1	
e)	1 - 2 - 5 - 3 - 6 - 7 - 4 – 1	
f)	1 - 4 - 7 - 6 - 3 - 5 - 2 – 1	
g)	1 - 3 - 2 - 5 - 6 - 7 - 4 – 1	

TABLE 7. Cost of New Chromosomes

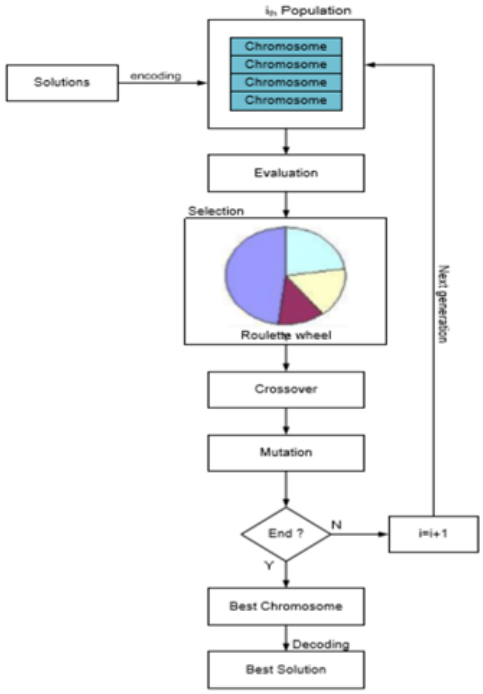

FIGURE 2. Genetic Algorithm Flow Chart

7.4. Mutation. The process of mutation is employed to create an updated generation. In an interchange mutation, two genes from a set of the Chrms are randomly selected and then swapped.

7.5. New Generation. If the new era integrates a solution that yields a yield that is sufficiently close to or equivalent to the ideal solution, the issue will be optimized. If this does not happen, the future generation will follow in the footsteps of their ancestors and mothers. It will be continued until a perfect arrangement is found.

7.6. Result. After finishing the quantity of cycles, the best visit will be acquired, and the interaction will be ended. The visit acquired with least route length is 34 for the problem of 7 urban areas. In the first, it has been seen that there is there is the littlest wellness esteem that does not change. If the figuring is continued up to the nth age, by then it is acknowledged that the most decreased health worth will remain unaltered. But the tally is enough disclosed up to the principal period, a nearby ideal plan has been found from the inherited estimation measure over, the result the course with the briefest ideal distance is 1-2-5-7-6-4-3-1.

8. Conclusion

We have obtained some solutions which is close to optimal solution. It can be acquired for this issue by utilizing all steps of GA. We have reviewed numerous methodologies and numerous mixes of hereditary administrators for this issue and the used mix of hereditary administrators in this study is the advanced one among them. For future expansion of this work, we can utilize numerous mixes of half and half hereditary administrators. Genetic algorithms seem to discover great answers for the STSP, anyway it relies particularly upon the way the problem is encoded and which hybrid and change strategies are utilized. Various number of GA have been examined and studied for tackling STSP. The provided method can be applied for different progressed models such as strategic organization, task booking models, Chinese mailman problem, vehicle route steering problems and so forth. The problem of the STSP can be enough settled utilizing hereditary calculations by GA. This approach can obtain the optimal route of this combinatorial problem with a few iterations. Although the optimal problem is experienced in countless urban areas. The beginning stage or introductory course of an excursion does not need to begin from city '1' just however can begin from another city. The generation will end if, after a few progressive generations, the least wellness esteem is acquired and does not improve. Wellness decides when a generation closes. Assurance of the fitness value relies upon the random value created on the grounds that the Genetic calculation works by utilizing RWSM or natural selection.

Key Highlights

In this paper, we have taken a Traveling Salesman Problem

Use the Stochastic Nature in formulation of this Problem

Solve the Combinatorial Optimization Problem by Genetic Algorithm with Roulette Wheel Method

Find the Optimal Route for the Problem with minimum distance value

Author Contributions

Introduction with conceptualization of the problem statement and solve the real-life Traveling Salesman Problem with Stochastic Nature are contributed by first author. Modeling and formulation with numerical problem are focused and contributed to the part of analysis, inferences and literature review by corresponding author.

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Research Scholar
Department of Mathematics and Statistics
Manipal University Jaipur
Email address: lokesh.201023602@muj.manipal.edu

* Associate Professor (Senior Scale)
Department of Mathematics and Statistics
Manipal University Jaipur
Email address: rizwansal@yahoo.co.in