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Optimizing Transport Routing using Travelling Salesman Problem

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***Abstract*— This paper focuses on the application of the Travelling Salesman Problem algorithm in calculating the shortest path to connect the top 29 most populated cities in the Western Sahara. With the world population continuously growing, it has become necessary to find efficient and effective solutions to connect different regions. The paper highlights the importance of the design and analysis of algorithms in solving real-life problems. The proposed algorithm in this paper aims to solve the problem of finding the optimal route to connect the 29 cities in the Western Sahara, which can be extended to other similar scenarios. The paper provides insights into the design and analysis of the proposed algorithm and its effectiveness in finding the shortest path.**

***Keywords*: Design and Analysis of Algorithm, Travelling Salesman Problem, world population.**

I. Introduction

For well-functioning of economic activities transport is the key which ensures social well-being and cohesion of populations. It plays vital role for production and distribution of goods ensuring mobility of people and goods within time. The economic development is highly crucial for development of any area. Shorter the routes of transportation cheaper would be the mobility of goods. Travelling Salesman Problem can solve the problem to identify the shortest route among the highly populated areas of the world which are eitherdeveloping or developed. The Traveling Salesman Problem (TSP) is a classic optimization problem in computer science and operations research. It involves finding the shortest possible route that a salesperson can take to visit a given set of cities and return to the starting city. The TSP has many real-world applications, including route planning for delivery vehicles, planning airline travel routes, and optimizing production schedules.
The importance of the TSP algorithm lies in its ability to find the most efficient route between a set of points. This can lead to significant savings in time, money, and resources. By using the TSP algorithm, businesses and organizations can optimize their logistics and transportation systems, reducing transportation costs and improving overall efficiency. In addition, the TSP is an important problem in the field of computer science and mathematics, and finding efficient algorithms to solve it has been a focus of research for many years. The TSP has also served as a benchmark for testing the efficiency of new algorithms and optimization techniques. Overall, the TSP algorithm is important for its ability to optimize transportation and logistics systems, as well as its contribution to the development of efficient algorithms in computer science and mathematics.
TSP can be used to solve real world problem such as most of the railways analyses the best routes available for a long-distance train with manystops with the use of the algorithm behind travelling salesman problem. They have observed significant use of the algorithm to identify the best route which has more travellers and takes minimal

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time and distance between first and last destination. This hasincreased the efficiency of the performance of railway department.
This paper is organized in below sections: Section 1 is an introduction part and the systematic literature review of the applications of travelling salesman problem algorithm is conducted in section 2. It is followed by section 3 which explains the methodology thatis the description of the algorithm, which is followed by the study of complexity of the algorithm which is discussed in Section 4. Dataset description and its analysis have been conducted in the section 5 and 6 respectively. Section 7 discusses about the result and analysis of the research conducted. Section 8 concludes the paper with its summary.

II. LITERATURE SURVEY

Several applications of travelling salesman problem have already been implemented to improve and find the solutions faced in our daily life. Related woks is as given below
"A Multi-Objective Genetic Algorithm for the Traveling Salesman Problem with Time Windows" by P. M. Pardalos et al. (2020) **-** This paper proposes a multi-objective genetic algorithm for solving the TSP with time windows, which is a variant of the TSP that includes time constraints for visiting each city[1].
"Hybridizing Metaheuristics for the Traveling Salesman Problem with Drone" by R. Farahani et al. (2020) **-** This paper proposes a hybrid algorithm that combines two metaheuristics, namely, ant colony optimization and particle swarm optimization, to solve the TSP with drones[2].
"Improved Genetic Algorithm with Memory and Adaptive Crossover for the Traveling Salesman Problem" by S. Tang et al. (2021) **-** This paper proposes an improved genetic algorithm with memory and adaptive crossover operators for solving the TSP[3].
"An Improved Iterated Local Search Algorithm for the Traveling Salesman Problem with Time Windows" by Y. Guo et al. (2021) **-** This paper proposes an improved iterated local search algorithm for solving the TSP with time windows[4].
"Solving the Traveling Salesman Problem with Time Windows Using a Novel Bat Algorithm" by S. S. Baragab et al. (2022) **-** This paper proposes a novel bat algorithm for solving the TSP with time windows, which is based on the echolocation behavior of bats [5].
"Solving the Traveling Salesman Problem Using Genetic Algorithms" by Whitley et al. (2016) explores the application of Genetic Algorithms (GA) for solving TSP. It discusses the representation; fitness function, selection operators, and genetic operators specific to TSP. Comparative results and computational analysis are also provided [6].
In Paper "Solving the Traveling Salesman Problem Using Particle Swarm Optimization" by Kennedy et al. (2018) authors presented an application of Particle Swarm Optimization (PSO) to TSP [7]. The paper describes the PSO algorithm adapted for TSP, discusses parameter settings, and provides computational experiments and comparisons with other methods.
"A Comprehensive Survey on Vehicle Routing Problem with Time Windows" by Ritzinger et al. (2019) focuses on the Vehicle Routing Problem with Time Windows (VRPTW), it is relevant for TSP as VRPTW is an extension of TSP [8]. The paper provides an overview of different solution approaches, including exact, heuristic, and meta-heuristic methods, for solving routing problems with time constraints.

III. METHODOLOGY

To evaluate every possible tour we can use the brute force approach and select the besttour out of it. For **n** number of vertices in a graph, there are $(n - 1)!$ number of possibilities.
The time complexity of the brute force approach is high therefore instead of brute force approach we use the dynamic programming approach. Although this method does not provide polynomial time algorithm but is efficient than the brute force approach.
Let us consider a graph $G = (V, E)$, where V is a set of cities and E is a set of weighted edges. An edge $e(u, v)$ represents that vertices u and v are connected. Distance between vertex u and v is $dist(u, v)$, which should be non-negative.
If we start at city 1 and after visiting some cities now we are in city k. We need to determine the value of k as it will state which cities are most convenient to visit next. To not repeat the cities visited we also need to know all the cities visited so far. Hence this can be an appropriate sub-problem.
For a subset of cities $X \in \{1, 2, 3, ..., n\}$ that includes 1, and $k \in X$, let $L(X, j)$ be the lengthof the shortest path visiting each node in **X** exactly once.

When $|X| > 1$, we define $L(X, 1) = \infty$ since the path cannot start and end at **1**.
Now, let us divide **L(X, k)** in terms of smaller sub-problems. We need to start from ***1*** andend at **k**. for selecting the next city we use-

$$L(X,k) = \min L(X-\{k\},i)+dist(i,k)$$

where $i \in X$ and $i \neq k$ $l(X,k)=\min L(x-\{k\},i)+dist(i,k)$ where $i \in X$ and $i \neq k$
There are at the most $2^n.n$ sub-problems and each one takes linear time to solve.Therefore, the total running time is $O(2^n.n^2)$.

Traveling Salesman Problem Algorithm

```
L ({1}, 1) = 0
for x = 2 to n do
for all subsets X ∈ {1, 2, 3, … , n} of size x and containing 1
      L (X, 1) = ∞
for all k ∈ X and k ≠ 1
      L (X, k) = min {L (X − {k}, i) + dist(i, k) for i ∈ X and i ≠ k}
Return mink L ({1, 2, 3, …, n}, k) + dist(k, i)
```

IV.DATASET DESCRIPTION

In this research paper we have used a dataset of all locations that are registered as populatedplaces across the globe including several research bases in Antarctica. It contains 1,904,711city instances of locations throughout the world. The dataset [9] we considered for our researchis a smaller instance of whole dataset of the world. The dataset was created on July 29, 2001and it contains instance of 29 Cities in Western Sahara.

TABLEI: DATASET (WESTERN SAHARA)

Sr No	Latitude	Longitude
1	20833.3333	17100.0000
2	20900.0000	17066.6667
3	21300.0000	13016.6667
4	21600.0000	14150.0000
5	21600.0000	14966.6667
6	21600.0000	16500.0000
7	22183.3333	13133.3333
8	22583.3333	14300.0000
9	22683.3333	12716.6667
10	23616.6667	15866.6667
11	23700.0000	15933.3333
12	23883.3333	14533.3333
13	24166.6667	13250.0000
14	25149.1667	12365.8333
15	26133.3333	14500.0000
16	26150.0000	10550.0000
17	26283.3333	12766.6667
18	26433.3333	13433.3333
19	26550.0000	13850.0000
20	26733.3333	11683.3333
21	27026.1111	13051.9444
22	27096.1111	13415.8333
23	27153.6111	13203.3333
24	27166.6667	9833.3333
25	27233.3333	10450.0000
26	27233.3333	11783.3333
27	27266.6667	10383.3333
28	27433.3333	12400.0000
29	27462.5000	12992.2222

V. EXPERIMENTATION AND RESULTS

In the Table1 latitude and longitude of each instance of the cities are specified in decimal form. The data isin the form of space separated city number, latitude and longitude. The data is given in decimal form rather than minutes and seconds. The data is adjusted to handle decimal degrees and scaled to provide the distance in meters rather than in kilo-meters. The latitude and longitude were treated as x-axis and y-axis respectively to calculate the distance betweentwo areas which were considered to be the nodes of the graph.

Dataset of Western Sahara - 29 cities

Number of cities	: 29
Optimal solution	: 27603
Solution Method	: Greedy algorithm, Travelling salesman problem
Solution Time	: 0.09 sec

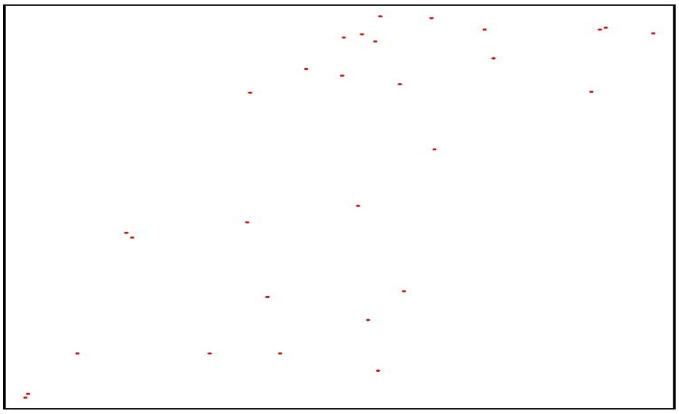

Figure1: Two dimensional representations of Cities in Western Sahara

Points in the figure1 represent the cities of Western Sahara. The Solution of 29 cities is of 27603 units. It is visualized in the figure2. Time of execution was observed to be 0.09 seconds.

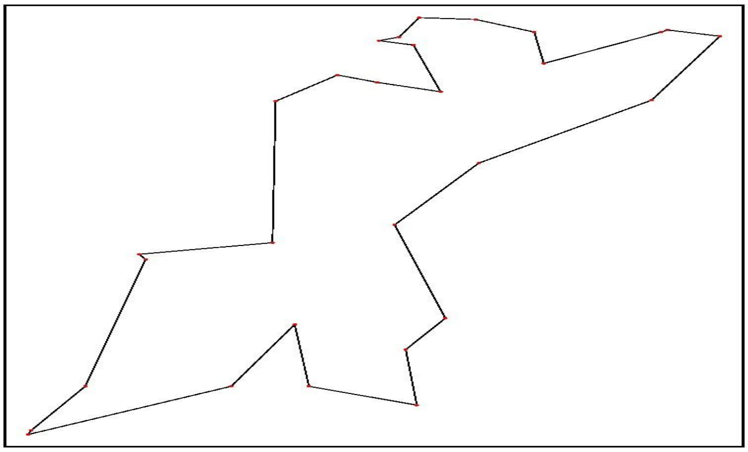

Figure 2: Graph plotted connecting the cities which are treated as nodes

VI. CONCLUSION

The goal of the Travelling Salesman Problem solution proposed in this paper was to reduce the travelling time as well as cost for transportation and exchange of services amongst the mostdensely populated of Western Sahara. Its implementation would result into a dramatic changein shipping efficiency, trust between the stakeholders and safety which is the major need of hour and help the developing areas for further development. In conclusion, this paper presents the application of the Travelling Salesman Problem algorithm to solve the problem of finding the shortest path to connect the top 29 most populated cities in the Western Sahara. The paper highlights the importance of algorithm design and analysis in solving real-life problems and provides insights into the effectiveness of the proposed algorithm in finding the optimal route. The results obtained from the application of the algorithm on the dataset of the Western Sahara cities show that the proposed algorithm can efficiently solve similar scenarios with high accuracy. Overall, the study demonstrates the potential of algorithmic solutions in solving real-world problems and emphasizes the need for continuous research and development in this area.

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BIOGRAPHIES

Dr. SWATI HIRA is currently an Assistant Professor at Shri Ramdeobaba College of Engineering and Management, Nagpur. She received her Ph.D. from Visvesvaraya National Institute of Technology India. She has co-authored a number of research articles in various journals, conferences, and book chapters. Her current research work includes the Development of coal quality exploration technique based on convolutional neural networks and hyperspectral images. The project is sponsored by the Ministry of Coal, Government of India with the grant of INR 1.03cr. She is a member of IAENG. Her research interests are Hyper spectral Imaging, Multidimensional Modelling, Statistical Data mining, Deep Learning, Computer Vision, and Machine Learning

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