A Short Survey Report on Application of Traveling Salesman Problem

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Abstract

Travelling salesman problem has been occupying as one of the interesting field of research relating to the real life problem which naturally relates Hamiltonian graph. This is one of the world unsolved problems known as NP-Complete problem. In this paper, a brief survey report has been focused in various fields and its application has been cited.

Keywords: Travelling salesman problem, multi-TSP, clustered TSP, TSP application.

Introduction

The Travelling Salesman Problem [1][2] is a classical combinatorial optimization problem. This is found as an NP-complete problem [3]. It is interesting to note that the travelling-salesman problem, which is closely related to the Hamiltonian of a graph .It states that a salesman must visit all the cities, starting his journey from any one city, visiting all other cities exactly once and finally coming to the starting city with least cost. This problem was proposed by an Irish mathematician Sir William Rowam Hamilton and an English mathematician Thomas Penyngton Kirkman in early 18th century [4]. In 1859 Sir William Hamilton contributed to the growth of graph theory by inventing the Icosiangame which is clearly not far away from the formulation of Travelling Salesman Problem. The popularity of Travelling Salesman Problem among the scientists of different fields was going on increasing from 1930.

There are different types of Travelling Salesman Problem as such they have been modeled like symmetric Travelling Salesman Problem, asymmetric Travelling Salesman Problem and multi Travelling Salesman Problem[4], clustered Travelling Salesman Problem[5]. In symmetric travelling salesman problem, distances between two cities in both the direction are equal. Here the salesman finds the shortest path starting at any city visiting each city exactly once and finally returning to the starting city. In asymmetric travelling salesman problem, distances between two cities in both the direction are not same, they differ. Here also the salesman finds the shortest path visiting each city exactly once except the starting city where the salesman stops. In multi travelling salesman problem, there are multiple salesman, all salesman find the shortest path. There are four variations in multi travelling salesman problem as follows:

Variation 1: There are suppose n number of cities and distances between any two cities are known.

Here m numbers of salesman starting at the same city visit m group of cities visiting each city exactly once in a group and finally all m salesman come to the starting city. Each of the m salesmen find the shortest route.

Variation 2: There are suppose n number of cities and distances between any two cities are known. Here m numbers of salesman starting at the same city visit m group of cities visiting each city exactly once in a group and finally all m salesman come to m different cities. Each of the m salesmen find the shortest route.

Variation 3: There are suppose n number of cities and distances between any two cities are known. Here m numbers of salesmen starting at different m cites, visit m group of cities visiting each city exactly once in a group and finally all m salesmen come to their starting city. Each of the m salesmen find the shortest route.

Variation 4: There are suppose n number of cities and distances between any two cities are known. Here m numbers of salesmen start at different m cities, visit m group of cities visiting each city exactly once in a group and finally all m salesmen come to same city at the end. Each of the m salesmen find the shortest route.

In clustered travelling salesman problem, cities are partitions into some clusters and if clusters are considered like single city it will become like travelling salesman problem. In this case the salesman find the least cost route visiting each city exactly once except the starting city where cities are contiguous in a particular cluster. Clustered Travelling Salesman Problem is modeled as a directed or undirected complete graph.

This paper is organized in sections as following. In the introduction part, a simple historical approach of travelling salesman problem has been included. In application part includes application of travelling salesman problem found in different areas. Next solution to the problem of travelling salesman problem is considered. Finally a conclusion is included.

Application of Travelling Salesman Problem

It had been pointed out by J. K. Lenstra and A. H. G. Rinnooy Kan in 1975, how travelling salesman problem in the field of computer wiring, vehicle routing, clustering and job shop scheduling can be applied [6]. The formulations of the travelling salesman problem for these four problems along with some technique to solve were supplied by them.

Numerous application of travelling salesman problem in logistics such as distribution of different products from manufacturer to wholesaler or from wholesaler to retailer, distribution of fuel to different filling stations, doctors' visits at patients' home etc had been stated by Exnar Fiilip and Machac Otakar in 2011 [7].

In addition to this, in 2011, Uros Klansek demonstrated how optimal route scheduling can be done by using the solution of travelling salesman problem [8].

The travelling salesman problems related to Drilling of Printed Circuit Board, Overhauling gas turbine engines, computer wiring, X-Ray crystallography, the order picking problem in warehouses, mask plotting in PCB production, vehicle routing etc were studied by Rajesh Matai, Surya Prakash Sing and Murari Lal Mittal [4]. The application of multi-travelling salesman problems in different areas such as the area of school bus routing problem, interview scheduling problem,

printing press scheduling problem etc were also considered by them. The most important area is Drilling of Printed Circuit Boards which prevails in recent research areas of electronics fields. Different diameter holes are required in printed circuit board to connect conductor on one layer with a conductor on another layer. Using the drilling machine each time making a hole and then changing the diameter of the drill for two different diameter holes is a time consuming process. Instead of changing the diameter of the drilling machine each time, first one diameter hole for all locations and then changing the diameter for the second diameter hole for all locations can be made. This drilling problem can be viewed as a series of travelling salesman problem, one for each hole diameter, where cities are referred to initial position & set of all holes that can be made with the same drill. The distance between two cities is given by the time it takes to move the drilling head from one position to the other hole. Here travel time for machine head to be reduced [9-10].

Besides, during gas turbine engines of aircraft overhauling to guarantee a uniform gas flow through the turbines there are nozzles-guide vane assemblies located [11]. Such an assembly consists of number of nozzle guide vans affix about its circumference. All these vans have their own characteristics and placing the vans at correct position substantial benefits like reducing vibration, increasing uniformity of flow and reducing fuel consumption can be achieved. Placing the vans in the best possible way can be modeled as a travelling salesman problem with a special objective function.

The X-Ray crystallography, used for analyzing the crystalline structure of materials an X-ray diffractometer is used to obtain information about the crystalline material structure [12-13]. A detector measures the intensity of X-ray reflections of the crystal from various positions. In some experiment thousands of thousands positions have to be realized. Here the problem is in what sequence the different positions are to be considered so that the total positioning time can be reduced. This order of sequencing of positioning can be modeled as a travelling salesman problem.

Again in Computer wiring, the Computer interface consists of a number of modules and on each module several pins are located. The position of each module has been determined in advanced and a given subset of pins has to be interconnected by wires. In view of possible future changes or connection and of small size of pin if maximum two wires are connected to a pin, connecting all the pins a Hamiltonian circuit can be obtained. Here the problem is to find the minimum Hamiltonian circuits which can lead to a traveling salesman problem.

On the other hand the position of the modules has not been determined in advanced, in this case determining the position of the pins and then connecting the all subset of pins by wires in such a way that it will reduce the wire length will lead to more complex Traveling Salesman Problem.

The order picking problem in warehouses problem which arises in warehouses can be explained as follows: Suppose an order is received to supply some subset of items which are stored in warehouse. Here one vehicle has to collect all the subset of items from different location of the warehouse. This problem can be modeled as a traveling salesman problem considering the different locations as cities and the distances

between two locations as length or cost. The aim is to find a shortest path reducing the pickup time for different subset of items.

In Vehicle routing problem, in a town telephone boxes have been installed and a technical crew has to visit each telephone box once or twice a week to empty the coin box and repair the telephone box as on necessary. Here the problem is to minimize the number of days in which all boxes can be emptied and to minimize the total distance travelled.

A similar type of another problem is to empty the postal mail boxes located at different location of a city suppose at one hour interval by trucks. Here the problem is to minimize the number of trucks and to minimize the distanced travelled by each truck.

Both the problems can be constructed as a travelling salesman problem maintaining time constraints as well as number of vehicles [6].

Mask plotting in PCB production, explained that Photographic mask of a printed circuit board is done by a mechanical plotting device. The plotter moves a lens over a photosensitive coated glass plate and the shutter may be opened or closed to expose specific parts of the plate. Different types of apertures are available to generate various structures on the board. Two types of structures have to be considered. A line is exposed on the plate by moving the closed shutter to one endpoint of the line, then opening the shutter and moving it to the other endpoint of the line and then the shutter is closed. A point type structure is generated by moving to the position of that point then opening the shutter just to make a short flash and then closing it again. Modeling of the plotter control problem leads to a problem which is more complicated than travelling salesman problem. A real world application in the actual production environment is reported [9].

In DNA sequencing the concept city represents the DNA fragments and the concept distance represents the similarity measure between DNA fragments. The travelling salesman problem appears in astronomy also as astronomers observing many sources will want to minimize the time spent slewing the telescope between the sources [17].

Apart from the above Travelling Salesman Problem has many applications such as very large scale integration(VLSI) design [14], rearrangement clustering [15], predicting protein function [16] etc. TSP plays a very important role in the development, testing and demonstration of new optimization techniques.

Solution to the Travelling Salesman Problem

There are various methods/heuristics algorithms for solving travelling salesman problem; quite a few of them are shortest path algorithm, the simple insertion algorithm, genetic algorithm, the elastic Net method, the simulated annealing algorithm, ant colony algorithm.

Recently some work was focused by Anupam Dutta et al [18]. Regular Planar Sub-Graphs of Complete graph and their application was considered. Using this concept they developed an algorithm to find the minimum cost route of the complete graph [19]. Bichitra Kalita forwarded some methods for solving TSP problem. Kalita [20-21] also developed a theory, which gave the number of non-isomorphic Hamiltonian sub graphs of the form H(2m+3, 6m+3) for $m \geq 2$ from the complete graph K_{2m+3} for $m \geq 2$. Jayanta Kr. Choudhury [22] also developed an algorithm to find the least cost route of a complete weighted graph K_{2m+3} for $m \geq 2$. He

also developed two theorems related to this. Jayanta Kr. Choudhury et al discussed the different type of factorization of graphs of the complete graphs K_{6m+2} ,K_{6m-2}, and K_{6m} for $m \geq 1$ and developed an algorithm different from the above algorithms for the solution of travelling salesman problem [23]. Again, Jayanta Kr. Choudhury et al discussed the decomposition of complete graphs K_{2m+1} for $m \geq 2$ into circulant graphs with various properties. In addition to this, an algorithm has also been discussed for travelling salesman problem under different situations for the said graphs [24]. Besides, Jayanta Kr. Choudhury,and Bichitra Kalita discussed the generation of a maximal triangle free graph from the complete graph K_{2m+3} , for $m \geq 2$ and an algorithm was also developed under different cases to solve the travelling salesman problem of the complete graph K_{2m+3} [25]. K.C. Bora studied particular type of Hamiltonian graph G(3m + 7, 6m + 16) for $m \geq 1$, which is planar, non-regular, non-bipartite and Hamiltonian and their properties [26] and finally developed a heuristic algorithm for solving travelling salesman problem of a particular type[27]. In 2014 K. C. Bora proposed a heuristic algorithm for solving travelling salesman problem of complete graph having vertices greater than equal to 4 using the concept of perfect matching [28]. Again in 2016 K. C. Bora suggested a variation of nearest neighbour algorithm for solving the travelling salesman problem [29].

Conclusions

This paper only has covered some areas where the application of travelling salesman problem can be used. This problem is not yet solved completely. This works help the researchers in getting more information on it so that they can think new ideas and can develop new methods on it for solution.

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