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ACO Based Routing and Euler Walks Routing of Solid Waste Management Transportation- A Comparative Analysis

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Introduction

Municipal solid waste management (MSWM) is an integral part of urban environmental planning [1,2,3,4 &5]. The characteristics and quantity of MSW arising from domestic, commercial and industrial activities in a region is not only the result of growing population, rising standards of living and technology development, but also due to the abundance and type of the region's natural resources[4]. The collection, transport, treatment and disposal of solid wastes, particularly wastes generated in medium and large urban centres, have become a relatively difficult problem to solve. To promote sustainable development, waste management has evolved into material flow management in many developed countries, and includes careful handling of raw materials and reduction of emissions as well as climate/environment protection. More than 90% of the MSW generated in India is directly disposed on land in an unsatisfactory manner .The problem is already acute in cities and towns as disposal facilities have not been able to keep pace with the quantum of wastes generated. It is common to find large heaps of garbage lying in a disorganized manner in every nook and corner in large cities. Thus transportation of these wastes in effective way is one of the major problem in Municipal Solid Waste Management.

To provide a waste management service which can be acceptable on existing financial constrains, the action plan proposed two elements of the plan firstly the creation of an efficient Management Information System (MIS) & Geographical Information System (GIS) and secondly the provision of planning and management such that there are possibilities of improvement in financial and institutional support. Due to the financial constrains it was suggested to incorporate those options which can promote the improvement in the system without a major capital investment. So it is proposed to create the MIS and GIS information.

Moreover, the successful implementation of GIS & MIS in designing of transportation pathway of solid waste has been aided by the exponential growth in computing power but comparative analysis between these proposed methods are till absent. Routing algorithms use a standard of measurement called a metric (i.e. path length) to determine the optimal route or path to a specified destination. Optimal routes are determined by comparing metrics, and these metrics can differ depending on the design of the routing algorithm used [3].The complexity of the problem is high due to many alternatives that have to be considered. Fortunately, many algorithms have been developed and discussed in order to find an optimized solution, leading to various different results. The reason for this diversity is that the majority of routing algorithms include the use of heuristic algorithms. Heuristic algorithms are adhoc, trial-and-error methods which do not guarantee to find the optimal solution but are designed to find near-optimal solutions in a fraction of the time required by optimal methods.

Graph theory has many applications and has proven to be an extremely useful tool in analyzing various practical problems which was first introduced by Euler during1736, a Swiss mathematician, in his solution of the now famous K¨onigsberg bridge problem. The city of K¨onigsberg (now Kaliningrad) was divided into four sections by the Pregel river, with seven bridges connecting the sections. It is said that residents spent their Sunday afternoons trying to find a way to walk around the city crossing each bridge exactly once and returning to where they started. Euler was able to solve this problem by constructing a graph of the city and investigating the features of this graph. The application of graph theory is vast, from electrical or telecommunications networks to traffic systems, from pipelines to flow charts, from biological evolutionary trees to chemical compounds, from organizational charts to computer data structures etc.

Ant Colony Optimization or ACO is the field of ant algorithms which are derived from the observation of real ants' behavior, and uses these models as a source of inspiration for the design of intelligent algorithms for solving optimization and distributed control problems. In ACO, a number of artificial ants build solutions to an optimization problem and exchange information on the quality of these solutions via a communication scheme that is suggestive of the one adopted by real ants. The behavior of artificial ants is based on the traits of real ants, plus additional abilities that make them more effective, such as a limited form of memory in which they can store the partial paths they have followed so far, as well as the cost of the links they have traversed. Each ant of the "colony" builds a solution to the problem under consideration, and uses information collected on the features of the problem and its own performance to change how other ants process the problem. Interestingly, ACO algorithms are based on the following idea:

- each path followed by an ant on a graph is associated with a candidate solution for a given problem. Ants perform stochastic walks in the graph, consisting of a series of stochastic steps until the termination criterion is reached.
- When an ant follows a path, the amount of pheromone deposited on that path is proportional to the quality of the corresponding candidate solution for the target problem. Moreover, artificial pheromone evaporation is often used to avoid premature convergence on a suboptimal solution (stagnation). When an ant has to choose between two or more paths, the path(s) with a higher amount of pheromone has a greater probability of being chosen by the ant. What is relevant to realize is that a stochastic choice is made based on the probability distribution. The possibility of an ant choosing a path with low probability is often

decisive because it enables the discovery of new solutions. The stochastic state transition rule is responsible for defining the relevance of different local variables, like the emphasis on pheromone values or other local heuristics.
Both ACO and Graph theory can be applied in Solid Waste transportation problem. In this paper comparative analysis of these techniques are described. Here the transportation problem of Chandannagar Municipality was considered.

2. Case Study

Chandannagore is a semi-urban area of Hooghly district of West Bengal, India [2,5]. This area is situated at the bank of river Ganga and therefore one of the most important environmental consequences of the process of Solid Waste Management (SWM) of this area is to protect this large river from uncollected or dumped garbage from where the waste is washed into water bodies, resulting to a negative impact on the environment. The poor quality of the services provided in terms of solid waste collection and disposal is the issues of concern. Chandannagar Municipal Corporation is responsible for collection of solid waste which is produced day by day from different areas of Chandannagar. It is noted that there are five borough and 33 wards in Chandannagar. There are 35,630 houses in this area which was considered in our study. There are several sources for solid waste generation in this city which are as follows:

i) Markets
ii) Play Ground/ Parks
iii) Domestic Buildings/ Houses
iv) Houses containing shops
v) Institutions
vi) Offices/Bhawans/Complex
vii) Hospitals

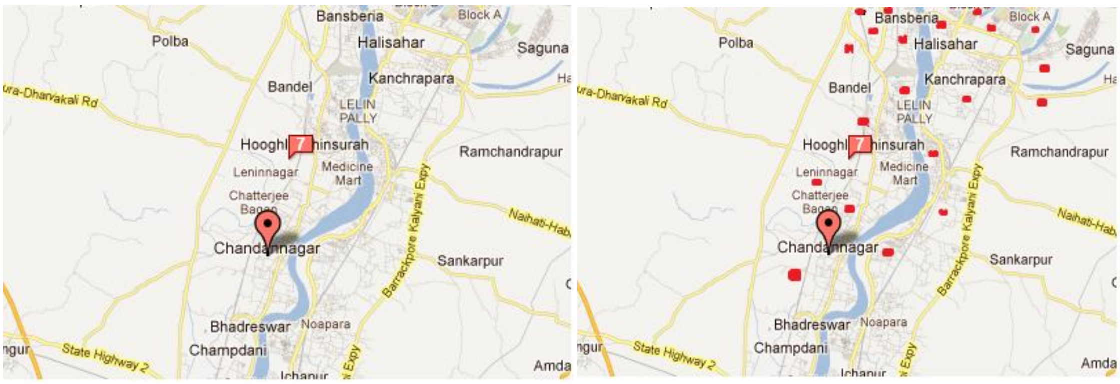
Following are the statistical information of producing solid waste (in kg) per day from different sectors depicted in Table 2 and Table 3 gives the details of seven wards which were densely populated:

Table: 2

Area	No. of borough	No. of ward	No. of house hold	Population	No. of Market	No. of Hospital
22.03 km^2	5	33	35630	162187	7	2

Table 3

Serial No	Ward Number	Number of Market	Population
1	6	1	4688
2	8	1	7632
3	18	1	5453
4	21	1	5919
5	23	1	4202
6	30	1	4994
7	31	1	3321



(a) (b)

Fig 1. (a) Map of Chandannagar Municipality and location of bins (red colored) in that area (b)

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We can apply the Euler's method as follows: consider that each position of bins is nothing but the node of a graph and path between consecutive bins is edge. Thus we can try to find whether there exists a walk across all bins that are situated in a particular municipal area. If we find then it will be the optimal solution of the above mentioned problem. After getting the solution we can analyze whether derived walk is an economically feasible or not on the basis of cost benefit analysis. Thus hypothetically the Euler walk of Chandannagar Municipal area may be as follows:

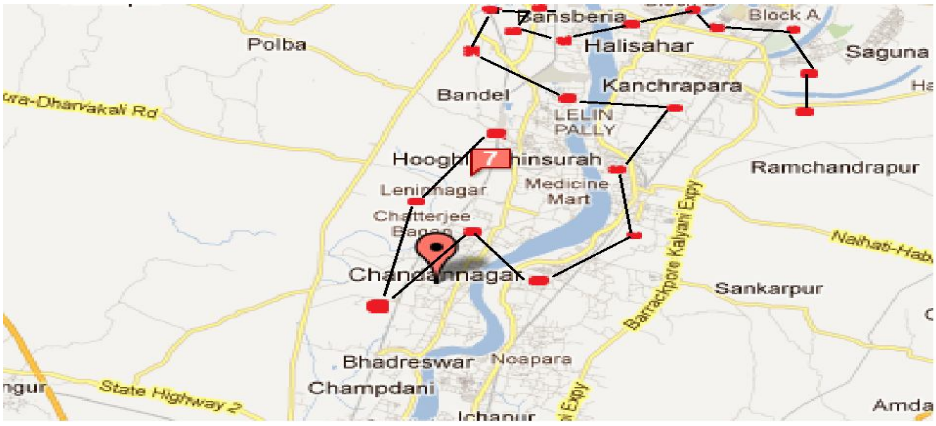

Fig. 2 Euler walk across all bins situated at Chandannagar Municipality

In our previous work we have applied a heuristic algorithm for depicting implementation of GIS in SWM. For sake of curiosity we have applied this heuristic algorithm for calculating routing length and the experimental results confirm an improvement of the optimum route by about 25.6% in ACO, in comparison with the heuristic method, and an improvement of the average route by about 10.45% with respect to previous one. This improvement reduces the collection and transportation costs of the trucks considerably, as might be expected. However, it should be noted that the ACO algorithm is time-consuming in terms of CPU time. Each execution of the ACO algorithm takes approximately 15–20 min, a fact which resulted in running the algorithm for several months, with all the aforementioned combinations of parameter settings.

Fig. 3 the proposed pathways (green colored) for garbage collection on the basis of ACO algorithm

3. Comparative Analysis

The length of each edge can be calculated providing the longitude and latitude information of each bin in Google map and a cost function is responsible for calculating cost of each edge by providing this length. So the derived walks of both cases should be optimal solutions.

However, on the other hand, a cost can be assigned to any delay in visiting the priority nodes. For various ratios between the costs assigned, we would in general get different optimal solutions to the optimization problem. For example, the solutions found here are valid for the case, where the cost of additional edges traversed is much bigger that the cost of delays and delay for the first priority node is much bigger than the cost of delay for the second node, and so on. From the last figure, it is clearly stated that the transportation pathways of these two methods are distinct. But the total length derived by the ACO algorithm is more or less 8%

shorter than the transportation pathway estimated by Euler method which ultimately reduced more or less 15% of solid waste transportation charges.

4. Conclusion

This work focuses on the collection and transport of solid waste from specific loading spots in the area under study, the problem is modelled as a TSP instance. Recent results in complexity theory indicate that a lot of network optimization problems such as TSP are inherently difficult to solve. In fact, it is unlikely that polynomial algorithms can be obtained for exact solution to these problems. Considering this, heuristic algorithms have become increasingly important. In this paper, an efficient and accurate heuristic algorithm for efficient solution of ACO algorithm with GIS are presented and evaluated and compared with our previous work. This innovative algorithm in this particular research area, is introduced and implemented, for monitoring, simulation, testing, and cost optimization of alternative scenarios for a solid waste management system. The experiments have revealed that applying ACO with GIS, for the solution of this every day problem, the tour length and eventually the total cost in time and money can be greatly minimized. More specifically, ACO achieved to calculate the most efficient route, closely followed by our previous heuristic based approach. However, both algorithms have investigated on limited amount of data. In future we will try to run both algorithms on voluminous data.

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