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AN ALGORITHM FOR GENERATION OF ROUTES FOR COLLECTION OF SOLID WASTE IN THE CITY OF MANAUS USING IOT DATA

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Abstract: The Internet of Things (IoT) is currently being widely studied in the area of smart cities for sensing, locating, tracking and managing smart things. The generation of routes for solid waste collection trucks in the city of Manaus can be inserted into an Iot application. The vehicle routing problem deals with a set of minimum-cost vehicle routes, originating and terminating at a central depot, and has development heuristics. This work proposes an algorithm for generating multiple routes, using the time-oriented and nearest-neighbor heuristic, with a specified origin and destination for the collection of waste at collection points with different volumes, then presents the results of quantitative simulations. made from the proposed parameters, in addition to the routes, the distance traveled and the time required for each route.
Keywords: Iot 1. VRP 2. Nearest neighbor 3.

INTRODUCTION

The Internet of *Things* (IoT) is one of the most used terms when talking about the current phase of industrialization. The IoT is the way all things are connected to the internet and communicating with each other, through smart sensing devices and software that transmit data to a network. It achieves the goal of identifying, locating, tracking, monitoring and managing intelligent things (Solomon, 1987).

The internet of things allows us to integrate practically everything around us. The shared information allows numerous applications of innovations to be made that vary from the most diverse areas of society, such as the environment, industry, commerce and *smart cities* and aims to improve people's quality of life.

The routing planning of garbage collection trucks in the city of Manaus is one of the applications in which the IoT can optimize with the help of intelligent sensing systems. In general, itineraries generations need to decrease costs and maximize productivity. For this reason, there are solutions related to the Vehicle Routing Problem (VRP), which concerns a combinatorial optimization problem, which involves the design of a set of minimum-cost vehicle routes, originating and terminating in a central depot, for a fleet of vehicles that serves a set of customers with known demands.

VRP concerns the logistics service. Goods from n customers have a demand for goods and these are delivered by a fleet of homogeneous vehicles. Vehicles need to make a journey from the warehouse location and deliver the goods to a subset of customers, taking into account demand and returning to the initial location. The routes of each vehicle cannot exceed the vehicle's capacity and the maximum time to complete the route. All customers' operational requirements and restrictions need to be met and the overall shipping cost minimized. This cost can be monetary, distance, time or otherwise. (Arakaki, 1998).

Formally, the VRP is defined on a directed graph G = (V, A) with the set of vertices V and the set of arcs A. The set of vertices V consists of the set of clients N = {1,. . ., n} and the vertices 0 and n + 1 that represent the deposit at the beginning and at the end. Each customer i ϵ N is associated with a time window [ai, bi], a non-negative service time si, a demand interval [qmin i, qmax i] and a profit ei ≥ 0 per unit of demand delivered. In addition, a time window [a0, b0] = [an + 1, bn + 1] is associated with the deposits to model the planning horizon (Tilk et al, 2019). Among the various types of routing algorithms, Solomon (1987) addresses in his study on algorithms for vehicle routing and scheduling problems with time window constraints. The algorithms are divided into sequential and parallel methods. Where sequential procedures build one route at a time until all customers are scheduled. And parallels are characterized by the construction of a series of routes simultaneously.

This work, of an exploratory nature and with a quali-quanti approach , describes the development of an algorithm for generating multiple routes for solid waste collection in the city of Manaus using data from an IoT system, based on heuristics oriented to time and nearest neighbor approached by Solomon (1987), where all routes are initiated by finding the unrouted client "closest" to the depot.

The metric used in this approach tries to explain the geographical and temporal proximity of customers. Let the last customer in the current partial route be customer i, and let j denote any unrouted customer that can be visited next. Then, the metric used, ci_{ij}, measures the direct distance between the two customers, d_{ij}, the time difference between the completion of the service in i and the beginning of the service in *j* , T_{ij}, and the urgency of delivery to the customer j , v_{ij}, as expressed by the time remaining until the last possible start of vehicle service (Solomon, 1987).

THEORETICAL REFERENCE

IOT (INTERNET OF THINGS)

Iot is a large network of equipment (things) linked together capable of generating a large amount of data that can be used in various applications. In their article, Talari et al (2017), states that IoT is enabled by the expansion of various things and communication equipment and involves smart equipment such as cell phones, appliances or sensors that collaborate towards a common goal.

VEHICLE ROUTING PROBLEM (VRP)

According to Barrier (2003), the vehicle routing problem consists of several customers, each one requiring a specific weight of the goods to be delivered. Vehicles dispatched from a single depot must deliver the required goods and return to the depot. Each vehicle can have a limited weight and can also be restricted in the total distance it can travel. Only one vehicle can visit each customer. The problem is to define a set of delivery routes that meet these requirements and offer a minimum total cost. In practice, this is generally considered equivalent to minimizing the total distance traveled or minimizing the number of vehicles used and then minimizing the total distance for that number of vehicles. One of the approaches to solve this problem uses the nearest neighbor heuristic.

NEAREST NEIGHBOR

The nearest neighbor algorithm is effective in solving highly complex problems such as VRP. These are mainly optimization problems. The K nearest neighbor technique usually using Euclidean distance or cosine comparability between tuples (Mohammed et al, 2017). In the nearest neighbor heuristic, the closest vertex to the last already inserted is added at each iteration. When all vertices are visited, the procedure is terminated.

METHODOLOGY

The proposed study is descriptive and exploratory, with a quantitative and qualitative approach to the implementation of a route generation algorithm for solid waste collection trucks within the city of Manaus. For its implementation, a time-oriented and nearest neighbor heuristic, presented by Solomon (1987) was used.

Each collectable point within the city was considered as a node of a graph. Due to the need to perform the collection activities, each collectable point (or graph node) was associated with a geographic region. For each region, a graph containing its collectable points is generated.

Collectable points have a weight that is calculated from the data obtained by sensing and stored in cloud servers and is defined by a conditional equation that takes into account their filling level, the number of days that are not collected and the level of gas inside it. For the execution of the algorithm, only the points that satisfied the condition of equation (1) below will be considered.

$$(Level > 80\%)\ or \quad (Level > 20\%\ and\ Days > 2) = true \tag{1}$$

In this step, the result is graphs, by geographic regions, totally disconnected, having only suitable collectable points, as shown in Figure 1.

In order for the algorithm to be executed, an undirected and fully connected graph is required. For that, edges were created at each node for all other nodes of the graph in the region, as shown in figure 2. Such edges have weights that are calculated according to the distance in meters and the time in seconds between each point.

As input to the algorithm, there are: origin, destination, maximum collection time for each truck, a list of trucks containing their capacity and a list of undirected and fully connected graphs by region, containing the collection points (graph nodes) and its edges found in the previous step. Below is a pseudocode of the generated algorithm:

```
generatorRoutes(source, destination, Tmax, Capacity, trucks, graphs)
    noCurrent = origin
    listRoutes = [[noCurrent]]

     for i in knife graphs :
       while graph[i].vertices.size > 0 knife :
    route = listRoutes.size
         if Tmax > listRoutes[route] .time and Capacity >
    listRoutes[route].capacity:
         listRoutes[route].add( NearestNeighbor(NoCurrent,
    graph[i]))
```

The preparation steps to enter the necessary data for the route generator include:

I. Analysis of collectable points able to be collected,

II. Division of the collection points in geographic regions of the city of Manaus (north, south, east, west, center-west and center-south), for this, the *Application Programming Interface* (API) of Google Maps was used,

III. graph generation, where its nodes are the collectable points and the edges are the distance (calculated by Google API) between each node and the other points.

RESULTS

The results below were obtained through data simulation, where data from the collection points were randomly generated (capacity, filling level and days without collection).

SIMULATION RESULTS

Randomly generated data from collectable points (coordinates on the Manaus map, fill level and days without collection) were used and a MacBook Air 2005 computer, with 4 gigabytes of RAM, 1600 megahertz, DDR3 and an Intel Core I5 Dual-Core processor., of 1.6 gigahertz. The collectible points used for the simulation are shown in table 1.

The collection points, described in table 1, were entered using latitude and longitude of their geographic coordinates and were separated into regions, which are called: north, east, south-central, west and south within the city of Manaus. Figure 3 shows the points arranged on the map.

The algorithm was implemented using JavaScript language through the Node.js framework in its version 10.16.3.

Table 2 shows which collectibles belong to each route, the distances required to complete the route in meters and the total time in

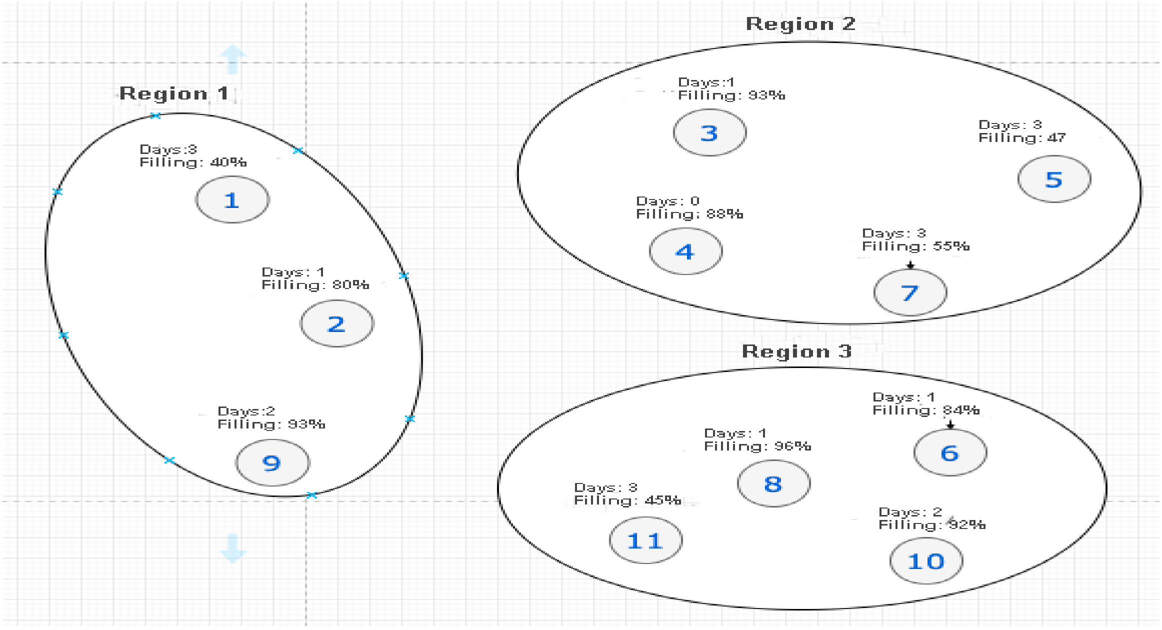

Figure 1 - Example of a disconnected graph by region containing the eligible collectible points

Source: Elaborated by the authors.

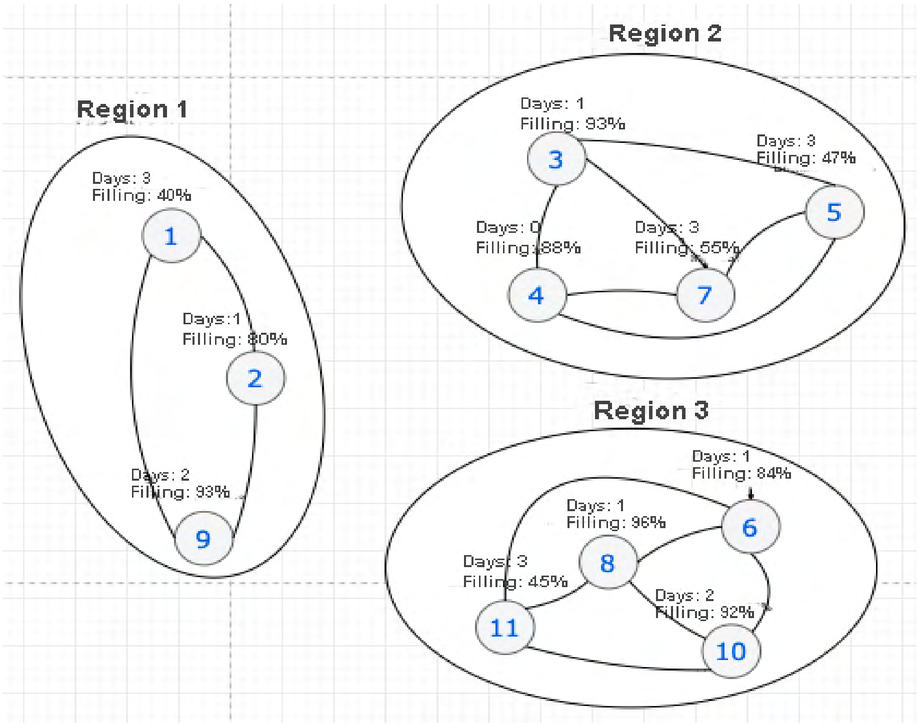

Figure 2 - Example of graphs by region with edges between all collectable points

Source: Elaborated by the authors.

Nro	Latitude Longitude	Region	Filling (l)	days without collection
1	-3.000140 / -60.002441	North Zone	150	1
2	-3.004274 / -59.980428	North Zone	180	1
3	-3.000118 / -59.972010	North Zone	120	2
4	-3.013564 / -59.939042	North Zone	200	1
5	-3.014602 / -59.938829	North Zone	180	1
6	-3.031978 / -59.989389	North Zone	140	2
7	-3.032043 / -59.985927	North Zone	100	2
8	-3.031977 / -59.989465	North Zone	160	1
9	-3.035027 / -59.939318	East zone	192	1
10	-3.044733 / -59.944959	North Zone	100	1
11	-3.050639 / -59.944833	East zone	70	2
12	-3.062960 / -59.950434	East zone	150	2
13	-3.075378 / -59.955009	East zone	180	1
14	-3.075872 / -59.957190	East zone	160	1
15	-3.058301 -60.006438	south-central zone	170	1
16	-3.066278 / -59.990212	south-central zone	140	2
17	-3.081527 / -60.024595	south-central zone	160	1
18	-3.091780 / -60.017621	south-central zone	160	1
19	-3.093316 / -60.021974	south-central zone	160	1
20	-3.091220 / -60.017978	West Zone	120	1
21	-3.094113 / -60.009411	south-central zone	100	2
22	-3.104551 / -60.026484	south-central zone	120	2
23	-3.104443 / -60.012300	south-central zone	160	2
24	-3.101366 / -60.056590	West Zone	140	2
25	-3.101133 / -60.053886	West Zone	160	2
26	-3.107280 / -60.053046	West Zone	160	1

27	-3.125645 / -60.026459	south-central zone	160	1
28	-3.129877 / -60.023451	South Zone	180	1
29	-3.127342 / -60.006121	South Zone	120	2
30	-3.128988 / -59.997934	South Zone	90	2

Table 1 – Collectable points used for the simulation.

Figure 3 - Collectable points displayed on the Manaus map

Source: Elaborated by the authors.

Route	Collectable Points (Nro)	Total Distance (m)	Approximate Total Time (min)
1	3, 7, 6	34000	59
2	8, 4, 5, 10, 2	52200	87
3	11, 12, 14	26000	53
4	13, 9	29000	54
5	16, 21, 23	22900	41
6	17, 19, 22, 18	16600	38
7	27, 15	25700	51
8	26, 25, 24, 20	18600	39
9	29, 30, 28	17600	47

Table 2 – Routes generated by the algorithm.

minutes of each route in minutes based on the characteristics of the collectibles in table 1.

The total distance and approximate total time shown in Table 2 were obtained using the Google Maps API for Directions, which allows you to enter an origin and destination and a list of stops in latitude and longitude format. The time shown does not take into account the period in which the collection truck will be parked to carry out the collection of waste from the collection points.

CONCLUSION

Algorithms involving Vehicle Routing Problem are often used in applications aimed at route optimization and for the development of innovations aimed at IoT systems. The implemented algorithm proposes a solution to trace routes that receives as input the origin, the destination, a list of trucks containing their capacity and a list of graphs per region containing the collection points (nodes of the graph) that combines the heuristics: oriented to time and the nearest neighbor.

For the proposed scenario, the analysis of the points suitable for collection was carried out, the division of these points into geographic regions, generation of the graph, where its nodes are the collectable points and the edges are the distance between each node and the other points. The algorithm divided the 30 points into 5 geographic regions and traced 9 routes with trucks with a capacity of 500 liters to collect 4382 liters of waste in a time ranging from 38 to 87 minutes.

For future work, it is intended to include for the sum of the total time that the truck will be stopped at each point, which can be done through a probabilistic average that will depend on physical aspects of how the collection will be made at the collection points, in addition to of the use of genetic algorithm to solve the routing problem.

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