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SUMO FOR DATA GATHERING IN DOOR-TO-DOOR GARBAGE COLLECTION - A SIMULATIVE APPROACH

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Abstract— In the 21st century, India has entered the age of industrialization and urbanization and is still tackling the problems caused by over population. One such prominent challenge is the solid waste management. In the current waste management system, the prime concerns of Door-to-Door garbage collection has been the focal point of the research. The paper addresses and proposes a way to alleviate the problems associated with waste collection through a simulative based model. Thus, the traffic simulator SUMO (Simulation of Urban Mobility) is used as a platform to perform the simulations of waste collection scenarios. The work describes the representation of the real world map within the SUMO environment by constructing a road network to perform the waste collection process. Python is made use of along with TraCI to generate randomness and extract the runtime and simulation parameters. Overall, the results show that SUMO was capable of simulating the waste collection process, validating its capability to generate realistic data.

Keywords— Garbage, Python, SUMO, TraCI, Waste Collection.

I. AN URBAN CHALLENGE

What is the roadmap for urban growth and that of sustainable urban development? From past many decades this particular question has received continuous attention from researchers and policymakers. The rapid change happening towards this has made all cities exhibit unstableness and show complex dynamics. As cities grow, good governance should devise plans to tackle and take up the challenge of providing water and electricity, habitual food, traffic management, local waste disposal, and so on; and this defines & classifies the class, of the life of the people living in cities. One such cause considered for research is the local waste management.In the 21st century, India has entered the age of industrialization and urbanization and is still tackling the problems caused by over population. One such prominent challenge is the solid waste management which the government has to find a solution for. In this modern era, where all fields of technologies are developing at a rapid rate, there is one area which has proven to be of utmost importance which can make the vision of a cleaner India come true i.e. Waste Collection.The waste collection process is one of the most crucial activities in the waste management system [1],

which acts as the main factor for a sustainable and an unpolluted environment. The reason to propose this effective waste collection system is to remove all the quandaries regarding the problems entangled around it. The general awareness of hygiene and health has increased amongst citizens and the general public hope for effective implementation of the regular pick up of waste which can result in a clean and refreshing city.

II. Related Work

Artemois G et al., has proposed a system where the goal of the work is to improvise the collection process of waste management by optimally managing the fleet operation making use of sensor networks, routing protocols and well participation of citizens [2]. The waste bin makes use of sensors for detecting the fill level and thousands of sensors are being deployed in the city to note the fleet operation with vehicles having RFID's to be detected appropriately. The information related to vehicle and city waste bins would be passed to the main center and also update the drivers and importantly citizens would be informed when they log into the portal or through the Dynacargo App. **Gupta Suyog** and **Dr. Pradeep Kumar**, deals with providing an automatic real-time system for monitoring and managing the solid wastes in real-time systems [3]. The proposed system helps in the monitoring the activities of solid waste from the point of generation to shifting them to disposal site by incorporating various technologies such as RFID and GSM and software packages. **Gaikawad Prajakta et al.**, in their study, suggests that automatic garbage collection can be developed, and information can be gathered with the help of GSM module using Image Processing Technology [5]. According to this idea, a camera is used to know the bin level above some threshold and notify the central unit about this for further action to be taken. **Krajzewicz Daniel et al.**, abbreviates SUMO as Simulation of Urban Mobility is a simulation platform for various research topics related to traffic management and vehicular communications[6]. A description of collection of applications in SUMO is provided that is used for creating different traffic scenarios and perform simulations runs. They also have shared as to how an external application can interact with sumo via socket connection allowing to listen on a port number to get various simulation artifacts related to the created scenario. The paper also projects the recent developments and research topics that include sumo as the base model for their work. A survey was done at large and from the few papers detailed in this section, it was noticed and understood that the works on Garbage collection have not been focused on the present method of collection in metropolitan cities i.e., Door-to-Door mode of collection, in providing an effective solution. Also an understanding of the drawbacks of these papers, it was able to ascertain the need for a system which maintains a proper data set, like Date, Arrival time and Departure time, service time, left-over points etc., so that it ensures all pickup points are guaranteed to be covered.

III. Waste Collection Method

Initially, metropolitan city municipal council deployed concrete dustbins at most of the street corners to collect the garbage from residents, and later it would be cleared. This mode of collection of waste had no positive outcome as residents

1) still made use of empty sites, vacant lands or gutters to throw waste or
2) once the concrete bins were full they used to litter garbage around making it into streets, to create a mess and also negative health and environmental impacts.

Also as per the directions of court, segregation at source is mandatory and is to be followed by each household. Consequently, at present concrete dustbins are replaced by the door-to-door garbage collection system with pickup points, which is also ineffective in its implementation. However, the Corporation is striving hard to ensure regular or consistent waste collection from the entire locality or ward and transport it to the disposal sites.

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But, the irregularity of service often results in citizens dumping the waste in empty plots or on roads, thus affecting public hygiene as shown in Fig. 1. This leads to increase in the mosquito population, contaminated water bodies, and spreading of deadly diseases. All these will again contribute to affecting the public's health thereby increasing infant mortality and also reducing the life expectancy.

Fig. 1. Pile up of Garbage on roads due to ineffective waste collection system.

Although the Corporation has allotted a definite route and a time slot for the waste collection vehicles, some of the problems in the process are irregularity, unsatisfactory service, and negligence of the labourers and also the lackadaisical attitude of the public.

IV. RESEARCH APPROACH

The current waste management system follows the method of door-to-door collection of waste. In this process, wherein the waste collection time for a particular day is either indeterminate or is dependent on the time of arrival of the primary collection vehicles, leads to difficulties for the people as sometimes the collector vehicle might turn up very early or may be running late or may not show up at all which leads to high ambiguity[4]. Thus, the prime objective is to automate the collection process by creating a better waste collection system that records data with which people can get to know if the waste collecting vehicle will be functional on the particular day accurately or not, and also provision to maintain a history of waste collection findings that are fool-proof.The garbage management system can be made smarter and efficient by ensuring proper pick-up and travel methodologies. Hence there is a need for Garbage Monitoring System where the status of the vehicle will be captured during its traversal and precise data gathered which will make it possible for analysis and can cut down the anomalies like time delay and maintain regularity of waste collection. This can be used as a reference model for the future functioning of the system in an effective way and any changes desired can be easily embedded into it to test, making it to be highly robust.But before moving on to implement this, one should try running simulations of the same so as to test its feasibility, reliability, etc., as direct implementations on a large scale without testing beforehand is not advisable.

A. SUMO Traffic Simulator

The acronym SUMO stands for Simulation of Urban Mobility and is one of the traffic simulators [7]. It is an open traffic simulation suite implemented in C++, released in 2001 and is used to model traffic systems which involve vehicles, pedestrians along with roads, traffic signals, bus stops etc.

SUMO allows one to build his own network using nodes and edges. This network can be used as the base for conducting the simulation. It also allows users to import a map of an actual area with the help of OpenStreetMaps, VISUM, etc.

B. Design View

The work here considers 3 vehicles that act as garbage trucks. These trucks are given pre-defined routes along which they traverse. While traversing, they stop at the garbage pick-up points which are also defined beforehand servicing for a fixed timeslot.

Fig. 2. Garbage pick-up points.

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From the Fig. 2, it can be observed that the layout pattern is divided as 3 routes with the first vehicle having eleven pick-up points marked in blue, the second having nine pick-up points marked in red and the third with ten, marked in green.

There are three scenarios considered

1) The vehicle arrives at a pick-up point, services it and then departs.
2) The vehicle arrives at a pick-up point but departs without servicing it.
3) The vehicle doesn't arrive at the pick-up point at all.

and all these require a traffic system to be followed that has both mobility and designated stops. SUMO has hence been used in this work for simulating a garbage collection scenario by designing a node-link based network for a real-world area considered and is as depicted in Fig. 3.

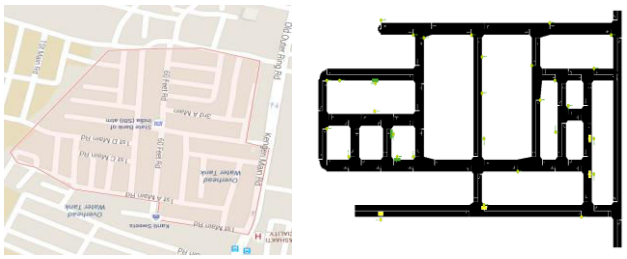

Fig. 3. Real World Geography and the corresponding SUMO Network.

Vehicles that are assigned as garbage trucks are made to ply on this network along a pre-defined route and stop at pick-up points for collecting garbage, which is mentioned in the SUMO files and thus complete the garbage collection simulation of the area. Once all the pick-up points are covered, the vehicles leave the simulation.

C. Need for Python and TraCI

SUMO also provides a module called TraCI, which is written in Python for the purpose of online interaction, i.e., it allows a python script to extract various values from the running simulation or change certain simulation parameters which cannot be done using the basic SUMO files. TraCI commands span across various domains, i.e., the functions that are used in TraCI can be used to retrieve values related to the simulation, GUI, vehicles, junction, person, etc. In this project, TraCI has been used to check the number of vehicles in the simulation and if any of the vehicles is at a stop.

Using Python and the modules that are available with TraCI, SUMO can be invoked using a client-server connection, between the Python script and SUMO. This is done by passing the path to open SUMO-GUI and the SUMO configuration file as arguments to the corresponding method.

Before SUMO-GUI is opened, the python file is also used for Randomization, i.e., the additional input file, which defines the stop times at pick-up points that are to be randomized. This is done by using the "randint" function to generate a random integer between the specified values and then replacing this value in the original file.

Once the simulation starts, the methods provided in TraCI are used to extract the runtime parameters. The extracted parameters are also stored in a text file for future use through Python. Few such parameters that can be extracted are the current time, the current simulation time, the position of a vehicle and the number of vehicles.

V. ALGORITHM

Parse the command line options to start SUMO with Generating a randomized input file as follows:

For vehicles 1 to n:
    For pickup points 1 to m:
        Rand_stop_time = rand_int (0 to 15)
    End For
End For
Open original input file
For vehicles 1 to n:
    For pickup points 1 to m:
        Stop_time = Rand_stop_time
    End For
End For
Specify the path to SUMO-GUI

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Start a sub-process and run a client-server based model through the specified port
Initialize SUMO on this port
Time_to_run = input ( )
position_list_array = [(x_1, y_1),'$stopID_1$', ... , (x_n,y_n),'$stopID_n$']
stop_arrival_service_tracking_array = [0,0,…0]
Initialize Step=0
While (vehicles in simulation) or (simulation_time <
Time_to_run):
Begin,
For each Simulation step:
If (at a pickup point("vehicleID")):
position = getPosition("vehicleID")
For i ranging from 1 to m:
If (position = = position_list_array[i]):
vehicle_stop_ID = position_list_array[i+1]
End If
End For
arrival_time = now ( )
Else:
departure_time = now ( )
service_time=depart_time – arrival_time
open ("output_file.txt")
print(vehicleID, vehicle_stop_ID, arrival_time, depart_time, service_time)
close ("output_file.txt")
If (service_time < threshold):

stop_arrival_service_track_arr[overall_stop_num]= -1
Else:

stop_arrival_service_track_arr[overall_stop_num]= 1
Endif
Endif
Increment step count by 1
Endfor
End
End While
open ("output_file.txt")
print the stops which have been visited but not serviced
print the stops where vehicle hasn't arrived at all
close ("output_file.txt")
Close the connection with SUMO

VI. RESULTS AND DISCUSSIONS

As the simulation runs the run time parameters are extracted and the output be written to the command line as well as a text file in the background. Each line of the output contains the vehicle id, the stop id, the arrival time at the stop, the departure time from the stop and the service time as shown in Fig. 4.

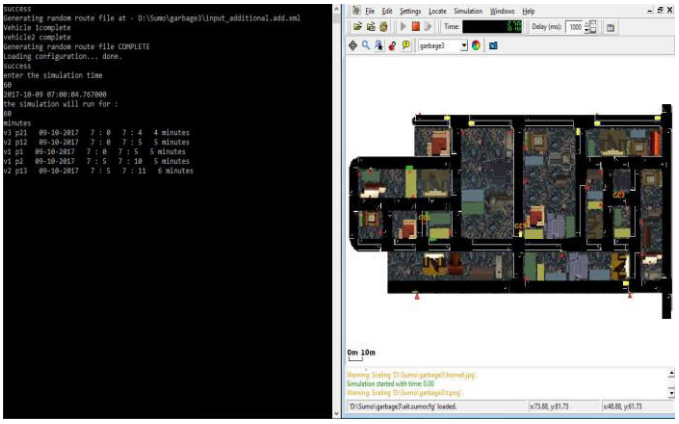

Fig. 4. Output at command prompt and in Text-file.

The final output stored in text file indicating the results of all 3 scenarios is shown in Fig. 5.

Remarks 1- The first scenario is when the vehicle travels along the specified route and services the pick-up point that has been assigned to it along its route. As and when the vehicle completes servicing a stop, the vehicle id, the pick-up point id, the arrival time, departure time at that pick-up point, and the duration for which it serviced that point are all written into the text file.

Remarks 2- The second scenario is when the vehicle arrives at a pick-up point but doesn't service it. As seen in Fig. 5, the highlighted stop in ellipse is not serviced, but the vehicle has arrived at the stop as the arrival time has been clocked for it as shown.

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Remarks 3 - The final scenario is when the vehicle doesn't even arrive at the stop. As seen from the Fig. 5, the highlighted box line shows that a vehicle has not visited a particular stop. It is also evident from the fact that there is no entry of arrival time at all that has to be clocked for that particular stop.

```
v1 p1   09-10-2017   7 : 0   7 : 0  Not Serviced
v2 p12   09-10-2017   7 : 0   7 : 1  1 minutes
v3 p21   09-10-2017   7: 0   7 : 1  1 minutes
v2 p13   09-10-2017   7 : 1   7 : 4  3 minutes
v3 p22   09-10-2017   7 : 1   7 : 6  5 minutes
v1 p2   09-10-2017   7 : 1   7 : 9  8 minutes
v2 p14   09-10-2017   7 : 4   7 : 10  6 minutes
v3 p23   09-10-2017   7 : 6   7 : 10  4 minutes
v2 p15   09-10-2017   7 : 10   7 : 14  4 minutes
v1 p3   09-10-2017   7 : 9   7 : 14  5 minutes
v3 p24   09-10-2017   7 : 10   7 : 15  5 minutes
v1 p4   09-10-2017   7 : 14   7 : 16  2 minutes
v1 p5   09-10-2017   7 : 16   7 : 19  3 minutes
v2 p16   09-10-2017   7 : 14   7 : 20  6 minutes
v3 p25   09-10-2017   7 : 15   7 : 21  6 minutes
v2 p17   09-10-2017   7 : 20   7 : 22  2 minutes
v3 p26   09-10-2017   7 : 21   7 : 22  1 minutes
v1 p6   09-10-2017   7 : 19   7 : 23  4 minutes
v2 p18   09-10-2017   7 : 22   7 : 28  6 minutes
v3 p27   09-10-2017   7 : 22   7 : 29  7 minutes
v3 p28   09-10-2017   7 : 29   7 : 29  Not Serviced
v1 p7   09-10-2017   7 : 23   7 : 31  8 minutes
v2 p19   09-10-2017   7 : 28   7 : 35  7 minutes
v1 p8   09-10-2017   7 : 31   7 : 37  6 minutes
v3 p29   09-10-2017   7 : 29   7 : 38  9 minutes
v2 p20   09-10-2017   7 : 35   7 : 40  5 minutes
v1 p9   09-10-2017   7 : 37   7 : 42  5 minutes
v1 p11   09-10-2017   7 : 42   7 : 50  8 minutes

stop 1 not serviced by vehicle1
stop 28 not serviced by vehicle3
stop 10 not visited by vehicle1
stop 30 not visited by vehicle3
```

Fig. 5. Output text file after simulation.

Graphs

The data or the attributes that has been obtained from a simulation run such as Vehicle_id, Pickuppoint_id, Date, Arrival_time, Departure_time and Service_time is used as a basis to present the required or useful information pictorially in the form of line graphs and fixed placement column graph. The travel time of vehicles to the pickup points are considered to be negligible.

A. Service Time Graph

A fixed placement column graph is considered for portraying the results in graphical form. The graph in the Fig. 6 shows a consolidated view of the service time duration for all pick-up points in the terrain for a particular date. It depicts the service time allotted to each pick-up point vs. the actual time taken by each vehicle to service it and has been overlaid in a transparent manner. For simplicity, the allotted service time is considered as 5 minutes and is common for all pickup points.

Fig. 6. Service Time duration at each Pick-up Point.

The graph in Fig. 6 shows 11 blocks where,

1) route1 having 11 pickup points has been serviced by vehicle1 shown till block 11 indicated in grey colour.
2) route2 having 9 pickup points has been serviced by vehicle2 shown till block 9 indicated in orange colour.
3) route3 having 10 pickup points has been serviced by vehicle3 shown till block 10 indicated in green colour.

On observation, it's found that some pickup points are given service more than the stipulated time and some are considerably less and some have not been serviced at all (the grey and green column in block 1, 8 and 10 respectively).

B. Arrival Time Graph

Here Line graph is considered for portraying the results in graphical form. The graph in the Fig. 7 shows the arrival time of the vehicle near the pick-up points in the terrain. It depicts the arrival time of vehicle at the 11 pickup points in route 1.

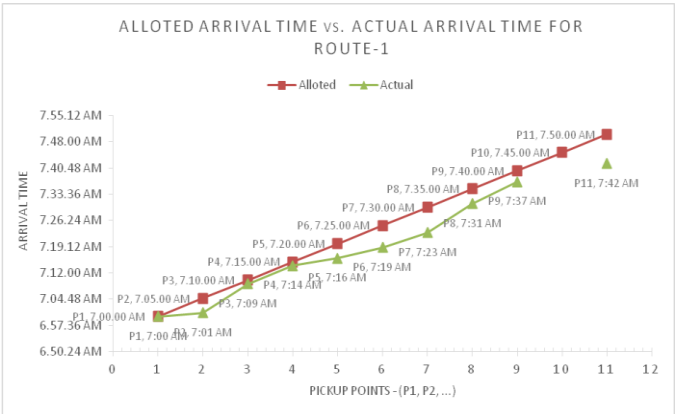

Fig. 7. Vehicle Arrival Time at each Pick-up Point for Route 1.

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The allotted arrival time has been plotted in pink and the actual arrival time is plotted in green. On observation, the line in green follows the variation in arrival times of a vehicle at route 1. The graph clearly indicates that the vehicle has arrived earlier than expected at all places. It shows non-arrival of vehicle at pickup point 10 and non-servicing at pickup point 1. This way, similar graphs can be plotted for the other vehicles for their respective routes as well.

C. Timeslot of vehicle for the Day

Here, line graph is again considered for portraying the results in graphical form. The graph in the Fig. 8 shows the total time duration the vehicle stayed in the collection process. It depicts for all the 3 vehicles, the arrival time to the first point and the departure time of the last point in the service.

The graph shows the time slot of each of the vehicle in the service for a day. From the graph an inference could be made as all 3 vehicles has started its service at 7:00 am and vehicle1 has done with its service at 7:50 am, vehicle2 at 7:40 and vehicle3 had completed its work at 7:38 am.

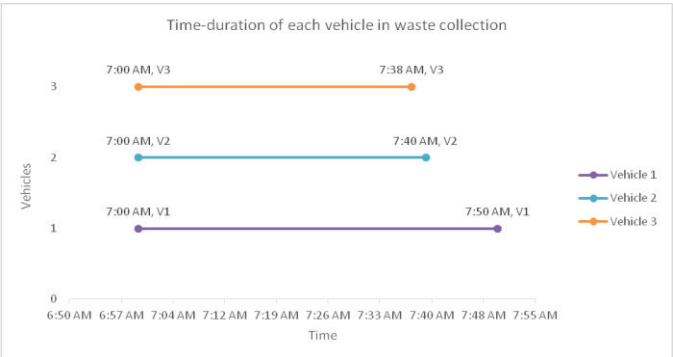

Fig. 8. Vehicle's Time duration for garbage collection in a day.

VII. CONCLUSION

The result of the work in providing a conceptual simulative solution to the Door-to-Door collection method of service definitely proves to be logical in handling the challenges or issues involved in the system of waste collection process. As a concluding remark, this design when implemented would be a useful tool for all the intended users like Garbage collection Personnel, Residents, Monitoring Officials, Reporting Authority and Data Analyzers so as to make their part of work more effective and efficient and most importantly to be foolproof with the stored information to stand as the justification. Undoubtedly it acts as an aid for the National missions incepted by our beloved Prime Minister Narendra Modiji and majorly it pushes the main aim of "Clean India" to be attained by 2nd October 2019, evidently marking the 150th birth anniversary of Gandhiji.

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