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Route Optimization to Manage the Medical Waste in Real-Time

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Abstract: Rapid waste creation contributes to the spread of infectious illnesses in the environment. The present rate of population expansion generates an unsanitary environment for a society's citizens in terms of waste output. This paper describes an Internet of Things (IoT) innovation for a smart garbage bin with a real-time monitoring system that incorporates numerous technologies. This study proposes a Medical Waste Collection Management (MWCM) for hospitals and clinics in smart cities through IoT to keep the city clean and monitor waste bins in real-time. An Android application is utilized to provide truck drivers with root mapping navigation directions. As a result, truck drivers have an easier time deciding where to collect medical waste in cities. The MWCM contains real-time statistics about each bin to avoid overpopulation. The purpose of this research is to develop an effective as well as outlay MWCM system that will deliver a clean, healthy, and green environment. Optimization algorithm help in route optimization in garbage collection station occupancy is maintained under control, and vehicle fuel economy and carbon emissions are reduced. Furthermore, the proposed system supports several of the sustainable development objectives to find the optimal solution. The proposed system decreases costs and saves time and labor work.

Keywords: *Smart Bin, Improved Bat Optimization, MWCM, IoT, Real-time and Route Optimization*

1. Introduction

Although every stage of waste management is important, there is one point that stands out more and affects the operation of other steps, collection [1]. Traditional methods cause time, energy, and fuel loss, and they are difficult to follow and irregular. Therefore, inefficient operations are inevitable. Route optimization solutions offered by digital waste management techniques are environmentally and economically sustainable. Utilize GPS technology for the smart waste management process and track the location of vehicles, control task fulfillment based on the location of the vehicles, analyze driver performance, and manage fuel consumption with a vehicle tracker [2].

Furthermore, with the help of route optimization, the environmental pollution caused by overflowing trash from garbage containers (i.e. visual, odor, noise, and water pollution) would be effectively eliminated because the software would determine the route according to the fullness levels of the garbage containers [3]. This would allow the truck driver to avoid going to empty or half-full containers and go instead to the ones that are actually in need of collecting. The vehicle tracker solution enables tracking of all vehicles' real-time locations. With its collected GPS data and all featured sensors on the vehicle along with CANBUS information such as speed, RPM, braking, geo fencing, and fuel level to transfer to the all-in-one Android Platform [4]. All the tracking devices can be integrated with all-in-one mobile applications. Vehicle tracker serves endless advantages with features designed with high technology. Users can obtain real-time or historical data that is transferred from tracking devices via GSM technology [5]. Through this detailed data, operation management features for waste collection and city cleaning services are managed easily on an all-in-one Android Platform. This structure provides a continuous flow from the field to the back office. Most of the operations in waste management are done by vehicles. Hence, an operation can be satisfied by only visiting the site or reading an RFID tag on-site. Moreover, the fleet is one of the parts that a business can take action for cost-saving activities by increasing productivity [6]. Of course, this action requires a fleet management company that can develop case-specific solutions and has proven its success.

The use of the Route Optimization solution leads to a reduction in the number of kilometers driven per kilogram of garbage collected, as well as the utilization of all available space and time inside vehicles [7]. The use of more effective routes helps to mitigate the negative effects of waste collection throughout the city by reducing the amount of noise pollution, air pollution, and the amount of time spent stuck in traffic.

2. Related Works

By using hardware products integrated with the vehicle,

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waste collection Management solutions provide live tracking, historical tracking, fleet performance, driver performance, preemptive maintenance insights, and fuel insights. It also keeps track of and records independent activities for businesses to build connections within their core operations [8].MWCM offers intelligent waste management solutions that are enterprise-grade for cities and enterprises. These solutions allow for more cost-efficient management of the waste lifecycle, which in turn improves both the environment and the well-being of people [9]. An ability to optimize and automate the design of garbage collection routes is made possible by route planning solutions. It combines the Driver Navigation App with the Medical Waste Management System, and it may include data through Smart Sensors.

Our Route Planning software makes it possible to automate the administration of garbage collection routes. This management is carried out based on exact data that has been predefined about waste collection trucks, warehouses, and the sides of landfills and incineration facilities [10]. Every single garbage collection route should be developed to maximize the efficiency with which your resources (fleet, full-time equivalent employees, and time), and minimize the amount of money that is required to do the task. This may "understand" the trash you manage and make choices that are data-driven and strategic with the help of a product called Smart Waste Analytics, which is an analyzing as well as reporting platform [11]. When using Smart Waste Analytics, users may choose from several unique perspectives to examine and make sense of the data, reports, and measurements that are associated with waste infrastructure, garbage monitoring, and waste collection [12]. Users can do the system follow-up from any device connected to the internet in real-time wherever they are. Alerts can be set via the web-based system, to inform the user of unexpected cases such as not completed tasks and location changes by SMS/e-mail [13]. It facilitates a fast reaction opportunity for potential safety issues for drivers with notifications, driver performance, and better service for customers. The essential features of a vehicle tracker are better and efficient resource planning, full control of vehicle utilization, easy tracking vehicle maintenance, and easy fulfillment realization. With periodic reporting that the vehicle tracker provides, you can track your vehicles' maintenance and fuel levels, analyze operation performance, utilize your sources better, and optimize costs [14]. An essential service that is enabled by the Android application is medical waste collection management. This service was made possible by the Internet of Things (IoT) technology and the Optimization algorithm. At this point, the management of garbage is a common concern in the majority of nations, and it requires constant priority for management. When it comes to conventional methods of trash management, the quick accumulation of waste results in public spaces that are unclean and unhealthy. The unsanitary conditions may put people at risk for a variety of fatal illnesses [15]. Previous studies concentrated their attention on a centralized system for the management of trash that is controlled by a centralized authority. In this research, we propose a smart waste management method for real-time monitoring of "trash bins" in able to acquire normal signals for cleaning the bins and preserving a disorder-free environment for the individuals. This would enable us to undertake daily steps for having to clean the garbage cans and establishing a disease-free environment for everyone.

3. Proposed Methodology

The trucks may be provided routes via Google maps API based on the information gathered to effectively navigate through all essential garbage bins and eventually reach the disposal place. The routes will indeed be made available via the Android workplace application. Clients will be able to acquire routes to the closest accessible bin via the development of a client application. This application may also be used to send comments, complaints, and so forth. The program is supposed to offer a convenient platform for all residents to engage in waste disposal in a city. On the internal side of the lid, facing the solid waste, an ultrasonic sensor would be installed. As the number of garbage rises, so does the range between both the ultrasonic as well as the trash. This real-time data will be sent to our microcontroller.

This research paper includes IoT solutions to construct a system that offers a system that effectively equips the municipal council to tackle the waste issue in a smart city. The residents, the laborers, and the administrators all engage with this system. Figure 1 depicts the system's block diagram, which consists of two bins containing sensors and Wi-Fi. Each bin communicates with the online application (for administration) and the Smartphone application through the Wi-Fi module (for workforce and user). In this technology, a trash can serves as an autonomous node in the process of waste management. Figure 1 depicts the smart bin mechanism in the form of a block diagram.

Waste collection is now inefficiently conducted utilizing fixed routes and timetables. Some garbage containers are overflowing, resulting in needless clean-up charges. Waste collection is optimized by a software and hardware combined solution, saving time, money, and the environment. A standard waste collection process begins with waste collection trucks following a pre-determined waste collection route. When the vehicle capacity is filled, it completes the collected waste by taking it to the waste transfer station. In this proposed system both the bins and trucks are supported by IoT technologies. IoT technologies can read collect and transmit physical data of things to the internet. Both trucks and bins are supported by sensors to pursue their occupancy.

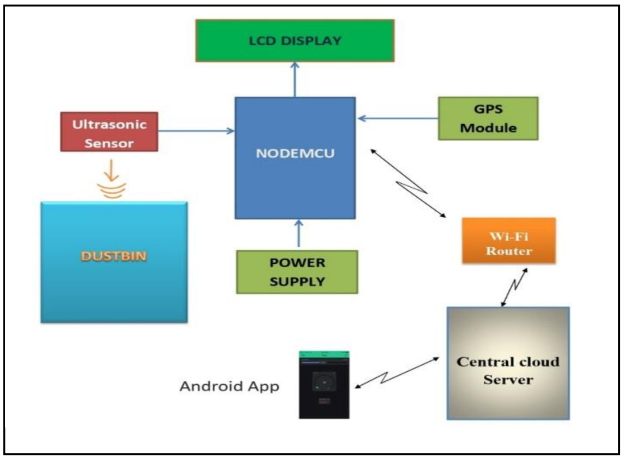

Fig 1 Hardware Model for Medical waste collection

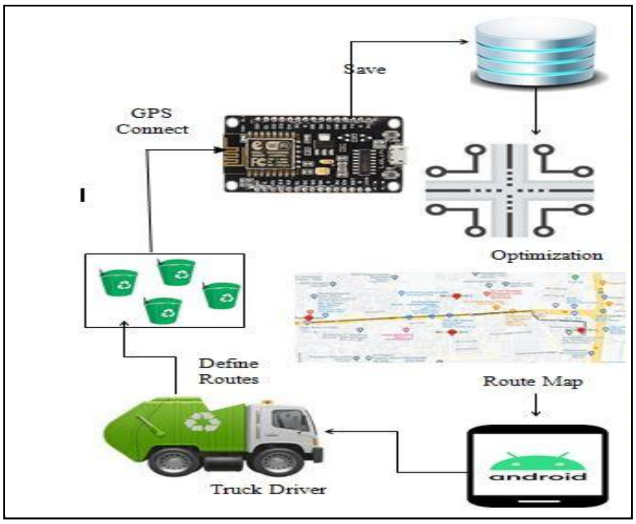

Fig 2. Architecture diagram for MWCM

Based on the output of sensors in bins algorithm of the system decides whether the bin will be visited or not by trucks. Then, the system algorithm generates a waste collection route for a truck. That route is shown in Figure 2. Drivers will be able to see the route through the mobile application. Additional technologies such as Access Network Interface, Batteries, Wi-Fi, Google Maps API, database, and electronic visualization tool are used to enable the system to work properly. The sensor recognizes how much rubbish has accumulated and compacts it automatically, allowing it to keep up to 10 times the quantity of waste as regular dumpsters. It also delivers fill-level data wirelessly to a remote server. There is also the sensible bin, which can be connected to waste bins to function as a Wi-Fi network, and the cleaning lid, which consists of a pin with an adequate sensor powered by either battery or solar energy. It is compatible with a wide range of bins, including wheelie bins, large garbage cans, and even underground dumpsters. It monitors the quantity of trash in the container and wirelessly transmits fill-level information to a cloud service. Users can connect to server networks for data analytics and real-time monitoring of smart bin fill levels. When collections are necessary, the server networks notify users and establish optimum routes for every collection. Consumers may explore smart garbage pickup routes as well as schedules depending on where the collection is genuinely necessary, rather than collecting garbage blindly via static routes and schedules. This ingenious method enables clients to retrieve with fewer trucks, less petroleum, and within a shorter time, reducing operational costs by 78%. It is the prudent choice for conserving money while also keeping streets clean. The IBO is an evolution metaheuristic based on bat echolocation. Bats in the wild transmit ultrasonic pulses into the surroundings to aid in navigation and hunting. Following the production of such pulses, bats react to the echoes and use them to find themselves as well as detect and locate prey and obstacles. Furthermore, each bat may locate the most "nutritious" regions by doing an independent search or by migrating towards a "nutritious" spot already discovered by any other element of the swarm, and it gives an optimum path to a trucker to collect hazardous material.

The method's primary phase starts after these startup stages. Every bat in the swarm moves via updating its location and velocity for each generation. The set of equations used to describe these movements is given below:

$$b_n = b_{min} + (b_{max} - b_{min})\,\beta \quad (1)$$

$$f_n^t = f_n^{t-1} + [x_n^t - x]b_n \quad (2)$$

$$x_n^t = x_n^{t-1} + f_i^t \quad (3)$$

Where the parameter β is an integer chosen at random between [0, 1]. Furthermore, x represents the swarm's current best solution, while x and f reflect the location and velocities of a bat n during time step t. Finally, the findings of Equation (1) are employed to regulate the speed and range of movement of the bats.

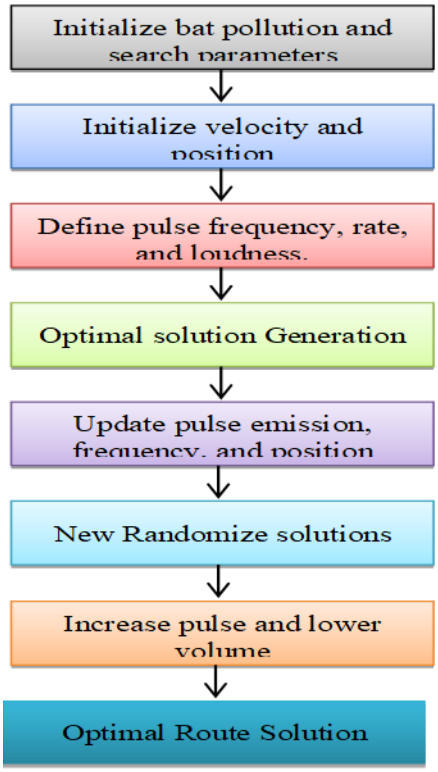

Fig.3 Waste Collection Process Flow.

Algorithm 1: IBO for Route Optimization

1. Identify the goal function $fn(x)$;
2. Establish the population base first.$Xn = 1,2, \dots n$;
3. for population do each $bat\ x_n$
4. pulse rate initialization r_i, velocity ve_i , $loudness\ l_i$;
5. Determine the frequency of the pulse $f_n$at x_n;
6. end
7. repeat
8. Equations1, 2, and 3 can be used to generate new possible solutions;
9. if $r > r_n$then
10. Choose the most effective option from those available;
11. Create a regional solution centered on the most effective one;
12. End
13. if $r > l_i$and $fn(x_n) < fn(x*)$ then
14. Embrace the alternative method;
15. Increase r_n and reduce l_i;
16. end
17. end
18. unless the criteria for the termination are not met;

Place each bat in order, and then return the one that is now considered to be the best of the population.

Furthermore, during the local search component, if one of the best solutions is chosen, a new method for each bat is produced using a stochastic process. As a result, we focus on meta-heuristic approaches that may yield adequate high-quality solutions in a reasonable computing time. This paper provides an updated bat method to get high-quality answers to real situations. Figure 3 depicts the fundamental procedure.

The waste collection process flow primarily begins with the entry of waste into the system. Then it is measured whether the waste bin has reached a level requiring its collection. If it is not at a level that needs to be collected, the humidity/temperature balance is measured. If the waste does not need to be collected as a result of this measurement, the system is put on hold until the waste enters the system again. In either measurement, if the waste bin needs to be disposed of, the location information of the waste bin is transferred to the cloud. The smart waste collection truck reaches the data of the waste bin via the cloud. Then, route optimization is performed using machine learning techniques. The waste truck reaches the waste bin on the route obtained as a result of optimization and collects the waste in the bin. After this stage, the flow returns to the beginning.

4. Experimental Results

Several routes were developed on a random day to test the total path length between these current routes and ideal routes. The number of routes parallels the number of vehicles available to service the area. The equipment component was provided with the Sensor as well as a Separator component to separate the hazardous material as well as put it in the appropriate container. Figure 4 shows the comparison of existing biowaste dustbins and smart dustbins.

Fig 4. Garbage Model for Collecting Medical Waste

A liquid-crystal display (LCD) is a flat panel display, an electronic visual display that provides bin level in percentage as shown in Figure 5. If the percentage level is more than 80 then the truck driver will get an alert message to collect medical waste from the garbage with the optimized route.

Fig 5. Bin Level Notification

Figure 6 depicts the first screen of the Android application, which has a user interface. It consists of two buttons: the User portal, which indicates the button for normal residents who dump garbage in their daily routine, and the Driver portal, which defines the button for drivers who are assigned to collect rubbish in their respective locations.

Fig 6. Medical waste collection.

Figure 7. Depicts the output for a typical user with the choice of locating the closest bin accessible from his present location.

Fig 7. Route (1) Optimization with bin level

The driver must go to each pinned position to empty the full bins, as seen in fig 8. The trail starts with the dot which represents the driver's current position.

Fig 8. Route (2) Optimization with bin level

Table 1 shows the present and recommended waste collection routing distance for trucks. The full estimates for energy consumption rate, Percent change in current and optimal routes based on distance Route optimization studies often concentrate on estimating the shortest route or minimal driving times for garbage collection and transportation. Our study has shown that adopting advanced routing with proper parameters and methods may result in considerable cost savings, which can be achieved by either lowering mileage/distance traveled or by increasing mileage/distance driven. As a result, real savings from current and projected routes are illustrated in Table 1 and graphically in Figure 9.

Table 1: Comparison table of the existing and proposed system.

Parameters	**Medical Waste Collection using Truck**	
	Existing Route	**Optimized Route**
Route Distance in Km	18.3	12.4
Fuel Consumption in a litre	0.68	0.23
Cost in Rupees	69.12	32.20
Km Difference	8.2	6.2
Efficiency %	52.3	78.9

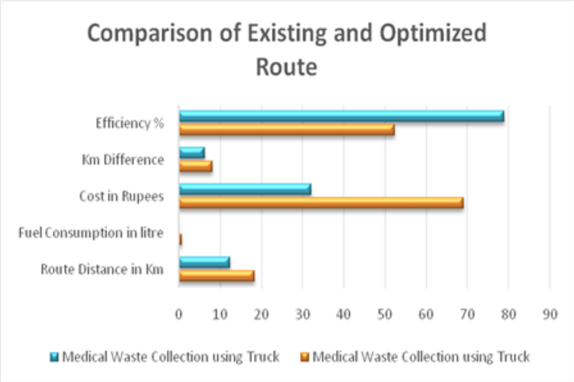

Fig 9. Comparison Graph for Existing and Optimized Route

5. Conclusion

A medical products delivery system with the pharmaceutical waste collection was presented and solved in this research. This system was designed as a rich vehicle routing issue, more specifically as a networked transportation problem including pickups as well as deliveries, asymmetric variable costs, and banned pathways. Medicine wastage is one such example. Its goal is to eliminate human involvement and completely automated the system of waste management for hospitals, laboratories, and pathological labs. The technology was meant to complete the whole plaster management strategy without requiring any human input or modification. The data created by IoT systems is derived from real-time sensor data, which is continually given to authority at their server, allowing full automation of a data monitoring system. The solution also lowers data transit costs by optimizing truck scheduling as needed. This is common in health care canters and other comparable businesses. Waste collection is now inefficiently conducted utilizing fixed routes and timetables some trash cans are overloaded, resulting in costly extra work to empty them. This wasteful practice has negative effects on both the economy and the environment. Waste collection is optimized by a combined software and hardware solution, saving time, money, and the environment.

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