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RESEARCH ARTICLE

A STUDY OF USE OF INTERNET OF THINGS AND MACHINE LEARNING IN SMART WASTE MANAGEMENT

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Abstract

Waste Management poses a big challenge in front of many Municipalities. The fixed routes and schedules of garbage collection are not that efficient. The monitoring of dustbins is also difficult since the number of such is large. Inclusion of Internet of Things and Machine Learning helps in improving the efficiency and makes the work easier for authorities. A lot of work has been done in this field and this article presents the various approaches used by various fellow researchers. The main contribution of this article is that it puts forward an architecture that can be used in the future. This study will help the researchers who want to quickly look at the work done till now in this field and investigate what can be done further.

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Introduction:-

Waste management is one of the major issues in developing countries like India. The issues in waste management include overflowing of bins, low efficiency and low time efficiency using the traditional methods. Use of IoT (Internet of Things) brings about changes in cities making them greener, safer and more efficient. Using IoT these issues can be resolved to maximum extent.

IoT devices used generally include Ultrasonic sensors, IR sensor for garbage depth measurement in garbage bins. Microcontrollers like Arduino UNO, ESP8266, and Raspberry PI.

This paper lists, organizes and summarizes recent research results from latest research works in research papers included below. These research works include use of different architectures, different devices and methodologies used.

This paper proposes its own system based on these research papers where, every garbage bin is mounted with ESP8266 along with Ultrasonic sensor (HC-SR04) for measuring fill level of garbage bin. Here, Wi-Fi is considered for network access technology. Real time data is sent to the Database for storage from which raw data can be processed by analytical server to produce a forecast of bin fill level in the future which will be used to calculate optimized route and dispatch garbage collection vehicle accordingly. This will provide cost and time efficiency and prevent overflow in garbage bins as well.

[1] proposed a smart waste collection and management system. Raspberry Pi and ultrasonic sensors were mounted on the garbage bin for waste capacity monitoring. Real time data was produced and machine learning analytics were

used to identify present and future predicted bin fill level. The results showed an increase in fuel efficiency and time efficiency when compared to traditional method. [2] proposed an e-monitoring system for smart garbage alert system. The micro controller used was Arduino UNO. An ultrasonic sensor interfaced with Arduino UNO was used to check garbage fill level. RFID tags were used to aid the garbage vehicle collector to identify the bins. [3] proposed a system where ultrasonic sensor was placed onto the garbage bins. This collected and forwarded the data once or twice a day. Wi-Fi was considered for network access technology. The database used was MySQL for storage of data from the IoT device. Appropriate machine learning and artificial intelligence algorithms were used to calculate optimized route. [4] proposed a system for alerts when a certain threshold was reached in the bin. An alert was sent twice to the concerning municipality department. The bin got locked as soon as the threshold was reached to prevent from overflow. An application for proper monitoring and visualization was used. [5] proposed a smart waste management to achieve dynamic waste collection and delivery to processing plants or special garbage tips. Top-k query based dynamic scheduling model was proposed to deal with real time scheduling driven by the data from sensory units. An android app along with proper GUI was developed for user friendliness and to evaluate waste collection scenario using experimental data. [6] proposed optimizing logistic procedure of waste collection, it used own genetic algorithm implementation. This paper presented a solution which provides calculation of more efficient garbage truck routes. Input was given as a set of simulations on mentioned area. Algorithms were implemented within the integrated simulation framework which is developed as an open source solution with respect to future modifications.

Related Work and its Analysis: -

[1] proposes an internet of things-based waste monitoring solution which is combined with data analytics. The work made use of Raspberry Pi running rasbian OS and ultrasonic sensor HC-SR04. The sensors were mounted on the bins. The setup used, helped to monitor not only the present values but also predicted the future values. Supervised machine learning approach was taken and standard C5.0 decision tree algorithm was used. In order to identify unique bins, MAC address of Raspberry pi was used. The Maximum bin fill threshold was set to 67.5%. The fuel threshold was set to less than 1% fuel cost of initial route. The predictions were made for future 24 hours. The application development was done in Python and PHP. In order to satisfy the routing and plotting work, Google maps API was used. The driver end of the application was created to run on Android. The data was sent from the microcontroller to the centralized server hosted at the local municipality at regular intervals. The analysis also helped in defining long term policies regarding waste management. During the trial and validation period of ten days, 38 bins were fitted with the relevant IoT sensors. The eleven service routes were completed within 220 minutes. Fuel efficiency noted was 46% while reduction in collection time was by about 18%. The work produced great results and addition of solar power in place of battery packs which needed to be serviced every 2 or 3 days would further increase efficiency and scalability. The security issues regarding transfer of data from IoT to centralized server need to be studied further to enhance security and ruggedness of the solution.

In [2], an IoT based smart garbage alert system was created using Arduino UNO. This work focused on creating a cleaner and healthier environment by timely servicing of bins that may overflow soon. The paper also proposed a design of Smart Dustbin. Main aim was on reducing the Municipal Solid Leftover (MSL). Ultrasonic sensor (HC-SR04) mounted on dustbins connected to Arduino UNO sent the data to municipality server for timely emptying. The bins were fitted with RFID tags to confirm the work of cleaning had been done by the driver who scanned the same. Arduino UNO was interfaced with Wi-Fi module. To monitor the work and get the alerts, Android application was created. The Arduino was programmed to monitor the dustbin on 4 levels, Level1 (>75cm): Cleaned, Level2 (50 cm to 75cm): (25-50%), Level3 (25cm to 50cm): Above 50%, Level4(<25cm): Send Alert. The alert is sent to Things Speak server and then to the Android application. The system allowed for proper monitoring and maintenance of garbage. It aided to diminish the need for human intervention. The system used Arduino UNO and WiFi module which could be replaced with ESP8266 NodeMCU which has built in Wi-Fi capabilities and is cheaper as well.

[3] proposed smart waste collection system based on the amount of waste present in the bins. The bin level data was obtained from the sensors and was passed to the server for storage and processing. The workers received shortest optimized route based on not only daily bin status but also predicted data which was updated based on previous experience with respect to factors like traffic, cost-efficiency. Based on this previous historical data, overflow of bins was predicted as well. The following Sensor devices were used: Ultrasonic sonar sensor that provides measurement from 2cm to 400cm with 3mm accuracy. For example, Ultrasonic Ranging Module (HC-SR04). Wifi was supposedly considered as network access technology. MySQL was considered for storage of all the data

acquired. Role of machine learning and artificial intelligence was to use historical data for an algorithm that will forecast the future bin waste level in order to prevent bin overflow. The following test cases were considered:

Traditional way: Here the garbage collection vehicle was dispatched to all the locations with no optimized route.

Case 1: Waste collection vehicle was sent to all locations using optimized shortest route.

Case 2: Waste collection vehicle was sent to all the locations where the garbage bin fill level was 70% or above.

Case 3: Optimized distance for vehicle schedule was based on the rate of waste fill being more than 10% every 30 minutes.

The following results were achieved:

Simulation for 5000 bins in over 10 locations was carried out for 3 cases.

When compared to traditional way of garbage collection:

Time efficiency (In order - Lower to Higher):

- 1.Traditional Method
- 2.Case 1
- 3.Case 2
- 4.Case 3

Cost efficiency (In order - Lower to Higher):

- 1.Traditional Method
- 2.Case 1
- 3.Case 2
- 4.Case 3

All of the cases show significance cost and time efficiency with case 3 being the most efficient. To conclude, a smart waste collection system was proposed using IoT sensing prototype. The data from this device was sent to the server for processing. This data was then used to calculate optimized routes for garbage collection workers which provided significant results.

[4] proposed smart trash management system using sensor, micro-controller, etc. There were two threshold limits set. An alert message was sent to the Municipality vehicle as soon as the threshold limit was reached for the garbage bin. It waited for the acknowledgement from the trash collection vehicle. The bin got locked, as soon as the bin reached its threshold limit with a message being displayed as 'OVERLOADED'. If the bin was not cleared within a certain time limit than a message was sent to higher authorities. The cost optimization was done as only bins with threshold reached were picked. Sensors used for garbage detection were weight sensor, infrared sensor and fill level sensors. Power supply, transmitter and receiver were some more of the components used. The output of IR sensor was given to the micro controller which was able to transfer data at 2400 bits per second. GSM was proved to be more efficient for communication. The project module was divided into 2 sections Transmitter section and receiver section. Mobile internet connectivity could be provided by modems. Modems send and received data through radio waves. Latest technology used was cloud to transmit large amount of data where data are stored in cloud space. This paper proposed implementation of smart trash management system using IR sensor, micro controller and cloud. The system ensured that the garbage was cleared as soon as it reached its maximum threshold. The bin was locked once this threshold was reached and if the bin was not cleared. Optimization was obtained by dispatching garbage collection vehicle to only those bins where a certain threshold was reached.

[5] Authors proposed a top-k query based dynamic scheduling model which addressed the challenges of near real-time scheduling which was driven by sensor data streams. The city was divided into multiple sectors which covered entire city area. Each sector contained a number of multiple intermediate waste depots, which were temporary waste storage areas. Out of the frontiers of the city there were number of multiple garbage tips used to store the waste collected from the depots. Further processing of the waste was performed by processing plants which were located near the garbage tips. Fleet of trucks was incorporated serving the waste collection infrastructure. Low-Capacity Garbage Trucks were used to collect garbage from different sectors which would be stored in depot and High-Capacity Garbage Trucks were transferring the garbage from depot to the garbage tips. At lower-level bins comprised of RFIDs for identification tagging, capacity sensors for gathering waste fill levels, wireless sensors to transfer data over the internet. All the data transmitted by bins was collected and handled by the system in order to provide different services for waste collection. A middleware hosted in cloud was responsible for gathering and cleaning the data transmitted from bins. This was provided to the engine implemented in OpenIoT. In the Database

which was storing all the data gathered had mobile top-k queries specifying the number of the completely filled bins to initiate dynamic scheduling. Dynamic routing was initiated on certain timing which had GPS data embedded in trucks which would provide drivers with instructions and routes in near real-time. The truck drivers provided with necessary information through an Android Application which had google map integration to provide routing and information about top-k bins to be emptied.

[6] Authors proposed their own genetic algorithm implementation to optimize logistic procedure of waste collection. This provided calculation of more optimized for garbage collection run. Solution is based on the idea of IoT infrastructure, which will provide with information for handling this Smart City issue more efficiently. The software framework implementation was made in line with C++11/ISO standard. The Scalable Vector Graphics with map coordinates were used as a program input, which allowed easy Extensible Markup Language editing. The map was suggested as a classical graph representation. The graph G is a pair of parameters (V, E) , where V represents vertices and E are lines. The E has following dependence: $E \subseteq \{ \{u, v\} \mid u, v \in V \}$. Let's have an edge $e \in E$, where e is pair of vertices (u, v) for $u, v \in V$. Here the vertices are considered as garbage bins and edges of roads. Each road had two parameters for both directions, which represented different weights for each direction. If needed, one-way road could be done with infinite value of the weight parameter. The weight was computed as a sum of all parameters which impact the road. The weight of road can be used to denote the index of expenses for the road. The SVG file would have the basic parameters and attributes for graph creation. These basic parameters would be ID of vertices, where it starts and ends and final number of vertices.

Proposed Methodology: -

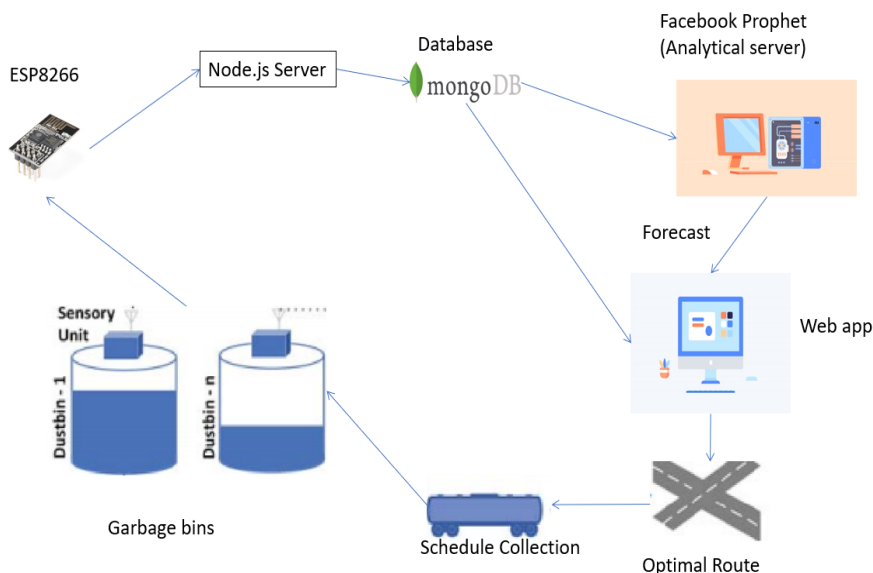


Fig 3.1:- Proposed Architecture.

We are using the basic ideas taken from other works mentioned in previous section, but instead of using the suggested IoT devices and methods we are using our own alternatives in our system design which are more cost friendly and provides the same functionalities. We are using latest and more up to date analytical methods on top of the proposed methods to make it more feasible and implementation friendly. The proposed system architecture comprises of the following processing modules:

1. **The Garbage Monitoring Unit:** This will monitor the capacity of the garbage bin with ultrasonic sensor which will be linked to NodeMCU ESP8266 that will collect and send data to our database at fixed interval of 10 seconds.
2. **Node.js Server:** NodeMCU ESP8266 will send a post request to a Node.js server which will be hosted in cloud which will handle that post request by sending data to the mongoDB database which will store that data.

3. **Database and Analytical Server:** The database that is used to store the collected data is a mongoDB database, mongoDB atlas is used to create a mongoDB database. We are using **facebook prophet** to perform machine learning analysis to the data that is stored in our database which will be provided to our web application. The mongoDB database will also provide data directly to web application.
4. **Web Application:** The bin status and other necessary information will be displayed to the operator via the web application with user friendly interface which will provide all the necessary information to the operator to monitor the entire operation.

From web application, the optimized route then will be provided to all the garbage collectors for their garbage collection run.

Advantages:

1. The Web app created makes it very easy to monitor the bins, helping the coordinator to monitor the status of many bins sitting at one place.
2. The Map view helps to locate the placed bins easily and new bins can be registered and existing ones can be edited with ease.
3. The time-series algorithm helps to identify the patterns which the managed bins exhibit and allow for efficient servicing.
4. The dynamic routes can be generated efficiently leading to a lot of saving of time, money and fuel.

Limitations:

1. The ESP8266 requires continuous access to internet in order to post the data to the cloud storage.
2. The ESP8266 needs constant power supply and sometimes arranging power source can be difficult.
3. Since the routing done using predictions is merely based on historical data, in case of exceptions, overflow cannot be avoided.

Conclusion:-

Internet of Things alone can be used in number of ways in waste management. Inclusion of Machine Learning helps to take things further. A lot of work has been done in this field which includes generation of alerts, real-time status reporting, dynamic route generation and automated bin locker to stop the overflow. Further work can be done in providing a more reliable and longer lasting power source like solar power, decay detection that will give more priority to the bin containing decaying waste, internet availability and making the data sent to the server more secure by encryption techniques. These areas will make the overall inclusion of IoT more robust, secure and efficient while maintaining the scalability.

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