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IOT Based Waste Management System

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Abstract

The rate at which waste is generated is increasing at an alarming rate as the cities expand at a very high rate. This has rendered waste management a significant issue particularly because the conventional means of waste collection are usually manual which is inefficient and results to some inconveniences such as overflowing bins and dirty environment. Our project aims to address this problem by introducing IoT-Based Waste Management System in order to introduce smart technology into the process. The system can be installed in garbage bins to determine the level of fullness of individual garbage bins in real time by installing sensors, which are ultrasonic sensors, into the garbage bins. This data is wireless transferred to a central server via Wi-Fi or GSM modules. Then it is shown on a convenient web or mobile application allowing authorities to have a clear picture about what bins should be emptied and when. The system also will be able to provide immediate notifications in case a bin is full or in case a suspicious activity occurs, which will make it possible to respond in shorter periods. On the whole, this solution saves time and resources and allows to make our cities cleaner and more environment-friendly due to the simple waste collection that is smarter and more efficient.

1. Introduction

The modern urban life has made waste management one of the most urgent problems. As cities rapidly adopt urbanization, industrialization, and a population that is steadily increasing, the volume of waste produced in cities has achieved terrifying levels. In most cities, the customary waste collection methods, in which the garbage can be collected with specific times whether the need arises or not, are no longer adequate. These are the ineffective practices that usually result in overfilled bins, bad smells, unhygienic streets, and environmental pollution. To make it worse, the poor utilization of manpower and fuel used in making collection rounds contributes to operation costs and carbon emissions. It is obvious that a smarter and more responsive way of handling waste in our cities needs to be implemented.

Technology, especially the Internet of Things (IoT), is a potentially effective solution in this regard. IoT is a network of physical objects, devices, vehicles, appliances, and other objects, which are embedded with sensors, software, and connectivity so that they can gather and transmit data. Applying IoT to waste management, it can be described as a highly effective solution to enhance the process of monitoring waste, collecting it, and processing. Through automating the process and ensuring data-driven approaches, cities will be able to obtain cleaner environments at minimum effort and cost.

The proposed project, IoT-Based Waste Management System, is expected to solve the inefficiencies of the existing waste disposal practices by providing an intelligent system that will be able to keep track of garbage levels in real-time. The idea is the easiest yet effective: to attach ultrasonic sensors to garbage bins so that constantly check the degree of their filling. These sensors are used to determine the height between the bin and a waste surface which provides a reasonable estimate of the fill level of the bin. When the threshold has been reached, the information is relayed to a centralized system through Wi-Fi or GSM modules. Municipal workers or waste management companies can access this system either via web or mobile application.

Real-time data, with this, the collection routing can be optimized and this means that there will be delivery of bins that must be emptied only. This will save time, minimise on fuel consumption, and unnecessary wear and tear of vehicles. Further it prevents the usual problem of full bins before the next scheduled pick-up, which does not only result in inconvenience, it has far-reaching health hazards to the population.

Also, the system can be programmed to automatically generate alerts when some unusual patterns are noted, e.g. when the level of waste increases suddenly, or when a bin is damaged, this will allow it to respond fast and be repaired. The data collected can be also analysed in the long run in order to know the trends of waste generation and this will assist the authorities in planning on how best to reduce their wastes.

To sum up, the IoT-Based Waste Management System is a product that unites the contemporary technology and the real-world urban demands to make the future smarter, cleaner, and more sustainable. By substituting the old manual practices with smart and automated ones, the cities will be able to enhance the quality of life of their citizens.

2. Literature Survey

In the last ten years, the issue of efficient waste management has become a growing concern in the interest of researchers, planners of cities, and environmentalists. As the population of cities is growing and the volume of waste also grows, the traditional waste collection methods turn to be inefficient, outdated and pose environmental risks to the environment. Consequently, various researchers have already investigated the ways in which contemporary technologies, specifically the Internet of Things (IoT), can be applied to develop smarter and more sustainable waste management systems. Several studies have given in-app solutions based on IoT in which sensors are mounted on garbage cans to determine the amount of garbage. These sensors are usually ultrasonic and are able to measure how far the waste is against the top of the bin and transmit this information via wireless communication to a central system. A case in point is a study by Singh et al. (2017), which proposed a smart bin operational system, which relies on GSM modules and enables the real-time notification of the amount of waste produced. Their effort revealed that this methodology may assist in preventing spilling overflowing bins and also to streamline collection paths. The other study by Al Mamun et al. (2019) was aimed at creating a smart waste monitoring system based on a cloud. In their model, they made use of ultrasonic sensors and Wi-Fi modules to broadcast data to an online dashboard. This enabled city official to see the level of waste and pickups to be planned more effectively. The paper also emphasized the way that these systems would decrease the cost of operation and environmental effects. Mobile waste monitoring is also an area of research that has been investigated by several researchers. The apps enable the user (both residents and authorities) to view the bin status in real time, take alerts, and even report on matters such as damaged bins. This kind of user interaction has

been identified to enhance the effectiveness of community involvement in waste management activities. Although the idea of smart waste bins is not a recent one, most of the existing systems have such issues like low network coverage, lack of scalability and high costs. Recent research indicates that some of these problems can be addressed with the use of low-power communication technologies such as LoRa or NB-IoT. Generally, the literature indicates that the concept of IoT has a high level of support with respect to changing our waste management. These systems will help cut costs, increase efficiency, and make urban environments cleaner by making the process more data-driven, real-time, and automated. Nevertheless, further research is required to come up with scalable, cheap, and effective systems that can be adopted both in the major urban areas and the small towns. The project is based on the experiences of other studies, which should result in the development of a convenient and economically viable system of waste monitoring based on the IoT that can be realized in the real-life environment of cities.

3. Proposed System

Our proposed system will primarily aim at making the waste collection more intelligent, efficient, and less reliant on manual monitoring. Rather than the traditional method whereby the waste is picked up at specific times whether the bins are full or empty, we have a system that makes the waste picked only when it is required, a saving of time, fuel, and manpower will go up as well as make the environment less polluted. Our system has ultrasonic sensors installed in garbage containers. The sensors are used to constantly monitor the waste by measuring the distance between the sensor and the trash surface. When the garbage is full to some extent, e.g. 80% full, the sensor sends out an alarm. This information is transmitted in real time either by a Wi-Fi node or a GSM node, as per the network. This wireless communication makes the information to be accessed remotely without necessarily having to check each bin manually. All the data gathered in the bins is relayed to one central server or cloud platform where the information is processed and made available via a user friendly web or mobile application. This dashboard indicates the position of all the bins, whether empty, half-full or full. With this information, waste collection crews can map out effective routes, not visiting those bins that do not need their contents emptied. This dictates out all the useless journeys, it saves the use of fuel and it prevents the overflowing of bins before the next scheduled pick up time.

We can also add the alert notifications to the system to make it even more efficient as they will be delivered to the staff of the municipal when a bin is almost full or when one sensor ceases to work. The system also has the capacity to store past records over time in order to analyse patterns of waste generation in various regions. This would allow the city planners to know which areas generate more waste and require more frequent collection or an increase in the number of bins. The system suggested is meant to be scalable and affordable implying that it is applicable both in small communities and in large cities. The hardware elements are comparatively cheap and the software can be configured according to the requirement of the local authorities or waste management agencies. Concisely, our system will be a fusion of real-time data collection, wireless communication, and smart decision-making to make the process of waste management more sustainable and clean. It is a pragmatic approach to a very real issue- and one that has both environmental and economic paybacks.

4. Implementation

The IoT-Based Waste Management System implementation presupposes a cautious combination of both the hardware and software to develop a robust, real-time surveillance system of garbage bins. The steps include the installation of hardware, in this case, the garbage bins are provided with ultrasonic sensors in each of them. This sensor is fitted on the top of the bin and it is charged with the responsibility of measuring the distance between the top and the waste material. The closer the bin is filled the smaller this distance becomes and thereby the sensor can easily tell the filling level. In order to process such data, a microcontroller like an Arduino or Nedelcu is employed. This tiny computer then picks up data of the ultrasonic sensor and whether the garbage is full enough to a certain specified point, like 80 percent full. When this is reached, the system will be ready to transmit the data to a central monitoring platform. To transmit the data wirelessly, the system is capable of adapting either a Wi-Fi module or a GSM module, depending on whether there is access to the internet in the location or not. Wi-Fi can be used in places with good network whereas GSM is more convenient in the remote areas where the mobile signals are more stable. Rechargeable batteries or direct power source can be used to power the system. Power saving modes are added to increase battery life such that the system will only transmit data periodically or when there is a substantial difference in the bin level. After collecting data and transmitting it, it arrives to a cloud-based server or central database, e.g. Firebase, Thing Speak, or AWS IoT. This back-end system stores and classifies the data, so that it is availed in real-time and can be analyzed. The system user interface will be a web-based dashboard or smart phone app showing the status of every bin, location and fill capacity. Municipal workers or waste management companies, as authorized persons, will be in a position of logging in to track all the bins within a particular specific location. The system will also send a notification or alert through the SMS or email or in-application pop-up messages when a bin is full or a sensor is malfunctioning so that they can respond in time, and eliminate overflow. To be even more efficient, route optimization should be added to the system. The platform can also use mapping APIs such as Google Maps to recommend the most efficient route that waste collection trucks should use so that they only reach bins that are to be emptied. This saves on fuel, time and general cost of operation. Once the components are put together and the system is programmed, the whole system is tested in a small scale environment to make sure that all things run well. This is verified then able to be implemented over larger regions. All in all, this implementation will result in a smart, scalable, eco-friendly waste monitoring system that can make a substantial change in the ways in which cities are handling their garbage collection service.

5. Experimental Results

In order to measure the efficiency and consistency of the IoT-Based Waste Management System, we made a set of experiments in a controlled condition with the help of prototype smart bins that have ultrasonic sensors, Nedelcu microcontroller, and GSM/Wi-Fi modules. The idea was to monitor the precision with which the system was able to monitor the fill level of the bins and send this information in real time and give a warning where needed. We began to simulate waste filling within the bin by parts 25, 50, 75 and100. The ultrasonic sensor measurements were documented and transmitted to the central server at every level. The information was presented on a web dashboard that was custom-made. We discovered that the sensor was able to identify the degree of waste with more than 90 percent accuracy. The margin of error was very minimal (1-2 cm) based on the shape or angle of some waste materials but this did not have a great impact

on the performance of the system. The system has raised an alarm when the amount of waste hit 80 percent mark (which we had set). This notification was received immediately through SMS (in GSM module case), or through a notification on web interface (through Wi-Fi). This ensured that the modules of communication were working well and capable of providing timely alerts that were not accompanied by significant delays. The mean duration of transmission and generation of alerts was 2-4 seconds. Besides the fill levels, we also tested the power consumption of the system. Sleep modes of the microcontroller were also useful in saving power and this meant that the system could be used over a long period in the outdoor environment. The system was tested during 24 hours and there were no performance and connectivity problems. The web dashboard which was linked to a real time database was automated and updated every time a change in bin level was detected. This enabled people to monitor easily which bins should be emptied and which ones should not. We also ran various bins which were linked to the same system to represent a small space, and the dashboard managed the concurrent updates of data without delays and misunderstandings. Altogether, the outcomes of the experiment proved that the suggested system is effective and convenient to operate, and it can significantly increase the process of waste monitoring and management. The prototype success demonstrates high prospects of expanding the system to large urban or municipal regions.

6. Discussions

The outcomes of the experiment of the IoT-Based Waste Management System show that technology could be an important element of the solution to daily issues such as garbage collection. Through our experiments, we realized that, with the addition of ultrasonic sensors, microcontrollers, and wireless communication modules, waste monitoring can be much more efficient and more responsive than the rest.

The real-time response of the system was one of the most encouraging ones. Alerts were being dispatched virtually right after a bin had hit the threshold level. It is a massive step up on the current method where the bins are emptied on a regular schedule, and therefore, this implies that a bin can overflow or that an empty bin can be collected even though there is no need to. Using our system, the process of waste collection turns into a data collection, which in addition to saving time and fuel also makes the process smarter.

The other aspect that needs to be mentioned is the precision of the ultrasonic sensors. Despite the fact that there was a very small margin of error since some waste was irregularly shaped or soft which could absorb the signal of the sensor, the performance was reliable and consistent overall. In a practical situation this degree of precision is more than adequate to determine the timing of emptying a bin.

Its communication modules which were the Wi-Fi and GSM also worked well in various conditions. The Wi-Fi was useful in places where the connectivity was consistent whereas the GSM module was handy in remote or outside places. This is what enables the system to be applied in numerous environments, both in the crowded metropolitan areas and in the countryside because of the low presence of the internet.

The possibility of scalability is one of the largest lessons of this project. On the one hand, we were only able to test the system on a small scale with few bins; on the other hand, the system setup is easy, and cost-effective to multiply it on whole neighbourhood levels (or even cities). It has a cloud-based dashboard, which allows handling many bins with the help of a dashboard and does not require a physical check.

Naturally, it can be still improved. In the future, the system might be made more sustainable with solar panels, or should have AI-based route optimization to map the optimal paths of collection vehicles. Nevertheless, the system, as it exists, is an efficient, cost-effective, and effective measure towards smarter city management.

To conclude, this project demonstrates that IoT may turn even the most mundane such as waste collection into an intelligent and efficient task. Not only does it aid in a cleaner and healthier environment to all, it also aids in the reduction of operating burden.

7. CONCLUSION

The process of creating and developing the IoT-Based Waste Management System has demonstrated that even tiny uses of technology can create a significant change in our lives. The process of waste collection is something that many would consider to be routine but in cases where waste is not controlled it may cause severe health, environmental and logistical issues. This project shows that by turning the system smarter and more responsive, we will be able to approach these issues in a more effective and efficient manner.

During the project, we have managed to reveal that the idea of real-time measurement of the garbage level with the help of the ultrasonic sensors can be used to eliminate the elements of guesswork in the former methods of garbage collection. Rather than gathering garbage every pre-determined time-frame, which may lead to empty or full containers, the smart system that we designed will make sure that the bins are emptied only when necessary. This does not only enhance sanitation in the society but also conserves fuel, lowers the cost of man power and avoids unnecessary pollution that arises due to the additional movement of vehicles.

The Wi-Fi and GSM modules enabled communication thus becoming flexible in regard to the location where the system can be implemented. Bins used in cities may have Wi-Fi and in remote or open location areas GSM may ensure that the transmission of data is not lost. The dashboard featuring cloud-related connectivity ensured that the users, such as the municipal employees or waste management companies privately, could monitor the status of the bins and receive notifications in addition to planning the most efficient pickage routes. Regardless of the low amount of resources, the system was efficient and consistent in performances during testing, indicating that this solution can be applied in practice and be scaled.

The fact that it can be expanded in the future is exciting. This system could be even stronger with solar-powered bins, AI-enhanced route optimization, and the use of the common reporting apps. Smart bins can be installed in schools, in parks, in bus stops and in markets. It may also promote the change in the way the general population will approach cleanliness and sustainability.

To sum up, the IoT-Based Waste Management System provides a relatively easy but effective means of updating the process that has not been updated recently. It demonstrates that with the proper application of technology we can transform our cities into smarter, cleaner and more sustainable. It is not only a technical issue that this project is solving a social need. And above all, it teaches us that innovation does not always need to be complicated; and sometimes all we need to do is to look at the problem in a different light and employ the resources we already have in a smarter manner.

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