Project Report: Smart Monitoring & Waste Management

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ABSTRACT

The smart monitoring system aims to optimize waste management by utilizing edge computing with a Raspberry Pi, input devices such as ultrasonic sensors, and output devices such as LCD displays. It utilizes Python codes to run the device handling data acquisition and takes the collected data into a CSV file which is later utilized for data analysis. The device can constantly measure the usage of each individual trashcan and the data can be used to analyze the usage throughout the days and weeks to optimize waste management schedules. Experimental testing showed working data acquisition and showed simple data analysis showing real-time updates of the usage over time. The conclusion reached is an efficient trash monitoring system that can help understand the utilization of the monitored bins.

KEYWORDS

IoT, Edge Computing, Waste Management, Efficiency

1 Introduction

Waste management inefficiencies often cause the overflowing trash bins that are often seen on The George Washington University campus. These overflowing trash bins cause unsanitary environments and lead to the attraction of rodents and pests. Other real-life effects are for situations where the trashcan is never properly taken out in a roommate situation. The motivation for the research comes from existing designs of smart waste bins, AI sorting, robot management, and waste level sensors that are costly, but a data-driven and industry 4.0 aligned plan [1]. The research presented addresses these concerns by developing a low-cost, IoT-based smart trash can system that continuously monitors the usage of trash bins. The research is influenced by the recent “smart cities”, where IoT devices are implemented in any achievable situation to collect data and strive for a more efficient city. Waste management is important for efficiency, cost reduction, resource optimization, real-time monitoring, and public health [2].

The device utilizes a Raspberry Pi to compute and run the system, ultrasonic sensors to measure the distance from inside the trash can, and multiple output devices to deliver real-time alerts and status updates. The collected data is then logged in a CSV file and used for analysis. Ultimately, the project aims to optimize waste management on select trash bins to understand when each trash bin is being used most and when it overflows.

1.1 Background and Literature Review

The research was done after an extensive understanding of past literature focusing on “smart city” development. Kumar’s article about the framework surrounding waste management in smart cities with Industry 4.0 technologies, focuses on developing countries and why smart city development is a possible solution for urbanization problems [1]. He focuses on the 3 IoT layers of sensing, network, and application and how industry 4.0 is directly connected to smart city development. It goes in-depth about the practice of smart waste management and why it should be focused on rather than the actual devices that are focused on in this research.

Dey’s article surrounding waste management solutions, focuses on the evolving technology that can be used to prevent the earth from becoming a “trash kingdom” [2]. The methods used in this article include Smart Waste Bin, which is focused on in this research, Sorting Waste With AI, Robots Managing Sorting Waste**,** and Waste Level Sensors. These methodologies were focused because of the importance of understanding and gathering data of how much trash is being created and placed, so data-driven actions can be taken especially because the cost of garbage management is expensive for the government and is a globally rising issue. Although no direct solution or product was mentioned, it introduced ideas and methods that can be used in a new environment to improve the efficiency of currently existing systems.

Using the background knowledge gathered from this literature, this research focuses on creating an IoT-inspired device that can be created at a low cost and implemented in any scale and environment.

2 Methods and Implementation Section

The Smart Refill Monitoring System is designed to track trash can fill levels in real time using an ultrasonic sensor connected to a Raspberry Pi. Distance measurements are taken at fixed intervals and processed by a Python script that calculates the percentage of the trash cans capacity used. Once a predefined threshold is reached, the system triggers an audio-visual alert using a buzzer and dual-color LED. Additionally, each reading is logged in a CSV file for further analysis. This approach follows edge-computing principles by handling data processing directly on the Raspberry Pi, minimizing the need for cloud resources.

A. Hardware and Software

The hardware utilized in the device, includes a Raspberry Pi 4 Model B for computation, Ultra Sonic sensors for measuring distance inside of each trash bin, a Touch Switch to toggle the alarm and system, a Passive Buzzer to audibly notify the usage, LED lights to visually showcase the usage for farther distance, LCD Display to visually showcase the accurate percentage and time till measurement. The software section for the research included a code base using Python scripts responsible for sensor data acquisition, calculations, CSV file management, and handling alert logic.

B. Implementation

The Smart Monitoring & Waste Management device was implemented using the hardware mentioned above to create a system capable of continuously monitoring each individual trash can controlled by edge computing devices such as IoT-based trash cans.

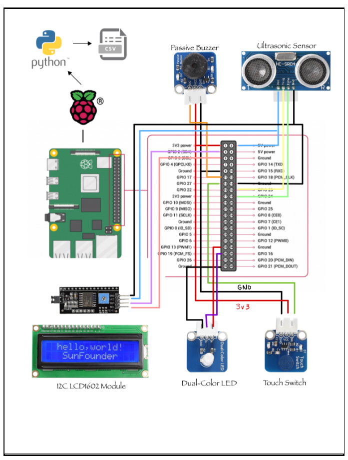

Figure 1: Schematics of Hardware / Software

Figure 1 shows the connection of each individual hardware that runs the device. The main method of the device utilizes the ultrasonic sensor as the main component to measure the data which is acquired by the Python scripts. The Python scripts then determine how much of the trash can is full by percentage, and visually showcase it using multiple outlets. If the trash is deemed full or overflowing, an alarm is sent out audibly alerting the surroundings. The code runs continuously and measures data every 10 seconds for our experiment and is inputted into a CSV file with its location, time, and fullness. The data can then be run through simple analysis and visualization to show the usage of each waste management system and create an optimal route.

C. IoT Layer / Structure

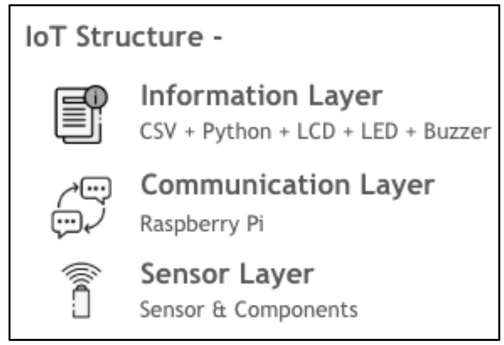

Figure 2: IoT Layer / Structure

3 Critical Discussion of results Section

Data acquisition was conducted using ultrasonic sensors to measure the distance filled with trash. The Python codes run the sensors and take the data collected and input it into a CSV file with the name of the specific trash can, time, and percentage filled. During the research, in the experimental phase, a test trash can was fitted with the IoT device to collect data over a 24-hour period. In the CSV file, it was filled with the data measured, which showed inconclusive results due to the small scale of the experiment. However, even in this small scale, the data showed that the trash was filled for hours and only increased which was visually shown on a simple graph. It also showcased that the trash was full overnight and needed to be managed over time. In the small-scale experiment, we can conclude that with a larger data set and sample size, a more optimal waste management schedule can be created and can visually represent the usage of the trashcan when nearby. This experiment was conducted at the author's house and does not represent any realistic values.

The results were as follows -
Real-Time Alerts: The integrated buzzer and LED systems proved effective in notifying nearby users when bins were at full capacity.
Actionable Data: The CSV logs provided a historical record of trash levels, enabling informed decisions on when and how frequently trash collection routes should be used.
Scalability and Feasibility: Though tested primarily on a single bin, the edge-based framework can be scaled to multiple bins across various locations.

4 Conclusions

The proposed Smart Monitoring & Waste Management addressed the ineffectiveness of the current system implemented by The George Washington University. The IoT-based system can continuously monitor trash bins that want to be analyzed and collect data that shows the real-time usage and history to understand patterns and optimize the scheduling around it. In conclusion, it is capable of monitoring trashcans for how full they are and using the information to make educated decisions on efficient waste management schedules.

New research questions presented after the completion of the prototype and initial testing revolved around the improvement of the system by adding more features. The main points included the utilization of the network and Wi-Fi capabilities to make it more universally accessible and have a wider range of applications. For example, adding a notification feature to show the data through other devices and possibly display data on apps. Additionally, the addition of more testing devices such as more trash cans to represent a more accurate environment where the optimization becomes even more important.

The implementation of the research must be on a larger scale than the testing environment. If the device is set up on multiple trash cans, even larger sets of data can be collected and show more of a pattern in the usage of the bins. It can then analyze the data to create an optimized schedule for real-life applications.

ACKNOWLEDGMENTS

I'm deeply grateful for the support provided by Professor Kartik Bulusu, for his guidance, mentorship, and providing of the materials used in the device. His support has allowed this research to expand past a conceptual stage and allowed the creation of a prototype and initial analysis and implementation on a small scale.

REFERENCES

[1] A. Kumar, "A novel framework for waste management in smart city transformation with industry 4.0 technologies," , 2024

[2] S. Dey, "4 Smart Waste Management Solutions That Are Revolutionising the Industry" EARTH.ORG , 2023