DEVELOPMENT OF AN INTERNET OF THINGS-BASED WASTE DETECTION SYSTEM FOR DRAINAGE CANALS: CLASSIFICATION AND MONITORING OF WASTE TYPES

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INTRODUCTION

Background of the Study

Technological advancements have paved way for the human to live in the modern world and connect with the environment ranging from cell phones to artificial intelligence and the like (Watts, 2023). And it will continue to strive for greater use and enhancing every aspect of life the human needs. The evolution of technology creates a space for a society to utilize and fulfill the people's needs and wants, and as of today both human and technology are inseparable as both needs each other to work (Kumar, 2024). The emergence of artificial intelligence proves that the evolution of technology is beyond and will continue to evolve throughout the years.

In a society that yearns for high tech style, the Internet of Things (IoT) provides small to big transformations to a society, providing basic necessity mixed with technology and internet. The existence of IoT creates better transportation, pollution control, better healthcare, home automation, and industrial automation which can be accessed through a smart watch or a smart phone and can access anytime and anywhere, which ultimately formed a smart city (Kumar, 2019). The Internet of Things opened many opportunities for the technology to grow even more from automation to data analytics and eventually, artificial intelligence.

Object detection according to Girshick *et. al* (2021) is a type of artificial intelligence focusing on providing vision from a computer to an object depending on the programmed part. Its goal is to detect object from different classes such as people, car, or faces in an image or a live camera, providing starting from basic details such as distance and gender to advanced details such as name, height, and direction of movement. Additionally, it uses neural network and machine learning to identify and

recognize objects that needs to be detected. Devices that use object detection is widely used in the fields of security, military, transportation, and medical sciences (Singh, 2022).

Statement of the Problem

The general problem of the proposed study is centered on the development of an Internet of Things (IoT) based waste detection system for drainage canals monitoring and waste category detection using object detection. The proposed application is beneficial for generating precise data on different categories on waste found.

The specific problems are the following:

- How can IoT technology be utilized to develop a waste detection and monitoring system for drainage canals?
- How accurate will be data of waste detection and classification of waste in an IoT-based system?
- What will be the effect in terms of efficiency and sustainability of an IoT-based waste detection and monitoring?

Objectives of the Study

The proposed application will be beneficial to the residents' association, environmental and governmental organizations to generate precise, efficient, and reliable data on waste materials in drainage canals.

Specifically, the study aims to:

- Develop and implement an IoT-based system that enables classification of waste materials and monitoring of waste in drainage canals.
- Provide accurate, reliable, and organized data on different classifications of waste materials and monitoring.
- Implement an efficient and sustainable IoT device that can detect waste materials in drainage canals.

Time and Place of the Study

The study is about the development of an IoT-based waste detection system for drainage canals using object detection. The study will be conducted in the month of December 2024 to January 2025, taking place in Cavite State University – Imus Campus under the supervision of Mr. Ramil V. Huele, Undergraduate Thesis Professor.

Scope and Limitations of the Study

In this application project, an object-detection based IoT and the ability to detect waste materials and generate data is designed for the residents' association, environmental and government agencies to provide precise data using percentage-based report and analysis. The following modules are the process and parts that are discussed and what the said system will handle.

Hardware. The hardware of the proposed device will consist of waterproof casing of the device, the IoT device that is Wi-Fi and Bluetooth enabled, sensors for detection of waste materials, and motors for propelling the device while submerged in canals.

Smartphone. The proposed device will be connected to the internet, which any smartphones can support and be used. If the device is currently detecting waste

materials, it will be processed and transfer to the smartphone via the internet for data analysis.

Connect Device Module. This will be the module upon opening the application where the smartphone will first connect to a nearby IoT device. After successfully connected, it will be redirected to the data report module.

Data Report Module. This module will handle all data analysis from the device, creating reliable and organized information that can be viewed by chart, graph, or text. It will also display the most number of trash according to the classification.

Due to budget restraints, time limit, and the preferred size of the device, the project will only detect common and homemade waste materials found in canals and will only provide the aspects of detecting waste materials and generating data and report.

Definition of Terms

5G Network – The fifth generation of wireless cellular technology, currently in use today.

Algorithm – Set of rules to be followed in problem-solving operations by a computer.

Arduino – A programmable device that enables interaction with external hardware devices using software programs.

Association – A group of people organized for a joint purpose.

Bluetooth – A technology standard used to enable short-range wireless communication between electronic devices.

Convolutional Neural Networks – Abbreviated as CNNs, it is a network architecture for deep learning that learns directly from data.

Environmental Organization – An organization seeking to protect, analyze, or monitor the environment against misuse or degradation from human forces.

Government Organization – A body that is responsible for specific functions within a government structure.

Infrared Sensor – An electrical device that detects infrared radiation, which is a type of electromagnetic radiation that is invisible to the human eye.

Internet of Things – Abbreviated as IoT, it is a network of physical objects that are connected to the internet and can share data with other devices and systems.

Microcontroller – A small, single-chip computer that controls specific tasks within a system without needing a complex operating system.

Moisture Sensor – A device that measures the amount of moisture in a material.

Object Detection – A technique that uses neural networks to localize and classify objects in images.

Region-based Convolutional Neural Network – Abbreviated as RCNNs, is a specific type of convolutional neural network (CNNs) designed primarily for object detection tasks.

Ultrasonic Sensor – A device that can measure the distance to an object and detects its presence without making physical contact.

Smartphone – A mobile phone that performs many of the functions as a computer.

Wi-Fi – A wireless network technology that uses radio waves to provide wireless high-speed internet access.

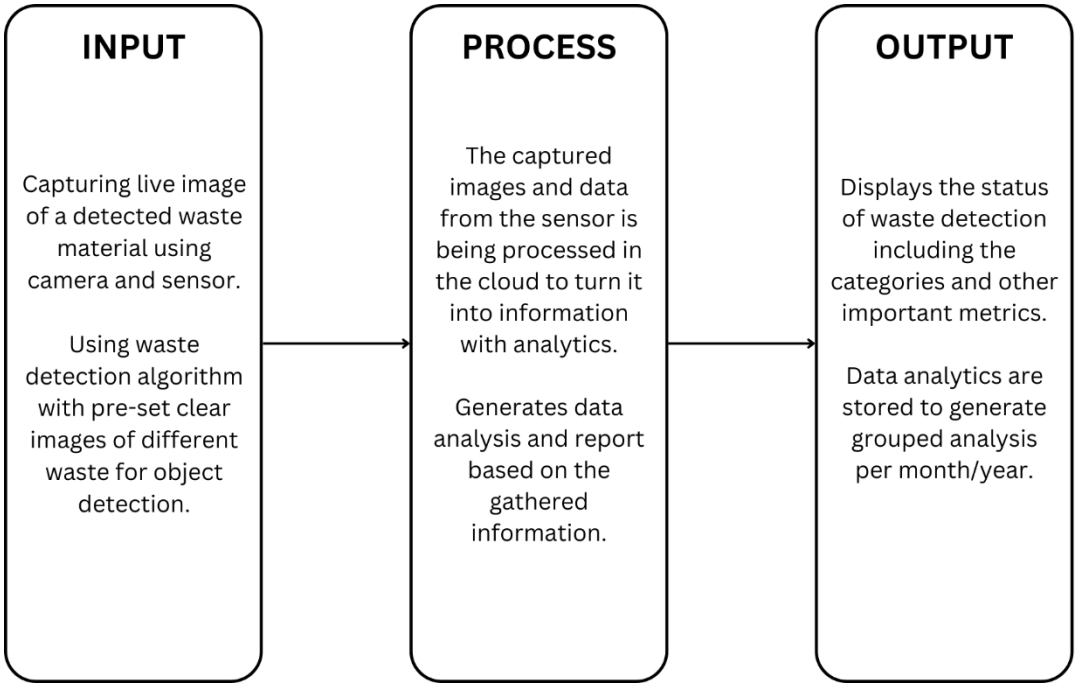
Waste Material – A material that has been used or served its purpose and is no longer useful of wanted.

You Only Look Once – Abbreviated as YOLO, it is a real-time object detection system that identify and classify objects in a single pass of the image.

Theoretical Framework of the Study

The idea of an IoT-based waste detection system for drainage canals was formulated by a conducted study that according to Karthik et. al (2021). According to their study, due to the dustbins not cleaned on time, it will become unsanitary and contaminated. Their solution is to create an ultrasonic sensor that detects the amount of trash in the trash can that is connected to a mobile phone. After a set limit has reached maximum level, it will be notified by the bin collector.

Another study was conducted by Lingaraju et. al (2023) in which they proposed a smart waste management system that can categorize waste into three types: wet, dry, and metallic. It also provides constant monitoring and reporting of air to relevant city authorities. The study also promotes the “Ecological Solid Waste Management Act of 2000” or RA 9003 that promotes waste reduction as well as proper waste disposal, improving the environment ecologically. The proposed idea helps the researchers’ study to formulate based on the classification and live monitoring of aquatic waste from drainage canals, as well as to strengthen the support of an efficient and reliable device that can handle data accordingly.


INPUT
Capturing live image of a detected waste material using camera and sensor.
Using waste detection algorithm with pre-set clear images of different waste for object detection.
PROCESS
The captured images and data from the sensor is being processed in the cloud to turn it into information with analytics.
Generates data analysis and report based on the gathered information.
OUTPUT
Displays the status of waste detection including the categories and other important metrics.
Data analytics are stored to generate grouped analysis per month/year.

REVIEW OF THE RELATED LITERATURE / STUDIES

Foreign Studies

Object detection refers to identifying object through a digital visual imagery. It uses on a wide range of applications and processes like medical diagnostic procedures and self-driving cars. It uses different detection algorithms that can analyze and comprehend visual data similar to human perception. In the field of deep learning, there are multiple approaches on identifying and detecting objects in images. One of those is region-based convolutional neural networks (RCNN) which uses segmentation capability which provides precise identification of waste in dirty water, highly accurate and can differentiate between waste and natural elements (Komnang, 2023).

In a study conducted by Singh and Tripathi (2022), the researchers conducted a real-time tracking for surveillance and security management using multiple cameras, which it tracks the surveillance system and extracts the feature and identification of extracted object. The study shows that the surveillance, object detection and tracking has increased interest in recent years, and the tracking of the object can identify the different positions of the object in a video.

The presence of IoT and deep learning helps the work to be done efficiently. A smart trash bin with microcontroller with multiple sensors and Wi-Fi and Bluetooth enabled aids real-time data to be sent through an android application in which it is processed and monitored. It uses convolutional neural network algorithm to sort biodegradable and non-biodegradable waste. After examining the efficiency of the model, it was proven that the classification accuracy is at 95% and the system usability

scale is at 86% (Rahman et. al, 2020). This concludes that the accuracy of detecting waste is high enough to continue usage on household activities.

In such cases that needed managing waste in big cities without having to monitor the parts manually, an IoT system was implemented to monitor the amount of waste deposited to each dumpster and segregate wet and dry waste. The IoT system is implemented with infrared sensor for detecting the waste, wet or dry, moisture sensor for detecting the wetness of the waste, and the segregation containers are equipped with ultrasonic sensors for measuring the distance or the amount of waste in the containers. If the container reached maximum capacity, then the alert message will be sent to the personnel (Vijay et. al, 2019). This study helps the waste management to maintain an efficient process on handling waste by using technology.

A smart system for waste management was being implemented which targets waste bins and its contents. Employing the principles of IoT, equipped with an Arduino microcontroller, ultrasonic sensors and servo motors to the dustbin, its goal is to maintain cleanliness in waste disposal areas. The model system waits the user's presence approaching the dustbin model, and opens the lid with the servo motor to let the user throw the trash, and closes after. The automated dustbin model according to the study, helps the environment and its surrounding areas to maintain cleanliness, economically accessible to public, as well as to improve the health hygiene to a societal perspective (Srivastava et. al, 2024).

Local Studies

The usage of artificial intelligence for practical solutions and national development in the Philippines have been widely recognized with the help of technological advancements integrated to the smartphones and computer systems. It can be utilized for agriculture, livestock, enhancing marine biodiversity, developing

degree programs and short courses, offering solutions for traffic management, maintaining hospital electronic records and more to add (Dabu, 2024).

The proposed system of Aguila et. al. (2019) comprised of an IoT device that can provide proper waste management to an urban area. Specifically, the researchers used an Arduino Uno for the system operation, and ultrasonic sensors for measuring the weight of the bin. Since the quality of waste are increasing, the system provides a help for the local government by alerting waste management to be notified in real time so that the waste can be collected immediately. The model also helps to maintain the environment where the solid waste is a problem in urban areas with population increasing.

A model that uses object detection that has object detection model was also tested in the environment of Pasig River in detecting plastic and paper. It uses a sub-type of YOLO (You Only Look Once) called Scaled-YOLOv4 in which a dilapidated trash dataset was used as the model's performance. Due to the deformation, occlusion, lack of light, and cluttered background, the model produced 67% precision for plastic and 59% precision for paper. Despite its average precision of 63%, the model can be used in detecting trash materials on the surface of Pasig River (Tomas et. al, 2022).

A garbage monitoring system was implemented in Cebu City to provide a countermeasure for clogging of drainages due to garbage flowing down. It uses IoT device with ultrasonic sensors to gather input data on the level of garbage in the drainage. These data will be transferred via internet to a web application using 5G connection and manipulated into a visualized data analysis. The data analysis then sent to the registered user in real-time. The results showed that the delivery of the data in real-time in terms of the delay of short message service (SMS), internet speed, and garbage level is desirable and can effectively provide operations considering that the registered user has internet connectivity (Parilla et. al, 2020).

The Philippines had the largest share of global aquatic waste in 2019 which started in the smaller water streams flowing to the seas and oceans connected. (Ramos, 2023). The evolution of technology can provide help to the people and the environment by using it as a device that can monitor and classify different waste scattered in the creeks, creating the term “Smart Waste Management”. In a study by Olawade et. al (2024), the artificial intelligence can provide roles for complex waste systems such as sorting, recycling and monitoring waste. It also describes the quality of data, privacy measures, lessen costs, and gives ethical considerations.

Table of Comparison

STUDY/ REFERENCE	FOCUS AREA	KEY FINDINGS	RELEVANCE TO PROPOSED SYSTEM
"Object Detection Literature Review"	Types of Object Detection that can be helpful to the proposed system	Usage of Convolutional Neural Networks (CNNs) to Classification and Monitoring Waste Types	The proposed system will use CNNs as the algorithm
"Object Detection Using Various Camera System"	Usage of Object Detection in tracking an object using multiple cameras	Tracking of the object can be identified with different positions of the object	Detection of waste in different angles
"Intelligent waste management system using deep learning with IoT"	Using CNNs algorithm to sort waste types	The accuracy of sorting waste is high	Classification of waste types in underwater drainages
"Smart waste management system using Arduino"	Automation of waste management using different sensors	Increases efficiency on processing waste	Finding the efficiency rate of automating waste management using sensors
"IoT based smart waste management	Accuracy of sensors in terms of distance and	Accurate response of sensor in distance, proven	Detection of waste in distance with challenges in

system using Arduino"	economically accessible	economically accessible	water visibility
"Using AI for Practical Solutions and National Development"	Usage of artificial intelligence in the Philippines for	It is widely recognizable in the Philippines with enough utilization for national development	Utilization of system as part of smart waste management system
"Development of smart waste bin with integrated volume and weight sensor"	Using sensor to measure the weight of the bin	Proven that a sensor can measure the weight	Potential help for accurately identifying the waste according to weight
“Trash detection for computer vision using scaled-YOLOv4 on water surface”	Detection of waste in the surface of Pasig River	The precision of detection is at average, but can still detect waste on the surface of the river	Provides insight on the accuracy of detecting waste underwater
“Low-cost garbage level monitoring system in drainages using Internet of Things in the Philippines”	Data transfer using 5G network	The data transfer can effectively provide operations, proving its reduced cost	Utilizing 5G network for internet connectivity, increasing availability in other areas
“Smart waste management: A paradigm shift enabled by artificial intelligence”	Usage of artificial intelligence for sorting, recycling and monitoring waste	The term smart waste management was created with the usage of artificial intelligence for complex waste systems	This study provides a strong foundation of the proposed system

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