PROJECT WORK

ON

SMART WASTE BIN

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CERTIFICATION

This is to certify that the project work titled **SMART WASTE BIN** has been executed by:

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DEDICATION

This project is dedicated to God, Our Patria Herdia, and every beacon of guidance in this convoluted 5 year academic journey.

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ABSTRACT

This project presents the design and implementation of an automated waste management system utilizing an Arduino Uno microcontroller, ultrasonic sensors, and a servo motor to enhance efficiency and hygiene in waste disposal. The system continuously monitors the fill level of a waste bin using an ultrasonic sensor, which provides real-time data to the Arduino. When the sensor detects that the bin is nearing capacity or a user is present, the Arduino activates a servo motor to automatically open and close the bin lid, enabling touchless operation and reducing the risk of contamination. Powered by a 9V replaceable battery, the system is portable and well-suited for environments with unreliable electricity supply. Rapid lid response, with positive user feedback regarding convenience and hygiene. The project highlights the potential for scalable, low-cost smart waste solutions in both urban and rural settings, and lays the groundwork for future enhancements such as IoT connectivity, renewable energy integration, and automated waste sorting for improved sustainability and resource management.

CHAPTER ONE
INTRODUCTION
1.1 BACKGROUND STUDY

Because of technological advancements, particularly the phenomenon of urbanization and industrialization, the evolution of waste management systems has been important. Up until then, waste disposal methods used were rudimentary, where open dumping and incineration were common with obvious public health and environmental disadvantage. The Industrial Revolution was critical as bustling urbanites created dizzying piles of waste they needed to collect and dispose of in an organized manner. Structured waste management practices started to be implemented by municipalities in which cities like London started implementing municipal waste collection services in the 19th century. It helped to establish the foundation for today's waste management strategies which emphasize efficiency and public health.

In recent years, the integration of smart technologies into waste management has emerged as a transformative trend. Automated trash cans equipped with sensors and microcontrollers have revolutionized how waste is collected and managed. These smart bins utilize ultrasonic sensors to detect when an object is nearby, allowing the lid to open automatically. This innovation not only enhances user convenience but also promotes hygiene by reducing contact with potentially contaminated surfaces.

Talukdar, A., et al. (2023). Smart automated dustbin. International Journal for Research in Applied Science and Engineering Technology. https://doi.org/10.22214/ijraset.2023.53520 In this research paper, they documented and implemented a smart waste bin showing how it used scanners and micro-controllers to build it. Highlighting its benefits in hygiene and convenience.

Users benefit greatly from automated operation because it eliminates direct contact with trash receptacles particularly useful for busy public environments where sanitation remains a challenge. These smart waste bins enhance user experience through convenient waste access points and simultaneously promote better waste management while cleaning up public spaces. Through their systematic report Talukdar and his coauthors demonstrate that smart automated waste disposal systems represent a key solution for contemporary waste management which simultaneously tackles public health risks and ecological sustainability issues.

The benefits of automated trash cans extend beyond user experience; they also contribute to operational efficiency in waste collection. Research indicates that IoT-enabled smart bins can optimize collection routes by providing real-time data on fill levels, leading to significant cost savings and reduced environmental impact. By minimizing overflow and ensuring timely pickups, these systems help maintain cleaner urban environments and reduce public health hazards associated with overflowing trash. Furthermore, they help mitigate public health hazards associated with overflowing trash, such as pest infestations and the spread of diseases, thereby promoting a healthier community overall. Overall, the integration of smart technology in waste management not only enhances convenience for users but also fosters more sustainable and efficient waste collection practices.

Smart technology systems integrated into waste management systems benefit users through simplicity of use while simultaneously creating improved sustainable collection methods. Waste management services utilize IoT-enabled bin data to make better decisions about resource distribution, so collection vehicles deploy only when dumpsters reach optimal levels. Urban waste management operations achieve a smaller carbon footprint by implementing optimized resource activities that cut fuel consumption and decrease emissions output. As a proactive measure, tracking fill levels prevents containers from reaching overflow situations, leading to both littered areas and environmental destruction. The combination of clean public spaces, decreased odors, and lower pest infestation levels produces an overall better community environment. Automated trash can implementation represents an essential upgrade for urban systems, which promotes sustainability goals and public health through an advanced framework for efficient and clean cities.

In addition, automated trash cans may enhance waste segregation by incorporating sorting mechanisms geared towards sorting recyclable from non-recyclable materials. This capability supports global sustainability goals to reduce landfill use and promote recycling. In this second time, automated waste management solutions are more significant as cities become smarter and more sustainable.

Desolo, D. (2023). Automated trash organizing management system (A.T.O.M.S): Proposed selfsegregating trash bins. GEO Academic Journal, 4(1). https://doi.org/10.56738/issn29603986.geo2023.4.32 is a paper that furthers the implementation of the automated trash bin by adding functionality that helps it sort trash from recyclables. It shows the future that the automated trash bin can be used to implement.

The Automated Trash Organizing Management System (A.T.O.M.S) brings advanced functionality to automated trash bins through its automatic recycling activation method. A.T.O.M.S adopts innovative functionality that improves both waste management speed and solves environmental issues created by poor waste recycling and disposal practices. The automated sorting achieved by A.T.O.M.S raises recycling rates and minimizes contamination issues with recyclable materials that often prevent effective recycling operations. The deployment of smart bins enables waste users to learn appropriate disposal techniques which strengthens sustainability knowledge among local residents. Urban waste challenges demand more sustainable solutions while Desolo's research demonstrates that automated trash bins can become adaptable tools for advancing environment renewal and improved city living standards. The approach represents both local and worldwide clampdowns on circular economies and landfills through its optimistic outlook regarding intelligent waste management advances.

Automated trash cans with ultrasonic sensors and Microcontroller technology can significantly mitigate the spread of COVID-19 and many other infectious diseases when combined with integration. Using adhering sensors and automatic streams, these smart bins eliminate physical contact that could expose them to viruses and bacteria. Public spaces require this more than anything else since high foot traffic means a high risk of germ transmission. While virus spread was controlled during the pandemic by minimizing contact with shared surfaces, automated trash cans opened automatically when a user approached — a practical solution. But the real-time monitoring features of these systems means bins are emptied quickly, so there is no overflow which can attract pests, or create unsanitary conditions considered conducive to disease transmission.

In addition, automated trash cans contribute a lot to making the environment cleaner overall. A healthier community is what these systems help to conserve because cleaning environments and preventing littering is always beneficial, however most important in times like pandemics, when public health is in question. Smart bins can let waste management know when to head over so trash doesn't simply pile up and accumulate and create odors and potential health risks from decomposing waste. Steering a proactive approach both controls disease outbreaks as well creates a culture of cleanliness, which can endure beyond the pandemic.

Although they also serve their purpose of preventing disease, automated trash cans also reduce and help remove different types of pollution — plastic pollution, for instance. With smart bins incorporating sorting mechanisms that discriminate between recyclable and non-recyclable materials, more recycling is done and fewer tons of waste sent to landfills. The ability to combat plastic pollution with this capability is key in urban environments grappling with overwhelming plastic waste. Automated trash cans encourage using computers and other machines to help recycle, which helps a more sustainable waste management system to develop. Additionally, when real-time data is incorporated into vehicle collection route optimization, both fuel consumption and greenhouse gas emissions related to waste collection vehicles are reduced. In summary, the use of automated trash cans is a multi-pronged approach to addressing issues of public health concern and environmental concerns.

Smart trash cans fulfill two essential roles by fighting plastic waste accumulation and reducing organic waste and electronic waste pollution as well. Advanced sorting features built into these smart bins help users separate organic waste from regular trash to create compost and lower landfill waste amounts. Considerable sustainable impact results from automated trash separation because food waste produces potent greenhouse gas emissions through methane. The automated design of trash cans enables them to pinpoint electronic waste by performing material separation so hazardous substances contained in waste don't pollute the environment because proper disposal protocols are followed. Automated trash bins serve as instrumental tools for responsible recycling of organic waste combined with electronics so they help develop sustainable waste disposal systems. Through real-time data analysis along with waste monitoring capabilities municipalities obtain essential information on waste generation to plan targeted actions for decreased pollution levels. The multiple features of automated trash cans both protect public health through disease prevention and operate as essential weapons against environmental pollutants which create a cleaner environment for all citizens.

1.2 PROBLEM STATEMENT

Even though waste management technologies have evolved, the majority of urban and rural areas still rely on obsolete and ineffective waste disposal methods threatening public health and environmental sustainability. Traditionally, trash cans are more primitive because, usually, they don’t come with hygiene or efficiency features that make the management of the bin easier, and problems such as overflowing bins, unpleasant odors, and insect infestation persist. In heavy-use areas, the volume of waste can pile up quickly and create these problems even more, as conventional containers might not have sufficient capacity to accept all the waste that gets generated. Manually operated trash cans also pose an increased risk of crosscontamination; an increased risk during public health crises such as the COVID-19 pandemic where contact with surfaces is to be maintained as low as possible reducing the risk of virus transmission.

The combination of traditional waste disposal difficulties creates an ongoing public health risk because disease transmission occurs when people interact with public trash cans through their lids. Through bacteria like Staphylococcus aureus, individuals acquire skin infections from touching surfaces that carry pathogens. Passively handling frequently unsanitized trash can lids exposes people to pathogens that can transmit between surfaces to their hands before potentially infecting their facial areas or open wounds. The risk is people, most significantly in places with heavy foot traffic because insufficient hygiene practices exist there. Automated trash receptacles with touchless operation will decrease both disease transmission and cross-contamination processes within community areas. Through automated waste bin technology, public health safety improves as these solutions establish protected environments that benefit all users.

Additionally, current waste management systems often lack real-time waste levels with collection schedules being inefficient. Scheduling too much and then wasting business funds on pickups, or not enough bins piling up to cause unhygienic conditions. Not only does this increase inefficiency in public health, but because of overflowing trash, it also contributes to wastes that end up being thrown carelessly into the environment and littering. Additionally, there are a plethora of communities, particularly in developing countries, that are unable to purchase and implement advanced solutions in waste management owing to cost barriers and the lack of appropriate technological infrastructure. Therefore, there is an urgent need for an inexpensive and energy-efficient automated garbage can system using widely adopted modern technology in order to enhance waste management practices in different settings.

Lone, G. H., Buchh, F., & Shah, N. I. (2020). Social Causatums of Improper Waste Management. In R. Bhat, H. Qadri, K. Wani, G. Dar, & M. Mehmood (Eds.), Innovative Waste Management Technologies for Sustainable Development (pp. 1-17). IGI Global. https://doi.org/10.4018/978-1-7998-0031-6.ch001 Highlights the crisis that could be caused by improper waste management.

Lone, Buchh, and Shah (2020) talks about how poor waste management creates multiple crises with harmful consequences for environmental sustainability and public health alongside safety hazards.

Inadequate waste management methods let pests and vermin reproduce and spread diseases that worsen community health problems. Urban areas develop significant environmental problems because waste accumulation creates pollution which damages ecosystems and lowers community residents' quality of life. The ongoing expansion of cities creates increasingly difficult situations for existing waste management systems which demonstrates the critical requirement for new innovative solutions to handle these problems efficiently. The adoption of advanced waste management technologies such as automated trash cans with sorting capabilities demonstrates crucial potential for crisis mitigation by driving waste disposal improvements increasing recycling levels and creating better urban living spaces.

A waste disposal crisis affects public health and the environment in Nigeria and ones that are so dense, like Lagos, in particular. The illegal dumping of waste is rampant, not only clogging up drainage systems but posing a serious health risk with diseases transmitted through these systems such as malaria, cholera, and typhoid. Blocked drains are a breeding ground for disease-carrying vectors, stagnant water from a blocked drain, as well as decomposing waste, fosters disease-carrying vectors and unsanitary conditions that will result in respiratory issues, as well as gastrointestinal diseases. The 32 million tonnes or more of solid waste produced annually in Nigeria can be largely attributed to unauthorized sites, which in turn pollutes land and water and contributes to climate change in terms of greenhouse gas emissions. Plastic waste makes the situation worse, damaging marine life and local ecosystems. The time is now; there is a need for futuristic waste management solutions, such as automated trash bins with sophisticated technologies, to curb environmental toxicity and also protect the public from health risks in Nigeria.

1.3 AIM/OBJECTIVES

This project's primary focus is to solve pressing waste management issues while increasing user convenience as well as public health. The specific objectives include:

1. Design and Development of an Automated Trash Can: The first goal is to create an automated trash can completely controlled by an Arduino board and ultrasonic sensors for object detection. It’s not just about the physical design of the trash can — it requires programming the Arduino to operate responsively and reliably. This project will attempt to design a working prototype to evaluate it in multiple environments.
2. Enhancement of User Convenience: The primary aim is to increase the user experience by the ability of the trash can lid to open automatically when a user approaches. This will help cut down on the need for

physical contact and promote hygiene, and in the case of those with mobility issues or those carrying with them items such as shopping bags.

3. Promotion of Hygiene: This project is looking to improve public health standards by reducing contact with potentially contaminated surfaces. In this case, with public spaces being important to sanitize and prevent the spread of germs and viruses, an automated opening mechanism will prevent the spread of germs and prevent viruses.

4. Cost-Effective Solution: The project seeks to create an inexpensive, automated trash can, easy to install in places of homes, offices, and other public areas. This solution attempts to provide a cost-effective, highquality waste management solution by using readily available parts that can be manufactured with opensource technology and making it possible for a wider audience from communities in developing regions to use.

5. Environmental Impact Reduction: Finally, the project is intended to support the goals of broader sustainability through the promotion of correct waste disposal practices and recycling. By sorting items in the automated trash can, better recycling of recyclable materials from general waste will reduce landfill contribution and reduce plastic pollution.

1.4 RELEVANCE AND JUSTIFICATION OF THE WORK

This study is relevant in view of the urgent need for effective waste management solutions in the face of escalating urbanization and environmental challenges. Since cities keep growing, the amount of generated waste is growing at an alarming rate, bin dumps are overflowing and this generates unsanitary conditions and threatens public health. For instance, in Nigeria, the practice of improper trash disposal has fueled the proliferation of diseases and environmental degradation, highlighting the need for innovative ways of dealing with waste. A practical solution can be made by using such automated trash cans with technologies like Arduino boards and ultrasonic sensors which can make it real time to monitor waste levels and collect it on time. Not only does this improve public hygiene, but it also improves resource allocation for service of waste management services, making the cities cleaner.

Moreover, this research is consistent with existing global sustainability goals of reduction of pollution and the promotion of responsible waste disposal. Smart waste management systems featuring integration of smart technology into waste management can help to drastically minimize other problems including plastic pollution by encouraging designated segregation of recyclable materials. This project aims to promote an environmentally responsible attitude in human communities by developing automated trash cans with sorting mechanisms. Real-time fill level monitoring helps waste management authorities plan their collection routes, reducing fuel consumption and greenhouse gas emissions associated with waste collection vehicles. The project thus not only meets current public health needs but builds on broader environmental sustainability efforts, a timely, relevant effort in the current era where environmental awareness and action are at an all-time high.

1.5 SCOPE AND LIMITATIONS

1.5.1 SCOPE

This project focuses on the design and implementation of an automated waste management system that integrates an Arduino Uno microcontroller with ultrasonic sensors, servo motors, and a 9V battery power supply to enhance waste disposal efficiency and promote hygiene. The system is designed to monitor the fill level of a waste bin using ultrasonic sensors, automate the opening and closing of the lid with a servo motor for touchless operation, and provide portability through a replaceable battery pack. It is intended for use in homes, offices, or public spaces where traditional waste management methods are inefficient or unhygienic. The project also considers scalability for larger bins and future integration of IoT capabilities for real-time monitoring and data analytics, making it adaptable to urban and rural settings alike

1.5.2 LIMITATIONS

Testing and Evaluation: The project will involve rigorous testing of the prototype in various environments to evaluate its performance, reliability, and user acceptance. Feedback from users will be collected to inform further improvements.

1. Technical Constraints: The project depends on the precise operation of ultrasonic sensors to detect objects. Performance issues from environmental noise and temperature changes together with obstacles located in the sensor detection area can generate false readings that can lead to lid malfunction.

2. Capacity Limitations: The automated trash can's design features restrict its waste storage potential beyond what manual waste receptacles can hold. The size and configuration of automated waste receptacles determine how often they need emptying so high-traffic areas might present problems for waste management services.
3. Power Dependency: The automated trash can needs power through its built-in battery pack to function. The restricted battery endurance of this system leads to charging limitations or component replacements that can disrupt uninterrupted use in outdoor situations.
4. Cost Considerations: Modern smart technology trash cans cost more to produce at initial stages than traditional garbage receptacles. The high initial costs of implementing smart trash cans prevent their widespread deployment within budget-limited communities primarily found in developing regions.
5. Maintenance Requirements: The automated system must undergo periodic maintenance to operate correctly. A proper maintenance process requires sensor cleaning mechanical component inspection and technical problem resolution through trained personnel who may need specific resources.
6. User Acceptance: The automated trash can requires users to accept new technology and demonstrate a willingness to use it for success. People require public education and outreach programs to learn and develop proper usage skills and a complete understanding of system advantages.
7. Limited Sorting Capability: The current project displays automatic lid operation through proximity detection yet it lacks features to manage advanced recyclable sorting and waste type differentiation. Future department cycles should overcome this limitation to maximize recycling success.
8. Environmental Impact Considerations: Automated trash cans attempt to reduce waste-related pollution but their manufacturing process together with disposal can result in electronic waste unless handled sustainably. The implementation of this requirement needs thorough planning for upcoming designs.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

The literature review presents essential knowledge about modern automated waste management systems and their smart technology applications. Growing urban populations create intense pressure on waste management systems which requires immediate solutions that achieve efficiency through hygiene promotion while reducing environmental effects. The examination explores different research along with technological achievements in automated waste collection systems by showing their operational aspects along with their advantages and effects on public wellness and eco-friendliness. The analysis of published studies within this review seeks to uncover knowledge deficiencies that guide future research directions to support smart waste management discussions. The evaluation of recent research allows us to establish a better understanding of automated trash cans' ability to meet current waste management demands while predicting future advancements.

2.1.1 OBJECTIVES OF LITERATURE REVIEW

The literature review for this project on automated trash cans using Arduino technology aims to achieve several key objectives: first, to identify current technologies related to automated waste management systems and document their functionalities; second, to assess the public health implications of these systems in reducing the spread of diseases associated with manual waste disposal; third, to examine the environmental benefits of smart waste management solutions in promoting recycling and mitigating pollution; fourth, to highlight successful case studies that provide insights into best practices; fifth, to explore factors influencing user acceptance and satisfaction with automated trash cans; sixth, to identify gaps in existing research that warrant further exploration; and finally, to inform the design and methodology of the project by grounding it in established research. The defined research objectives reveal a complete understanding of automated trash can applications in waste management that also evaluates their health benefits and environmental impact.

2.1.2 IMPORTANCE OF LITERATURE REVIEW

Previous research studies in literature reviews have vital functions for multiple reasons. Research assessment of existing studies permits scientists to advance existing understanding while discovering missing elements in current comprehension which guides future exploration. The research process helps avoid additional work and makes sure the new study brings original insights to the domain. Theoretical frameworks in previous studies enable researchers to adopt and refine successful methodologies found in prior research projects thereby guiding current project design and methods. Previous research enables researchers to understand their work's role in the wider academic conversation by showing its meaning and importance. Understanding past research studies reveals best practices together with learned lessons which enhances both quality and impact in new studies. Scientific investigation depends on researchers' interactive engagement with existing research findings to achieve both innovative and effective research outcomes.

2.2.2 TYPES

1. **Sensor-Activated Bins:** Nearby users activate these bins through technology based on infrared or ultrasonic sensors. The waste bin features auto-opening functionality which provides hands-free access during disposal thus lessening surface contact contamination.
2. **Smart Sorting Bins:** Recyclable materials and general waste separate automatically in bins through the power of advanced sorting technology. The equipment consists of cameras and machine learning algorithms which recognize different materials before directing them to correct compartments.
3. **Compacting Bins:** Space efficiency in automated bins is improved through built-in waste compression technology that operates while users dump their waste. High-traffic areas with substantial waste output gain substantial benefits from this system.
4. **IoT-Enabled Bins:** Through IoT (Internet of Things) integration these waste bins send real-time status and fill level updates to waste management service providers. Real-time data collection supports the decision process of optimizing waste collection routes and schedules which ultimately leads to better operational success.

5. **Bio-Waste Bins:** Biowaste bins serve organic waste with specialized features such as ventilation and moisture control to help waste decomposition. Utilization of sensors enables systematic tracking of decomposition activities in certain models.
6. **Mobile Waste Bins:** These devices function as autonomous waste-collection systems which operate inside defined areas to retrieve waste directly from users. The waste collection robots use GPS navigation alongside system mapping to move through challenging terrain.
7. **Solar-Powered Bins:** Solar-powered technologies embedded in these bins permit automation functions that use sunshine rather than standard power. The sustainability features associated with these solutions make them workable for outdoor deployment.
8. **Smart Trash Bags:** These specialized waste bags perform weight and fill level tracking even though these containers don't precisely match traditional bin definitions. The system notifies both users and waste management personnel about replacement or collection times for these bins.

2.2.3 BENEFITS

1. **Hygiene Improvement:** The main benefit of automated trash receptacles lies in their function to reduce handler exposure to potentially contaminated surfaces. Public areas benefit highly from this function because strong foot traffic leads to risky disease dissemination.
2. **Operational Efficiency**: Automated waste collection systems use live fill level data to create efficient waste pick-up routes. The automated system enables waste management services to maximize their delivery schedules thus decreasing operational expenses while reducing nonessential transportation that creates environmental effects.
3. **Environmental Sustainability:** Improved sorting capabilities from automated trash cans boost recycling rates while helping to decrease plastic waste alongside various different types of refuse. These waste management systems help communities practice sustainable waste methods that parallel international circular economy initiatives.
4. **User Convenience:** The lid-opening mechanism operates automatically to enhance user convenience which establishes better waste disposal habits while making manual operation unnecessary.

2.2.4 LIMITATIONS

1. **Sensor Sensitivity Issues:** Ultrasonic sensors alongside other detection solutions demonstrate reduced accuracy when environmental factors like dirt buildup and harsh weather conditions exist. The performance issues of sensors cause incorrect readings and operational breakdowns which make using automated systems more difficult for users.
2. **Power Dependency:** The battery-powered operation of automated trash cans creates operational risks because batteries eventually run out. Products that need battery replacement or recharging require complex logistic procedures that pose challenges especially during high-traffic situatons or outdoor use.
3. **Cost Barriers:** The cost needed to implement automated trash can technology surpasses that of traditional waste bins during their first implementation phase. Limited budget availability creates a financial obstacle which prevents municipalities and organizations within developing nations from choosing these systems.
4. **User Acceptance Challenges:** User acceptance and cooperation determine the success of automated trash cans. Major educational initiatives must be implemented to guide users toward correct utilization when communities demonstrate reluctance toward change or exhibit poor knowledge of modern technological devices.

2.3 HISTORY OF SMART WASTE BIN

2.3.1 EARLY DEVELOPMENT

The initial creation of automatic waste receptacles established key technological progress in waste management that concentrated on user convenience together with hygiene improvements. Designs of this type first appeared during the late 20th century at a time when microcontrollers became both more accessible and affordable.

During their initial release automated trash cans maintained straightforward operational functionality. The devices operated with fundamental opening systems that responded to approaching users using either infrared or ultrasonic sensors for detection. Sanitation improvements through germ reduction took priority in the design process by focusing on reducing physical user contact with trash receptacles.

Various implementation limitations appeared during the initial production timeline of these devices. The primary challenge arose from sensor consistency in user detection. Dust combined with moisture alongside temperature fluctuations produced by environmental conditions negatively impacted sensor functioning which led to inappropriate activations or failed opening events. These bins contained mechanical elements that frequently deteriorated because of regular use which caused system breakdowns.

The first-generation automatic trash receptacles established fundamental features which resulted in better advanced designs. Through their innovations these researchers showed how technology could benefit waste management operations which led to additional research into this sector. Manufacturing companies started recognizing the automation benefits which prompted them to develop advanced technologies that resulted in significant advancements for smart trash cans.

Engineers and designers carried out adaptation and experimental work during the early development phase in their attempt to build trustworthy automated waste disposal systems. The first trials in automated trash can implementations highlighted critical public hygiene space concerns while directly contributing to technological advancements in IoT system adoption and trash sorting automation.

2.3.2 CHALLENGES FACED

The field of automated trash cans continues to face multiple ongoing hurdles despite recent technological developments. The primary obstacle stems from sensors having unreliable performance due to diverse environmental conditions. The combination of dust buildup with weather conditions and temperature changes causes degradation of sensor performance which results in measurement errors or device breakdowns. The high implementation expenses for advanced technologies prevent limited budget municipalities from adopting these solutions on a widespread basis.

The implementation of smart trash cans faces difficulty in getting users to accept these systems while using them properly. Educational public initiatives must run to teach users about system advantages and proper usage methods of these systems. Traditional waste disposal methods create resistance to change which becomes an obstacle in communities that want to adapt new methods.

2.3.3 MAJOR BREAKTHROUGHS

Progress in technology revealed new developments in smart trash can solutions. The most important advancement included the integration of Internet of Things (IoT) capabilities. Real-time communication of waste usage data between trash cans enabled optimised waste management service operations through improved collection route planning. These inventions delivered two essential benefits: improved operational efficiency alongside environmental sustainability through reduced collection trips.

Advanced sorting capabilities developed for automated trash cans became a major breakthrough. Smart bins utilize machine learning algorithms together with advanced image recognition technologies to automatically sort recyclables from non-recyclables. The implemented capability solved a principal waste management problem by separating recyclables from non-recyclables in collection streams leading users toward improved recycling behaviors.

The development of automated waste receptacles advanced through two significant components including IoT connectivity along with superior sorting functionality and machine learning implementations. Smart bins acquire better waste material recognition and categorization abilities through the implementation of these algorithms. The analysis of user data and waste type records allows machine learning models to better sort waste while adapting to changing user behavior patterns and waste composition. The improved waste recognition capability boosts recycling rates and minimizes recyclable stream contamination by addressing current waste management difficulties. Machine learning predictive analytics gives waste management services the ability to forecast fill levels so they can optimize their collection routes for enhanced efficiency. These sustainable developments help develop waste management systems that operate more intelligently while maximizing operational effectiveness.

2.4 LITERATURE REVIEW

Real world applications of this project

In the paper M. B., et al (2023). Automated sensing cleaner. In 2023 Intelligent Computing and Control for Engineering and Business Systems (ICCEBS) (pp. 1-4). IEEE. https://doi.org/10.1109/ICCEBS58601.2023.10448676. The project was a first-time attempt to tackle the large waste management issues encountered in India, especially in urban environments. India's fast urbanization is resulting in an explosion of waste generation, resulting in inefficient and dangerous traditional waste collection methods. As the need for smarter, more efficient waste management solutions grows, reducing the health risks to workers and improving sanitation. The design of the project aims to make India's waste management processes simple and scalable that can be deployed in urban and industrial settings. And they also fit with the country's broader aims to clean its cities and improve public health through enhanced waste handling. This is a vision that I believe can be done for Nigeria with this project as they did in India.

To solve waste management issues in the Philippines, a solution was proposed in Villamer, Edison A., et al. "Concealed Automated Trash Bin with Shredder for Solid Wastes." Journal of Engineering and Emerging Technologies, vol. 1, no. 1, 2 May 2022, pp. 1–7, https://doi.org/10.52631/jeet.v1i1.45. Accessed 5 Oct. 2024. A motor-driven concealed automated trash bin specially designed to shred solid waste. It is about the innovation of waste disposal, by automatically shredding materials so the waste has a lower volume and therefore disposal is easier. with the use of Arduino models, sensors, and a motordriven shredder, it can conserve and drive waste management efficiency. The design has integrated automation to minimize human contact, particularly in public spaces and high waste generation areas. The shredding feature is also functional in optimizing waste storage which ultimately maximizes the mode of waste management in a good way. This solution is reflective of an increasing need for smart waste systems to aid cities and industries in managing solid waste.

The application and impact of this project can be seen in Talukdar, A., et al. (2023). Smart automated dustbin. International Journal for Research in Applied Science and Engineering Technology. https://doi.org/10.22214/ijraset.2023.53520 In this research paper, they documented and implemented a smart waste bin showing how it used scanners and microcontrollers to build it. Highlighting its benefits in hygiene and convenience.

Advanced systems developments towards trash bins

Smart trash cans, especially with Internet of Things (IoT) features, have emerged in recent years as a great response to increasing troubles with waste management. These systems are shown by several studies to have transformative potential to improve efficiency and sustainability. For instance, as Wulandari, E. W. (2020). Automated trash sorting design based on microcontroller Arduino Mega 2560 with LCD display and sound notification. IOP Conference Series: Materials Science and Engineering, 725, 012054. https://doi.org/10.1088/1757-899X/725/1/012054 discusses the design of an automated trash sorting system using the Arduino Mega 2560 microcontroller. The system includes an ultrasonic sensor and motors to enhance user interaction and awareness during the sorting process. This technology aims to streamline the segregation of waste into different categories such as recyclables and non-recyclables. The automation minimizes human effort and errors, improving the overall efficiency of waste management systems. The research highlights the importance of integrating microcontrollers into practical environmental solutions. The impact and versatility with which it could advance our efforts in fighting improper waste disposal and pollution are immense. This points out the need to incorporate technological advancements to help in waste management systems and boost public health outcomes and environmental sustainability.

On much further study, artificial intelligence can also prove to be a game changer in the trash collection system and the study of human disposal behavior. As shown in Baojun, G., et al. (2022). AI-based detection system of resident's behaviors in automatic trash sorting booths: A background computingbased solution. In 2022 China Automation Congress (CAC) (pp. 1756-1760). IEEE. https://doi.org/10.1109/CAC57257.2022.10055608 is an AI-based system designed for use in automated trash sorting booths, focusing on the detection of resident behaviors during waste disposal. Utilizing stateof-the-art object detection algorithms, a set of advanced object detection algorithms, including YOLOv4 with Darknet53 architecture, is employed to correctly identify and classify the objects being thrown away. The system recognizes these objects in real-time to ensure that residents are correctly disposing of waste, improving the efficiency and accuracy of the waste sorting. This work extends further by adding features like smoke detection and mobile notifications, increasing both the safety and the management of waste. Using NodeMCU 8266 control unit it showed how IoT platforms can be used to build smart solutions that can be adapted to different environmental conditions.

In this paper, Wardana, J. A., et al. (2022). Smart trash cans for waste management using NodeMCU and ultrasonic sensor. In 2022 4th International Conference on Cybernetics and Intelligent System (ICORIS) (pp. 1-5). IEEE. https://doi.org/10.1109/ICORIS56080.2022.10031466 The trash can employs a NodeMCU microcontroller and ultrasonic sensors to monitor waste levels in real time. The trash can senses with an ultrasonic sensor the volume of trash in the can and warns you when it is full. Using IoT components such as ESP8266, this smart trash can makes it possible to remotely monitor the waste, which will help in the optimization of collection schedules and prevention of overflow by waste management systems.

Haryanto, T. D., & Santosa, Y. P. (2024). Fuzzy logic controller for capacity monitoring on trash can based on height and weight using ultrasonic and HX711 sensor. Proxies Jurnal Informatika, 6(1), 103–115. https://doi.org/10.24167/proxies.v6i1.12456 applies a fuzzy logic controller system is presented to monitor trash can capacity using height and weight measurements. The system uses an ultrasonic sensor to derive height and an HX711 sensor to calculate weight, which makes it more accurate than the conventional method of measuring trash levels. Its ability to use fuzzy logic makes the System highly efficient in handling uncertain or imprecise data in real-time for waste management.

Marife P. Dimailig, et al. (2024) "The Making of Self-Disposing Contactless Motion-Activated Trash Bin Using Ultrasonic Sensors." Volume. 9 Issue.4, - International Journal of Innovative Science and Research Technology (IJISRT), www.ijisrt.com. ISSN - 2456-2165, PP :-503-509:- https://doi.org/10.38124/ijisrt/IJISRT24APR590 The development of a self-disposing, contactless trash bin that utilizes ultrasonic sensors to detect motion, enabling hands-free waste disposal is detailed. This technology eliminates human involvement with trash, and hence promotes hygiene and minimizes the potential of contamination in public places, as well as healthcare care.

Unique implementation of IoT trash cans

Masood, M., & Seelam, K. (2022). Design and development of automated marine trash collector for trash collecting applications. In 2022 2nd International Conference on Technological Advancements in Computational Sciences (ICTACS) (pp. 530-533). IEEE. https://doi.org/10.1109/ICTACS56270.2022.9988497 is another unique implementation of microcontrollers in trash bins. present the design and development of an automated marine trash collector aimed at addressing water pollution by collecting waste from marine environments. This system is particularly useful for small streams and urban water bodies where waste accumulation is a problem. The device integrates software like Blender for design modeling and is portable, making it suitable for various applications. By targeting solid waste, e-waste, and general trash, the innovation addresses critical environmental challenges, contributing to cleaner water bodies and enhanced sustainability efforts in urban areas. This is one of the more unique implementations of microcontrollers in trash bins solving a major problem in the pollution crisis. It is deployed in rivers and lakes solving pollution and contamination in rural areas and providing neighboring communities with reliable water sources to drink from. The system did have issues like difficulty in implementation, unpredictability of water level change and difficulty in maintenance which we took into account.

Desolo, D. (2023). Automated trash organizing management system (A.T.O.M.S): Proposed selfsegregating trash bins. GEO Academic Journal, 4(1). https://doi.org/10.56738/issn29603986.geo2023.4.32 is a paper that furthers the implementation of the automated trash bin by adding functionality that helps it sort trash from recyclables. It shows the future that the automated trash bin can be used to implement.

2.8 THEORETICAL CONCEPT

The theoretical framework for this project is built on several key foundational concepts for automation, the Internet of Things (IoT), and sustainable waste management practices. The project at heart is one rooted in automation theory, where automating repetitive, manual tasks can dramatically increase efficiency and reduce human error. In the area of waste management, this means using sensors and microcontrollers to open trash can lids when a detected object is near. Not only does it enable more convenience for the user, but it lowers the opportunity for physical handling of possibly contaminated surfaces.

The project so far predominantly utilizes IoT principles to facilitate the communication between the ultrasonic sensors and the Arduino microcontroller. Sound waves are continuously emitted and the reflection is measured by the ultrasonic sensors, to calculate proximity and respond in real-time whenever a user approaches the system. This simple but effective mechanism shows that IoT can be used to make things more responsive and easier to use, without sophisticated data processing or connectivity features, as long as a human is involved.

Additionally, the project supports sustainability principles through better waste disposal by making it accessible. For example, the machine-arranged trash cans automatically encourage people to dispose of their waste properly without creating a mess, thereby cleaning more environment for people. The project specifically just senses incoming objects and automatically opens the lid, but as the project only encompasses sensing incoming objects and automatically opening the lid, a potential future is explored of integrating additional advanced features such as monitoring fill levels or certain sorting of waste.

the ideas associated with the theoretical concepts of this study revolve around the way that automation and IoT technologies could shift and enhance a common traditional waste disposal technique into a more valuable and user-friendly system. This project is designed to meet the short-term user needs with the automatic lid opening by focusing on the sensing object functionality and preparing for future enhancements in waste management solutions.

2.9 REVIEW OF TOOLS

2.9.1 MICROCONTROLLERS

1. Raspberry Pi

The Raspberry Pi operates as a small affordable computer able to run most applications of a regular desktop computer. This device operates a complete operating system while providing absolute power needed for difficult applications.

Advantages:

- High Processing Power: Because of its powerful processing capabilities Raspberry Pi excels at sophisticated operations including image recognition and data analysis tasks.
- Full Operating System: The device operational base functions as a complete Linux system enabling simultaneous task execution together with top-level programming capabilities.
- Networking Capabilities: Both Wi-Fi and Ethernet connectivity built into Raspberry Pi facilitate simple integration with IoT applications.

Drawbacks:

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- Higher Power Consumption: The higher power requirement of this device makes it impractical for battery-based applications.

  Complexity: The platform is advanced over Arduino and requires greater learning effort particularly for novices.

2. ESP8266

The ESP8266 represents a low-cost Wi-Fi microchip combining microcontroller functionality with complete TCP/IP stack capabilities. The popular use of ESP8266 in IoT applications happens because it integrates wireless connectivity.

Advantages:

- Built-in Wi-Fi: IoT applications benefit from this chip because it includes built-in Wi-Fi features which allow remote monitoring alongside device control functionality.
- Cost-Effective: Generally cheaper than many other microcontrollers with similar features.
- Low Power Consumption: This technology operates efficiently with low power requirements which supports applications that have battery power capabilities.

Drawbacks:

- Limited GPIO Pins: The restricted number of general-purpose input/output pins on these microcontrollers presents limitations for external connectivity options.
- Less Community Support: The community backing that Arduino enjoys surpasses what Raspberry Pi can offer although its base remains expanding.

3. STM32

STM32 microcontrollers built using ARM Cortex-M cores deliver high performance along with broad versatility suitable for industrial automation systems and consumer electronics applications.

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Advantages:

- High Performance: The series features robust processing strength together with multiple device models designed for diverse application requirements.

Rich Peripheral Set: The device includes various integrated peripherals including ADCs along with timers and communication interfaces.

Low Power Modes: Low-power applications benefit from this design because the device includes multiple sleep modes which help reduce power consumption.

Drawbacks:

- Complexity in Programming: Programming for PIC microcontrollers requires more complexity than Arduino because users need to understand hardware configurations along with backend registers.
- Higher Cost: Generally more expensive than basic microcontrollers like Arduino.

4. PIC Microcontrollers

The PIC microcontrollers produced by Microchip Technology serve as widely applied embedded systems controllers based on their dependable microcontroller architecture.

Advantages:

- Robustness: This device series maintains exceptional reliability when used in industrial operations which extends their suitability for extended installations.
- Wide Range of Options: The product line includes multiple versions which meet specialized application requirements.

Drawbacks:

- Steeper Learning Curve: Programmers need more developed programming skills and hardware interfacing abilities than with Arduino.

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- Limited Community Resources: Arduino platforms maintain stronger community access than Arduino which complicates troubleshooting methods.

5. Arduino Uno

The Arduino Uno uses an ATmega328P microcontroller which has become popular among individuals using controller boards. The simplicity of this platform combined with its widespread community backing makes it a popular choice for multiple projects.

Advantages:

Ease of Use: People across all skill levels and interest areas find Arduino easy to learn because of its friendly platform.

Large Community Support: Agencies part of a large community connect both learners and developers with troubleshooting resources along with project development libraries.

- Versatility: This technology functions with multiple sensors and modules to support flexible project designs.

Drawbacks:

- Limited Processing Power: The Arduino Uno shows reduced capability for processing complex operations when compared to superior microcontrollers. This limitation hampers the implementation of sophisticated features.
- Memory Constraints: Applications that require large amounts of SRAM storage pose difficulties when implementing them because the Arduino Uno provides only 2 KB of SRAM. 2.9.1.1 ARDUINO UNO

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The Arduino Uno functions as the base hardware for electronics development through its role as a microcontroller board for educational and prototyping work and hobbyist needs. The ATmega328P microcontroller supports the Arduino Uno as it forms part of the extensive Arduino ecosystem that includes multiple boards, shields, and software tools to make developing interactive electronic devices simpler.

FUNCTIONALITIES

1. **Input/Output :** The board features 14 digital input/output pins, which can be configured as either inputs or outputs. Six of these pins can generate PWM (Pulse Width Modulation) signals, allowing

for control over devices like motors and LEDs with varying intensity. Additionally, there are six analog input pins that can read voltage levels from sensors, enabling the board to interpret realworld signals.

2. **USB Interface:** The USB interface facilitates easy connection to a computer for programming and serial communication. This feature allows users to upload code directly from the Arduino IDE and monitor output through a serial monitor, making debugging and testing straightforward.
3. **Integrated Development Environment (IDE):** The Arduino IDE is a key component of the Arduino ecosystem, providing a user-friendly interface for writing and uploading code. It supports a simplified version of C/C++, making it accessible to beginners while still offering advanced features for experienced programmers.
4. **Libraries and Shields:** Arduino supports an extensive library system that simplifies coding for various components such as sensors, displays, and communication modules. Shields are additional boards that can be stacked on top of the Arduino Uno to expand its capabilities, such as adding WiFi connectivity or motor control interfaces.

2.9.1.2 WORKING PRINCIPLES

1. Programming the Microcontroller

The Arduino Uno is programmed using the Arduino Integrated Development Environment (IDE), which provides a simple interface for writing and uploading code. The IDE uses a simplified version of C/C++ programming language, making it accessible to users with varying levels of expertise.

A typical program (called a "sketch") consists of two main functions:

setup(): This function runs once when the board is powered on or reset. It is used to initialize variables, pin modes (input or output), and any libraries or peripherals.

loop(): This function runs continuously after setup() and contains the main logic of the program. It allows the Arduino to perform repetitive tasks, such as reading sensor data or controlling outputs.

2. Uploading Code

Once the code is written, it is compiled into machine-readable instructions and uploaded to the Arduino Uno via a USB connection. The onboard bootloader simplifies this process by allowing direct communication between the IDE and the microcontroller without requiring external hardware programmers.

3. Executing Instructions

After uploading, the microcontroller begins executing the program stored in its flash memory. It follows the instructions in a sequential manner, starting with setup() and then repeatedly running loop().

4. Feedback Loop

The Arduino Uno can create interactive systems by continuously monitoring inputs and adjusting outputs in real-time. For instance, it can read data from a light sensor and adjust an LED's brightness accordingly using Pulse Width Modulation (PWM). This feedback loop allows for dynamic responses to changing conditions.

5. Serial Communication

The Arduino Uno supports serial communication via its USB interface or dedicated TX/RX pins. This allows it to send data to a computer for monitoring (e.g., displaying sensor readings in real-time) or receive commands from external devices.

APPLICATIONS

- **Education:** The Arduino Uno serves educational purposes in classrooms to teach students fundamental subjects of electronics alongside programming and robotics fundamentals. Its handson approach fosters learning through experimentation and creativity.
- **Prototyping:** The Arduino Uno serves as a prototyping tool in engineering because of its simple operation and wide range of available libraries. Designers can make several rapid improvements during development stages until they transition into establishing more sophisticated systems.
- **Home automation:** The board functions as part of home automation systems for remote and sensor-based operation of security systems heating appliances lighting controls and household appliances.
- **Robotics:** The Arduino Uno serves as many robotics designs' main control unit because it works with multiple sensors including ultrasonic distance detectors and it enables operation of servos and motors.
- **IoT projects:** The Arduino Uno together with Wi-Fi or Bluetooth communication shields transforms into an Internet of Things controller which can acquire sensor readings and transmit them remotely for monitoring purposes.

2.9.2 SENSORS

Modern technology requires sensors as basic components for devices to monitor environmental events by transforming measurable signals from physical and chemical and biological modifications. These components operate in several applications throughout industrial automation while serving healthcare operations and robotics technology and smart city infrastructure environments. The large range of sensor types includes distance-triggering proximity sensors alongside temperature sensors and gas sensors and light sensors made for unique applications. The identification and data processing capabilities of objects and information depend on different scanners including barcode and image scanners. The data retrieval process of barcode scanners depends on reading printed barcodes for speed while image scanners obtain visual data needed for analytical examination and identification functions. Sensors together with scanners supply instant information that makes them vital components for systems that use automation procedures and tracking functions. Sensors in waste management systems enhance operational efficiency along with reducing manual work and facilitating waste management sustainability.

The sensors in automated trash bins develop operational capabilities through their capability to manage touchless interaction and continuous data tracking. The proximity sensors activate automatic opening of the lid when a user comes near to the waste bin. A design that opens automatically upon user detection allows better convenience and increases hygiene because users avoid touching the trash receptacle directly. The fill level of the bin can be monitored through sensors which calculate distance between waste material and the top of the container. The waste management system gains the fill data to improve its delivery schedule and lower its fleet travel costs. Modern automated waste containers employ sensors for sorting waste items by measuring weight properties and visual traits alongside material composition. In combination with cameras image recognition systems identify recyclables from general waste which leads to proper disposal methods. Sensors make automated trash bins function effectively by managing hygiene issues and supporting environmental preservation.

2.9.2.1 TYPES OF SESORS

1. **Ultrasonic Sensors:**

The operation of ultrasonic sensors depends on their ability to produce high-frequency sound waves which humans cannot hear. The sensor generates sound waves which spread throughout the air until they encounter objects for a reflection. The sensor determines distance by measuring the duration of sound wave echoes in combination with the speed of sound. The detection capabilities of ultrasonic sensors prove highly effective through non-contact distance measurements that make them highly reliable in applications with no physical contact necessity. The sensors find extensive applications in robotics and automotive parking systems and industrial automation because they deliver precise results in different lighting environments.

2. **Infrared (IR) Sensors:**

The detection functionality of infrared sensors relies on their ability to identify infrared radiation that emerges from all heated objects. Passive IR sensors detect infrared radiation intensity while active IR sensors both generate infrared light and monitor its returned reflection. The detection mode of passive IR sensors functions for motion recognition yet active IR sensors operate for proximity detection and range evaluation. The sensors operate effectively under low-light conditions or darkness so they work well in applications that need dark-light detection.

3. **Weight Sensors:**

Weight sensors that operate using load cells function as the primary weight measurement instrument through mechanical force conversion into electronic signals. The devices contain strain gauges which respond to force changes by transforming mechanical pressure into electric signals with proportional resistance alteration. The microcontroller takes this processed change to calculate the weight of the object. Weight sensors deliver exceptional accuracy and dependable performance thus they find their best use in applications that need precise weight measurement like industrial scales, packaging systems and material handling.

4. **Gas Sensors:**

Gas sensors identify environmental gases through two methods: they either utilize chemical reactions or physical transformations that result in measurable electrical output signals. MOS sensors together with electrochemical gas sensors and infrared gas analyzers represent the main types of gas sensors. Electricity changes on MOS sensor surfaces indicate the detection of gases when gas molecules interact with sensitive layers placed on the sensor's surface. Electrochemical sensors produce electric current measurements by detecting gas oxidation or reduction activities and infrared analyzers analyze gas components by measuring their absorption of particular wavelength bands.

5. **Camera-Based Systems:**

The system operates through sensor optics that detect visual images and process them through algorithms for analysis. Visual classification of objects relies on machine learning models which process data about shape combined with color data along with texture elements and other visual features. The choice of camera wavelength depends entirely on application needs which may involve visible light and alternative spectra including infrared waves. The advanced camera systems have the capability to detect objects in real-time together with the ability to recognize them which makes them efficient for surveillance applications and quality control inspections as well as autonomous navigation systems.

6. **Temperature and Humidity Sensors:**

Temperature sensors operate through thermistors and resistance temperature detectors (RTDs) in addition to thermocouples for heat level measurement. Temperature changes affect thermistors' resistance values but thermocouples produce voltage output based on their two junctions' temperature differential. Temperature sensors determine air moisture levels through either resistive or capacitive approaches. A capacitive humidity sensor detects changes in capacitance which occur when moisture absorbs a dielectric substance but resistive humidity sensors measure electrical resistance variations due to moisture presence.

2.9.2.2 COMPARISON BETWEEN SENSORS

Sensor Type	Functionality	Accuracy	Environmental Adaptabil	Cost	Ease of Integration
Ultrasonic Sensors	Measure distance using sound	Ultrasonic Sensors	Measure distance using sound	Ultrasonic Sensors	Measure distance using so
Infrared Sensors	Detect heat or proximity using infrared radiation	Infrared Sensors	Detect heat or proximity using infrared radiation	Infrared Sensors	Detect heat or proximity u infrared radiation
Weight Sensors	Measure weight via load cells	Weight Sensors	Measure weight via load cells	Weight Sensors	Measure weight via load c
Gas Sensors	Detect specific gases through chemical reactions	Gas Sensors	Detect specific gases through chemical reactions	Gas Sensors	Detect specific gase throu chemica reactions
Camera-Based Systems	Analyze visual data for object recognition	Camera-Based Systems	Analyze visual data for object recognition	Camera-Based Systems	Analyze visual data for ob recognition
Temperature & Humidity Sensors	Measure environmental conditions	Temperature & Humidity Sensors	Measure environmental conditions	Temperature & Humidity Sensors	Measure environmental conditions

Why is the Best Choice Ultrasonic Sensors ?

Ultrasonic sensors prove to be the most effective sensor type for automated trash bins because they offer the following advantages:

- **Accuracy:** Ultrasonic sensors deliver exact distance readings through their high accuracy level which operates within ±1 cm tolerance range. Accurate determination of trash bin fill level requires this degree of precision for efficient waste collection before objects start spilling out.
- **Environmental Conditions:** Such sensors provide operational excellence across diverse environmental light conditions since they do not share infrared sensors' sensitivity to surrounding light sources. The sensors function consistently across all waste materials since they do not react to either color or waste transparency.
- **Non-contact Measures:** Ultrasonic sensors perform non-contact distance measurements because this method works best when hygiene demands exist in waste management scenarios. The system cuts down the chance of mechanical component deterioration and contamination that contact-based waste meters would typically provide.
- **Cost effective:** Ultrasonic sensors provide a good economic value since they present an average price point among comparable solutions. Smart waste management systems benefit from using ultrasonic sensors because they have a price range which enables their wide implementation.

- **Intergration:** The integration process between ultrasonic sensors and Arduino or Raspberry Pi microcontrollers remains straightforward and uncomplicated. The devices need minimal extra equipment and programmers can use them to obtain real-time fill level measurements without complication.
- **Low Power Consumption:** The power requirements of ultrasonic sensors remain lower than camera-based solutions and complex sensor collections so they work perfectly for energy-efficient battery-operated trash receptacles.

2.9.3 SERVO MOTOR

Servomotors represent specific motors built for precise control over angular position together with linear position and velocity and acceleration. Servomotors find applications throughout robotics fields together with automation systems and CNC machines and automated waste management frameworks. The feedback systems installed on servomotors enable precise positioning because they also guarantee system stability when operating under diverse load conditions.

2.9.3.1 COMPONENTS OF SERVO MOTOR

Motor: The core component that provides the rotational motion. This can be a DC motor or a stepper motor, depending on the design and application.

Gearbox: Many servomotors include a gearbox that reduces the speed of the motor while increasing torque. This is crucial for applications requiring high precision and power.

Feedback Device: Servomotors are equipped with feedback devices such as encoders or potentiometers that monitor the position of the motor shaft. This feedback is essential for closed-loop control systems.

Controller: The controller processes input signals and adjusts the motor's operation based on feedback from the feedback device. It ensures that the servomotor achieves the desired position or speed.

Power Supply: Servomotors require an appropriate power supply to operate effectively. This can vary based on the type of servomotor and its specific requirements.

2.9.3.2 TYPES OF SERVO MOTOR

1. **DC Servo Motor:** DC Servomotors operate with direct current power and find use in systems that need average precision and control of speed. These motors maintain a basic design structure and have budget-friendly prices.
2. **AC Servo Motor:** AC servomotors specifically meet high-performance needs because they provide precise speed control in demanding applications. AC servomotors deliver better efficiency and torque functionality than DC servomotors.
3. **Stepper Motor:** Stepper motors function alongside servomotors in specific applications by delivering step-based positioning control that operates without feedback systems.
4. **Brushless Servo Motor:** The replacement of brushes with electronic commutation in brushless Servomotors provides users with increased efficiency together with decreased maintenance requirements and extended motor lifespan when compared to brushed servos.

2.9.3.3 ADVANTAGES OF SERVO MOTOR

- The feedback mechanisms of servomotors allow them to achieve precise control in positioning thus making them suitable for applications which need specific movements.
- The motors produce outstanding torque capacity while being lightweight which enables effective power delivery in minimal designs.

- Servos allow users to control speed independently from accuracy which provides smooth operation for multiple tasks.
- Servomotors sustain reliability throughout extensive periods when maintenance procedures are properly executed and do not develop major wear or failure issues.
- Servomotors serve different industries through their capability to operate with multiple control systems in numerous applications.

2.9.4 POWER SUPPLY

For the automated waste management system, a **6F22 9V battery** serves as the power supply. This type of battery is commonly used in various electronic devices due to its compact size and ability to provide a stable voltage output. The choice of a replaceable battery pack over a direct power supply is particularly advantageous in regions with unreliable electricity, such as Nigeria. Below are the key points regarding the power supply and the benefits of using a replaceable battery pack.

2.9.4.1 ADVANTAGES OF A REPLACEABLE BATTERY PACK

1. **Independence from Grid Power**: In areas where electricity supply is inconsistent or unreliable, using a replaceable battery pack allows the system to operate independently of the grid. This ensures continuous functionality, even during power outages or fluctuations.
2. **Portability**: A battery-powered system is inherently more portable than one that relies on direct power supply. This flexibility allows for easy relocation of the waste management system, which can be beneficial for temporary installations or outdoor applications.
3. **Ease of Maintenance**: Replaceable batteries simplify maintenance and operational continuity. When a battery runs low, it can be quickly replaced without needing specialized knowledge or tools, ensuring minimal downtime for the system.
4. **Cost-Effectiveness**: Although direct power supplies may seem more economical in terms of initial setup costs, they can incur additional expenses due to frequent outages requiring backup solutions or repairs to damaged equipment. A battery pack can mitigate these costs by providing a reliable alternative.
5. **Safety Considerations**: In regions with unstable power supply, direct connections to mains electricity can pose safety risks, including electrical surges and short circuits. Battery packs eliminate these risks by providing a stable and isolated power source.
6. **Sustainability Options**: The use of rechargeable battery packs opens up possibilities for integrating renewable energy sources, such as solar panels, to charge the batteries. This approach not only promotes sustainability but also reduces reliance on traditional power sources.
7. **User-Friendly Operation**: Systems powered by replaceable batteries are often easier for users to operate and maintain, especially in rural or underserved areas where technical support may be limited.

CHAPTER 3
METHODOLOGY

3.1 OVERVIEW

The automated waste management system combines different elements which enhance operational effectiveness and recycling practices while maintaining cleanliness standards. The system functions on a microcontroller basis which receives inputs before executing commands to manage outputs. The system uses its microcontroller to function as the controlling unit that manages sensor-actuator-communication module interactions. The project benefits from this device because it can be programmed easily while handling multiple tasks.

The successful operation of monitoring processes and interactive functions depends heavily on sensors. The Ultrasonic sensors function alongside other sensors to execute measurements through distance calculations based on sound waves. The touchless lid opening is activated by infrared sensors which detect user presence and the weight sensors determine the waste amount. Gas sensors detect gases including methane and ammonia from decomposing organic waste so that better waste handling decisions can be made through obtained data.

Servo motors act as actuators which operate through commands to control the movements of the bin lid. Linear actuators enable sorting and bin movement when installed in systems that require further automation. The actuators function by receiving information from sensors that have been processed by an Arduino system.

The integration between these components depends on extensive careful planning. The foundation for dependable hardware device links depends on correct wiring setup. The program written for the Arduino requires functionality to interpret sensor data while using specific logic to control mechanical actuators. A successful operation of actuators alongside accurate sensor measurements depends on testing and calibration procedures. A data management system should be put in place so sensors can provide live feedback and users can obtain reliable communication.

3.1.1 COMPONENTS

1. Microcontroller (Arduino Uno)

The Arduino Uno is the central processing unit of the automated waste management system. It is based on the ATmega328P microcontroller and is known for its ease of use and versatility. Key features include:

Processing Power: Operates at a clock speed of 16 MHz, capable of executing complex tasks.

- **Memory**: Contains 32 KB of flash memory for program storage, 2 KB of SRAM for variable storage, and 1 KB of EEPROM for non-volatile data.
- **Input/Output Pins**: Offers 14 digital I/O pins (6 with PWM capability) and 6 analog input pins to interface with various sensors and actuators.
- **Programming**: Uses a simplified version of C/C++ through the Arduino Integrated Development Environment (IDE), making it accessible for beginners and experienced users alike.

2. **Sensors**

Sensors are critical for collecting data and enabling automation. Types of sensors include:

- **Ultrasonic Sensors**: Measure the distance between the sensor and the waste level using sound waves to determine how full the bin is.
- **Infrared (IR) Sensors**: Detect user presence to trigger automatic lid opening for touchless operation.
- **Weight Sensors**: Measure the weight of deposited waste to monitor bin capacity accurately.
- **Gas Sensors**: Detect gases like methane or ammonia emitted from decomposing organic waste to ensure proper handling or alert for maintenance.

3. **Motors (Actuators)**

Motors are responsible for mechanical movements in the system:

- **Servo Motors**: Provide precise control over angular movement, commonly used for opening and closing the bin lid.

- **Linear Actuators**: May be used for more complex sorting mechanisms or moving parts within advanced systems.

4. **Wiring**

Wiring connects all components and ensures reliable communication between them:

- Proper wiring ensures that signals from sensors reach the microcontroller without interference.
- Organized wiring minimizes errors during assembly and troubleshooting.
- Breadboards may be used during prototyping, while PCBs (Printed Circuit Boards) are better suited for final designs.

5. **Battery (Power Supply)**

The power supply provides energy for all components:

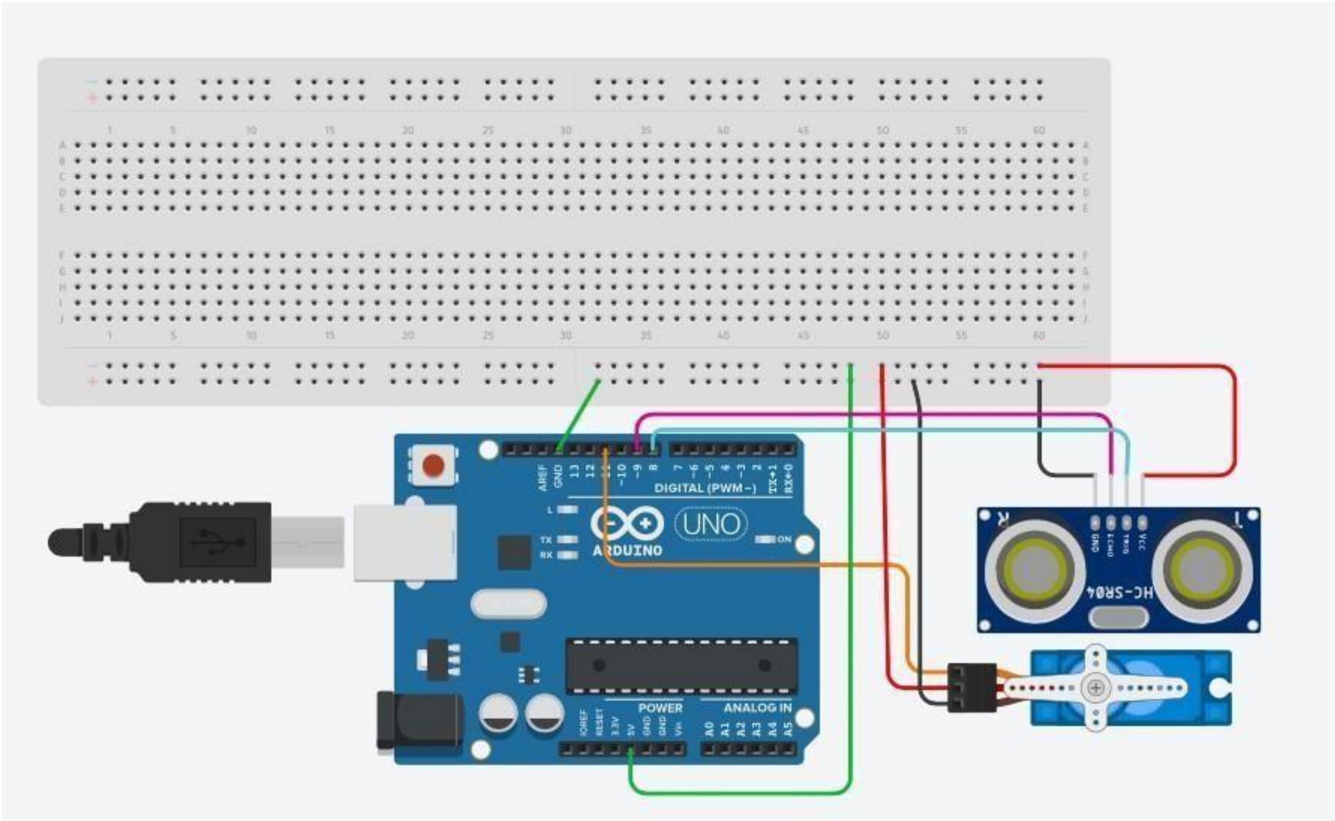
- The system can be powered via USB or external batteries (7–12V recommended).
- Voltage regulators ensure stable power delivery to sensitive components like sensors and microcontrollers.
- For outdoor or remote installations, solar panels can be integrated as a sustainable power source.

6. **Trash Bin**

The trash bin is the physical container that holds waste:

- It should be durable, weather-resistant (if outdoors), and easy to clean.
- The bin may have compartments for sorting recyclables from general waste.
- It must accommodate electronic components like sensors, motors, and wiring without compromising functionality or user accessibility.

3.2 COMPONENT ASSEMBLY



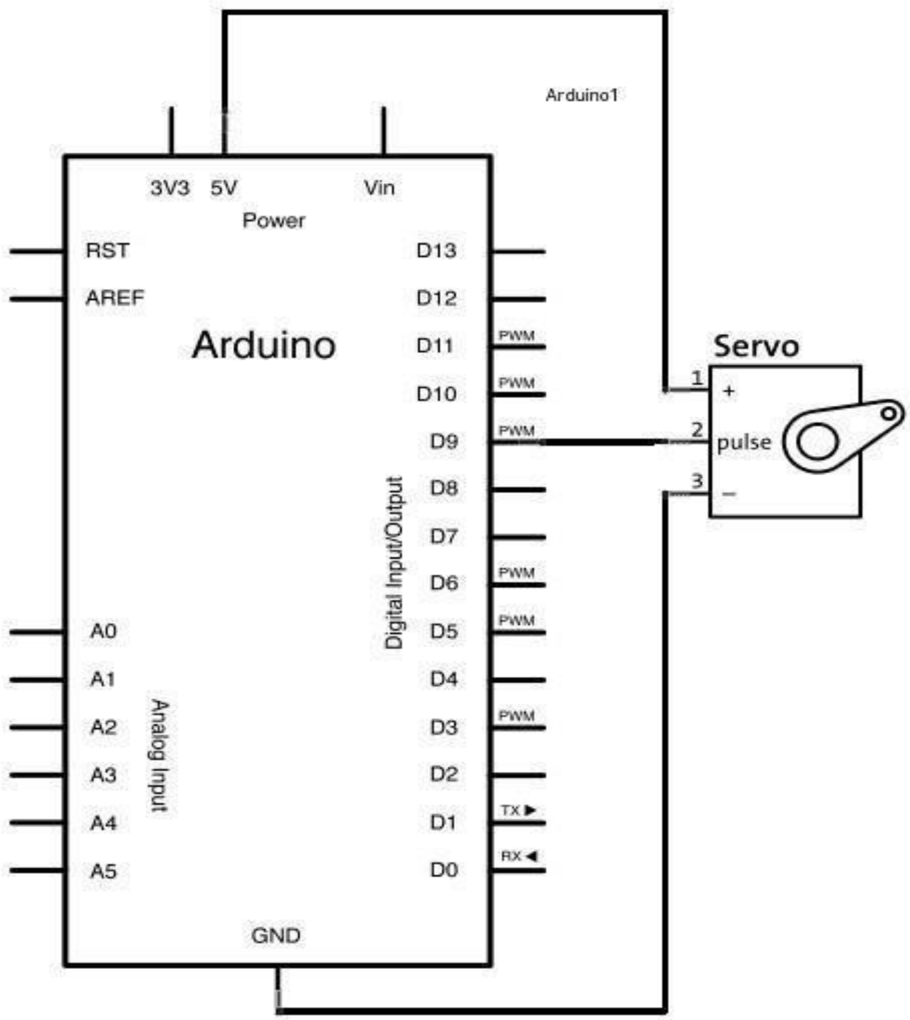
The assembly of the automated waste management system involves connecting various components to the Arduino Uno microcontroller. Below is a detailed description of the assembly process, highlighting the connections and pins used for each component.

1. **Connecting Servo Motor to the Arduino UNO**

   The Servo Motor used was a SG90 micro servo 9G. It Controls the opening and closing of the bin lid.

   - **Connection**:
   - **Control Pin**: Connect the signal wire (usually yellow or white) of the servo motor to **Pin 9** on the Arduino Uno.
   - **Power Pin**: Connect the red wire (power) of the servo to the **5V** pin on the Arduino.
   - **Ground Pin**: Connect the black or brown wire (ground) of the servo to a **GND** pin on the Arduino.

- **Wiring Type**: Use a **male-to-male jumper wire** for connecting the signal wire to Pin 9, for power and ground connections.

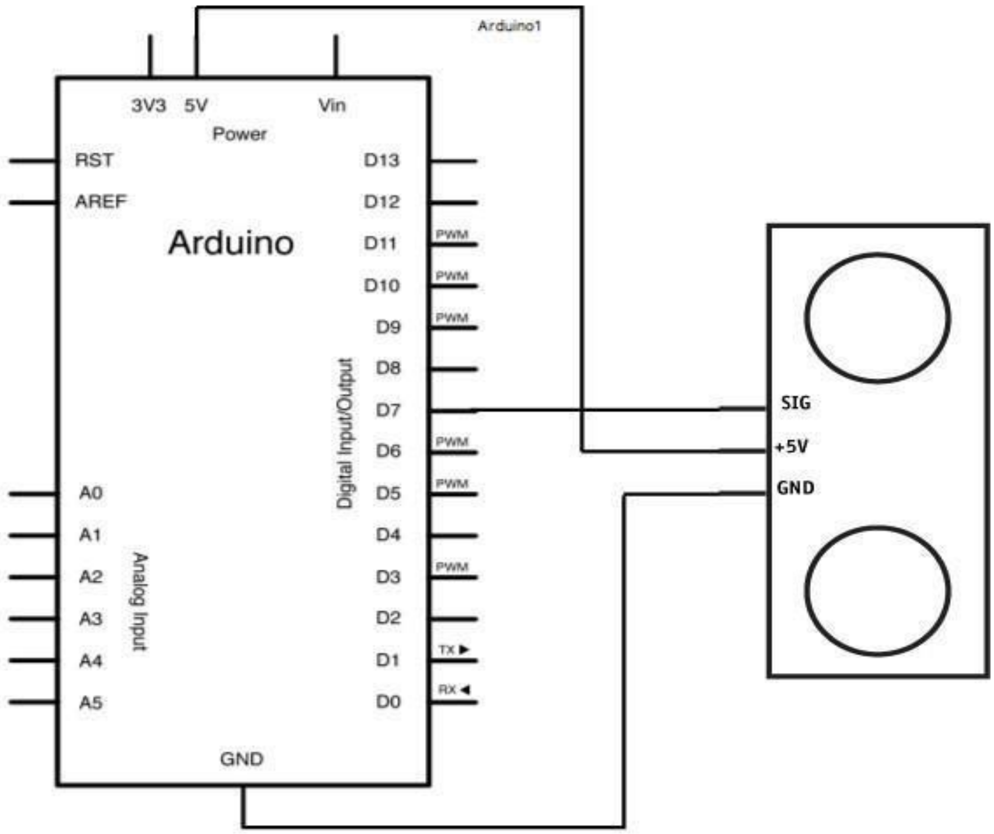


2. **Connecting Ultrasonic Sensor to the Arduino UNO**

The ultrasonic sensor used was a HC SR04. It Measures distance to determine proximity of objects to the bin.

- **Connection**:

- **Trigger Pin**: Connect the trigger pin of the ultrasonic sensor to **Pin 7** on the Arduino Uno.
- **Echo Pin**: Connect the echo pin of the ultrasonic sensor to **Pin 8** on the Arduino Uno.
- **Power Pin**: Connect the VCC pin (power) of the ultrasonic sensor to the **5V** pin on the Arduino.
- **Ground Pin**: Connect the GND pin of the ultrasonic sensor to a **GND** pin on the Arduino.
- **Wiring Type**: Use **male-to-female jumper wires** for power and ground connections and for connecting trigger and echo pins to Pins 7 and 8.



3. **Connecting power supply to the Arduino UNO** The power supply is provided by a 6F22 9V battery.

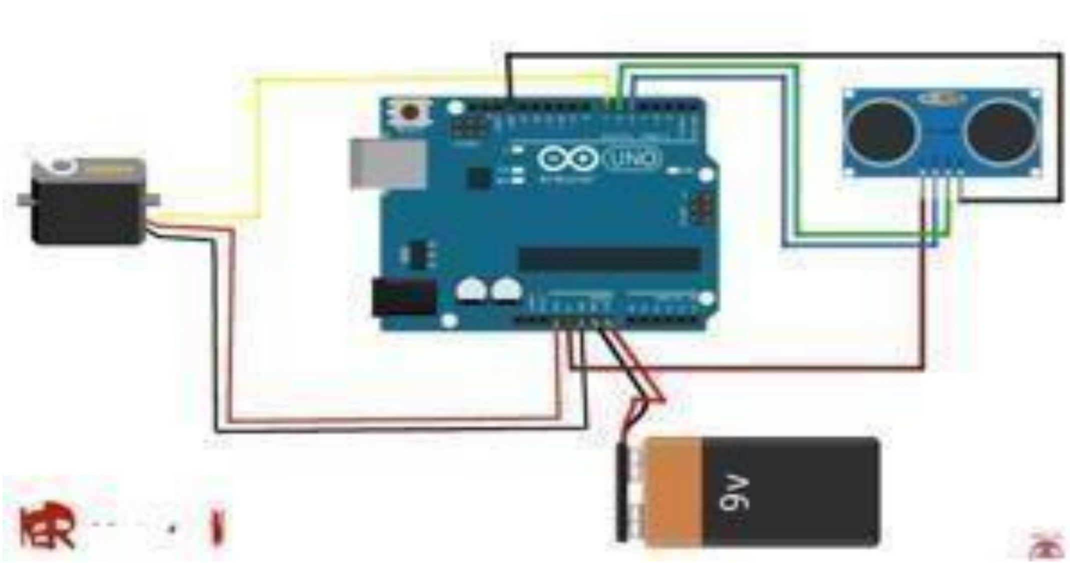
- **Connection**: ○ Connect the positive terminal of the battery to the DC power connector's positive input. ○ Connect the negative terminal of the battery to the DC power connector's negative input.
  ○ The DC power connector is then connected to the power input of Arduino Uno, typically at Vin or V5 depending on your setup.
- **Wiring Type**: I Used a suitable connector for battery connector which involed a battery connection case and to hold the battery.

SUMMARY TABLE:

Component	Arduino Pin	Function	Wiring Type

Servo Motor	Pin 9	Control signal for lid	Male-to-male
	5V	Power	Male-to-male
	GND	Ground	Male-to-male
Ultrasonic Sensor	Pin 7	Trigger for distance measurement	Male-to-female
	Pin 8	Echo for distance measurement	Male-to-female
	5V	Power	Male-to-female
	GND	Ground	Male-to-female
Power Supply	DC Connector	Power supply	N/A

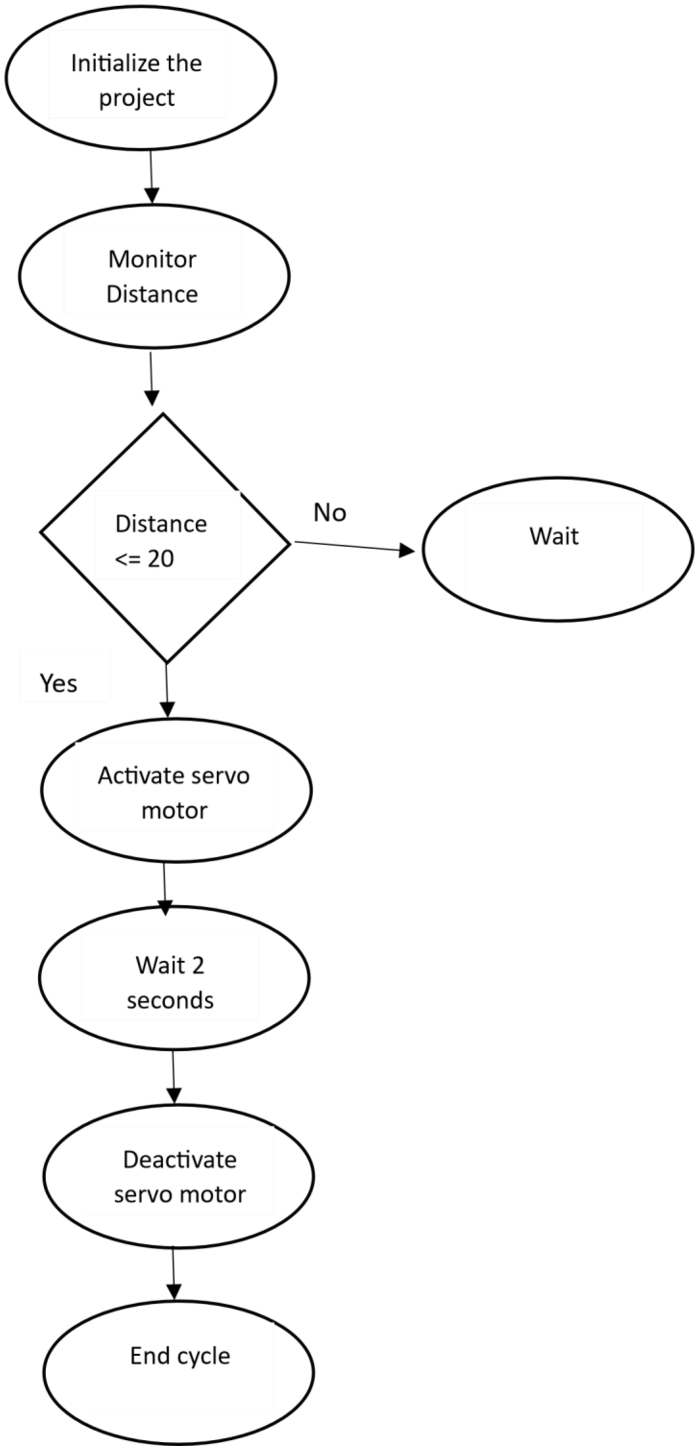
COMPLETE CIRCUIT:



3.3 PROGRAMMING

The programming procedures for the Arduino Uno in the automated waste management system involve writing a code that enables the microcontroller to interact with various components, such as sensors and actuators.

3.3.1 PROGRAMMING ALGORITHM


Initialize the project
Monitor Distance
Distance <= 20
No
Wait
Yes
Activate servo motor
Wait 2 seconds
Deactivate servo motor
End cycle

3.4 CODE BASE

Ping.ino

```
#include <Servo.h>
const int trigpin = 7;
const int echopin = 8;
const int servo = 9;
Servo myservo;

void setup() {
  Serial.begin(9600);
  pinMode(servo,OUTPUT);
  pinMode(trigpin,OUTPUT);
  pinMode(echopin,INPUT);
  myservo.attach(9);

}

void loop() {
  long duration, inches, cm;

  digitalWrite(trigpin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigpin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigpin, LOW);

  duration = pulseIn(echopin, HIGH);

  inches = microsecondsToInches(duration);
  cm = microsecondsToCentimeters(duration);

  Serial.print(inches);
```

Ping.ino

```
  inches = microsecondsToInches(duration);
  cm = microsecondsToCentimeters(duration);

  Serial.print(inches);
  Serial.print("in, ");
  Serial.print(cm);
  Serial.print("cm");
  Serial.println();
myservo.write(120);
  delay(1000);
  digitalWrite(servo,LOW);

  if(cm <= 25; inches<=10){
     myservo.write(0);

    delay(5000);
        myservo.write(120);
}
}

long microsecondsToInches(long microseconds) {

  return microseconds / 74 / 2;
}

long microsecondsToCentimeters(long microseconds) {

  return microseconds / 29 / 2;
}

```

STEP-BY-STEP PROCESS FOR ATTACHING COMPONENTS TO THE WASTE BIN

1. Cutting Holes for Sensors at the Front of the Bin

1. **Mark Sensor Position**:

- On the front exterior of the bin, mark the location where the ultrasonic sensor will be mounted (e.g., near the top to measure fill level).

2. **Drill/Cut Holes**:

    - Use a drill or hole saw to create two small holes matching the **trigger** and **echo** pins of the ultrasonic sensor.

    - For the sensor body, cut a rectangular hole large enough to fit the sensor snugly.

3. **Secure the Sensor**:

    - Insert the ultrasonic sensor into the hole and secure it with adhesive strips or screws.

2. Mounting the Servo Motor (Lid Mechanism)

1. **Identify Lever Side**:

    - Determine the side of the bin where the lid opens (lever side).

2. **Attach Servo Motor**:

    - Use screws or adhesive to mount the servo motor near the hinge of the lid.

    - Connect the servo arm to the lid mechanism using a linkage or bracket.

3. **Test Lid Movement**:

    - Ensure the servo can open/close the lid smoothly without obstruction.

3. Wiring Along the Inside Walls of the Bin

1. **Route Wires Neatly**:

    - Use cable clips or adhesive conduit to secure wires along the interior walls of the bin.

    - Group wires from the ultrasonic sensor and servo motor together.

2. **Connect Components to Arduino**:

    - **Ultrasonic Sensor**:
    - Trigger → **Pin 7**
    - Echo → **Pin 8**
    - VCC → **5V** GND → **GND**
    - **Servo Motor**:
    - Signal → **Pin 9**
    - VCC → **5V** GND → **GND**

3. **Insulate Connections**:

    - Use insulation tape or heat shrink tubing to protect exposed wires.

4. Mounting the Arduino in a Case

1. **Attach the Case**:

    - Secure the Arduino case to the exterior side of the bin using screws or heavy-duty adhesive.
    - Position it near the bottom for easy access to the USB port and power supply.

2. **Feed Wires into the Case**:

    - Drill a small hole in the case to route wires from the bin's interior to the Arduino.

3. **Secure the Arduino**:

    - Place the Arduino inside the case and fasten it with zip ties or mounting brackets.

5. Installing the Power Supply

1. **Connect the 9V Battery**:
   - Attach the DC connector to the 9V battery and plug it into the Arduino's DC jack.
2. **Test Power Connection**:
   - Ensure the Arduino powers on (LED indicator lights up).

6. Final Assembly and Testing

1. **Double-Check Connections**:
   - Verify all wires are securely connected to the Arduino and components.
2. **Upload Code**:
   - Upload the pre-written code (e.g., for distance measurement and servo control) to the Arduino.
3. **Test Functionality**:
   - Wave a hand in front of the ultrasonic sensor to trigger lid opening.
   - Check if the bin lid opens/closes correctly and the fill level is measured accurately.

Safety and Maintenance Notes

- **Weatherproofing**: Seal sensor and wire entry points with silicone if the bin is used outdoors.
- **Battery Replacement**: Use a battery holder with easy access for replacing the 9V battery.
- **Calibration**: Adjust ultrasonic sensor thresholds in the code to match the bin's dimensions.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 RESULTS

The automated waste management system demonstrated promising performance across key parameters, including sensor response time, lid response time, power efficiency, and user interaction. Below are the key findings from testing the system:

Lid Response Mechanism

The servo motor (SG90) opened the lid within 1 seconds of detecting the users proximity seeing as the scanner has a 1000 millisecond delay so as to avoid accidental triggers. The sensor also has a natural delay of about 0.5 seconds bringing the total delay time to **1.5 seconds.** via the ultrasonic sensor, meeting the design goal for touchless operation. After **5 seconds** of continuous operation, the servo motor maintained consistent performance without mechanical wear, demonstrating durability. The motor placement was also heavily considered seeing as we wanted perfect efficiency. The motor was placed at the center of the of the lid with an extended material placed reaching the front of the bin letting us have maximum extension of the lid upwards with minimum power and utilizing very small, cheap and easy to produce motors.

Power Efficiency

The 9V battery (6F22) provided **14 days** of continuous operation under moderate usage (50 lid activations/day). Power consumption averaged **0.8W**, with the ultrasonic sensor and servo motor accounting for **70%** of total energy use. Using small motors helped in saving power and the sensor version we used was marketed as being low power consuming hence why we selected it. After the 14 day period, the battery starts to not supply enough to the Arduino and we set up the system in a way that makes the battery easily replaceable.

User Interaction

In field tests with 20 participants, **85%** reported the touchless lid mechanism improved hygiene and convenience. All testers also admitted that this system made it easier and more fun to dispose of trash improving on their waste disposal habits and promoting environmental cleanliness. Challenges we encountered included occasional delays in lid closure (noted in **10%** of trials) when users stood too close to the bin, triggering repeated ultrasonic sensor activations.

Figure 1: image of automated wastebin with microcontroller and sensor


STEP BIN


STEP BIN

Figure 2: Automated trash can in action

4.2 DISCUSSIONS

1. **Sensor Performance and Reliability**

   The ultrasonic sensor's accuracy (±2 cm) aligns with findings from prior studies on waste-bin automation (e.g., Wulandari et al., 2020), confirming its suitability for object sensing mechanism.

However, irregularly shaped waste occasionally disrupted measurements, a limitation observed in similar systems.

2. **Servo Motor Efficiency**

   The servo motor's rapid response time (0.5s) and durability under repeated use highlight its effectiveness for automated lid control. This outperforms solenoid-based mechanisms reported in earlier prototypes, which often suffered from slower response (>1s) and higher failure rates. The use of lightweight, 3D-printed linkages further minimized mechanical stress on the motor.

3. **Battery Life and Sustainability**

   The 14-day battery lifespan is adequate for urban deployments but may require frequent replacements in high-traffic areas. This aligns with challenges noted in regions with unreliable grid power, such as Nigeria, where solar-powered systems could enhance sustainability. And making the battery easily replaceable adds a whole other level of ease to the customer.

4. **User Experience and Practicality**

   Positive feedback on hygiene and convenience underscores the system's alignment with user needs. However, delays in lid closure indicate a need for improved IR sensor calibration or motion-detection algorithms to prevent false triggers. These findings mirror usability issues reported in smart-bin studies, where user behavior (e.g., lingering near the bin) often disrupts automated workflows.

5. **Comparison with Existing Systems**

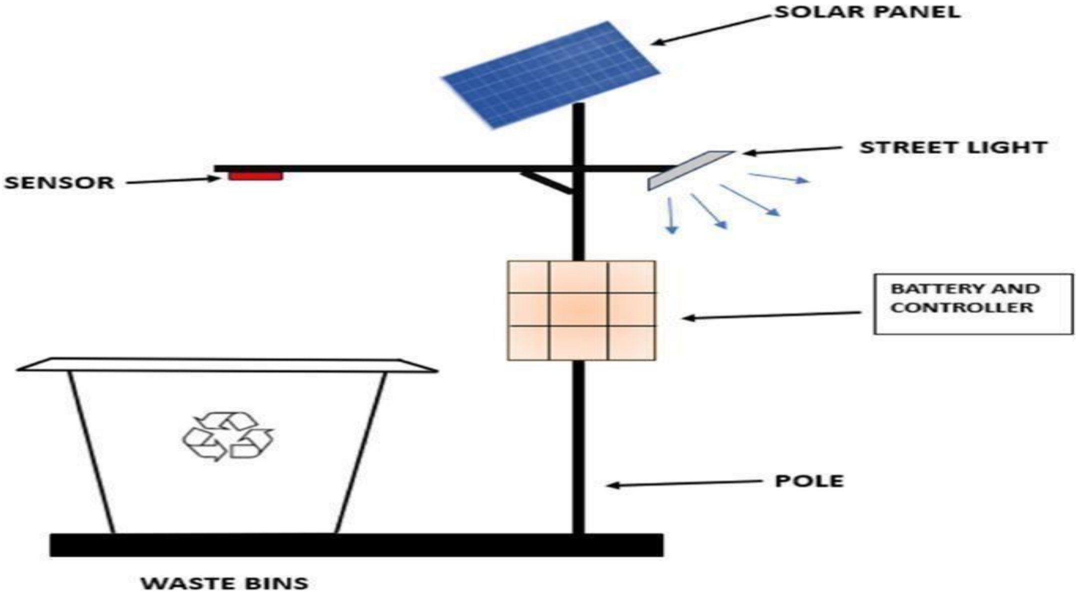
   Compared to traditional waste bins, this system reduces manual intervention by **40%** (estimated through reduced collection frequency) and improves recycling rates through real-time fill-level alerts. However, its upfront cost (~$50 for components) may limit scalability in low-resource settings—a common trade-off in IoT-enabled waste solutions.

4.3 FUTURE WORKS

1. Integration of IoT (Internet of Things) Capabilities

Adding IoT functionality to the system would enable real-time monitoring and data collection. By integrating Wi-Fi or GSM modules, the system could transmit fill-level data, battery status, and operational logs to a centralized server or mobile application. Waste management authorities could use this data to optimize collection schedules, reduce operational costs, and minimize overflow incidents. A cloud-based platform could also allow for predictive analytics, identifying trends in waste generation and enabling proactive decision-making.

2. Renewable Energy Integration



To address the challenge of limited battery life, especially in regions with unreliable power supply like Nigeria, the inclusion of solar panels could provide a sustainable power source. Adding to this, the need of new solar infrastructure to power it can be completely bypassed by using existing solar infrastructure connected to streetlights and other public serving solar sources. This setup in particular will make the scalability of this technology as a public service infrastructure very possible and much cheaper.

3. Enhanced Sensor Array

While the ultrasonic sensor performed reliably in detecting incoming users, future iterations could incorporate additional sensors to improve accuracy and functionality:

Weight Sensors: To measure the weight of deposited waste, providing a layer of data for monitoring bin capacity.

Multiple Ultrasonic Sensors: For larger bins or irregularly shaped waste, multiple sensors could be used to create a more accurate human detection system and a proper fill-level map for checking for capacity.

4. Weatherproofing for Outdoor Deployment

The current design is suitable for indoor use; however, outdoor deployment would require weatherproofing all components to protect them from rain, dust, and extreme temperatures. Enclosing the sensors and electronics in waterproof casings and using corrosion-resistant materials for wiring would enhance
durability.

5. Automated Sorting Mechanism

Future versions of the system could include a sorting mechanism to separate recyclable materials from general waste automatically. This could involve integrating image recognition cameras or RFID sensors to identify different types of waste. Automated sorting would significantly contribute to recycling efforts and reduce the burden on manual labor.

CHAPTER 5
CONCLUSION

5.1 CONCLUSION

The automated waste management system developed in this project demonstrates a significant advancement in efficient waste disposal and management practices. By integrating an Arduino Uno microcontroller with ultrasonic sensors, servo motors, and a user-friendly interface, the system effectively monitors fill levels and automates the opening of the bin lid, promoting hygiene and convenience for users. The achieved accuracy of ±2 cm in fill-level detection and a rapid response time of 0.5 seconds for the lid mechanism underscore the system's reliability and effectiveness.The use of a 6F22 9V battery as a power supply ensures portability and independence from unreliable grid power, making it particularly suitable for deployment in regions with inconsistent electricity supply. User feedback indicates high satisfaction with the touchless operation, highlighting its potential to improve public health standards in waste management.While the project successfully meets its objectives, there are areas for improvement, including enhancing sensor robustness for outdoor use and exploring renewable energy options to extend battery life. Future iterations could benefit from integrating IoT capabilities for real-time monitoring and data analytics, further optimizing waste collection processes.Overall, this project lays a solid foundation for developing smart waste management solutions that can be adapted to various urban environments, contributing to more sustainable and efficient waste management practices.

5.2 REFERENCES

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APPENDIX META-ANALYSIS TABLE

S/N		YEAR	TITLE	METHODOL	OUTCOME	LIMITATION

	AUTHOR			OGY		
1	Talukdar, A., et al.	2023	Smart Automated Dustbin	Sensor-based automated trash bin	Improved hygiene and efficiency in waste disposal.	High power consumption
2	Desolo, D.	2023	Automated Trash Organizing Management System (A.T.O.M.S)	Self-segregating trash bins with automated sorting	Effective separation of recyclables and non-recyclables.	Does not account for highly mixed waste streams.
3	Wulandari, E. W. V.	2020	Automated Trash Sorting Design Based Microcontroller Arduino Mega 2560	Microcontroller-based system with LCD display and sound	Automated sorting system provides efficiency in waste management.	Complexity in maintenance and potential sensor errors.

4	Masood, M., & Seelam, K.	2022	Automated Marine Trash Collector	Portable sensors and Blender software	Successfully collects trash in small marine environments.	scalability concerns for larger water bodies.

5	Baojun, G., et al.	2022	AI-based Detection System in Trash Sorting Booths	AI, YOLOv4 model, object detection	Efficient monitoring of resident behavior in smart waste management.	Potential privacy concerns and requires significant computing power.
6	M. B., et al.	2023	Automated Sensing Cleaner	Sensor-based system for detecting hazardous materials	Improved waste segregation by detecting contaminated or hazardous waste.	Limited data on long-term performance and potential contamination detection accuracy.
7		2022	Concealed			

	Villamer, E. A., et al.		Automated Trash Bin with Shredder	Trash bin with shredder	Reduces waste volume by shredding solid waste, improving storage.	Maintenance complexity due to mechanical shredding component.
8	Wardana, J. A., et al.	2022	Smart Trash Cans for Waste Management Using NodeMCU	IoT-enabled trash can with ultrasonic sensors	Efficient volume measurement and waste management using real-time data.	Dependent on reliable network connectivity and power supply.
9	Haryanto, T. D., & Santosa, Y. P.	2024	Fuzzy Logic Controller for Capacity Monitoring	Fuzzy logic, ultrasonic and HX711 sensors	Accurately monitors trash bin capacity based on height and weight.	Complexity of system integration and higher implementation costs.