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BIOMEDICAL WASTE SEPARATOR

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Abstract
The challenge of waste segregation is a significant issue commonly encountered in healthcare settings. At times, even medical professionals may face difficulties in accurately segregating waste, leading to the inadvertent mixing of biodegradable and non-biodegradable materials. Improper segregation complicates the waste degradation process and poses potential environmental hazards. This issue is especially critical in medical waste management, where waste is typically categorized into five main types: biodegradable, non-biodegradable, metallic, plastic, and glass.
The distinction between biodegradable and non-biodegradable waste is achieved through a moisture analysis technique using a **moisture sensor** to detect biodegradable, blood-soiled, or wet materials. Metallic and glass waste types are identified using a combination of **proximity sensors** and **infrared (IR) sensing technologies**. The implementation of this automated segregation system significantly enhances the efficiency of medical waste management by minimizing contamination risks and safeguarding public health.
Keywords— waste segregation, moist sensor, metal detection, IR sensor, microcontroller, proximity sensor

I. Introduction

The management of medical waste is a critical component of healthcare infrastructure, focusing on the proper and safe handling and disposal of waste generated from medical activities. **Biomedical waste**, also known as **healthcare waste**, includes a variety of materials produced in healthcare settings such as hospitals, clinics, laboratories, and research facilities. These materials range from sharp objects like needles and scalpels to biological waste such as tissues and blood, as well as pharmaceuticals, chemicals, and even radioactive substances.

Proper management of biomedical waste is vital due to the potential risks it poses to public health and the environment. Inadequate handling, storage, or disposal of such waste can lead to the spread of infectious diseases, contamination of water sources, and harm to ecosystems. Furthermore, exposure to biomedical waste endangers healthcare workers, waste handlers, and the general population.

Efficient biomedical waste management involves a comprehensive process encompassing segregation, collection, transportation, treatment, and disposal. Adherence to strict regulations and guidelines established by health authorities and environmental agencies is essential to ensure public and environmental safety. Improper segregation of biomedical waste can result in the mixing of infectious and non-infectious materials, increasing the risk of infection. According to the **World Health Organization (WHO)**, approximately **15% of healthcare waste** is hazardous, including infectious materials such as bodily fluids, tissues, and blood.

II. Motivation

The advent of automation and IoT-based applications is transforming industries worldwide, including the healthcare sector. IoT-based products are gaining popularity due to their compactness, portability, and user-friendly nature. Biomedical waste management, a critical aspect of healthcare, requires innovative solutions to mitigate its environmental impact. Improper handling of biomedical waste poses severe threats to ecosystems, water supplies, and air quality, highlighting the urgency for an effective waste segregation system.

An efficient **automated segregation system** can significantly reduce environmental pollution by addressing the adverse effects of improper waste disposal. Biomedical waste often contains chemicals, medications, and other hazardous materials that can contaminate the environment, including water and air, if not properly segregated and disposed of. A study published in the *Journal of Environmental Management* emphasizes the risks of poor biomedical waste disposal, citing its potential to endanger human health and ecosystems through groundwater contamination.

To address these challenges, a waste separator system is an ideal solution. The proposed IoT-based system utilizes multiple sensors, including:

- **Moisture Sensor**: To detect wet and biodegradable waste.
- **Proximity Sensor**: To identify metallic and glass materials.
- **Infrared (IR) Sensor**: To aid in precise waste classification.

These sensors are integrated with a **microcontroller**, such as the **Arduino Uno**, which serves as the central processing unit of the automated segregation system. The system detects and classifies waste items, segregating them into appropriate bins based on their classification. Additionally, the system incorporates safety features such as:

- **Malfunction Detection**: To ensure consistent performance.
- **Bin Overflow Alerts**: To prevent overloading and maintain reliability.

This IoT-based biomedical waste separator is a step toward safer, smarter, and more sustainable waste management practices.

III. Objectives

The **Internet of Things (IoT)** is revolutionizing industries with its wide range of applications, including innovative solutions for challenges in the healthcare sector. By integrating sensor modules and microcontrollers, IoT provides effective tools for addressing biomedical waste management issues.

The primary objective of this project is to enhance waste segregation by accurately identifying and categorizing various types of waste, including **metallic, plastic, glass, biodegradable, and non-biodegradable materials**. Specifically, the project aims to implement an advanced system with the following goals:

1. **Accurate Waste Classification**: Utilize **moisture analysis techniques** to separate biodegradable waste, such as wet materials and blood-soiled cotton, from non-biodegradable components.
2. **Effective Detection of Glass and Metallic Waste**: Integrate **metal detection** and **infrared (IR) technology** for precise identification of glass and metallic materials.
3. **Smart Waste Segregation at Disposal**: Employ cutting-edge technologies controlled by a **microcontroller** (e.g., Arduino Uno) to ensure that waste is correctly categorized at the point of disposal.
4. **Automated Waste Handling**: Design the system to sense the type of waste material and direct it to the appropriate container, ensuring efficiency and accuracy in waste management.

This project seeks to create a smart and sustainable solution for biomedical waste segregation, minimizing environmental risks and optimizing healthcare waste management practices.

IV. Social Relevance of the Project

Inadequate waste segregation poses a significant threat to the environment, ecosystems, and public health. Improper management of biomedical waste can lead to the contamination of water sources, exposure to hazardous materials, and the spread of infectious diseases. These risks underscore the urgent need for effective waste segregation and disposal systems.

The proposed **automated waste segregation system** directly addresses these challenges by:

1. **Protecting Public Health and Safety**: The system minimizes infection risks and safety hazards for medical professionals, waste handlers, and the community. By effectively segregating hazardous materials, it reduces the likelihood of exposure to dangerous substances and infectious agents.

2. **Reducing Environmental Impact**: The system decreases healthcare entities' contributions to environmental pollution. By ensuring proper waste classification and disposal, it helps prevent contamination of water, air, and soil, safeguarding ecosystems and natural resources.
3. **Improving Operational Efficiency**: Automating waste segregation reduces labor costs, streamlines operations, and lowers the risk of errors associated with manual sorting. This enhances overall efficiency and reliability in waste management.
4. **Optimizing Resource Allocation**: By automating the waste segregation process, healthcare facilities can allocate their resources more effectively. This allows them to focus on providing high-quality care to patients while ensuring compliance with environmental regulations and best practices.

The project contributes to creating a sustainable and safer healthcare environment, aligning with the goals of protecting public health, preserving ecosystems, and promoting efficient waste management practices.

V. Literature Survey

1. Anh H. Vo, Le Hoang Son, Minh Thanh Vo, and Tuong Le (2019)
   This study highlights the need for automatic smart waste sorting machines in today's densely populated society. It proposes a deep neural network model (DNN-TC) for classifying trash from images. The model is designed to integrate with sensors in waste sorting machines. Trained and tested on the VN-trash and Trashnet datasets, the model achieved accuracy rates of 98% and 94%, respectively, outperforming existing methods. This demonstrates the potential for machine learning to enhance waste segregation systems.
2. M. Hu, C. Yang, Y. Zheng, X. Wang, L. He, and F. Ren (2019)
   This research addresses the growing waste problem due to population increases and urbanization, which often leads to unhygienic environments in cities. The authors introduce an Automatic Waste Segregator that categorizes waste into wet, dry, and metallic types using sensors. This system reduces the reliance on manual workers, minimizes health risks, and increases efficiency in waste management. Additionally, the system is cost-effective and regularly updates waste disposal data on a server for effective management.
3. Miko Pamintuan, Shiela Mae Mantiquilla, Hillary Reyes, Mary Jane Samonte (2020)
   This work discusses the environmental hazards posed by a growing population and waste accumulation. Using IoT technology, the project creates an automated waste segregation system with sensors integrated into trash bins for intelligent sorting and monitoring. Employing image recognition and machine learning, over 2000 samples were trained to classify biodegradable and non-biodegradable waste, resulting in an efficient prototype for trash classification. This innovation provides a promising solution to address the escalating waste management challenge.
4. S. Murugaanandam, V. Ganapathy, R. Balaji (2018)
   This study focuses on improving household waste management through smart city initiatives. It emphasizes the significance of outdoor dustbin monitoring to maintain cleanliness. The proposed system integrates IoT technology with sensors, detectors, and actuators for intelligent waste management. It suggests implementing an alert-based smart bin system to notify authorities for timely waste collection, aiming to improve waste management services and maintain cleanliness in urban areas.
5. Himani S. Bansod, Prasad Deshmukh (2023)
   This study highlights the importance of proper biomedical waste (BMW) management in healthcare facilities due to its infectious and hazardous nature. It outlines the categories of BMW and references India's Biomedical Waste Management Rules, 2016, which provide guidelines for handling,

transportation, and disposal. The study emphasizes improving waste segregation and treatment to reduce environmental pollution, advocating for collective efforts, government support, and continuous monitoring to achieve effective BMW disposal and a cleaner environment.

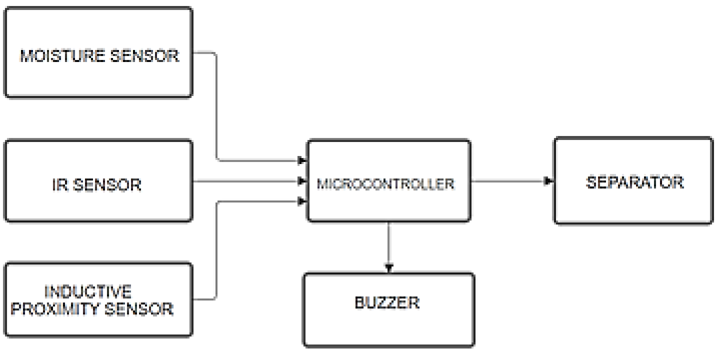
6. Asfa Hussain, Yusra Shah, Pradyumna Raval, and Nicholas Deroeck (2020)
7. This study focuses on the safe disposal of sharps in a 730-bed UK hospital to prevent needle-stick injuries and blood-borne disease transmission. An initial audit in November 2019 found that 56% of sharps containers were overfilled, indicating non-compliance with disposal protocols. Following awareness efforts and a re-audit during the COVID-19 pandemic in July 2020, the percentage of overfilled containers decreased to 17%, improving overall compliance from 44% to 82.64%. The research highlights the importance of regular audits and awareness campaigns for enhancing sharps management and reducing health risks.
8. Himani S. Bansod, Prasad Deshmukh (2023)
9. This paper underscores the critical role of waste segregation in achieving Reuse, Recycling, and Recovery (RRR) objectives. It explores challenges faced by developing countries like Tanzania, such as limited awareness, weak regulatory frameworks, and insufficient economic incentives. A study conducted in the Kimara ward, Dar es Salaam, observed informal reuse and recycling practices, hindered by inadequate facilities and enforcement. Community suggestions included better infrastructure and financial incentives. The paper recommends formalizing RRR policies and strengthening enforcement mechanisms to enhance waste management systems.
10. Household Interventions for Waste Segregation (2020)
    This systematic review examines the effectiveness of household interventions in promoting waste segregation at the source. While these interventions are time-intensive, they are critical for sustainable waste management and environmental conservation. The study emphasizes the need for understanding behavioral impacts and the efficiency of such initiatives to encourage consistent segregation practices and support long-term environmental goals.
9. Household Solid Waste Management in East Coast Malaysia
    This study investigates household solid waste management practices and the associated perceptions of residents in the East Coast of Malaysia. It highlights the risks posed by manual waste separation, which can lead to infections and discomfort among residents. The research sheds light on the challenges faced by households in effectively managing solid waste, emphasizing the need for improved waste segregation practices and systems to mitigate health risks and enhance community well-being.
10. Deep Learning for Waste Segregation
    This research explores the application of deep learning techniques in garbage waste segregation, with a specific focus on shape-based classification methods. By utilizing advanced algorithms, the study aims to improve the accuracy and efficiency of waste segregation processes. The findings indicate the potential of deep learning to revolutionize waste management practices, paving the way for more automated and precise solutions.

Visual Representation:

A conceptual visualization of a **smart waste segregation system** using sensors and deep learning techniques in a residential environment. The image shows automated bins with embedded technology and visual indicators for biodegradable and non-biodegradable waste. Nearby, residents are depicted engaging with the system in a clean, organized setting.

VI. SYSTEM DESIGN

The microcontroller-based waste separator is distinct from traditional or conventional methods, specifically designed to handle the separation of biomedical waste. This introduces unique challenges in achieving the desired outcomes and performance, especially through the use of IoT. The Internet of Things (IoT) is a network of interconnected devices, such as sensors, detectors, monitors, and microcontrollers, collectively referred to as embedded systems. This system incorporates components like the Arduino UNO microcontroller, moisture sensor, IR sensor, and proximity sensor. These sensors facilitate the separation of objects, directing them into designated trash bins.



Traditional waste classification methods employed in many waste management processes today are labor-intensive, error-prone, and inefficient. Hospitals relying on these conventional procedures fail to optimize resource utilization and cost efficiency while exposing healthcare personnel to hazardous risks.
Improper segregation often leads to cross-contamination between various waste streams, complicating recycling and proper waste disposal. For instance, mixing recyclable materials with infectious waste can render the entire waste stream non-recyclable, significantly increasing the volume of waste requiring disposal.

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Proper segregation of biomedical waste is crucial to safeguard waste handlers and healthcare personnel from hazardous materials. Careless handling of dangerous chemicals, medications, and sharp objects such as scalpels and needles can result in infections, injuries, and other serious health risks.

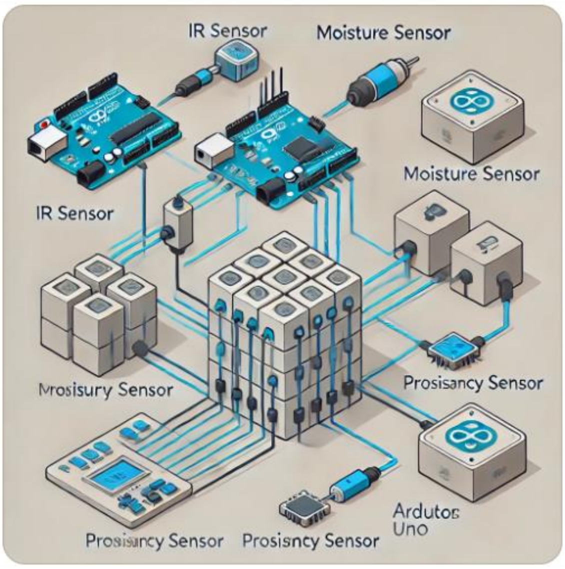
Proposed System

In our project, a **waste separator** is designed using multiple sensors such as **IR Sensor**, **Proximity Sensor**, and **Moisture Sensor**. The system focuses on **medical waste management**, categorizing garbage into five types: **biodegradable, non-biodegradable, metallic, plastic, and glass**.

1. **Moisture Analysis**:
   - A **Moisture Sensor** is employed to differentiate between biodegradable and non-biodegradable trash, distinguishing materials such as wet waste and cotton.
2. **Metallic and Glass Waste Identification**:
   - A combination of **Proximity Sensor** and **Infrared (IR) Sensor** technology is used to identify metallic and glass waste.
3. **Integration with Arduino UNO**:
   - These sensing components are connected to an **Arduino Uno Microcontroller**, which processes the sensor inputs and controls the waste segregation process.
4. **Mechanized Bin Separation**:
   - The system includes a second layer that tilts to direct the identified waste material into the appropriate bin based on the sensed substance.

VII. BLOCK DIAGRAM

The block diagram showcases the interconnected components, including sensors (IR Sensor, Moisture Sensor, and Proximity Sensor), the Arduino Uno microcontroller, and the actuators responsible for bin separation.



VIII. EXISTING METHODS

1. **Deep Learning**:
   - The proposed system aims to resolve trash segregation challenges in India by eliminating human intervention while increasing efficiency.

- It involves the development of an **image classifier** using **Convolutional Neural Networks (CNN)** such as:
    - **ResNet50**
    - **DenseNet169**
    - **VGG16**
    - **AlexNet**
- These CNN models, pre-trained on **ImageNet**, extract features from images to accurately classify waste products, thereby enhancing the recycling process's effectiveness.

2. **Manual Separation**:
    - Manual separation of biomedical waste is a physical sorting process performed by workers, usually in healthcare facilities.
    - Workers manually sort different types of biomedical waste into designated containers, such as:
        - Sharps
        - Infectious waste
        - Pathological waste
        - Pharmaceutical waste
        - Non-hazardous trash
    - **Challenges**:
        - Careful handling is required to prevent exposure to hazardous materials and cross-contamination.
        - The process is labor-intensive and time-consuming.
        - Susceptibility to human error may result in improper segregation, causing health and environmental hazards.
    - **Automated Solutions**:
        - Automated systems provide a safer and more efficient alternative, reducing the risks associated with manual separation.

Hardware Components

1. Arduino Uno Microcontroller

- **Microcontroller Chip**: ATmega328p
- **Key Features**:
    - 14 digital I/O pins (6 PWM outputs)
    - 6 analog input pins
    - Clock speed: 16 MHz
    - Flash memory: 32 KB (0.5 KB used by bootloader)
    - SRAM: 2 KB; EEPROM: 1 KB
    - Operating voltage: 5V
    - Input voltage (recommended): 7-12V
    - On-board LEDs (Pin 13) for debugging
- **Power Options**:
    - USB connection (from PC or system)
    - External power source (via VIN pin)
- **Additional Components**:
    - USB connector, power jack, and reset button
    - Built-in voltage regulators (5V and 3.3V)

2. Sensors for Waste Detection

- **IR Sensor**:
  - Used for detecting the presence of objects based on infrared radiation.
- **Moisture Sensor**:
  - Identifies wet garbage by measuring moisture levels in waste.
- **Proximity Sensor**:
  - Detects the type of material, such as metal or glassware, based on proximity.

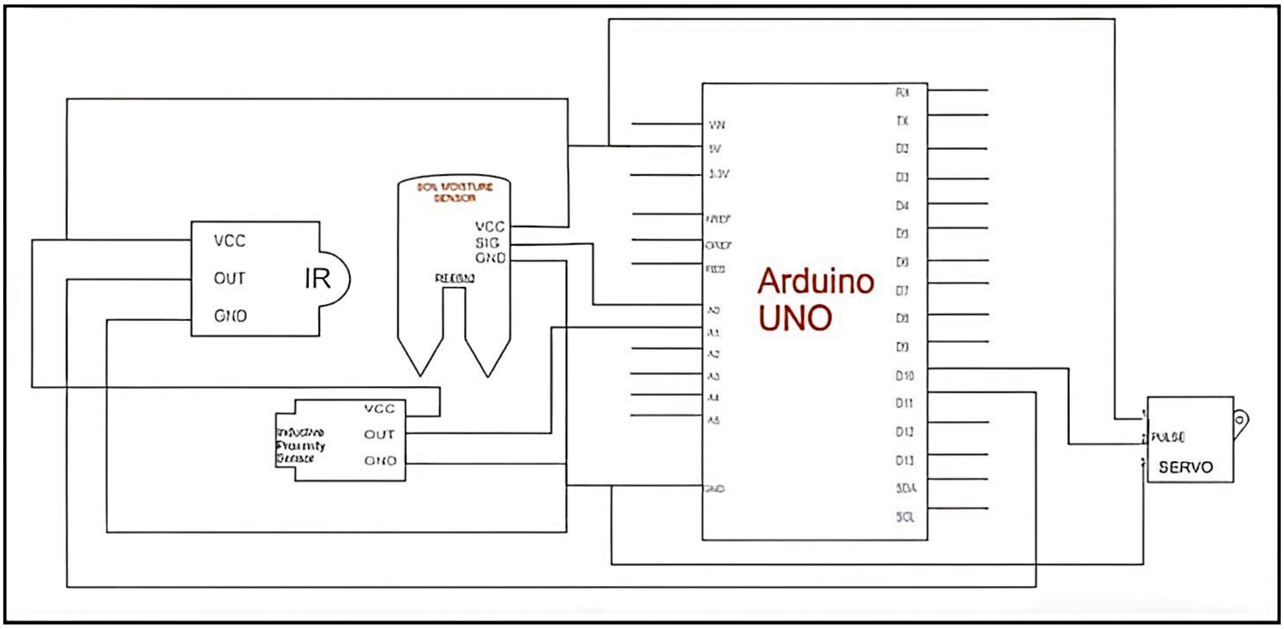
3. Actuators

- **Servo Motors**:
  - Responsible for tilting and directing the second layer of the mechanism to the appropriate bin based on sensor input.
  - Precise angular movements enable accurate separation of waste.

4. Waste Segregation Mechanism

- **Second Layer Movement**:
  - Controlled by servo motors.
  - Sensors detect the type of waste, triggering the mechanism to tilt the layer and drop waste into the correct bin (e.g., metal, glassware, fluids, wet garbage).

X CIRCUIT DIAGRAM



System Analysis for the Waste Separator Project

System analysis in this project focuses on understanding and optimizing the waste management process to ensure efficient segregation of medical waste into predefined categories. Below is a structured analysis:

Objective

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The main goal of the system is to automate medical waste segregation into five types: biodegradable, non-biodegradable, metallic, plastic, and glass. The system aims to enhance accuracy, reduce manual labor, and support environmental sustainability.

Key Components of System Analysis

1. Problem Identification

- **Issues**:
  - Inefficiency and inaccuracies in manual waste segregation.
  - Potential hazards due to improper handling of medical waste.
  - Environmental harm from poor waste disposal practices.
- **Goals**:
  - Develop an automated, reliable system for medical waste classification.
  - Ensure safety and compliance with environmental standards.
  - Minimize human intervention while maximizing precision.

2. System Breakdown

- **Input Components**:
  - **IR Sensor**: Detects the presence and type of material.
  - **Proximity Sensor**: Identifies specific materials (e.g., metallic objects).
  - **Moisture Sensor**: Analyzes moisture levels to classify waste as wet, cotton, or biodegradable.
- **Processing Unit**:
  - **Arduino Uno Microcontroller**: Serves as the brain of the system, processing data from sensors and issuing commands to actuators.
- **Output Components**:
  - **Servo Motors**: Actuates the second layer for bin separation.
  - **Binning Mechanism**: Physical redirection of waste into designated bins.
- **System Integration**:
  - Real-time data collection from sensors.
  - Signal processing and decision-making by the Arduino Uno.
  - Mechanical execution of waste sorting through servo motors.

3. Operational Workflow

1. **Waste Detection**:
   - Sensors identify the type of waste (biodegradable, plastic, metal, glass, or wet).
   - IR sensor detects material composition, while proximity and moisture sensors refine classification.
2. **Data Processing**:
   - Sensor data is transmitted to the Arduino Uno microcontroller.
   - The system categorizes waste based on predefined thresholds and logic.
3. **Waste Segregation**:
   - Arduino signals the servo motors to tilt the second layer to the appropriate bin.
   - Bins are arranged to collect specific waste types as per classification.

4. Performance Metrics

- **Accuracy**:
  - High precision in waste categorization due to sensor integration.
- **Speed**:
  - Faster waste segregation compared to manual methods.

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- **Sustainability**:
  - Reduced environmental harm through accurate waste disposal.

XII. Results and Discussion

The implementation of the advanced automated waste segregation system has proven effective in revolutionizing medical waste management. The results highlight its ability to accurately identify and categorize waste materials, improving the overall segregation process. Below is a detailed discussion of the outcomes:

Key Outcomes

1. Enhanced Waste Management

- **Accurate Categorization**: The system efficiently classifies waste into biodegradable, non-biodegradable, metallic, plastic, and glass categories.
- **Moisture-Based Differentiation**: High precision in distinguishing between biodegradable, cotton, and wet waste through moisture sensors.
- **Sensor Integration**: IR and proximity sensors ensure reliable detection of metallic and glass waste.

2. Mitigating Risks

- **Reduced Contamination**: Proper segregation minimizes the inadvertent mixing of waste types, lowering contamination risks.
- **Improved Public Health**: Accurate disposal reduces hazards associated with improper waste management.

3. Operational Efficiency

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- **Dynamic Tilting Mechanism**: The second layer's automated movement ensures waste is directed to the correct bins seamlessly.
- **Sensor Monitoring and Alerts**: Warning systems for sensor malfunctions and bin capacity alerts enhance user safety and system reliability.
- **Speed and Accuracy**: Automated operations surpass manual methods in both efficiency and precision.

4. Environmental Impact

- **Sustainability**: Proper segregation supports recycling efforts and reduces environmental harm.
- **Waste Reduction**: Prevents unnecessary landfill use by ensuring correct disposal.

Discussion

The integration of cutting-edge sensor technology and a microcontroller has set a new standard for waste management in healthcare settings. The system’s ability to operate autonomously while maintaining high accuracy levels addresses the critical need for efficient waste segregation. Moreover, the inclusion of real-time alerts not only ensures smooth operations but also provides a fail-safe mechanism to address potential issues. By aligning with sustainable waste management practices, the system contributes to environmental preservation and demonstrates the potential for broader applications in other waste-intensive industries.

XIII. Conclusions

The automated waste segregation system exemplifies innovation in medical waste management, offering substantial benefits in accuracy, efficiency, and environmental sustainability. Key conclusions include:

1. **Efficient Categorization**:
    - Accurately classifies medical waste into five categories: biodegradable, non-biodegradable, metallic, plastic, and glass.
    - Moisture sensors provide precise differentiation of biodegradable and wet waste.
2. **Technological Advancements**:
    - Proximity and IR sensors enable accurate identification of metallic and glass waste.
    - The Arduino Uno microcontroller ensures seamless coordination of sensor data and mechanical operations.
3. **Operational Excellence**:
    - Dynamic tilting of the second layer optimizes waste disposal into designated bins.
    - Sensor warnings and full-capacity alerts improve safety and operational reliability.
4. **Environmental and Public Health Benefits**:
    - Reduces contamination risks and safeguards public health.
    - Supports environmental sustainability by ensuring proper segregation and disposal.

This innovative system serves as a model for advanced waste management practices, promoting a cleaner, safer, and more sustainable healthcare environment. It paves the way for further enhancements and adaptations across various sectors in need of efficient waste handling solutions.

REFERENCES

[1]. T. Vo, T. Nguyen, and C. T. Le, "Race recognition using deep convolutional neural networks," *Symmetry*, vol. 10, no. 11, p. 564, 2018.

[2]. T. Vo, T. Nguyen, and C. T. Le, "A hybrid framework for smile detection in class imbalance scenarios," *Neural Comput. Appl.*, vol. 31, no. 12, pp. 8583–8592, 2019.

[3]. M. Hu, C. Yang, Y. Zheng, X. Wang, L. He, and F. Ren, "Facial expression recognition based on fusion features of center-symmetric local signal magnitude pattern," *IEEE Access*, vol. 7, pp. 118435–118445, 2019.
[4]. U. R. Acharya, H. Fujita, S. L. Oh, Y. Hagiwara, J. H. Tan, and M. Adam, "Application of deep convolutional neural network for automated detection of myocardial infarction using ECG signals," *Inf. Sci.*, vol. 415, pp. 190–198, Nov. 2017.
[5]. X. Meng, Z. Wen, and Y. Qian, "Multi-agent based simulation for household solid waste recycling behavior," *Resources, Conservation and Recycling*, vol. 128, pp. 535–545, 2018.
[6]. Archer, D.B. and Kirsop, B.H., *The Microbiology and Control of Anaerobic Digestion*, in *Anaerobic Digestion: A Waste Treatment Technology*, A. Wheatley (Ed.), Elsevier Applied Science, Oxford, 2018.
[7]. Barres, M., Grenet, Y., Millot, N., and Meisel, A., "Sanitary landfilling in France," in *International Perspectives on Municipal Solid Wastes and Sanitary Landfilling*, J.S. Carra and R. Cossu (Eds.), Academic Press, London, pp. 78–93, 2016.
[8]. Biala, J., "Economic implications of separate collection and treatment of organic waste materials," *Waste Disposal and Water Management in Australia*, March/April, pp. 10–25, 2018.
[9]. Corbitt, R.A., *Standard Handbook of Environmental Engineering*, 2nd ed., McGraw-Hill, New York, 2017.
[10]. Elmiyeh B., Whitaker IS, James MJ, Chahal CA, Galea A, and Alshafi K., "Needle-stick injuries in the National Health Service: a culture of silence," *J R Soc Med.*, vol. 97, no. 7, pp. 326–327, 2023.
[11]. Blenkharn JI., "Sharps management and the disposal of clinical waste," *Br J Nurs.*, vol. 18, no. 14, pp. 860–864, 2019.
[12]. L. J. V. Escobar and S. A. Salinas, "e-Health prototype system for cardiac telemonitoring," *2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 2016.
[13]. P. Bhadani and V. Vashisht, "Soil Moisture, Temperature and Humidity Measurement Using Arduino," *2019 9th International Conference on Cloud Computing, Data Science & Engineering (Confluence)*, 2019.
[14]. M. S. Chaudhari, B. S. Patil, and V. S. Raut, "IoT based Waste Collection Management System for Smart Cities: An Overview," *2019 3rd International Conference on Computing Methodologies and Communication (ICCMC)*, pp. 802–804, 2019.
[15]. M. R. D. Bondad, J. M. S. Borcer, K. V. C. Lopez, and R. B. Aguilar, "Auto-Bin: Automatic Lid Opening Trash Bin with Content Monitor."
[16]. V. R. K. R. Galarpe, "Review on the Impacts of Waste Disposal Sites in the Philippines," *Science International*, pp. 379–385, Mar. 2017.