**Standard format for a research proposal when applying for funding.**

**1. Cover Page**

* **Title of the Research Project:** Automated Paper and Plastic Sorting system using Computer Vision.
* **Principal Investigator(s):** Department of Information Technology
* **Institution or Organization:** Ramrao Adik Institute of Technology, D Y Patil Deemed to be University
* **Funding Agency:**
* **Date of Submission:** 3rd March 2025

**2. Abstract (Executive Summary)**

This project addresses the urgent need for efficient and accurate recycling solutions by introducing an automated system that classifies and sorts paper and plastic waste. Manual sorting is often labor-intensive, error-prone, and can lead to cross-contamination, thus undermining recycling outcomes. In response, this initiative leverages advanced sensing technologies and a robust control architecture to enable real-time material identification and coordinated mechanical actuation. A network of sensors detects incoming waste, while an intelligent mechanism directs each item into the correct bin. Strategic lighting methods further enhance detection reliability, and a dynamically controlled entrance flap modulates the flow of materials.

Key objectives of this project include reducing contamination rates, optimizing operational efficiency, and advancing sustainable waste management practices. By integrating state-of-the-art detection algorithms with carefully designed hardware components, the solution demonstrates a high degree of accuracy and scalability, suitable for both residential and large-scale industrial applications. Funding this research will expedite the development of a system that not only promotes environmental stewardship but also delivers significant return on investment by streamlining the entire recycling process.

**3. Introduction**

* **Background and Context**:

With the growing emphasis on sustainability and responsible waste management, institutions such as corporate offices and colleges generate significant amounts of recyclable waste, particularly paper and plastic. Despite existing waste segregation policies, manual sorting remains inefficient, leading to misclassification, cross-contamination, and reduced recycling effectiveness. Many organizations struggle to implement effective recycling programs due to the lack of automated solutions tailored to institutional settings.

Traditional waste sorting methods require human intervention, which is labor-intensive, prone to errors, and inconsistent. While industrial-scale recycling facilities have adopted automation, there is a gap in affordable and scalable solutions designed specifically for institutions like offices and academic campuses. Addressing this issue requires an intelligent, automated system that can efficiently sort paper and plastic waste at the point of disposal, ensuring higher-quality recycling and reducing waste management costs.

* **Research Problem**:

Corporate offices and colleges generate large amounts of **paper and plastic waste,** but existing waste sorting methods are **inefficient, error-prone, and reliant on manual effort**, leading to **contamination and reduced recycling effectiveness.** Current automated sorting solutions are **designed for industrial-scale operations and are too costly or complex for institutional use.** This research aims to **develop an affordable, AI-powered automated sorting system** that can efficiently classify and separate **paper and plastic waste** at the point of disposal, improving recycling efficiency and sustainability in institutional environments.

* **Purpose of the Study**:

The primary goal of this research is to develop an AI-powered automated waste sorting system specifically for corporate offices and college campuses. The system will leverage computer vision and sensor technology to accurately classify and separate paper and plastic waste at the point of disposal, eliminating manual sorting errors and improving recycling efficiency. This project aims to create a cost-effective, scalable, and easy-to-deploy solution that enhances institutional waste management practices.

* Improved Recycling Efficiency – By accurately sorting paper and plastic waste, the system reduces contamination, ensuring higher-quality recyclable materials.
* Reduced Manual Effort – Automation eliminates the need for manual sorting, making recycling more efficient and less labor-intensive.
* Cost-Effective Waste Management – Institutions can lower operational costs by reducing reliance on labor-intensive sorting processes.
* Environmental Sustainability – By increasing recycling rates and reducing improper waste disposal, the project contributes to institutional sustainability goals.
* Scalability and Practical Implementation – The system is designed to be compact, affordable, and adaptable to various institutional settings, ensuring easy deployment and widespread adoption.
* **Literature Review**:

Effective waste sorting and recycling play a crucial role in promoting environmental sustainability. While automated waste classification has been extensively studied and applied in industrial-scale recycling facilities, the development of cost-effective and compact solutions tailored for corporate offices and college campuses remains an underexplored area. Research in artificial intelligence (AI) and sensor-based waste sorting has demonstrated significant progress in improving the accuracy of material classification, but existing solutions are often cost-prohibitive, computationally intensive, or impractical for institutional settings. This study builds upon previous research in computer vision, sensor-assisted waste detection, and mechanical sorting to design a scalable, affordable, and efficient waste sorting system specifically for institutions.

One of the most extensively studied areas in waste automation is computer vision-based classification. Research has shown that deep learning models, particularly convolutional neural networks (CNNs), are highly effective in identifying different waste materials. Studies by Zhang et al. (2022) highlight that AI-based image processing can distinguish between recyclables with high accuracy, yet the performance of these models is often influenced by lighting conditions, object occlusion, and variations in material appearance. Traditional machine learning methods require large labeled datasets and substantial computational resources, making them challenging to implement in real-time, small-scale sorting applications. To address these challenges, researchers have suggested integrating AI models with optimized lighting conditions and preprocessing techniques to improve detection accuracy in dynamic environments (Li et al., 2021). This study builds upon these findings by developing an optimized classification system that balances accuracy and computational efficiency, ensuring real-time processing in institutional waste sorting applications.

Beyond AI-driven classification, sensor-assisted detection technologies have been widely explored as a means to improve waste recognition beyond visual analysis. Several studies have demonstrated that ultrasonic sensors, infrared detectors, and hyperspectral imaging can enhance waste sorting accuracy by detecting material properties such as density, reflectivity, and composition (Singh & Patel, 2020). Industrial waste sorting plants often rely on infrared sensors to differentiate between plastic types based on their spectral signatures, but these technologies are too expensive and complex for deployment in non-industrial settings. A more practical approach for institutional environments is the integration of ultrasonic and optical sensors to detect waste presence, trigger sorting mechanisms, and complement computer vision-based classification. This study contributes to the field by developing a hybrid system that merges sensor data with AI-based image recognition, enhancing the reliability and adaptability of automated waste sorting in offices and colleges.

Another important aspect of automated waste sorting is the mechanical actuation of the sorting process. Industrial-scale recycling plants typically employ conveyor belts, robotic arms, or pneumatic separation systems, which are effective in high-volume processing but require specialized infrastructure, high maintenance, and significant financial investment (Chen et al., 2020). For smaller-scale applications, research suggests that stepper motors, servo mechanisms, and rotary sorting disks can provide a more practical and cost-efficient alternative for waste segregation (Yuan et al., 2021). This study builds upon these insights by implementing a semi-circular rotating disk mechanism that directs waste into designated bins based on classification results, ensuring a space-saving and energy-efficient sorting process suitable for institutional settings.

Despite the advancements in AI-based classification, sensor-driven detection, and mechanical sorting mechanisms, there remains a significant gap in solutions specifically designed for corporate and academic institutions. Many existing automated waste sorting systems are either too expensive, too complex, or designed primarily for large-scale industrial recycling, making them unsuitable for small-scale institutional waste disposal. While some research has explored smart waste bins and AI-based classification models, few studies have successfully integrated these technologies into a complete, self-contained sorting system that is practical for institutional use.

This study contributes to closing this gap by developing a compact, AI-powered waste sorting system tailored for offices and colleges. By combining computer vision, sensor-based detection, and a low-cost mechanical sorting mechanism, this research aims to provide a scalable, affordable, and efficient solution that institutions can implement with minimal infrastructure modifications. Unlike large-scale industrial systems, the proposed solution focuses on real-time, point-of-disposal sorting, reducing contamination in recycling streams and improving waste management efficiency within institutional environments. By bridging the gap between large-scale industrial automation and small-scale institutional needs, this study offers a practical, scalable, and cost-efficient waste sorting solution that can significantly enhance sustainability efforts and recycling practices in corporate offices and educational institutions.

**4. Research Objectives and Hypotheses**

* **Objectives**:

1. To design and implement an AI-based classification system that accurately distinguishes between paper and plastic waste in real-time.
2. To integrate sensor-based detection mechanisms (such as ultrasonic and optical sensors) to enhance classification reliability and automate the sorting process.
3. To develop an automated mechanical sorting system that efficiently directs classified waste into the appropriate bins with minimal human intervention.
4. To evaluate the system’s classification accuracy, sorting speed, and reliability in real-world institutional environments.
5. To assess the cost-effectiveness, scalability, and practical feasibility of the system for deployment in corporate offices and college campuses.
6. To promote sustainable waste management practices by increasing recycling efficiency and reducing contamination in recyclable materials.

* **Hypotheses**:

1. The AI-based classification model will accurately differentiate between paper and plastic waste with a classification accuracy of at least 90% under controlled lighting conditions.
2. The integration of sensor-based detection will enhance classification reliability by reducing false positive and false negative errors in waste sorting.
3. The automated sorting mechanism will improve efficiency by reducing manual intervention and increasing sorting speed compared to traditional methods.
4. Implementing the system in corporate offices and college campuses will lead to a measurable increase in recycling rates and a reduction in waste contamination.
5. The proposed system will provide a cost-effective and scalable alternative to manual sorting, making it feasible for widespread adoption in institutional environments.

**5. Methodology**

**Research Design**: This study adopts a trial-and-error experimental approach, where the prototype and hardware components are developed before collecting the dataset and training the AI model. This iterative process ensures that the system’s mechanical and sensor-based functionalities are optimized before integrating AI-driven classification. The research follows a build-test-improve cycle, where findings from each stage guide refinements in the next.

**Data Collection Methods**: Collecting a dataset of waste images, specifically focusing on paper and plastic items. These images will be captured using the installed camera under controlled conditions to ensure consistency in lighting, angle, and object positioning. The collected dataset will then undergo preprocessing techniques such as noise reduction, contrast enhancement, and data augmentation to improve the robustness of the AI model and enhance classification accuracy. After preprocessing, a deep learning model based on convolutional neural networks (CNNs) will be trained to distinguish between paper and plastic waste in real-time. The model will be evaluated using standard performance metrics such as accuracy, precision, recall, and F1-score to determine its effectiveness in classification. Once the AI model achieves satisfactory performance in a controlled environment, it will be integrated into the prototype and tested under real-world conditions to assess its adaptability and accuracy in institutional waste disposal scenarios. This final testing phase will help validate the system's classification performance, ensure seamless integration with the hardware components, and refine any remaining limitations before deployment.

**Sampling and Participants**: Since this study is focused on system performance rather than human behavior, there will be no direct human participants. However, waste samples will be collected from corporate offices and college campuses to ensure realistic testing conditions. A diverse set of paper and plastic waste items will be used, including:

* Office waste: Printed paper, notebooks, plastic folders, wrappers.
* College waste: Study materials, packaging, disposable plastic items.
* General institutional waste: Cups, packaging, paper towels.

**Data Analysis**: The mechanical performance analysis of the system will focus on evaluating its sorting efficiency, which will be measured based on key parameters such as sorting time per item, system reliability, and mechanical response time. The responsiveness and accuracy of the sensor components, including ultrasonic and optical sensors, will also be tested under varied lighting conditions and different object orientations to ensure consistent performance in real-world scenarios.

For the AI classification model analysis, the system’s accuracy will be assessed using standard performance metrics, including precision, recall, F1-score, and confusion matrices, to determine its effectiveness in distinguishing between paper and plastic waste. Additionally, an error analysis will be conducted to identify false positives and false negatives, helping refine the model by understanding potential misclassification patterns and optimizing detection reliability.

To further assess the system’s overall effectiveness, a comparative performance assessment will be conducted by benchmarking the automated sorting system against manual sorting methods. The evaluation will focus on efficiency improvements, processing speed, and classification accuracy to quantify the benefits of automation. Furthermore, a cost-benefit analysis will compare manual labour costs with the operational costs of the automated system, determining its economic feasibility and long-term viability for institutional deployment. Data analysis will be carried out using Python-based tools, including TensorFlow and OpenCV for AI model evaluation, and Pandas for statistical analysis, ensuring a comprehensive and data-driven validation of the system’s performance.

**Timeline**:

Table 1: Project Timeline

|  |  |  |
| --- | --- | --- |
| **Stage** | **Task** | **Duration** |
| 1. Hardware & Prototype Development | Build mechanical system, test sensors, optimize sorting mechanism | 30 Days |
| 1. AI Dataset Collection & Training | Collect images of waste, preprocess data, train AI model | 15 Days |
| 1. System Integration & Testing | Deploy AI model into prototype and optimize accuracy | 15 Days |
| 1. Refinement | Final adjustments | 15 Days |
| 1. Documentation | Prepare research report, compile findings, propose deployment plan | 15 Days |
| **TOTAL** |  | **90 Days** |

**6. Expected Results and Impact**

**Expected Outcomes**

This research is expected to result in the successful development of an AI-powered automated waste sorting system tailored for corporate offices and college campuses. The system is anticipated to demonstrate high classification accuracy in distinguishing between paper and plastic waste, with a precision rate of at least 90% under controlled conditions. The sensor-assisted sorting mechanism is expected to enhance reliability and efficiency, reducing errors in waste classification. Additionally, the automated system is likely to outperform manual sorting in terms of speed, consistency, and accuracy, leading to a measurable increase in recycling rates and a reduction in contamination of recyclable materials. Furthermore, the system is expected to be cost-effective and scalable, making it a viable solution for institutional waste management. By integrating machine learning, sensor technology, and mechanical automation, the research aims to develop a low-cost, energy-efficient waste sorting system that can be easily adopted in offices and colleges without the need for significant infrastructure modifications. The research findings will also provide quantitative performance metrics, helping institutions evaluate the feasibility of transitioning to AI-based waste management solutions.

**Impact**

The implementation of this research is expected to have a significant impact on waste management practices in institutional environments. By automating waste sorting at the source, the system can help increase recycling efficiency, reduce the burden on waste collection services, and minimize the amount of recyclable materials that end up in landfills due to misclassification. This project aligns with sustainability goals by promoting better waste segregation habits and reducing the carbon footprint associated with improper waste disposal. From an academic and technological standpoint, this research will contribute to the field by demonstrating the effectiveness of AI-driven waste classification in real-world institutional settings. It will provide valuable insights into the integration of machine learning with low-cost mechanical systems, paving the way for further innovations in smart waste management solutions. Additionally, the findings could inform policy changes by highlighting the economic and environmental benefits of automated waste sorting, potentially influencing institutional recycling policies and sustainability initiatives.

At a societal level, the adoption of such technology in institutions can set a precedent for automated waste sorting in public spaces, encouraging broader implementation in urban settings, schools, and commercial buildings. By making waste segregation more efficient, accessible, and cost-effective, this research has the

potential to enhance waste management strategies, contribute to a circular economy, and support global efforts toward environmental sustainability.

**7. Budget Justification**

|  |  |  |  |
| --- | --- | --- | --- |
| **Category** | **Item Description** | **Quantity** | **Estimated Cost in (INR)** |
| Hardware Components | Stepper Motor (NEMA 17, 4.2kg/cm) | 1 | 940/- |
|  | Servo Motor (SG90 or MG995) | 2 | 400/- |
|  | Ultrasonic Sensor (HC-SR04) | 1 | 70/- |
|  | LED Strip for Illumination – 1m | 1 | 250/- |
|  | Microcontroller -Arduino Uno | 1 | 350/- |
|  | Motor Driver (L298N) | 1 | 400/- |
|  | Power Supply (12V DC, 5A) | 1 | 600/- |
|  | High-Resolution Camera | 1 | 6000/- |
| Waste sample collection | 100 unique samples of each paper and plastic | 200 | 1000/- |
| Mechanical Fabrication & Prototyping | Metal 8 ft X 4ft – 37Kg – 5mm  **OR**  Sun board 8ft X 4ft – 5mm  **OR**  MDF Board 8ft X 4ft – 4mm | 2  **OR**  3  **OR**  3 | 18500/-  OR  1500/-  OR  1400/- |
|  | CNC machining, 3D printing, fabrication | NA | 25,000/- |
| Miscellaneous | Unforeseen expenses, minor repairs, system modifications | NA | 20,000/- |
| Computing Hardware | |  | | --- | | Laptop with GPU Support (for AI model processing)  **OR**  Cloud Computing  Amazon Web Services (AWS) Elastic Compute Cloud (EC2)- NVIDIA V100 GPU |  |  | | --- | |  | | 1  **OR**  Per Month | 1,20,000/-  1,92,300/- |
| **TOTAL** | **Approximate for Cloud Support** |  | **76410/- + Recurring 1,92,300/-(Cloud Expenses for AI training)** |
|  | **Approximate for Laptop with GPU** |  | **1,93,910/-** |

**8. Team and Institutional Support**

* **Principal Investigator and Research Team**:

Dr. Jyoti Kundale – Project Guide

* **Institutional Support**:

The college is equipped with an **AI lab** that utilizes **Intel chips for AI training**, providing the necessary computing resources for model development and optimization.

**9. Ethical Considerations**

* **Ethical Approval**:

This research involves the development and testing of an **AI-powered automated waste sorting system** within an institutional setting. Since the study does not involve human participants directly, traditional ethical concerns such as **informed consent or personal data protection** are minimal. However, institutional approval will be obtained to ensure compliance with **environmental and operational policies.** The AI model will be trained using **waste images collected from institutional waste disposal areas**, ensuring that no **personally identifiable information (PII) or sensitive data** is included in the dataset. Proper waste handling and disposal practices will be followed in accordance with **institutional sustainability guidelines** to minimize environmental impact.

* **Risk Management**:

1. System Malfunctions & Safety Measures
2. AI Model Errors & Bias
3. Environmental Compliance

**10. References**

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