WASTE: **W**aste **A**utomation for **S**orting and **T**rash **E**limination

Blake Godwin Christian Johnson
Ryan Smith Jesse Witt

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Abstract

In this proposal we outline the development of our ideas in relation to a major issue that we are often faced with today. We still live in a society that produces mass amounts of waste and recycling efforts are often futile due to other found ease. We propose a solution aimed at this issue, an autonomous intelligent recycling sorting system. We will discuss in detail the formulation of the ideology behind the technologies relevant to this proposal, as well as some specifics to the system architecture.

Department of Computer Science and Engineering
University of Arkansas – Fort Smith

Contents

1 Introduction

The following sections will provide more information regarding the problem and proposed solution.

1.1 Problem Statement

Large initiatives have been campaigned and carried out globally for recycling to try and combat the mass amounts of waste produced all around the planet every year. According to the Environmental Protection Agency (EPA) in 2018 there were 292.4 million tons of waste produced in the United States with the majority being buried in landfills and just 69 million tons being dealt with through the efforts of recycling [1]. Recycling is often an afterthought or dismissed altogether, and although the percentage of items recycled in the United States is growing, there is only a small acceleration towards a solution to a problem that is proven to be increasing.

Recycling is often seen as an arduous task that is not undertaken lightly by communities in the United States as well as around the globe. Recycling sorting centers to process collected materials are of a great cost to municipalities that operate them. The current accepted solution of implementation is manpower that requires these centers to keep staff of sorters to minimize the amount of non recyclable waste ending up in the recycling bin.

The overall processing of recyclable materials today is highly inefficient in the amount of labor resources required. These inefficiencies not only have great monetary determinants to the operation but also to the future of such programs and to the development of new procedures. There is a great need for optimization in this field, there are countless ways that more efficient and autonomous processes could be implemented to start moving this field into the future and to start building what the future of sustainability truly looks like.

1.2 Objective

At its core, efforts for Recycling solve problems of their own, as we aim to solve issues related to recycling efforts, those efforts aim to keep material out of overflowing landfills, and provide a more sustainable approach to manufacturing. Many areas of modern day commerce and day to day life are dependent on availability of resources and that all comes back to a system of sustainability and reuse of materials.

Our overall goal is to provide a flexible system that could combat this highly prevalent problem that has been presented to you. Our proposal entails an autonomous system for classification of materials as they are carried via a conveyor system in order to sort recyclable materials from the waste that may be thrown in amongst it. This proposed system takes the manpower out of the sorting that happens at recycling centers across the country every day.

We will implement an Artificial Intelligence driven program that is capable of using computer vision to accurately tag items as to their ability to be recycled. The successful development and implementation of this AI sorting system will contribute significantly to achieving waste reduction, promote a sustainable solution for responsible waste management, and overall support the transition towards a more sustainable and environmentally friendly future.

2 Background

The following sections will provide the necessary background and information regarding the technology to be utilized.

2.1 Overview

Our project revolves around the development of a robotic arm that detects an article of trash on a moving conveyor belt, classifies it, picks it up and puts it in the right bin. It is a cheap fusion of hardware and software components designed to autonomously detect, locate, collect, and classify trash items. At its core, the Raspberry Pi serves as the computing powerhouse, enabling onboard object detection and classification.

The mechanical aspects are equally vital, Servo motors offer efficiency and precision in movement, a crucial element when controlling the robotic arm. The HIWONDER AI Vision Robotic Arm 5 allows the robot to pick up the detected trash and place it in the appropriate bin.

Power is provided by a 22.2V LiPo battery, ensuring sufficient energy for the arms operations. On the software front, Apache2 serves as the backend server, React and JavaScript create a user-friendly web interface, while Python, with its numerous libraries, including NumPy and OpenCV, powers the arms decision-making, image processing, and object detection and classification through tensorflow lite which is specifically designed for light hardware boards.

In unison, these components create a cheap and easy to assemble trash picking up robot arm capable of detecting, classifying, and placing trash items in the right bin while being remotely monitored through a user-friendly web interface. The project aims to automate the challenging task of waste management and environmental cleanup in a cheap and autonomous way.

2.2 Technology

Raspberry Pi A Raspberry Pi is a small powerful computer specifically for IOT applications this board will do the computation of the object detection and classification as well as move the robotic arm.

Camera We need a camera for doing object detection and classification. Specifically a Raspberry Pi HQ Camera Module for Raspberry Pi 4 3 Model B, with 12.3MP IMX477 Sensor which is a high quality camera module for raspberry pi.

Motor Drivers It will use ECS's (Electronic Speed Controllers) connected to the raspberry pi to send signals to our motors from our raspberry pi and control their speed thus the direction and speed of the conveyor belt.

Motors It will use stepper motors for the belt, this is for efficiency and precision since the belt will only have a certain amount of battery life to work off.

Arm The arm will be the HIWONDER AI Vision Robotic Arm 5 which has will be connected to the raspberry pi to make it move and grab objects

Conveyor The conveyor belt will either be made using pvc pipe, a stepper motor, some bearings, a frame and a controller or bought.

Power Supply The power supply will be a single 22.2V lipo battery which should give us 20 - 30 minutes of time depending on how much power the model uses.

3D Printer We will need access to a 3D printer for the production of the mount for the camera and arm.

Apache2 is a free open-source web-hosting platform that will run well within the linux server environment that we intend to use.

React is a free and open-source front-end JavaScript library for building user interfaces based on components. It is maintained by Meta and a community of individual developers and companies. React will be implemented for the creation of the interfaces within the website.

Javascript is a programming language that is one of the core technologies of the World Wide Web, alongside HTML and CSS. As of 2023, almost 99 percent of websites use JavaScript on the client side for webpage behavior, often incorporating third-party libraries.

Python this will be our language of choice for the ease and wide variety of libraries that it has including numpy for numerical computations including matrix math. Numpy forms the foundation for many other scientific and data analysis libraries in Python also cv2 (opencv) which provides a range of tools and functions for tasks such as image and video processing, object detection, face recognition, and more it also includes tensorflow lite which we will be using for our object detection tensorflow lite is considered one of the best and most popular object detection algorithms for small board like the jetson nano or raspberry pi.

2.3 Related Work

There have been many projects aimed at solving the issue of waste management and classification. One project that used YOLO and multiple CNN models for their classification was able to achieve a high performing model [2]. This project was able to perform well but it doesn't take into account that the majority of classification of garbage is done via conveyer belts so the arm doesn't have to overcome the issue of the object moving.

Another project that was successful in being able to classify garbage used a different method than YOLO with great success. This project used an SSD(Single shot MultiBox Detector)[3] model in order to be able to create a more realistic map of the garbage that was presented. However, this project also handled the collection via a flat, stationary surface where we plan on implementing a conveyer belt in order to automate more of the process.

3 Design

The following sections will provide information regarding the requirements and analysis of the project.

3.1 Project Requirements

1. Process trash that is fed via a conveyor belt.
2. Detect individual items of garbage independently.
3. Accurately distinguish between recyclable and non recyclable items using computer vision.
4. Sort items according to predetermined criteria with high levels of accuracy.

3.2 Architecture

Our project is aimed to effortlessly maneuver physical components in line with programmatic tasks. We will be using the python programming language for its workability with artificial intelligence models of which we plan to use. We will have a raspberry pies that will control separate functions of operation while computationally classifying articles of trash. Mechanical components will be essential to the overall success of the project and the achievement of a model in relation to the problems presented.

The brain of the system lies in the AI and machine learning algorithms that power the robotic arm's decision-making process. These algorithms employ computer vision to recognize and categorize objects in real-time. The AI analyzes the items on the conveyor belt, determining their material composition and recyclability. It then guides the robotic arm to precisely sort these items into designated containers, separating recyclables from non-recyclables. The architecture is simplistically designed with scalability in mind, allowing for the addition of multiple conveyor belts and robotic arms as needed to handle varying waste volumes and types.

3.3 Risks

1. **Overlapping Materials** –The density of items does not allow for proper sorting when thrown mass amounts of congested material.
2. **Failure of processing** – The model fails to properly classify specific elements that then creates waste of renewable resources.
3. **Physical breakdown** –Physical mechanism failures with the timing of the conveyor and arm alongside processing.

3.4 Tasks

1. Gather physical components as specified in the parts list
2. Assemble mockup
3. Create Git Repository
4. Collect data set for training
5. Implement data management and program outline
6. Implement the object detection model
7. Train the object detection for trash
8. Implement the classification model
9. Train the classification model for sorting purposes
10. Production testing
11. Work on punch list items
12. Presentation preparation

3.5 Schedule

Task	Assigned	Start	End
Acquire necessary parts	Christian	Week 3	Week 4
Aquire training data	Everyone	Week 3	Week 4
Assemble mockup	Everyone	Week4	Week 5
Create GIT	Ryan	Week 5	Week 5
Initial data management and I/O	Blake & Ryan	Week 5	Week 6
Object detection	Christian & Jesse	Week 5	Week 7
Testing of object detection	Everyone	Week 7	Week 7
Classification model	Christian & Jesse	Week 8	Week 10
Testing of classification	Everyone	Week 8	Week 10
Initial production testing	Everyone	Week 11	Week 12
Punch List items	Blake & Ryan	Week 12	Week 14
Presentation Preparation	Everyone	Week 14	Week 15

3.6 Deliverables

1. Project Proposal
2. User Interface Design Drawings and Flowcharts
3. Machine Learning Model Code (in Jupyter Notebook Format)
4. Application Development Code (ReactJS and JavaScript)
5. Final Report

4 Project Members

4.1 Team Members

Blake Godwin (4023) Blake Godwin is a Information Technology major with a concentration in Programming in the department of Computer Science and Engineering at the University of Arkansas - Fort Smith. He has completed relevant coursework for the proposed project by completing CS 2003 - Data Structures, CS 2033 - Web Systems, CS 2043 - Database Systems II, CS 3103 - Algorithm Design, CS 3003 - Distributed Systems, CS 3113 - Artificial Intelligence, CS 4343 Natural Language Processing, CS 4903 - Spec Top JS Frame. He will be responsible for the front end development and assisting with the AI Implementation.

Christian Johnson (4023) Christian Johnson is a Computer Science major with a concentration in Data Science / Artificial Intelligence and a minor in Mathematics in the department of Computer Science and Engineering at the University of Arkansas - Fort Smith he has completed relevant coursework for the proposed project by completing CS 3113 – Artificial Intelligence, CS 4373 – Information Retrieval, CS 4333 - Machine Learning, CS 3103 – Algorithms, CS 2033 – Web Systems, CS 3043 – Database Systems, and CS 2003 – Data Structures. He has completed a quadcopter build using a similar model. He will also be responsible for leading the build on the trashBot and helping with the implementation of the AI.

Ryan Smith (4023) is an Information Technology major with a concentration in Networking in the department of Computer Science and Engineering at the University of Arkansas - Fort Smith. He has completed relevant coursework for the proposed project by completing CS 2003 - Data Structures, CS 2033 - Web Systems, CS 2043 - Database Systems II, CS 3003 - Distributed Systems, CS 3113 - Artificial Intelligence, CS 4503 - CyberOps Network Security. He will be responsible for server configuration and development as well as assisting with the front end and AI Implementation.

Jesse Witt (4023) Jesse Witt is a student at the University of Arkansas - Fort Smith in the Computer Science and Engineering department. He is studying to receive a bachelor's degree in Computer Science with a minor in Mathematics. Coursework relevant to the proposed project that he has undertaken includes CS 2003 - Data Structures, CS 2033 - Web Systems, CS 3113 - Distributed Systems, CS 3113 - Artificial Intelligence. He will be responsible for back end development and assist in the creation and implementation of the artificial intelligence component of the project.

4.2 Departmental Advisors

Our project was supervised by Professor Israel Cuevas and Professor Andrew L. Mackey of the department of Computer Science and Engineering at the University of Arkansas – Fort Smith.

5 References

References

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[3] P. Ma, "Trash and recyclable sorting robot arm," Hackster.io, https://www.hackster.io/Nyceane/trash-and-recyclable-sorting-robot-arm-975282 (accessed Sep. 11, 2023).