Smart Plastic Container Recycling System

ECE 445 Senior Design

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Team 7

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1. Introduction

1.1 Problem

Recycling maintains a lot of benefits for the community around us, especially as we aim to tackle the effects of climate change. The benefits of recycling are countless, but recycling works to reduce waste and pollution, conserve energy and natural resources, and create and support jobs domestically. Unfortunately, a lot of people struggle with determining which materials can be recycled and where they can effectively recycle them and the recycling infrastructure in the United States is outdated [1].

While other countries have effectively taught their population how to correctly recycle their items from a young age, the United States lacks education on proper recycling. This leads to contamination of other recyclables, ultimately preventing them from being recycled. In fact, estimates show that over 50% of waste ends up in landfills instead of being recycled [2]. We usually think of plastics as recyclable, but depending on the jurisdiction, some plastics may not be able to be recycled. If they are accidentally recycled, they run the risk of contaminating all of the other recyclables, which is a mistake we can no longer afford as the potential effects of climate change loom ahead.

1.2 Solution

Our solution to this problem is a device with an imaging system that reads the symbols printed on plastic containers. This device will be mounted by a user's recycling container. We will have a camera sensor that reads the numbers printed on the plastic container and also a GPS sensor that determines the location of the user using latitude and longitude coordinates. That information will be utilized to determine if that specific plastic container can be recycled in the user's location using RecycleNation API. Once the determination has been made, we will have a sorting actuator that places the plastic in the proper bin and a web application explaining more about the type of plastic and if there are recycling centers nearby.

1.3 Visual Aid

Figure 1: Visual Aid

1.4 High Level Requirements

1. Camera detects the plastic being positioned in front of it 95 ± 1% of the time and system is able to correctly identify the symbol listed on the plastic container 95 ± 1% of the time
2. GPS location sensor determines the user's location within a 10 meter radius and pulls the data regarding recycling in that area
3. System correctly determines 95 ± 1% of the time if the container is recyclable or not and places the container in the proper bin, web application displays specific information about plastic being recycled/specific location centers that accept this type of plastic.

2. Design

2.1 Block Diagram

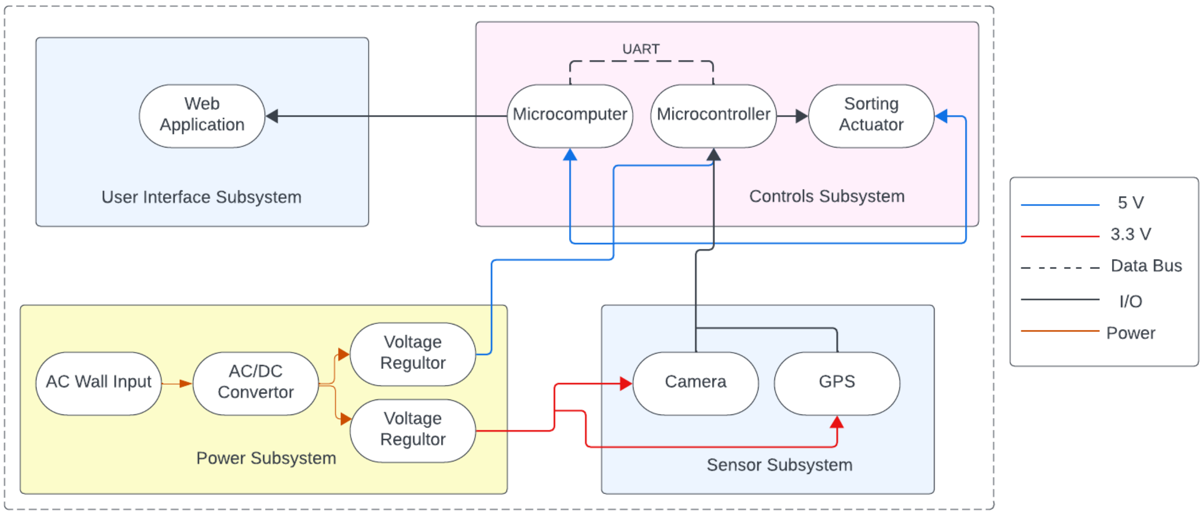

Figure 2: Block Diagram

2.2 Subsystem Overview

2.2.1 Sensor Subsystem

The sensor subsystem contains the hardware necessary for the device to capture an image of recycling symbol on the container via the camera and for it to locate the user's coordinates using a GPS. The camera will be positioned to take an image of the user's plastic container and it will transmit the image data to our microcontroller. A GPS will also be located on the sensor subsystem to determine the user's location and those coordinates will be sent to the microcontroller for processing.

2.2.2 Power Subsystem

The power subsystem contains the AC supply, converter and voltage regulator in order to provide power to the other subsystems. The AC input supply will be plugged into the wall, as the main power supply. The voltage regulators will be used to provide the power supply to the sensor and control subsystem.

2.2.3 Control Subsystem

The control subsystem contains the microprocessor necessary to collect data from the sensor subsystem and transmit it to the microcomputer used to analyze the data using the UART communication protocol. The sorting actuator, a servomotor, is also included in this subsystem as positional feedback is necessary to accurately control the sorting. The microcontroller is slated to be the ATmega32u4. The microcontroller will then pass the information to the microcomputer needed to process the image using OpenCV and confirm geographical recycling data using RecycleNation API, and it will receive data confirming whether or not the item is recyclable.

2.2.4 User Interface Subsystem

The user interface will consist of a web application where information about the specific plastic the user is attempting to recycle is displayed, in addition to the locations of specific recycling centers that accept the type of plastic inputted. The user interface will receive this information from the microcomputer and use that to display the necessary information.

2.3 Subsystem Requirements

2.3.1 Sensor Subsystem

1. The image the camera produces must be at least 40 pixels to ensure that the symbol can be read properly.
2. The GPS must provide coordinates within a 10 meter radius given that the device is in a location free of large obstacles.

2.3.2 Power Subsystem

1. The system must provide a stable power supply of 3.3V for the camera and GPS sensor.
2. The system must provide a stable 5V (±0.2V) supply for use by the MCU and servo

2.3.3 Control Subsystem

1. The servomotor must be able to rotate the physical sorting mechanism by enough to move the plastic (at least 40° in either direction)
2. The servomotor must be able to return to a level position (±1°)
3. The MCU must be able to facilitate data collection from the sensors and two-way data transfer with the microcomputer

2.3.4 User Interface Subsystem

1. The web application must display information of the type of plastic the user is attempting to recycle.
2. The web application must be able to display recycling locations within a 30 mile radius, if applicable to a user's location.

2.4 Tolerance Analysis

The primary element of this system that needs to be analyzed in power supply and voltage regulation for the various subsystem components. Voltage stability will be achieved through the use of linear voltage regulators. All components require stable power supply, but it is most important from our design perspective in the MCU and the servomotor.

The current design is set to use standard 120V wall outlets as a source, with a pre-bought 12V AC adapter to a barrel plug output. The WSU050-4000 adapter for example has a maximum 200 mV ripple with a maximum current of 4A, which would be sufficient for supplying our system. Our raspberry pi microcomputer is expected to draw 1.2 A maximum, up to 1A for the servomotor, and less than 500 mA for the microcontroller. The other components do not have nearly as high of power requirements, so 20W should give enough head room. Linear voltage regulators will step down the voltage to 3.3V for the camera, GPS, and other components as applicable, and to 5V for the MCU and actuator (a servomotor).

When looking at linear voltage regulators, the two primary concerns are dropout voltage and thermal limits. Dropout voltage must be above the voltage difference between input and output voltages as follows:

$$Vin - Vout > Vdropout$$

$$4.8 - 3.3 > Vdropout$$

We use 4.8 for the input voltage to account for maximum expected ripple. This tells us to choose a dropout voltage less than 1.5 V.

Thermal requirements can be estimated by first estimating the dissipated power using $P_D = i_{out} * (V_{in}-V_{out})$. Assuming the linear regulator has a maximum operating temperature similar to that of the AZ1117CD-33TRG1, we just need to confirm that the heat will not cross this using the estimation equation from the course website, rearranged to solve for i_{out}:

$$iout = (Tj - Ta)/((Vin - Vout)(\Theta jc + \Theta ca)$$

This is rearranged because we have not finished calculating the estimated current draw for our 3.3A components. If we once again make an assumption that the parameters are similar to the course website's example (Tj = 150, Ta = 38, Θ_{jc}=10, Θ_{ca}=90), the maximum i_{out} that we can allow is 659 mA. Currently, we believe we only need the 3.3V for the gps and camera components, which will require current on the order of < 400 mA, meaning we are well below tolerance requirements according to this estimate. If more 3.3V components are added or we choose to run our MCU off of 3.3V, a second regulator may be used to avoid exceeding the thermal bounds. Once specific parts are finalized for our regulator and casing, we will re-estimate the thermal losses with data more accurate to our own design.

It is our current belief that the pre-bought converter will regulate the 5V AC enough to not require an additional regulator, since the datasheet confirms the voltage will be clamped between 4.8 and 5.2 V. If we upgrade to a 12V converter for a more powerful motor or better regulation, we will make use of a switching regulator (buck converter) to step the voltage down to 5V, since this same tolerance analysis for a 12-5V linear regulator gives a maximum current of 128 mA, which is too low for our application.

3. Ethics and Safety

3.1 Ethics

3.1.1 Seek honest criticism/feedback of our technical work and acknowledge the feedback [3]

Per IEEE Code of Ethics, we must follow the feedback that we receive from our TA and professor regarding the implementation of our project and make changes accordingly. Throughout the project, we will be consistently meeting with our TA to review our designs and prototypes before implementation and seek feedback. We will also thoroughly review and research any ideas if necessary before implementing and make sure to cite any resources that we use.

3.1.2 Treat all people with fairness and respect [3]

Per IEEE Code of Ethics, we must be fair and respectful to everyone in the team and our mentors. To ensure that we are all communicating well and working well as a team, we have a group text as well as a Discord server for coordinating meetings, etc. In addition, we have a shared Google drive folder where we will have all of the project related documents, resources, etc. GitHub will be used for our lab notebook as well as for collaborating on the code.

3.1.3 Learn and apply new skills through design and implementation [3]

Per IEEE Code of Ethics, we must learn any new technical skills necessary for the design and implementation of the project. All of the team members have completed the safety and CAD training, and plan to review additional resources as necessary. The team consists of hardware, application development and AI/ML experience, and we will collaborate together throughout the project development process. We will also consistently meet with our mentors and TAs for feedback.

3.2 Safety

3.2.1 Follow all lab safety guidelines [3]

Per lab safety guidelines, we will make sure to follow all of the lab safety rules as we design and build our project. Although we do not anticipate significant safety hazards in our design, we recognize that we are working with current and voltage which can pose a safety risk.

3.2.2 Data Privacy [3]

Per IEEE Code of Ethics, we will make sure to protect data and consider data privacy pertaining to data collected such as the location. We will also make sure to follow any software license terms and cite any resources that we use.

References

[1] EPA. “The U.S. Recycling System” (2022), [Online]. Available: https://www.epa.gov/circulareconomy/us-recycling-system#:~:text=For%20the%20environment%2C%20recycling%3A,and%20process%20new%20raw%20materials. (visited on 09/12/2023).

[2] A. Bradford, A. Truelove, S. Broude. “Trash in America: Moving From Destructive Consumption to a Zero-Waste System” (2018), [Online]. Available: https://frontiergroup.org/resources/trash-america/#:~:text=Currently%2C%20though%2C%20the%20majority%20(,much%20material%20at%2034.6%20percent. (visited on 09/09/2023)

[3] IEEE. “”IEEE Code of Ethics”.” (2016), [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html (visited on 09/13/2023).