R^3

(Reduce Reuse Recycle)

2017-18

Project Information:

Grade: Middle School

School: Patapsco

State Representing: Maryland

Project Outline: Efficient recyclable identification

Project Technology: Arduino

MESA Coordinator: Ms. Danielle Stephenson

Grade: Middle school

Team Name : The RoboKnights

Team Members:

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Ms. Gemma Evans

Recycle Coordinator

Howard County Dept. of Public Works

Columbia, MD

Mr. James Irvin(Jim Irvin)

Director

Howard County Dept. of Public Works

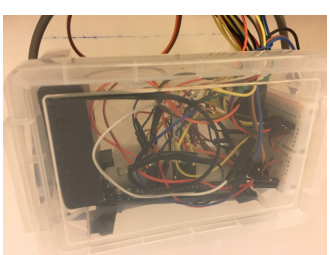
Ellicott City, MD

Problem Statement: Everyday, many recyclable items are being thrown into the trash and being sent to landfills. Within the United States, only 36.4% of municipal waste collected is recycled, and of the 36.4 % recycled materials, metal objects only represent 8.8% of the recycled materials. Our client, Gemma Evans, a recycling coordinator for Howard County, tasked us to create a device to help our community by effectively identifying recyclable items and preventing the intermixing of recyclable items with trash. R3 is a device that meets all of our client's need by identifying recyclable items and preventing the intermixing between recyclable items and waste. R3 detects metal items and prevents the user from throwing them in the garbage and prompts the user to recycle the metal items. The limitations of our model include objects thrown away cannot be more than 8mm away from the metal detector, trash levels should remain under the device (as the box is not water resistant and could cause damage to the equipment), and the user has to check the power supply on a regular basis. Based on our research no distinct product can identify all types of recyclable items with appropriate prompts to avoid intermix of trash and recyclable items, and there was an inability to segregate recyclable items from waste efficiently. Our product is a device that will efficiently identify recyclable items, therefore reducing landfill, increasing recyclable items and minimize environmental pollution.

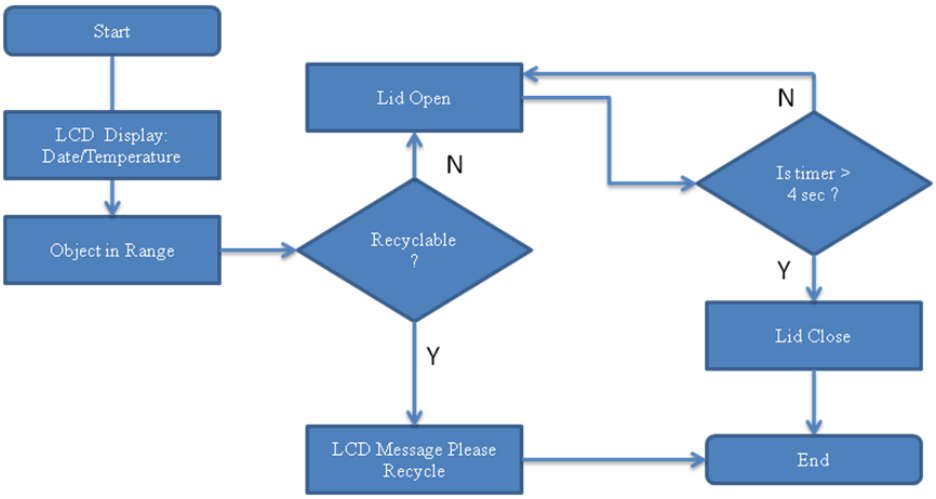
Design Process: *Process Overview:* Our inspiration stemmed from researching the chemicals ending up in landfills, the amount of land devoted to landfills and the loss of a potential energy source. Our product focuses on detecting metal items for the consumer to recycle the item compared to throwing into the trash. We testing we used different metal items depending on the results we went back to improving the product. The R3 prototype has an 100% accuracy at detecting metal items and instructing the user to recycle the item. *Research:* We researched cases studies on how our communities recycling efforts and how community waste it ends up in

landfills. Knowing that if we recycle one soda can we could run a TV for 2 hours approximately, manufacturing products from recycled paper and plastic reduces water pollution by 35% and air pollution by 73%; we developed a device to reduce the number of recyclable items deposited in landfills. Our design needed to identify recyclable items, restrict recyclable items intermixed with trash, weatherproof, avoid damage from debris inside the container and have display panel for friendly usability. We performed research on existing tools capabilities and deficiencies. We examined "Touchless Trash Cans" that utilized an infrared sensor to open the lid, however this model does not detect recyclable items. In fact, none of the devices in the market, surprisingly have a display, prompting and notification capabilities. After our research, we brainstormed, built, tested and determined that our fundamental design choices had to include an accurate proximity sensor for recyclable items, used within a home and commercially, ensure that the recyclables should be fed individually to a container and that the recyclables need to be clean, dry and empty. To extend our research and potential future product, we researched Sweden where they incinerate all recyclable items as a form of alternative energy, thus reducing their heavy metal emissions by 99% . *Design Processing and Testing:* We brainstormed and compared prototypes with and without a lid to the trash can. The idea was to create a device to identify trash and recyclable items that get thrown into the trash bin. To identify the recyclable items, we drafted a plan that incorporated an inductive proximity (IP) sensor, PIR sensor, capacitive sensor, an LCD, and a buzzer. Although meeting the needs of our client, we experienced challenges finding appropriate and inexpensive sensors for our device. We determined that a trash can without the lid would not prevent the user from throwing recyclable items into the trash, debris would not pass the sensor one at a time or trash may be covering other recyclable therefore






unable to able identify recyclable material. Therefore, we developed our first iteration to incorporate a lid to prevent the free flow of trash. *Iteration 1:* We used IP sensor, capacitive and PIR sensor as our input and LCD and buzzer as output sensors. One design modification we overcame included that we replaced the PIR sensor with the ultrasonic sensor because the PIR sensor has a too wide of a range; detected everything, therefore we wanted to integrate the capacitive sensor. In addition, we determined that the capacitive sensor did not determine if the refuse items' composition was plastic. Trying to overcome this design challenge, we investigated if we could incorporate a sensor to detect the densities of each material but could not find a sensor with a large enough range. We calculated the density of several household items and determined that the density of the materials, regardless if the item was recyclable was not a reliable calculation to determine if the item was recyclable. *Iteration 2:* For our final iterations, we identified metal recyclable items and the LCD for prompts the user along with buzzer and the lid automatically open/close based on the identification of objects. As we explore future usage, we thought it would be beneficial for our community to monitor their recycling, therefore we added an RTC sensor display the date, time and temperature. Within our model development and testing, we experience many challenges. For example, the first program for the IPS module code did not get uploaded to Arduino Mega due to Arduino Board/Process/Port were not configured and we had to adjust the configuration. Additionally, we experimented and determined that the battery power 4.5v was not sufficient and we needed to increase to 6v. In Motion Detector module, DC Servo did not work due to the compatibility of the model, therefore we needed to incorporate the DC Servo model MG55g. LCD Display Panel initially did not work, and after debugging, we found that the related circuit connections were wrong and fixed it and then customized RTC library code to display set time format. Prior to building the prototype, the



process that most impacted the development of our product was the sensors. We needed to ensure that we met the needs of our client and ran into difficulty trying to incorporate all sensors that would detect of the items that needed to be recycled. Throughout the process of selecting sensors and selecting the type of recycling bin, we constantly revisited the expectations of the client to ensure that their needs are accounted for. *Prototype Development:* Our final iteration integrated the following sensors: The Metal Detector (**Inductive Proximity**) is the inductive proximity sensor and been used in our project in the context of detecting the metal items. The Inductive Proximity sensor detects most metals (iron, copper, aluminum, brass and lead) and has a range of 8 mm. It uses serial signals upon identification of metal, sends a message to the code deployed on the Arduino and communicates with LCD module to display the relevant prompts for the user to recycle if it is a metal. The **Ultrasonic Sensor** DS3231 detects the motion of objects within a range of 5 cm to 15 cm and sends serial signals to the Arduino, programmed to open /close the lid. This module is integrated with the metal detector module to identify type of material and execute lid open/close action. The **DC Servomotor** is used to lift the trash bin lid. The **RTC: The Real Time Clock - Temperature** sensor detects the real-time clock and ambient temperature and then displays the information on the LCD panel. The **Display Panel (LCD)** and **Buzzer** respond based on signals received from metal detector module to displays relevant prompts. e.g., If it is metal or plastic, it presents “Please Recycle.” These prompts help to recycle the debris. A **Potentiometer** adjusts the brightness of the LCD display. The logic

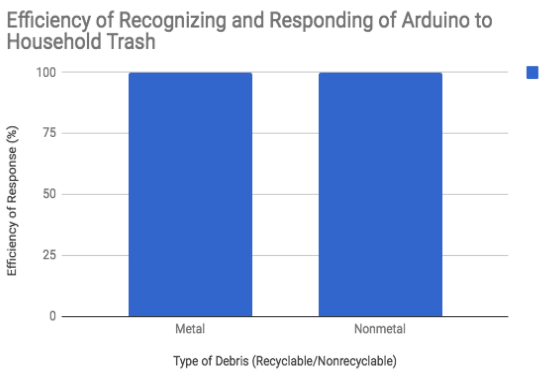
diagram shows the process the prototype goes through. The object is placed within the given range and the US sensor detects motion. A message is sent to the Arduino and signals the IP sensor to detect if the item is metal. If the item is metal, a message is sent to the LCD, initiates the buzzer and the Servomotor does not open the lid. If the item is not metal, a signal is sent to the ServoMotor causing the lid to open. Once the lid is open, there is a delay of 4 seconds for the user to throw the debris in the trash and the lid closes. *Discussion of electronics hardware integration:* We assembled R3 prototype device in a box which contains Arduino, power supply, buzzer, potentiometer, RTC Sensor and breadboard. Ultrasonic Sensor, Servo Motor, IP Metal Detector are attached to the trash bin lid for better sensing proximity. Our team used Arduino code references from libraries and functions from Arduino official website. We then developed the code for each module separately based on the sensor used in R3 and tested the code independently for the metal detector, motion/ temperature detector and display panel modules. Once these modules code is working as expected, we integrated the code for Metal Detector module and Motion/Temperature Detector modules and tested these two. And then integrated third module which is Display Panel module to the above two module code. **Conclusion and Recommendations:** This integrated code was the final code that we tested thoroughly and used the combined working code our source code repository. We were very methodical and tried to ensure we could catch any errors, therefore, first, we connected the LCD circuit and tested the circuit to make sure everything was working after uploading the display panel module code to the Arduino. Then we attached the Metal detector circuit to the Arduino and uploaded the integrated code of metal detector and display panel modules. After that, we combined the motion sensor, temperature sensor, and motor circuit connections which were all in the motion detector module to the Arduino board. Lastly, we tested integrated R3 and worked as expected. One of

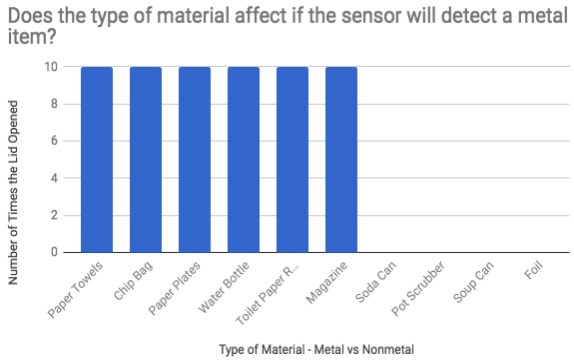
the challenges we faced in our circuit connections was that we used some of the digital pins in more than one module. We fixed this problem by using analog pins as digital pins by using the pin-mode function to classify the pins used by each sensor. We did this because pinmode library function works the same way for either digital or analog pins. Finally, we soldered all of the pins to ensure that each pin adequately connected to the board. One thing we could add later on that could help is to change the code so that you wouldn't need to reset the trash bin every time. Additionally, we have a delay of 15 to 20 second between when the sensor collects the data to when the motor opens the lid, so in the future, we would modify the code so the trash can lid open quicker. Discussion of software development: In the beginning, we wrote the code for each sensor individually. Then we tested the code for each module and made sure it worked correctly. Once we verified the code, we integrated each separate code to an integrated module. The code sends serial signals to the boards allowing the device to detect the material and depending on that the LCD and Buzzer will do what is needed. **Results:** The efficiency of our device was 100% with metal and non-metal items, testing everyday things consumer products. Testing Procedures. The product provides the user with an LCD message and buzzer for prompting the user to recycle the debris which is very beneficial for the user if the waste is recyclable and the lid does not open automatically. Based on our results, our product minimizes the intermixing of recyclable items, reduces the number of recyclable items within landfills and potentially creates an alternative form of energy. **Key strengths** are the uniqueness of the product to deliver various capabilities like metal detection, and LCD and auto lid open/close, the efficiency of recyclable items identification and lastly, the product has the foundational framework with focused capabilities but has potential to be fully extendable to meet broader diversified needs. A *weakness* is that the inductive proximity sensor range is limited to 8 mm. When we tested our

design, we put household metal items on top of the metal detector so it can detect the metal item and not our motion (ultrasonic sensor detects motion so if it detects our movement it will allow the lid to open), the metal item placed within a range of 8mm. The non-metal items can be placed anywhere near the top put within a 5 to 15 cm range, so the ultrasonic sensor can detect the motion allowing the lid to open.

Recommendations: A few capabilities for future enhancements for release are that we could find more sensors to detect items such as plastic, paper, and glass (etc.) to have a product that can recognize all recyclable item. Another enhancement could be to create an app by programming to send the user about how much they recycled that month and how they improved from the last month. The app would give the user an idea about their "recycling data." Currently, we have a metal sensor which is the inductive proximity, and it has a range of 8mm, and it would be more beneficial for the user if it had greater range, meaning that they would not have to place the object is a specific location for the debris. If our product could increase the number of items recycled in our community, then we could apply Sweden's innovation of burning recyclable material to a usable form of energy. We can extend product capabilities from residential to common community usage. Extend product capabilities from residential to common community usage.

Appendix: ***Data Table***





This data table shows the response of the lid

Module	Scenario	Qualitative Results
Module 1 - Metal Detector	Place metal items in front of the trash bin to see if the lid would open.	Trash bin lid did not open
	Place Non metal item in front of the trash bin to see if the lid would open.	Trash bin lid opened.
Module 2 - Motion and Temperature Detector	Tested with 4.5 volts battery as the DC Servo works from 4.5 volts onwards to 6 volts.	The motor did not rotate well as that the battery power is not sufficient and worked well when we increased the battery power from 4.5v to 6v
	We created some motion signals by putting our hand near to the Motion Detector.	We see the motion signals flow through our code print statements in Arduino IDE - > Tools -> Serial Monitor
	Temperature inside bin expected	Temperature displayed on LCD in Fahrenheit
Module 3 - Display Panel	Sent a text message 'Please Recycle' from the program to observe the same text on LCD display and test for four seconds.	Consistently Found 'Please Recycle' text on LCD display panel and also displayed for four seconds.
	Place metal items in front of the trash bin	Found 'Please Recycle' text on LCD display panel
Integrated Device (With 3 Modules)	Place a metal soda tin in front of the device	Trash bin lid did not open and found 'Please Recycle' text on LCD panel
	Put non metal soda tin in front of the device	Lid opened and no text displayed on LCD panel
	Temperature and RTC expected on LCD	LCD displayed Temperature ^{0}F & RTC -Day of the week, Date and Time

Type of Material	Minimum range in millimeters (mm)	Minimum thickness in millimeters (mm)
Iron (Metal)	3	0.5
Copper (Metal)	3	2
Aluminium (Metal)	4	0.25
Brass (Metal)	2	4
Lead (Metal)	1	1

This data table shows the different types of metals we tested with our device. This is relevant to the accuracy of our device because it tells at least how far the different types of metals have to be from the metal detector. This data table also shows at least how thick the different types of metals have to be to be detected by the metal detector

Detailed Budget Sheet:

Part	Unit Dimensions	Retail Price	Price per Unit	Qty Used	Total Cost	Retail Source
Elegoo MEGA 2650	2.2 x 4.09 x 0.39 in	$14.96	$14.96	1	$14.96	https://amzn.to/2kODbjG
Inductive Proximity Sensor	7 x 3cm/2.8" x 1.2"	$6.98	$6.98	1	$6.98	https://amzn.to/2JlnKNU
Breadboard Solderless	84 x 55 x 8 mm	$8.21	$2.73	1	$2.73	https://amzn.to/2Jyvw75
Ultrasonic Sensor (part of the Elegoo Upgraded 37 in 1 Sensor Modules Kit)	45mm x20mm x15mm	$29.98	$.81	1	$.81	https://amzn.to/2stzGme
Liquid Crystal Display (Elegoo Kit)	80.0mm x36.0mm x1.6mm	$29.98	$0.81	1	$.81	https://amzn.to/2stzGme
Active Buzzer (Elegoo Kit)	18.5mm x 15mm	$29.98	$0.81	1	$.81	https://amzn.to/2stzGme
360 Degree Continuous Rotation Servo Motor	40.8 x 20.1 x 38 mm	$11.95	$11.95	1	$11.95	https://bit.ly/2xtLudK
Potentiometer (set of 4)	1.1 x 0.6 x 0.3 inches	$5.84	$1.17	1	$1.17	https://amzn.to/2kOcRpV
Energizer Batteries - 4 AA Battery	2 in v .5 in	$3.59	$3.59	1	$3.59	https://amzn.to/2JlfQ73
Project Box	6.5 in 4 in x 3.5 in	$2.50	$2.50	1	$2.50	
Trash Can	11in x 9inx17.5in	$5.50	$5.50	1	$5.50	
Metal Hinge Joint (saw tooth hangers 6 pack)	4 in x .5 in	$1.59	$1.59	2	$0.53	https://bit.ly/2sGt7wE
Screws	.75 in x.25 in	$1.46	$0.03	2	$0.06	https://bit.ly/2LjjjjK
Multi colored Dupont Wires	8 in	$7.86	$0.065	45	$2.94	https://amzn.to/2JwShbE
				Total	$55.34	

```
R3 program identifies Motion of the object with the help of
Ultrasonic Sensor and also identifies metal with the help of
Inductive Proximity Sensor.
The serial signals will be sent to the microcontroller
user wiht a message "Please Recycle!" on Liquid Crysta
If the object is not recyclable item (non-metal in thi
then Ultrasonic Sensor will send the signals to microc
and finally trash bin lid will be opened for 4 seconds

All times the LCD will be displayed with the below inf
* Day of the Week
* Inside bin temperature in Fahrenheit
* Date
* Time

We used Ananlog pins as Digital pins as some of
the digital pins that we used for LCD were needed for
Ultrasonic sensor also, so we used Analog pins along w
pinMode(.,.) as Digital pins, to avoid same pin connec
to different components.

 The circuit as explained below:

* Ultrasonic Senson as Motion Detector Input Device.
* Trigger pin as Analog pin A3
* Ultrasonic sensor power pin to Analog pin A4
* echo pin to Analog pin A2
*
* Inductive Proximity sensor as Metal Detector Input D
*
* DS3231 as Real Time Clock (RTC) and also
* acts as a Temperature Sensor Input Device.
*
* DC Servo as Output Device
* Servo pin to Analog pin A5
*
* Liquid Display (LCD) as Output Device.
* LCD RS pin to digital pin 12
* LCD Enable pin to digital pin 11
* LCD D4 pin to digital pin 5
* LCD D5 pin to digital pin 4
* LCD D6 pin to digital pin 3
* LCD D7 pin to digital pin 2
* LCD R/W pin to ground
* LCD VSS pin to ground
* LCD VCC pin to 5V
* 10K and 100 ohm resistor:
* ending to +5V and ground
* wiper to LCD VO pin (pin 3)
*
* Passive Buzzer as Output Device:
```

```
//-------------------- SETTINGS ----------------------
#define maxH 15            // working distance. Initially it was 50cm and
                           //
#define cap_time 4         // time while cap is open, 4 seconds
#define open_angle 10      // open angle
#define close_angle 155    // close angle

#define debug 0            // debug information (0 off, 1 on)


//---------------- Motion Detector connections ----------------------
/*
#define trigPin 3
#define echoPin 2
#define sensorVCC 4
#define MOSFETpin 6
#define servoPin 5
*/
#define echoPin A2
#define trigPin A3
#define sensorVCC A4
#define servoPin A5
#define MOSFETpin A6

//---------------- Include Libraries Code -------------------------
#include <LiquidCrystal.h> //for LCD module
#include <Servo.h>    //servo library,for motion detector module
#include <DS3231.h> //for RTC and Temperature module

//---------------- Declare Variables start -------------------------
DS3231  rtc(SDA, SCL);
int tempC;
int tempF;

// initialize the library by associating any needed LCD interface pin
// with the arduino pin number it is connected to
const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

// Below are the Metal detector vars
float metal_detected;
int monitoring;
int monitorPin = 1;
int var = 10;
int piezoPin = 8; //for buzzer

Servo servo;
```

Arduino code reference

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