IMDL Final Report

Michelle Gilliard
WALL-E
EEL 5666
Dr. Eric M. Schwartz
Dr. A. Antonia Arroyo
Tim Martin, TA
Ryan Stevens, TA
Josh Weaver, TA

Table of Contents

Abstract

This document details the intended idea and design for a trash collecting robot similar to that of Disney's WALL-E. The version of WALL-E described below is designed to identify, collect, and store magnetic colored trash along with obstacle avoidance. Its body resembles that of a cube with decorative "eyes" on top to give it human-like characteristics. WALL-E also has two arms on the side of its body attached together at the bottom rim used to collect trash and provide more anthropomorphism to the robot.

Executive Summary

WALL-E is a small cubed-like autonomous trash collecting robot whose main purpose is to locate and collect objects that are specified as trash. Once WALL-E has located the trash using its color detection, he will introduce himself. Then he will get closer to the trash, using a Hall Effect sensor to further locate the trash. Once the trash is in reach of his mechanical arm, he will use an electromagnet to pick up the trash and place it inside a tray which is housed inside of his body. Once his task is completed WALL-E will say "ta-da."

WALL-E is controlled by a sbRIO donated by National Instruments. He utilizes a number of sensors and actuators to accomplish his task. Wall-E uses two DC motors to drive himself around. He uses another DC motor to move his collection drawer. Wall-E has one servo to move his head and another servo to move his arms. To detect obstacles, Wall-E has two sonar sensors: one in each eye. Wall-E uses an IP camera to roughly locate his trash. The video feed is communicated to a laptop via a wireless router on the robot. He then uses a Hall Effect sensor to further locate trash and an electro magnet to pick-up the trash.

As a whole, the project was a success. I ran into quite a few road blocks, one of them namely being when my sbRIO was out for repairs. It took a total of three weeks to get my board back. Despite the massive amount of downtime that was incurred, I was able to successfully finish the project and learn a lot about robotics while doing so.

Introduction

WALL-E was a movie made by Walt Disney Pictures and Pixar Animation Studios in 2008. The main character, WALL-E is a robot whose purpose is to clean up earth years after humans cluttered it with litter. WALL-E is a very advanced robot that can recharge itself, clean up trash, and feel human emotion. The robot I plan to build is a much simpler version of Disney's character in the sense that it can only clean up trash. The WALL-E that I am constructing will collect colored magnetic trash, through the use of an IP camera, mechanical arm, Hall Effect Sensor, and electromagnet. The robot will also have obstacle avoidance via the use of sonar, in case something tries to stop it from collecting trash.

Integrated System

WALL-E is controlled by a Single Board RIO (sbRIO) evaluation board which is an FPGA with a real-time microcontroller donated to me by National Instruments. The evaluation version of the sbRIO is like a regular sbRIO except it had a pre-made breakout board attached to it that contains the following: quadrature encoder, switches, LEDs, push buttons, analog I/O, digital I/O, temperature sensor, and potentiometer. This breakout board helps to make prototyping even quicker but does not utilize all ports on the sbRIO. I will use this board to test all aspect of the robot before attaching it to more permanent I/O of the sbRIO. A picture of the sbRIO can be seen below in figure 1 with the breakout board in figure 2.

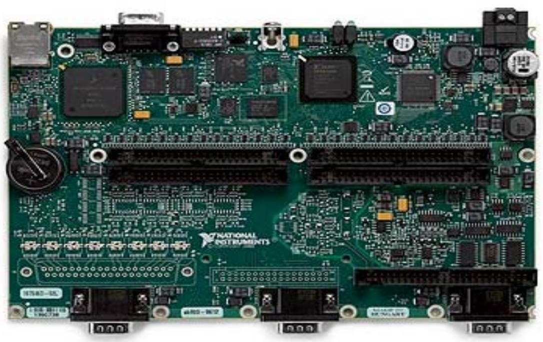

Figure 1: Single Board RIO

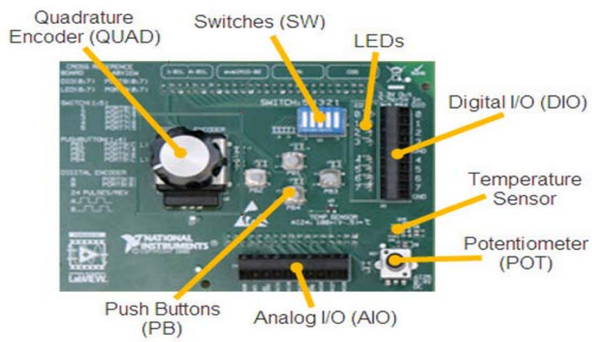

Figure 2: Single Board RIO Breakout Board

Mobile Platform

The housing for WALL-E is made out of wood. It is boxed shape and very similar looking to Disney's WALL-E as pictured below in figure 3. My robot is pictured in figure 4. My robot has a square wooden body with a drop down door with a pull-out tray for trash collection. Its arms hang down on both sides, but, unlike Disney's WALL-E, they are connected together at the bottom below the opening on the body's door. This makes arm operation easier. The robot's drive train consists of three components: two wheels for forward motion and a castor for rear support. There are fake all-terrain wheel covers on the side to make the robot appear to be more like WALL-E. There are a pair of "eyes" on top of the robot body which house the unit's sonar and will swivel via a servo motor. There is a layer in the box body that houses the sbRIO while the camera is glued to the inside of the shell. A LabVIEW front panel is used to update spectators on the current function of WALL-E.

Figure 3: Disney's WALL-E – Aesthetic Inspiration for Robot Case

Figure 4: My Version of WALL-E

Actuation

There are three types of actuators for WALL-E: servo motors, geared motors, and an electromagnet. Servo motors are used to swivel the sonar which broadens the area seen by the robot and control the arms. Geared motors are used to operate a rack and pinion which moves the trash tray that extends out of the robot body. Geared motors are also used to maneuver the robot. The electromagnet is used to attract and secure the trash. The electromagnet is constructed from a nail with magnetic wire wrapped around it and has the ability to reverse polarity to remove and attract the trash accordingly. I used a motor driver to give my electromagnet the ability to attract and repel the trash. This works because a motor driver has an H-bridge. A list of the actuators used can be seen below.

- Servo motors
- Geared motors
- Electromagnet

Sensors

WALL-E uses a number of sensors to achieve its desired functionality. As stated earlier, an IP camera with color detection is utilized to locate trash. All image processing was done on my laptop using LabVIEW since I was able to prototype it during my downtime period when my sbRIO broke. Two sonar sensors are housed in the eyes and swivels around on servo motors. The sonar is only used to detect obstacles. A Hall Effect sensor is placed on the robotic arm to precisely pin point the trash. A complete list of intended sensors used can be seen below.

- IP camera
- Sonar
- Hall Effect sensor

The special sensor used on the project is the Axis M1011 Wired Network Camera. The camera will output a MJPEG file with speeds up to 30 fps. Using this camera and LabVIEW's IMAQ toolkit, I was able to detect specific colors. I specified green paper blocks to be trash. The IP camera is directly connected to the wireless router via an Ethernet cord. The data collected from the IP camera is sent to a laptop, processed on the computer in LabVIEW and then sent to the sbRIO. The sbRIO can communicate with the computer using LabVIEW in real-time.

Wall-E also used sonar to detect obstacles and avoid them. Two sonar sensors are housed in the eyes which sit on a servo motor, allowing the eyes to move 180 degrees, broadening its range of "vision." The sonar used in the project is the Maxbotix LV-EZ2 which has a 20Hz scan rate and was connected to the sbRIO via an analog senor input voltage. The various readings from this sensor can be seen below in figure 5 with a corresponding data in table 1.

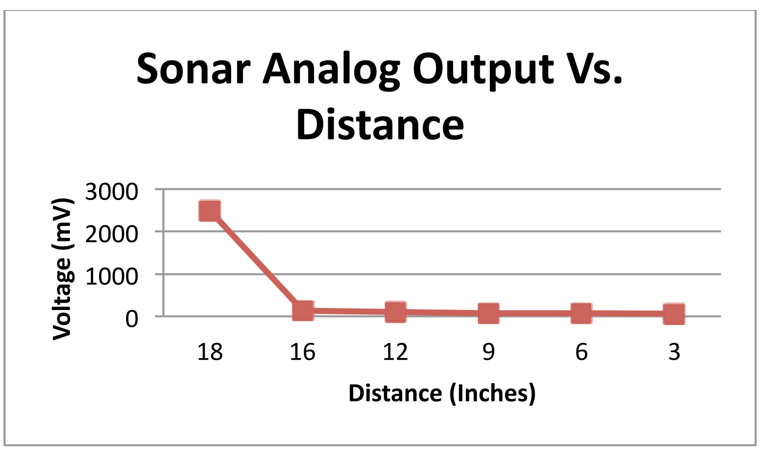

Figure 5: Sonar Analog Output Vs. Distance

Distance (Inches)	Voltage (mV)
18	2480
16	130
12	101
9	73
6	65
3	63

Table 1: Sonar Data Table

The final sensor used in the project was the Hall Effect sensor which was bought from Sparkfun. The sensor sharply changes analog input voltage depending on what pole on a magnet is placed near it. This sensor was used to further detect the presence of magnetic trash. An example of this latching as read in by an analog input port on the MyDAQ can be seen below in figure 6. Note that every instance where the voltage more or less drastically changes is when a magnet's polarity was flipped.

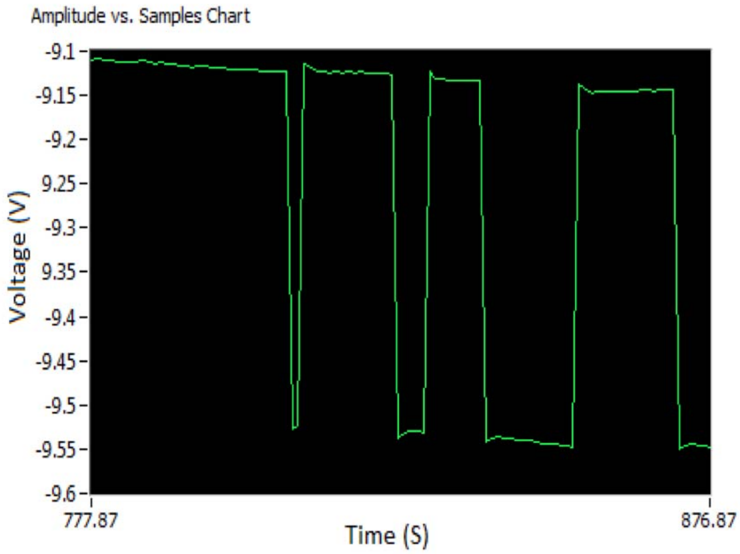

Figure 6: Hall Effect Sensor Operation Example

Behaviors

WALL-E will go through a series of movements to locate, grab, and dispose of the colored magnets it designates to be trash. First, WALL-E will drive forward using its IP camera and color detection to attempt to locate trash. At the same time it will be using its sonar to determine if an obstacle is present. If there is an obstacle is present, WALL-E will reverse and turn either right or left depending on where the obstacle is located. Once the colored trash is located, WALL-E will stop and say his name. He will then drive forward and further locate the magnetic trash with his Hall Effect sensor. If the trash is missed, he will back up and begin locating the trash again with his color detection and eventually try to locate it again with the Hall Effect sensor. Once located, the electromagnet will be activated and he will raise his arm. He will then open the door located on its body and reverse the polarity of the electromagnet to drop the trash into the drawer. Once this is accomplished, he will close the drawer, lower his arm, and begin surveying for more trash. A flow chart of the intended series of motions to accomplish this can be seen in the flow chart below in figure 7.

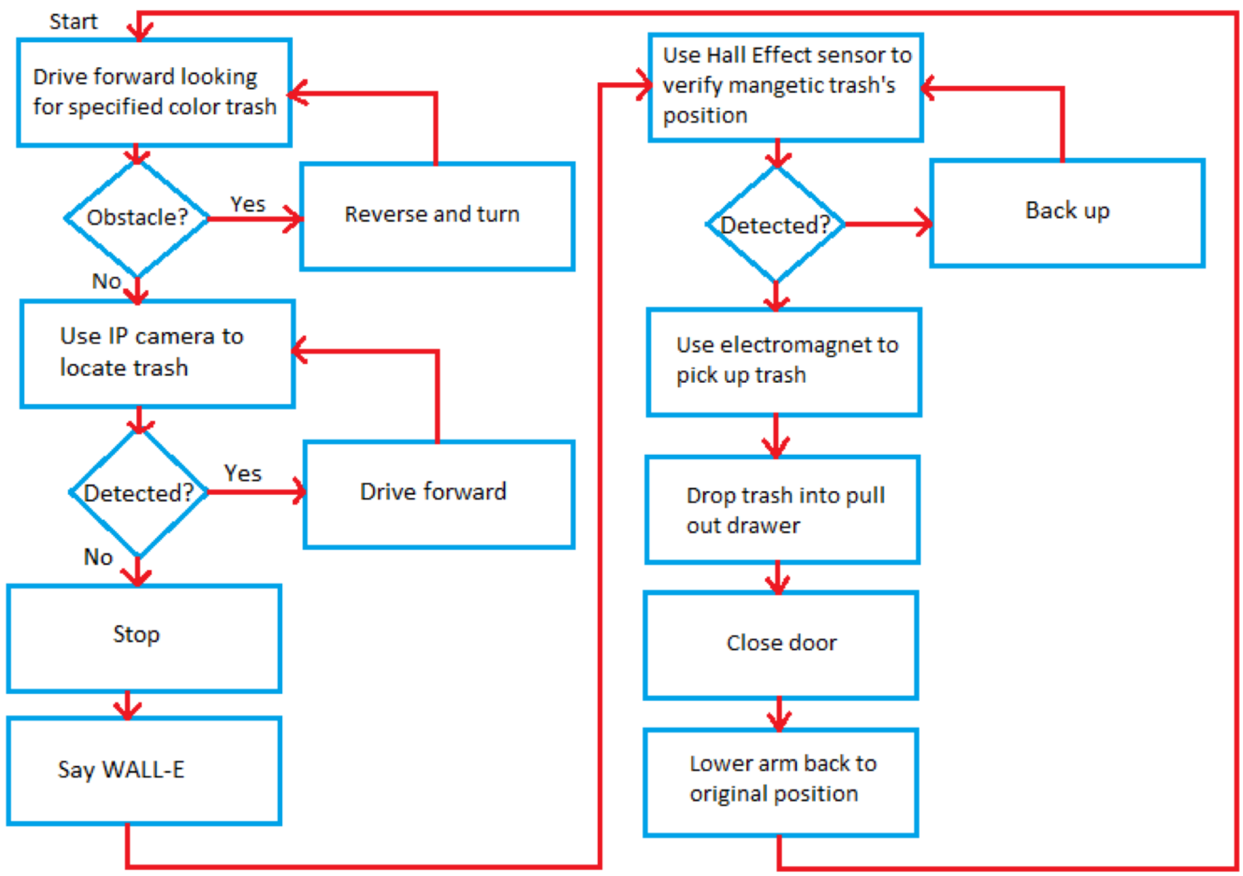

Figure 7: WALL-E Basic Control Flow Chart

Conclusion

WALL-E is an automated robot used for locating, picking up magnetic trash, and storing it inside its body. The robot is controlled using a Single Board RIO. It uses servo motors and geared motors as actuators to allow robotic movement. The robot incorporates sonar to detect obstacles. It also uses an IP camera to do image processing, allowing WALL-E to detect colored trash. It then uses a Hall Effect sensor to verify the location of magnetic trash and an electromagnet to grab the trash. The casing of the robot resembles that of Disney's WALL-E.

Documentation

Figure 1: http://sine.ni.com/nips/cds/view/p/lang/en/nid/205898

Figure 2: http://zone.ni.com/devzone/cda/tut/p/id/7783

Figure 3: http://www.empireonline.com/100-greatest-movie-characters/default.asp?c=63