EECE 461 Project Documentation

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May 2015

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1 Environment

In order to test the functionality of our system, it was imperative to carry out an experiment in various environments. We ran tests of the S.T.U, whose sorting algorithm functions largely on the principle of infrared reflection sensing, in situations of both low and high light intensities (once at a group member's house, and once in the IOEC 510 lab). This was to test if, and how much, our decision was vulnerable to changes in the environment. In addition to the formal tests carried out, our project was displayed and demoed outdoors during the IBDAA competition, with similar performance results.

The percent fullness part of the system is independent of the surroundings, although the way in which the garbage can is situated on the force sensor can greatly influence the reading obtained. This is a fact that must be taken into account.

2 Test Setup

In order to test the system, we split the task up into two main segments, material sorting test and percent fullness test:

2.1 The material sorting test:

The first part of the system test was set up as indicated in Figure 1. The object to be sorted is placed on the sensing platform, directly above the infrared sensor, and immediately adjacent to the inductive proximity sensor. In order to test the system's functionality and repeatability, we placed various objects on the sensing platform and observed the system's decision. The experiment was carried out with glass and plastic bottles being placed in *precisely* the correct position. Any variation in the position of the object placed could cause miss-identification (particularly with plastic). Plastic and glass must be placed in their **upright position, inside the circle drawn on the sensing platform**, while paper and metals can be placed in any way as long as they come into contact with the sensor. A metal object must be less than 6mm away from the sensor. The test was organized as follows:

- Glass (four types of glass, and two light intensities) .... ten trials each
- Metal (four types of metal, and two light intensities) .... ten trials each
- Paper(four types of paper, and two light intensities) .... ten trials each
- Plastic(four types of plastic, and two light intensities) .... ten trials each

In order to compute values of precision, four types of each material were used, both at high and low levels of light in the environment. The accuracy for each material sensor was then obtained from the total number of all trials made. Since the outputs of the STU system are binary in nature, the precision and accuracy were computed through statistical methods (i.e. number of correct decisions).

2.2 Percent fullness test:

In order to test this part of the system, we began by obtaining an eight liter plastic trash can. We then threw clumps of papers into the trash can, which was situated on top of a calibrated force sensor. Based on our estimate of paper's density to be around 0.7 g/cm^3 on average [1] , we calculated the approximate mass of paper that corresponds to a volume of 8 liters to be 5.6 kilograms. Weighing this mass of paper on a simply bathrooms scale, this quantity of paper was used as our 100% full level of the can. The performance of this subsystem was tested by observing the output reading for various amounts of paper. The system is designed to output percent fullness readings of 0%, 20%,

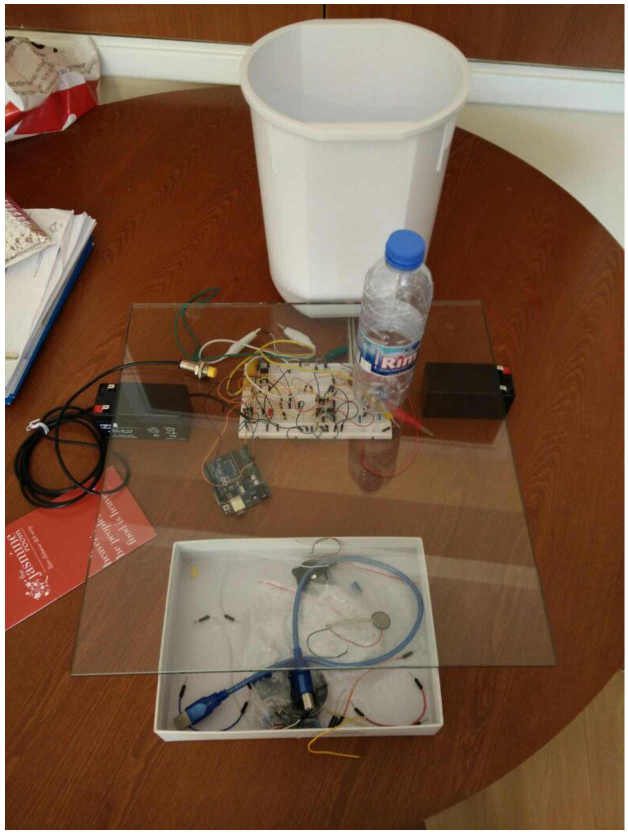


Figure 1: Experimental Setup

40%, 60%, 80%, and 100%. Our tests were carried out to see how well the sensor was able to correctly place its load amount with an uncertainty of ±20% of its actual value. Similar to the material sorting test, the output of the percent fullness sub-system is discrete. Therefore to compute the precision and accuracy of our system, we took several trials at different weights.

- Mass ±20% of 0% .... ten trials
- Mass ±20% of 20% .... ten trials
- Mass ±20% of 40% .... ten trials
- Mass ±20% of 60% .... ten trials
- Mass ±20% of 80% .... ten trials
- Mass ±20% of 100% .... ten trials

3 Results

Due to the fact that the outputs of our two systems are binary in nature, our description of accuracy and precision must have a different formulation than for the continuous values case. We intend to use the following set of formulae:

$$accuracy = \frac{true\,positives + true\,negatives}{true\,positives + true\,negatives + false\,positives + false\,negatives} \tag{1}$$

$$precision = \frac{true\,positives}{true\,positive + false\,positives} \tag{2}$$

3.1 Results of the material sorting tests

These tests were carried out on the set of materials in Table 1,with the results displayed in Figure 2. It should be noted that plastic and glass are complementary, since both metal and paper yield 100% accuracy and precision. Whenever glass is misidentified, it is identified as plastic and vice-versa, as such the False Negatives of glass are the False Positives of plastic and vice versa.

Table 1: Sets of test items

3.2 Results of the percent fullness tests

The results of these tests are displayed in Figure 3.[1]

[1] All measurements are taken with a $\pm 20\%$ resolution. We have calibrated our force sensor to read in 20% increments only. This resolution suffices for our purposes since we only care if the can is full, not exactly how full the can is.

Material	Plastic (/10)				Paper (/10)				Metal (/10)				Glass (/10)			
	Plastic1	Plastic2	Plastic3	Plastic4	Paper1	Paper2	Paper3	Paper4	Metal1	Metal2	Metal3	Metal4	Glass1	Glass2	Glass3	Glass4
High Light	8	9	7	8	10	10	10	10	10	10	10	10	7	5	7	6
Low Light	7	7	8	8	10	10	10	10	10	10	10	10	6	6	5	7
Precision (high light)	0.680851064				1				1				0.757575758			
Precision (low light)	0.652173913				1				1				0.705882353			
Accuracy	0.846875				1				1				0.846875			

Figure 2: Accuracy and precision of STU on sorting different materials.

	Actual Amount in Can					
Amount displayed by sensor	0%	20%	40%	60%	80%	100%
0%	8	2	0	1	0	0
20%	1	4	3	2	1	0
40%	0	3	6	0	1	0
60%	1	0	1	6	0	1
80%	0	1	0	0	7	0
100%	0	0	0	1	1	9
True Positives	8	4	6	6	7	9
False Positives	3	7	4	3	1	2
True Negatives	32	36	34	34	33	31
False Negatives	2	6	4	4	3	1
Precision	0.727272727	0.363636364	0.6	0.666666667	0.875	0.818181818
Accuracy	0.888888889	0.754716981	0.833333333	0.85106383	0.909090909	0.930232558

Figure 3: Accuracy and precision of STU on estimating percent fullness of trash can.

4 S.T.U - User Manual

4.1 Meet S.T.U:

S.T.U, the Smart Trash Unit, is a device designed to simplify the process of filtering waste based on its recyclable properties. The garbage disposal unit is made to automatically sort plastics, paper, metals, and glass into separate bins, without necessitating any change in the user's habits. In addition, the garbage can will provide a percent fullness reading on the paper waste basket. This will help save on garbage bag waste, since often paper is compressible beyond what appears full.

4.2 Installation:

S.T.U is powered by a 12 V DC supply, therefore a connection to a power outlet is the only requirement for the proper installation of the disposal unit. Simply locate a space large enough to accommodate the product, and the S.T.U is ready to sort! [2]

4.3 Instructions:

4.3.1 For Sorting:

1. Open the lid to the sorting compartment.
2. Drop the object to be sorted into S.T.U
3. Close the lid to the compartment and walk away.

[2] S.T.U requires a power adaptor to generate 12V DC, 40mA from the electric power outlet.

4.3.2 For Fullness:

1. If the paper bin's reading is anything below 100% full, then despite how full the basket may appear, its contents can still be compressed in order to fit more paper inside.
2. If the bin reads "100% full," then it must be emptied.
3. Remove the garbage bag.
4. Replace the now-empty bin in its compartment.

5 Data Sheet

5.1 Sorting System Specifications

Response Time: < 100 mSec
Optimal Operating Distance: < 2.5mm
Maximum Operating Range: < 6mm
Absolute Maximum Voltage Rating: 12VDC
Operating Temperature Range: -25°C - 80°C

Accuracy	
Plastic:	0.846875
Paper:	1
Metal:	1
Glass:	0.846875

Precision	
Plastic @ high light:	0.727272727
Plastic @ low light:	0.652173913
Paper @ high light:	0.6
Paper @ low light:	1
Metal @ high light:	1
Metal @ low light:	1
Glass @ high light:	0.757575758
Glass @ low light:	0.705882353

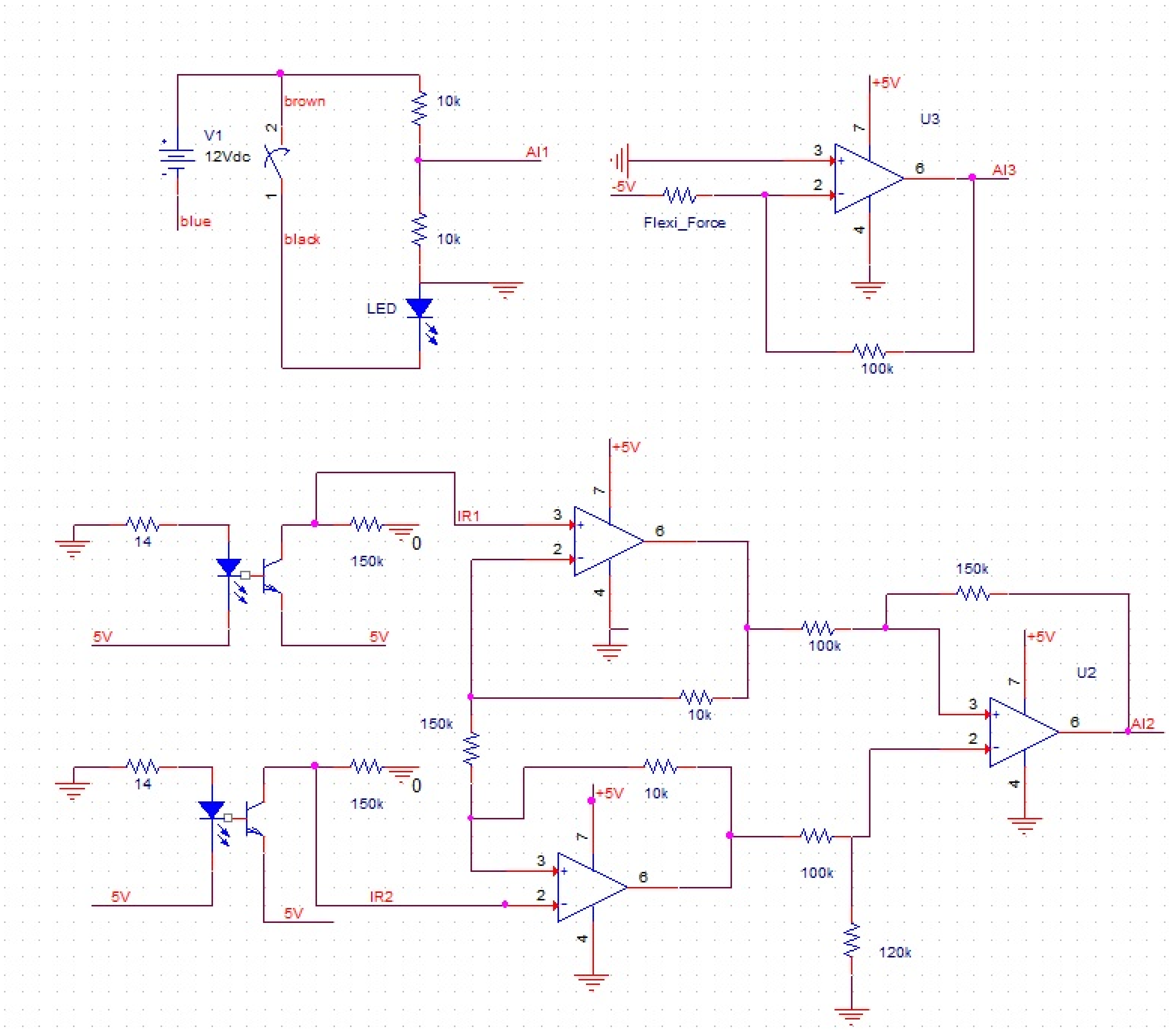
5.2 Percent Fullness Specifications

Response time: < 100 μSec
Resolution: 20%
Maximum volume: 8L
Absolute Maximum Voltage Rating: 12VDC
Operating Temperature Range: -9°C - 60°C

Accuracy	
0% full:	0.888888889
20% full:	0.754716981
40% full:	0.833333333
60% full:	0.85106383
80% full:	0.909090909
100% full:	0.930232558

Precision	
0% full:	0.680851064
20% full:	0.652173913
40% full:	0.6
60% full:	0.363636364
80% full:	0.875
100% full:	0.818181818

5.3 STU Schematic



References

[1] *http://www.paperonweb.com/density.htm*

[2] *http://en.wikipedia.org/wiki/Accuracy_and_precision#In_binary_classification*