## Executive Summary

Our group is assigned the project of constructing a plastics discriminator to distinguish between two types of plastic, PET and PVC. Our approach in doing so is using Near-IR light reflection from the plastic. The final design takes advantage of the fact that different materials absorb different amounts of light. In order to accomplish this, the design has two light sources shining on our plastic that then reflects to a photodiode to detect the intensity of the light being reflected back. This intensity of light will change with the material being detected. The final design also consists of a light filtration system and a conveyor belt. In order to filter outside light that is not reflected from the plastic, a black box that covers the sensing area was installed to ensure that the majority of the light that the photodiode is exposed to is light reflected back from the plastic, and not light from the room that the user may be using the device in. A conveyor belt was then implemented to allow for the steady flow of plastic to be detected so that the system could potentially be installed in a much larger scale system.

## Introduction and Problem Statement

In order to remediate and reduce the difficulty of recycling plastic from our oceans, in the form of pollution, we set out to design and build a system that could detect between PET and PVC. With more and more plastic being dumped in the oceans and causing harmful impacts on the environment, tools to help sort this plastic become increasingly vital. Being able to distinguish between PET, an easier to recycle plastic, and PVC can help with these efforts to reduce the amount of less environmentally friendly plastic.

*Table 1: Objectives and Metrics Table*

| **Objectives** | **Metric** |
|---|---|
| Should be able to detect between PET and PVC better than by eye | Success Rate > 90% |
| Can be made part of a larger assembly system | 1 input area and 1 output area |
| Should be completely automated | 1 button for the user to operate |
| Should be able to handle multiple plastic pieces at once | Can handle loads from a $0.5m^3$ bin |
| Used indoors | Operates at room temperature 21-25 °C |

Above are the objectives that we described and believed could be met with the associated metrics. We want the device to do much better than just a human guessing (which should on average be 50%), and so we set our goal at a 90% success rate. A large goal of ours was to make this system capable of being integrated into a larger industrial process. To accommodate this, a conveyor belt was implemented to allow for a continuous system with one input area (start of the belt) and one output area (end of the belt) that can be incorporated into a larger scaled system. For example, our system of detecting the type of plastic could be utilized between a system that cuts and cleans the plastic into shreds and a system that uses the information from our detection system and sorts the plastic into separate bins. The implementation of our conveyor belt also makes the design capable of handling larger loads of plastic to detect, given that the plastic is spread out along the middle of the conveyor belt. In addition, we aimed for an automated system, so we designed the device so that it only needs to be plugged into the wall in order to work.

*Table 2: Constraints and metrics table*

| **Constraints** | **Metric** |
|---|---|
| Should detect in parts | As small as 1 $mm^2$ |
| Should fit on a tabletop | Base is within 150 x $30cm^2$ |

| | |
|---|---|
| Must be made within the budget of the client | Cost $400 or less |
| Must be completed under given time frame by client | Complete by end of Fall 2018 semester |

The constraints (see Table 2) were eventually met by our design. Our design takes account of any size of plastic, as long as the piece of plastic is placed so that it is along the center of the conveyor belt in order to allow the light from the design to shine onto the plastic and have that light (now with an intensity lower than that of the original light that was shone onto it) reflect back to the photodiode to make its readings. In addition, the design is small enough to fit on a tabletop, did not go over budget, and was finalized and close to fully functioning by the end of the semester.

**Design Alternatives Considered**

During the design process, the team conducted research into how we could differentiate between the two plastics and use that difference in our favor. In our research, we found a few ways people in the industry typically separate types of plastic from each other (see Table 3). The most notable options we considered were electrostatic separation, floatation separate, and light reflection (which is what we ended up choosing). Electrostatic separation stopped being a contender when we gathered more information on how it was to be conducted: there were many different parts of this system that were not feasible to implement by the end of the semester. Floatation separation required making a solution of salt water with a specific concentration of salt to create an environment where one type of plastic floats and the other sinks. This would require the user to very regularly refill and clean a detection chamber and conduct regular checks on the system itself to ensure that there is no leaking. In the end, the team chose to go with light reflection in order to detect between different types of plastic.

To implement light reflection detection, the design had to account for light filtration in order to ensure that the only light to be detected by our photodiode was from light being reflected off of plastic. Two ideas to address light filtration were generated: surrounding the system in a black box or installing a pipe with washers inside of it to ensure that only light coming from the plastic. The team initially decided on the pipe and washer route for easier incorporation of the system. This way, a user wanted to integrate our system into a larger system, they would not have to install a large black box around this detection system. However, upon implementing this light filtration method, the team discovered that the photodiode was not picking up the light because the pipe was filtering out too much light, causing not enough light to obtain a reading from the photodiode. Instead, the team returned to the black box idea and surrounded the detection area with a black box to ensure that no outside light reached the photodiode to interfere with the reading.

*Table 3: Our functions and means table:*

| **Functions** | **Means** | | | | | |
|---|---|---|---|---|---|---|
| Feeding of Plastic | chute | human input | robotic arm | conveyer belt | | |
| Detection | hydrocycloning | infrared light | O2 and CO2 permeability | electrostatic separation | floatation separation | depolymerization/purification/repolymerization |
| Delivery of Plastic | chute | conveyer belt | collecting bin | robotic arm | | |
| Power | cord | battery | solar | | | |

Yellow - Not chosen

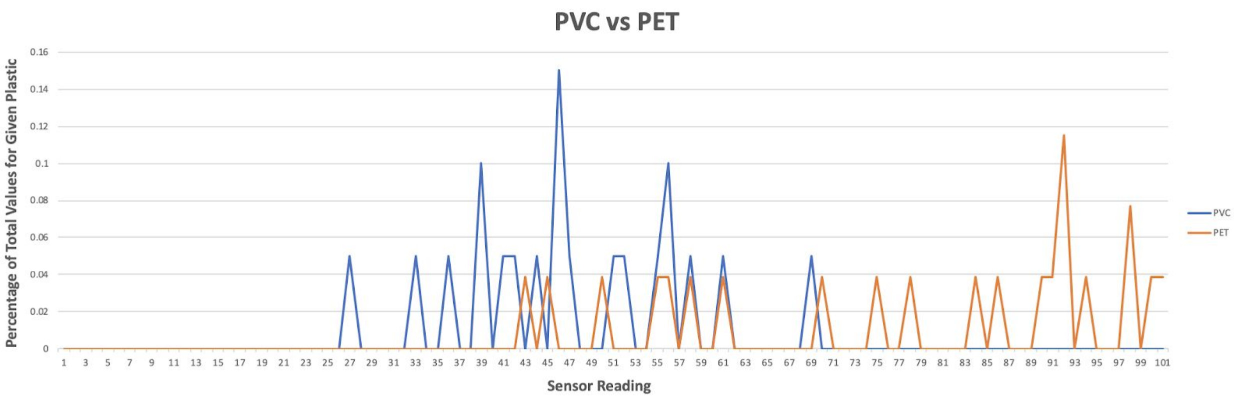
Green - Chosen to accomplish function

**<u>Basis for Design Selection</u>**

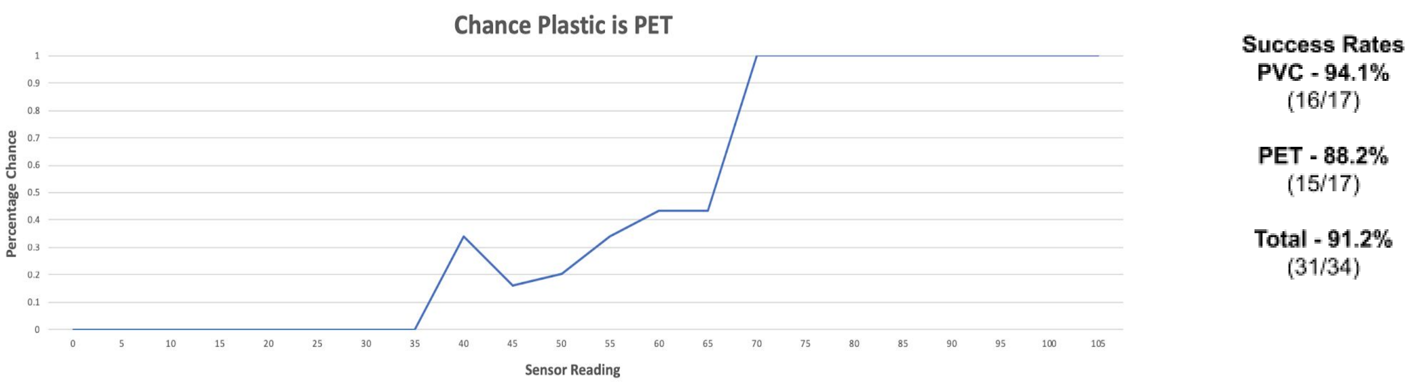
The system is comprised of two key components: the conveyor belt and the light detection system. The team chose to implement a conveyor belt (see Figures 1 & 2 in Appendix A) because it allowed for the system to be easily incorporated into a larger process in an industrial setting. Light reflection detection was chosen to determine the type of plastic because this method seemed like the best option for our goals. The method only requires a light source and photodiode (reliability in detecting different materials was assured in modelling, Appendix C, Model #2) along with a way of ensuring that only a limited amount of outside light is detected. In order to address this light filtration, the team chose to surround the light detection system with a black box so that no outside light could interfere with the reading from the photodiode. Lastly, since there were no power constraints on this project, we are powering this system through cords to the wall and a laptop as well as a battery. A detailed functional analysis is provided in Appendix E.

**Evaluation of Results**

By the end of the semester, the team accomplished its main goal, which was to create a device that could distinguish between PVC and PET plastic that has the potential to be integrated into a larger scaled industrial process. The final design strayed from the original design in some aspects because the team was learning as the design was coming together; the team was able to better judge what kind of problems may arise and how these problems could be solved in our short time frame. This design meets the metrics of our starting objectives: it has a roughly 90% success rate (See Graphs 1 & 2), has one input area and one output area, no buttons for the user to operate (it is always running), operates at room temperature (21-25 °C), and can be able to handle loads from a $0.5m^3$ bin as long as the load is placed spread out along the conveyor belt in the line of the photodiode's vision. This plastics discriminator also meets the constraints: it can detect parts as small as 1 $mm^2$ (as long as it is carefully placed on the belt), the base is within 150 x $30cm^2$, it is within the $400 budget (see Appendix D), and its main functions were completed by the end of the Fall 2018 semester (see more on specifications in Appendix B). Overall, the final design met objectives and constraints set by our client and can indeed test between PET and PVC.




*Graph 1: Reflectance of PET vs PVC*




*Graph 2: Percentage Chance for PET detection*

**<u>Appendix:</u>**

**<u>A: 3D Model and Dimensioned CAD Drawing</u>**

*Figure 1: Physical Model made in PTC Creo*

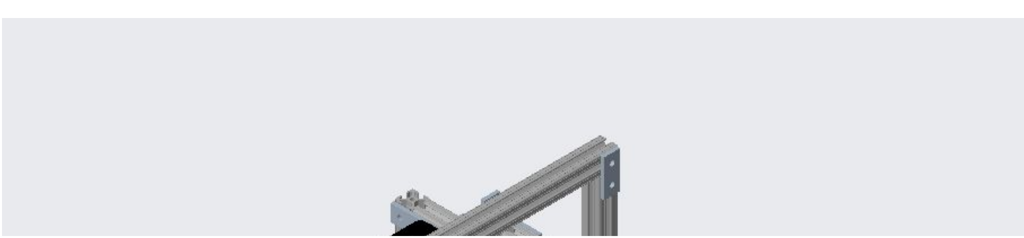
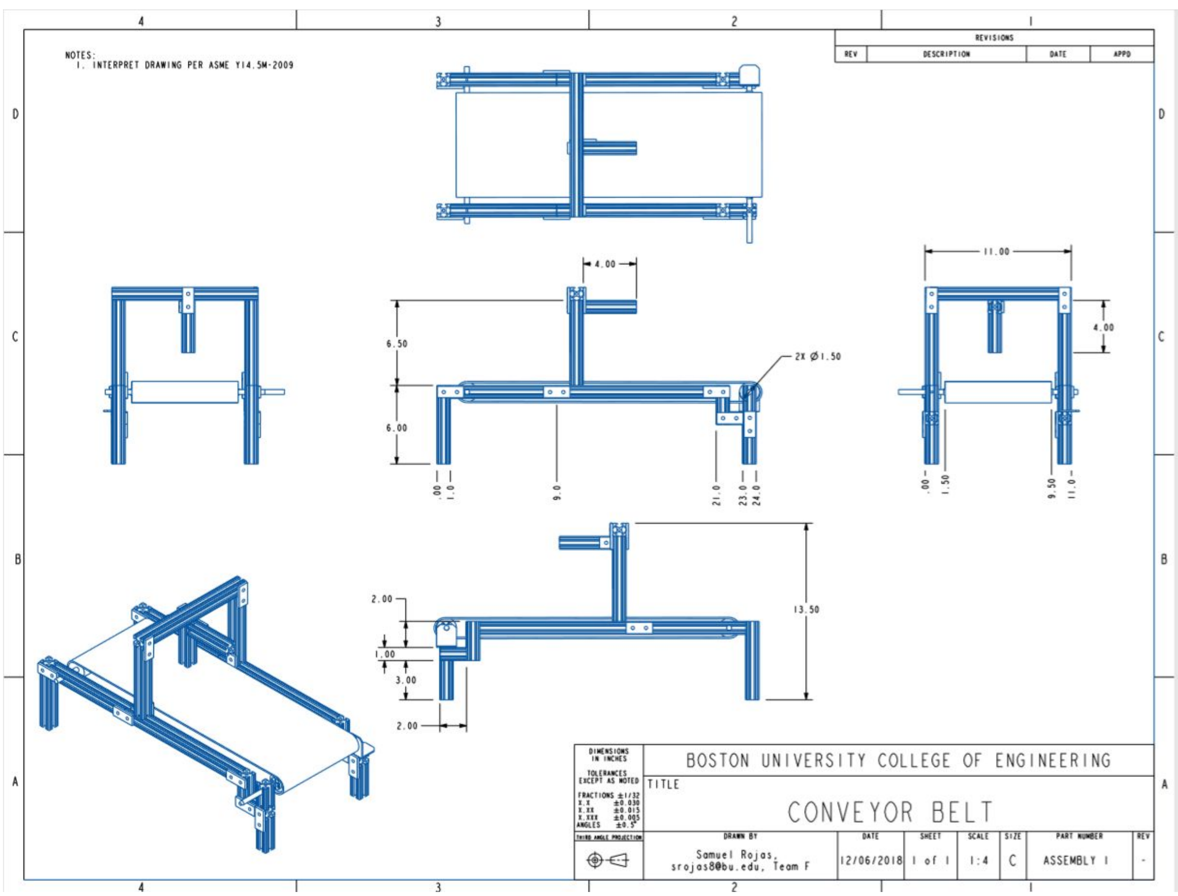


*Figure 2: Dimensioned technical drawing made in PTC Creo*

**B: Specifications**

The goal for the plastics discriminator is to detect between PVC and PET plastic with the potential to be used in an industrial setting. In order to meet this goal, the project mainly took on two parts: the conveyor belt and the light detection. One of the client's requirements was that the device could fit onto a table top, which meant the base of the conveyor belt had to be within 150 x 30cm$^2$. In addition, to move the conveyor belt, 6V DC motors were used and powered by an Arduino plugged into the wall. The conveyor belt delivers the plastic to the sensing area to be categorized as PET or PVC. The light detection system is comprised of a light filtration system and the circuitry/Arduino. In the initial design with the pipe and washer light filtration system, the

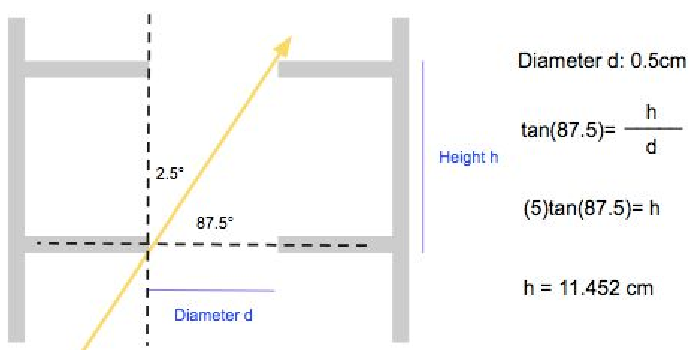


specifications were calculated (0.5cm diameter holes in the washers and 11.452cm long pipe between the washers as specified in Appendix C model #1), however this system provided too little light for the photodiode and was replaced by a black box covering the sensing area to block out outside light. The circuitry was comprised mainly of resistors, a pair of 940nm IR light sources, the photodiode, and an LED connected to an Arduino. When the photodiode reads above a value of 70, then the plastic being scanned is PET and the blue LED lights up, indicating to the user that the piece of plastic that just passed was PET. Overall, the system is able to correctly identify PET or PVC 90% of the time.

## **C: Modeling Results**

Model #1-

*Figure 3: Finding the specifications for our initial light filtering system*




In order to filter out the light that the photodiode is exposed to, a pipe-washer system was first implemented. The system is comprised of a pipe as well as two washers with specific diameters causing a maximum angle of 2.5 degrees from vertical so that the photodiode has limited exposure to any outside light, and instead be only exposed to the light that is reflected back from a piece of plastic at the bottom of the pipe. However, upon implementing this system, the team found that the pipe did not allow enough light to reach the photodiode so that the photodiode could make a reading. With more time for testing, perhaps this method could have been successfully implemented, but instead the team went with putting a black box over the system to block out any outside light.

Model #2-

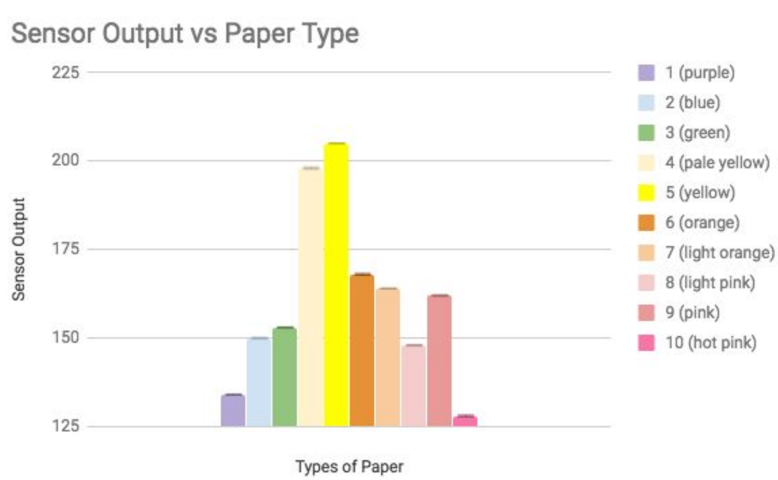
Data from sensor testing:

*Table 4: Demonstration that our sensor can give reliable and distinguishable readings for different materials*

| | 1 (purple) | 2 (blue) | 3 (green) | 4 (pale yellow) | 5 (yellow) | 6 (orange) | 7 (light orange) | 8 (light pink) | 9 (pink) | 10 (hot pink) |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean Sensor Reading | 134.1 | 149.9 | 153.1 | 198 | 205 | 167.7 | 164 | 146.9 | 161.9 | 128.1 |
| Standard Deviation | 0.316 | 0.316 | 0.316 | 0.417 | 0 | 0.483 | 0 | 0.316 | 0.316 | 0.568 |
| Standard Error | 0.1 | 0.1 | 0.1 | 0.149 | 0 | 0.153 | 0 | 0.1 | 0.1 | 0.18 |

*Graph 3: Graphing of data from sensor testing*

The purpose of this model was to show the reliability of the photodiode in distinctly telling




between different colors of paper. The data shows that there is little deviation and that the readings from the photodiode are very reliable. In addition, this data shows that the photodiode can indeed show a difference in readings based pieces of paper with different properties. This acted as a proof of concept for distinguishing between two different types of plastic, PVC and PET.

**D: Budget**

*Table 5: Breakdown of budget*

| PART DESCRIPTION | PRICE |
|---|---|
| DC motors | $29.96 |
| 1 foot by 3 foot 50A Medium rubber, 1/32 inch thick | $24.42 |
| Photodiode | $4.60 |
| 940 nm Light Source | 34.05 |
| Rod (for wheels) | $3.12 |
| Metal disks (for inside pipe) | $14.99 |
| Hubs that mount to our DC motor shaft with the set screws | $13.89 |
| metal pipe | $7.54 |
| Wooden disk (for making wheels) | $6.99 |
| Red LEDs for PVC signal | $6.57 |
| Wooden base | $18.82 |
| Mounting Bracket | $12.99 |
| Power converter: wall to arduino | $7.99 |
| Arduino Uno | $21.80 |
| 80/20 | $30.54 |
| 80/20 Connectors | $41 |
| 80/20 Bolts | $16 |
| T-Slotted Framing, Silver, 1" High x 1" Wide, Solid, .5 ft | $13.68 |
| T-Slotted Framing, Silver, 1" High x 1" Wide, Solid,3 ft | $21.14 |
| T-Slotted Framing, Silver, 1" High x 1" Wide, Solid,1 ft | $17.52 |
| Silver Corner Bracket, 2" Long for 1" High Rail, Extended Corner w/ mounting fasteners | $31.50 |

| | |
|---|---|
| Silver Straight Surface Bracket, 2" Long for 1" High Rail, w/ mounting fasteners | $12.14 |
| **TOTAL (with quantities of each part included)** | $391.25 |

## E: Functional Analysis

*Figure 4: Glass Box Analysis*