Automated Real-Time Sorting and Storage of Recyclable Materials and Waste

Nathaniel Ortiz[1], Mahmood Shaheen[1], Kyle Stark[2], Jakeb Tivey[3]

Bourns College of Engineering, University of California, Riverside[1]

School of Business, University of California, Riverside[2]

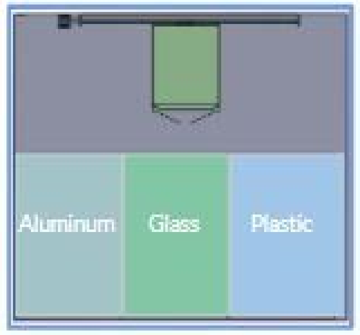
College of Arts and Sciences, University of Redlands[3]

Abstract: We devise a system that automatically identifies, sorts, and refunds upon validation of a proper CRV eligible recyclable. Our device aims to simplify the process of providing cleaner streams of recyclable material through object recognition and mechanical separation. By providing the users with incentives to use our machines, we can increase the diversion rate of plastic, glass, and aluminium material from commingled waste.

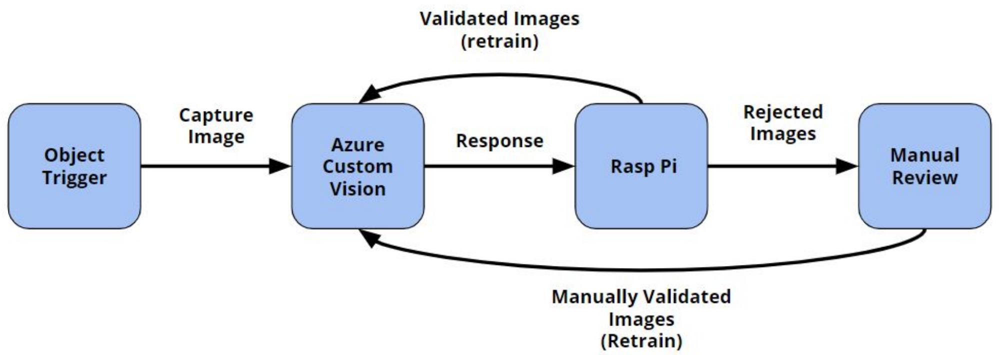
Problem: American universities and the country at large have significant waste volume issues. Studies of university waste management reveal that the average college student produces over 640 pounds of trash annually, much of which is composed of underutilized recyclable material[1]. Much of the generated material such as aluminum metals, glass, and plastics all used as beverage containers go unrecycled, causing a drastic recycling program deficit[2]. In 2017, the EPA reported that 27% of all glass products were recycled, with a mere 8% of plastics returning for reuse[3]. Further data suggests that more than 60 million bottles are thrown into landfills or incinerated every day[4] We believe that in order to have a more sustainable future, we need to change how people recycle. With climate change and sustainability being a common conversation in university spaces, we see that people care about the environment but currently lack a compelling additional incentive to recycle. Many people do not recycle, and when they do they often contaminate recycling streams through misidentification. Costly cement bins are used to collect recycled material, require frequent collection, and are created using processes that are harmful to the environment. Paired with the closure of nearly 40 percent of Californian recycling centers in the past 5 years, measures to encourage recycling have been ineffective. We seek to solve these issues by devising a system that sorts recyclable materials upon insertion into a wastebin, allocating their CRV value to the user, while logging capacity and usage.

Solution: Our project, dubbed SARU (Smart Automated Recycling Unit), aims to incentivize recycling by developing a low-maintenance, solar-powered outdoor recycling unit that instantly identifies recyclable material and sorts it internally, allocating CRV (California Refund Value) directly back to the user through their payment method of choice. SARU will feature internal sensors that will record and analyze data such as the type of product recycled, the amount of material inside the unit at a given point, the amount of usage, and the geolocation of the unit. By coupling these sensors with object recognition, we can accurately identify recyclables with no human intervention necessary. These features will increase recycling rates, provide cost-reduction strategies to the host property, and allow consumers to receive money back for recycling, instantly and reliably.

Mechanical Design: In comparison with old 'reverse vending machine designs,' which are bulky and have limited locations,our core design principles emphasize recycling accessibility and user convenience. Our main body dimensions will be 61in x 27.5in x 51in and our storage bins will be 19in x 19in x 27.5in. Made with versatility in mind, SARU merges its compact and sleek design for maximum spatial efficiency. Its 5ft x 2.25ft x 4.25ft frame is constructed from aluminum v-rails and plated with galvanized steel, making it a lightweight, portable solution for identifying and sorting recyclables anywhere from office spaces to sports stadiums. The top surface of the device will feature a 5' x 1.25' custom-made solar panel, giving us an output power capacity of $120W$. Using the equation $P = A * \rho$, where ρ is power density in $\frac{W}{cm^2}$, we can determine the power output of the top of the unit. Yielding $\rho = 0.0195$ and using an area $A = 5800cm^2$, we are able to obtain a power capacity of $\sim 110W$.

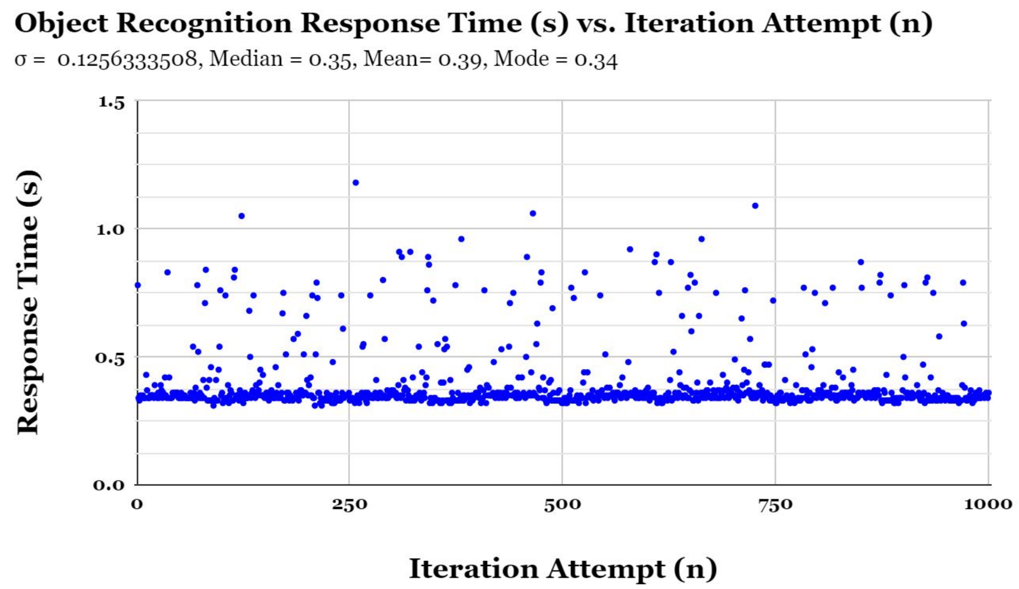


Electrical Design: Upon the user depositing a bottle, the bottle enters the transport bin where the bottle is identified and deposited into the correct bin using a linear actuator controlled by a Raspberry Pi. We selected the Raspberry Pi due to its inclusion of networking hardware, display output, GPIO, USB, low power usage, and small footprint. By using Microsoft Azure's Custom Vision, we have trained a model that accurately identifies recyclables based on the type of material (e.g. aluminum, glass, and plastic). Upon the user inserting a bottle, a picture of the recyclable will be taken, uploaded to Azure, and will then sort based on the response received. Once validated and sorted, the user will then immediately receive their CRV refund in the electronic method of their choosing. In addition, by using weight and height sensors placed in



each bin, we can determine how full each recyclable bin is, thus only requiring the machine to be emptied when necessary. As bottles and cans constantly have new designs and labels, it is necessary to continuously update the object recognition model with new images in order to prevent any false negatives. This issue, however, is easily combated, by continuously retraining the model with the correctly validated images, as well as images that were rejected, but manually reviewed and validated. This allows us to reduce the instances of false negatives over time and increase our overall accuracy.

Object Recognition: Using our model, we had a response time from Azure of around 0.35s. This time is inclusive of the time it takes to upload, process, and send the result back. Our times are very uniform, with the exception of occasional outliers beyond our control (network latency, other resources having priority, etc).



Conclusion: The SARU device is an integrated bin that uses object recognition to sort collected recyclables and return predetermined monetary value (CRV) back to the users. It is complemented by client and consumer companion applications to facilitate efficiency, empowering firms with live data on the status of each unit's capacity and enabling consumers to reclaim their benefits conveniently. SARU addresses modern problems with recycling by improving diversion rates through the sorting and subsequent cleaning of waste streams, incentivization to the consumer, and cost-reduction of the host property. Our device further allows users to observe and take an active role in the positive effects of recycling via charity point counters, the ability to track key milestones in their success, and business partnerships accessible with the mobile application. By providing an automated and innovative instant CRV-allocation system to campuses, comprehensive positive user experience, and dynamic data collection and telemetry, SARU reimagines modern recycling.

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