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Smart Bin: Automatic Waste Sorter to Promote Sustainability

This project aims to design and create a device to eliminate some inherent human inaccuracy displayed in incorrect recycling habits. Studies show that about 62% of trash sent to a landfill could have been recycled or composted. An entire recycling bin can be contaminated by one dirty candy wrapper, a half-empty Coke bottle, or a greasy pizza box. This project offers a customized approach involving gathering and analyzing campus-specific recycling data and using said data to train and validate a machine learning model, ensuring an accurate recycling solution for WRA. Our product will detect the object, obtain data on the said object, transmit the data to a program, interpret the data into ‘recyclable’ and ‘non-recyclable,’ and finally drop the object into its corresponding bin. The software for our product examines previous research on efficient automated recycling supervised machine learning algorithms using neural networks and deep learning to accurately predict an object's recyclability. The effectiveness of the program relies on the identification of key characteristics within each of the potentially recyclable objects, a task performed by our product's integrated camera system. In pursuit of precision and relevance within Western Reserve Academy's campus, our system will collect and analyze recycling data specific to the institution. Our product will ensure precise recycling at the deployment location while also providing education to those who use our product. The system encourages greater environmental awareness and responsibility among the Reserve community.

Reflection Paper

Waste management has always been a process subject to human error. The simple mistake of one object being placed in the wrong container can spoil an entire recycling load, disrupting city efforts toward sustainability. I proposed Smart Bin, an autonomous sorter, to bring an innovative solution to the Western Reserve Academy community. My project has two main goals: first, to develop a highly efficient physical sorter capable of accurately categorizing objects into their designated bins, and second, to create an engaging and interactive user experience that imparts valuable insights into proper recycling practices.

I first began to research machine learning algorithms capable of sorting images into various categories before determining it's recyclability. Prior to algorithm execution, the program must detect objects in the camera's view. Utilizing TensorFlow's object detection API facilitates real-time identification, a prerequisite for algorithmic processing (Mitra 13). Once the object is identified and the image is processed, the next step involves crafting a model through neural networks to categorize the identified object. Among the array of neural network models available, the optimal choice for image identification emerges as the Convolutional Neural Network (CNN) algorithm. Particularly notable is CNN's prowess in recognizing diverse categories within images, surpassing the limitations of single-category identification. To address the need for discerning multiple categories such as glass, plastics, paper, and more, our approach will incorporate the Region-based Convolutional Neural Network (R-CNN) algorithm (Ozdemir 9). The program will receive rewards for accurate categorization and penalties for inaccuracies. This incentivized framework is the foundation for training our neural network model, enabling it to continuously refine its categorization capabilities through a dynamic feedback system (Nielsan

25). As the program iteratively learns, it will become increasingly adept at precisely categorizing objects within the waste management system.

The precision of the model hinges significantly on the quality of the data it is provided (Ng et al. 3). In order to maximize results, I will create my own custom dataset tailored specifically to Western Reserve Academy's unique recycling habits. To do this, I plan to run an experiment by searching through recycling bins to find a number of the most recycled objects and list those as the "categories" in my model. Then, I will take a number of photos of each category (at least 100 per object) in diverse positions and conditions, forming the foundational training data for the model. I will iterate through training, testing, and accuracy checks in a continuous cycle to refine the model iteratively. Drawing from insights gathered in prior projects, the targeted goal for accurate classification within this endeavor falls within the established range of 85% to 92% (Elo 84).

As my project progresses, I aim to continue exploring ways to improve Smart Bin's algorithms and interactive experience. Upon successfully integrating the algorithm relying solely on image detection, I hope to expand the program's inputs to include additional factors such as weight, plastic-type, and more. This augmentation will significantly enhance the program's capabilities, allowing for a more comprehensive and nuanced analysis of recyclable items. Furthermore, a program that is able to crop the images before the program and use image-enhancing techniques to process the input image would allow for a smoother, less chaotic set of data, which makes it easier to judge which bin it goes in. I aim to position the finalized project in a prominent location on campus, fostering student interaction. Accompanying the Smart Bin will be informative materials highlighting the significance of recycling creating an educational hub to promote awareness towards sustainability.

Works Cited

Ahmed, Alim Al Ayub, and A.B.M. Asadullah. "Artificial Intelligence and Machine Learning in Waste Management and Recycling." *Engineering International*, vol. 8, no. 1, 2020, pp. 43-52. *Academia*, abc.us.org/ojs/index.php/ei/article/view/498/986.

This journal article is a secondary source. The authors, A.B.M Asadullah and Alim Al Ayub Ahmed, are professors at Jiujiang University and International Islamic University Malaysia respectively. This article details the author's analysis of using machine learning / artificial intelligence in waste management.

The author details the newer technologies being used in waste management such as Radio Frequency Identification Rations (RFID) and Sensor Networks (SN). The article stresses the advantages of these newer technologies and how they are useful. The article also gives examples of efficient newer technologies such as the SamurAI Robot which sorts waste faster than any human can. The article ends by mentioning how if all of the sorting is happening in the factory, inefficiencies can occur.

Since the focus of my project is centered around the benefits of machine learning models in the recycling industry, I wish to take note of the do's and don'ts with waste management. I will use this source to better explain the benefits of machine learning within a waste management scenario.

Elo, Kristofer. *Automation in the Recycling Industry Recycling of Plastics and Large Liquid Crystal Displays*. 2013. Linköping U, PhD dissertation. *Diva Portal*, Uppsala University, www.diva-portal.org/smash/get/diva2:613551/FULLTEXT01.pdf.

This master's thesis is a secondary source. The author, Kristofer Elo, is a philosophical doctoral student at Linköping University at the Department of Management and Engineering and the Division of Manufacturing Technology. This essay details the author's project, identifying problems and solutions in the recycling of plastics and large liquid crystal displays in order to better cope with current recycling requirements.

The author focuses on the question (What technical problems may occur in automatic sorting and separation for the recycling of plastics / dismantling of large liquid crystal displays?) from a technical perspective and thus not sustainability but rather the work environment and economic issues. This paper not only examines the technology behind the creation of such a sorter, but also the surrounding areas that may affect such research. The paper goes into a detailed view of the chemistry behind plastics and how to identify them within the sorter. Then the author details the specific steps needed to efficiently recycle both plastics and liquid crystal displays on electronics. The author concludes that there are many factors and problems that go into creating such a sorter, especially with an especially large stream of objects.

This source masterfully goes into detail about the state-of-the-art sorters in recycling plants and the methodology they use to sort plastics. For my project I wish to incorporate some element of plastic analysis so that the Smart Bin can identify the recyclability of the plastic as a parameter within the software. This source will help me understand what parameters I need to choose in order to correctly identify recyclable plastics.

Gibson, Tom. "Recycling Robots." *Mechanical Engineering*, vol. 142, no. 1, Jan. 2020, pp. 32-37. *Academic Search Premier*, https://doi.org/10.1115/1.2020-jan2.

This journal article is a secondary source. Tom Gibson is a consulting mechanical engineer specializing in machine design, green building, and solid waste in Milton, PA. This article details the resurgence in AI technology in recycling factories in order to more efficiently sort out the recycling from the waste.

The author details a vision-based machine learning algorithm created from a dataset of millions of images that classifies an object's recyclability similarly to how humans classify objects (a neural network). Using robotics and these new AI image-processing technologies, the author details the benefits and how this is "only the tip of the iceberg."

Since the focus of my project is centered around the benefits of machine learning models in the recycling industry, I wish to take note of some of the benefits of this technology that is heavily detailed in the article. This source provides an example of how AI can improve the recycling industry which is imperative to my project.

Mitra, Arghadeep. *Detection of Waste Materials Using Deep Learning and Image Processing*. 2020. California State U, San Marcos, PhD dissertation. *Scholar Works*, scholarworks.calstate.edu/downloads/gx41mn74q.

This master's thesis is a secondary source. The author, Arghadeep Mitra, is a student at California State University who has a Masters in Computer Science. This essay details the author's project, creating an image-based detection software

for waste segregation, and the findings he had as a result of his machine learning network.

The author details the importance of CNN (conventional neural networks) and how he optimized his model. He then details his image-processing techniques to eliminate possible distortions in the image/video taken of the object. He then collected, labeled, and processed data to train the network with NumPy, Matplotlib, OS, TensorFlow, Utils, and OpenCV.

Since the focus of my project is similar to the project in this thesis paper, I wish to take note of his process to help expedite my project. I will also use this source to make sure I don't make the same mistakes the author in the source made, such as creating a dataset not tailored to the environment the machine learning model will test. This essay will be very helpful to my research as it is the closest source of a similar project with an image processing machine learning model.

Ng, Davy Tsz Kit, et al. "Fostering Secondary School Students' AI Literacy through Making AI-Driven Recycling Bins." *Education and Information Technologies*, 19 Sept. 2023. *Google Scholar*, https://doi.org/10.1007/s10639-023-12183-9.

This journal article is a secondary source. The authors, Davy Tsz Kit Ng, Jiahong Su, Samuel Kai Wah Chu, are professors at The University of Hong Kong. These authors have written countless articles on the applications of AI and its uses in the industry. This article details the development of AI literacy through the development of "AI Recycling Bins" serving as a perfect base of learning.

The article details an experiment where they had 35 secondary school students in an AI maker program, where AI-driven recycling bins were employed as a project-based learning intervention. The study provides design principles and an instructional design framework to assist future educators in creating meaningful maker-based learning experiences in AI education.

One of the aspects I want my project to focus on is the educational aspect of the project whether that is understanding AI or bettering certain recycling habits. This source will allow me to apply some of the same methods used in the article to make the Smart Bin more interactive and educational for the user.

Nielsan, Michael. *Neural Networks and Deep Learning*. neuralnetworksanddeeplearning.com.

This open-source book is a secondary source. The author, Michael Nielsan, specializes in quantum computing and artificial intelligence working as a research fellow at Astera Institute. Nielsan has written many open-source books detailing specific problems to explain the mathematics behind artificial intelligence as well as other topics such as Quantum Computing. This book details the core concepts behind deep learning and neural networks.

The author explains the mathematics behind neural networks while using the pretext of creating a neural network to analyze and recognize handwritten numbers, a simple example. Using this project as a basis for his teaching, Nielsan goes on to detail the intricacies of back propagation algorithms, mathematical proofs to support the reliability of neural networks, the hidden layers within a neural network, and how the GPU is used to train the model using deep learning.

This source is invaluable to my project as the book goes step-by-step explaining how to efficiently train a neural network while providing code snippets in Python to provide examples for the reader. This book is one of the only sources I could find that efficiently detailed the process along with giving mathematical reasons to support their findings along with the code needed to achieve said process. I will use this source to explain the mathematical and logical elements behind a machine learning model and how it works.

Ozdemir, Merve Erkinay, et al. "Applying Machine Learning Approach in Recycling." *Journal of Material Cycles and Waste Management*, vol. 23, no. 3, 17 Feb. 2021, pp. 855-71, https://doi.org/10.1007/s10163-021-01182-y.

This journal article is a secondary source. The authors, Merve Erkinay Ozdemir, Zaara Ali, Balakrishnan Subeshan, and Eylem Asmulta, are professors at Iskenderun Technical University and Wichita State University respectively. Merve Erkinay Ozedemir specializes in electrical electronic engineering, while Zaara Ali, Balakrishnan Subeshan, and Eylem Asmulta all specialize in mechanical engineering. This article details a compilation of the most recent developments in machine learning used in recycling industries.

The author begins by detailing the current problems with recycling and mentions how certain machine learning algorithms are already efficiently used in environment associated industries. The article goes on to give an overview of machine learning algorithms and describes several main types of related machine learning algorithms for waste sorting along with the issues that each of those algorithms present in terms of efficiency. The article ends with the conclusion that

certain algorithms are tailored for certain types of recyclable materials, depending on which type of neural network used directly correlates with the efficiency of the program for certain objects.

The article perfectly details different algorithms and their related advantages and disadvantages which is certainly an aspect I will need to consider when creating the algorithm for Smart Bin. I will take note of the apparent advantages of certain algorithms to attempt to make the ideal program fitted to the dataset.