# Squander: Waste Detection Mobile Application Using Image Recognition

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***Abstract*—Waste management is very important for maintaining a healthy and sustainable environment. With a growing population and development, the amount of waste generated has increased rapidly. For proper waste decomposition and recycling, the first step is waste detection and segregation, separating the waste into different categories. The presence of models or strategies which help people to sort waste has become extremely important in the right disposal of that garbage. Even though there are various sorts of recycling categories, many people remain confused or cannot appropriately recognize how to decide on the right trash bin to dispose of every waste. The two areas where the waste segregation process can be automated are – the place where waste is generated, like homes, schools, cafes, etc., and the dumping yard where the waste is separated manually by the workers working at waste companies.**

**This paper offers a solution to create an automated waste detection system using a machine learning algorithm that will gather the waste images or videos from a camera with object recognition, detection & prediction, and categorize the waste materials like cardboard, glass, metal, paper, plastic, and trash so that the waste can be properly dumped in the recyclable and non-recyclable bin.**

**Key Words: Machine Learning, Object Detection, Image Classification, TensorFlow, Faster R-CNN, Waste Classification, Waste Management, etc.**

## I. Introduction

Successful waste management is one of the world's biggest problems, and if the waste is not handled properly it can lead to many diseases and cause damage to the environment. In the next 30 years [1], global annual waste production is estimated to increase by 70%, powered by rapid urbanization and rising populations. Regular production of waste per capita in high-income countries is estimated to rise by 19% by 2050 relative to low-and middle-income countries, where it is predicted to increase by nearly 40% or more [2]. The world produces 2.01 billion tons [2] of urban solid waste yearly, with the United States [1] being the highest producer of waste. According to the Environmental Protection Agency (EPA), it is estimated that 75% of the waste generated in America can be recycled but only 30% of it is recycled [3]. Depending on the amount of waste produced, its quality as well as how the waste is treated, it is expected that 1.6 billion tons of $CO_2$ were produced by waste disposal and management in 2016, accounting for around 5% of global emissions [4]. With the increase in the number of industries in the urban area, the disposal of solid waste is really becoming a big problem, and the solid waste includes paper, wood, plastic, metal, glass, etc. The main method of managing the waste is landfilling, which is inefficient and expensive and pollutes the natural environment. For example, the landfill site can affect the health of the people who stay around the landfill site. Another common way of managing waste is burning waste and this method can cause air pollution and some hazardous materials from the waste spread into the air which can cause cancer[5]. Hence it is necessary to recycle the waste to protect the environment and human beings' health, and we need to separate the waste into different components which can be recycled using different ways.

The Squander application can be broken down into two major components: a trained machine learning-based model for image classification, and the front-end-user interface. The learned model used for this study is one based on a Keras Sequential neural network or SNN, and it receives its image inputs for classification from uploads through a dynamic mobile application that serves as the user interface, with the two being integrated via a classic client-server model. Both components will be discussed in more detail in the sections to follow, with II and III examining current machine learning studies and the specific algorithms used as well as existing applications for waste detection respectively, IV giving a brief overview of Squander's base requirements, V discussing the technologies used, VI detailing the [current] results of both the classification model and the mobile application, and lastly, VII to provide some closing remarks.

## II. Literature Review

Automated systems for waste separation using image processing and artificial intelligence have been a topic widely studied in recent years. Machine Learning techniques empower many aspects of modern society, like recommendation systems, text-to-speech devices, or objects identification in images[1][2]. The waste management problem has attracted a lot of interest, where the main goal was to create a Machine Learning-based image recognition system to sort litter[3][4][5]. The majority of the proposed approaches are based on machine learning algorithms utilized in the computer vision field. This research is going to focus on the development of a classification model for waste images using processing techniques and classical machine learning algorithms. This article compiles the results of an exploratory study on the implementation of two different methods of feature extraction for the development of a bounded version of the waste classification problem something Squander attempts to cater to. In 2016, Thung and Yang [1] built two classification models using SVM and CNN on the TrashNet [7] dataset. They used the Scale-Invariant Feature Transform (SIFT) to train the SVM model which helped in reducing the training time. The CNN classifier with 11 layers was developed which was like the architecture of AlexNet. As CNN requires a large amount of data for training data augmentation was performed. The SVM model was able to classify the waste 63% accurately; however, the CNN model did not perform well by giving only 22% of accuracy. Although CNN was supposed to perform better than SVM, the authors mentioned that the CNN model was not trained with optimal parameters which resulted in low accuracy. The CNN model has the advantage of automatic feature extraction from the input image whereas for the SVM model it has to be done manually. The main focus of their research was to classify a single piece of waste object. However, in 2018, Knowles et al. [6] built OscarNet by using CNN VGG-19 (pre-trained on the ImageNet dataset) to classify the waste objects into 7 categories. The authors used the TrashNet [7] dataset consisting of 6 classes to which they added images of the non-waste category. The fully connected layer of the pre-trained model was removed with 1 hidden dense layer. With transfer learning, the authors utilized the pre-trained VGG-19 network to classify the waste with 88.42% accuracy. The research shows how a pre-trained network can be effectively used for classifying waste objects. After analyzing various research studies done on the waste segregation process it can be seen that most of the research work was focused on single object waste classification with few waste categories. Almost all the research work has used the TrashNet dataset for their experiments. Although the TrashNet is the only available good dataset for waste items, it still has some drawbacks. The dataset has very fewer waste images and it does not include images of food waste. The dataset also has an imbalanced number of images in different classes. In terms of algorithm, most of the research work has used a deep convolutional neural network which is a good choice for the image classification tasks, but these models require more images for training. However still, less work has been done on the detection of multiple item wastes. Thus, given the existing studies analyzed—all their outcomes and considerations—Squander becomes the first application of its kind that can identify a larger variety of objects, and multiple waste objects in the same picture to help in faster sorting of trash by using Keras Sequential Neural Network ( KSNN ). And in doing so, the application both exists as a manifestation of convenience and accessibility while also creating a means for users to save both time and money.

## III. Current Solutions

There are various waste management application available which uses machine learning model to recognize waste from the image and classify them into recyclable and non-recyclable waste. These applications help to minimize human efforts for waste sorting and provide a way for its proper disposal. The efficiency of application depends upon how accurate the model is, which is achieved by proper training and testing the model. People are becoming more curious about waste recycling as the impact of waste on environment is degrading its natural beauty. The following four points are mainly emphasized for waste management that are Source Reduction,Recycling or Composting, Energy Recovery and Treatment and Disposal.


Source Reduction and reuse accounts for lowering quantity of waste production at source and plan for reuse. Recycling or composting uses various approach to recycle waste so that it do not contaminate the environment.The amount of energy produced by burning waste is the energy recovery and disposal of waste in landfill and its treatment is the final stage.

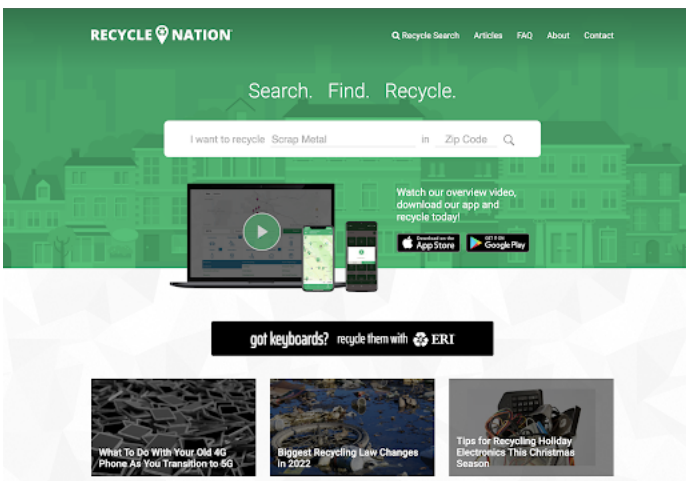
Considering the waste management hierarchy squander application helps to recognize waste from image and get the list of items that can be recycled. It allows to plan for waste disposal by sending result of scan to the recycling company. People can keep track of amount of waste produce and lower the generation of waste through source reduction.Currently, their are 3 waste management applications that are Recycle Nation, WhatGoesWhere, and WM app. This apps use various techniques for waste recycling and provides solution to user for proper disposal. Each application has its own feature that encourages people to recycle waste.

Recycle Nation is mobile and web application. It was launched in 2007 since then it has helped over 10 million customers to find locations to recycle various types of items, Figure 1 contains the screenshot of RecycleNation application. If a user has to recycle a particular item, then he makes a search for this item by providing item name and zip code of his desired location. The search result would be a list of recycling location near to zip

Table 1.Waste Management Applications

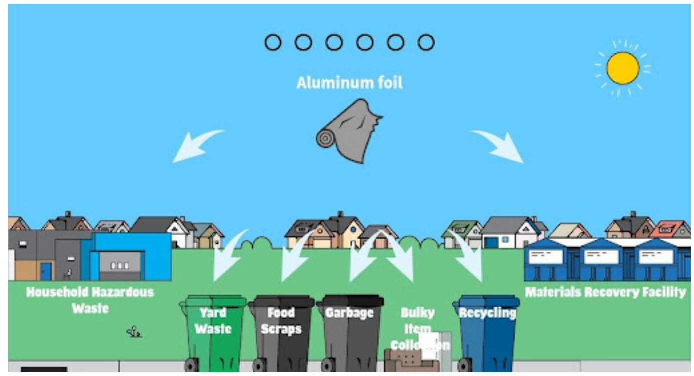
| AppName | Platform | Image Recognition | Function |
|---|---|---|---|
| Squander | Mobile Application | Yes | Uses Image recognition to detect waste and allows to find proper recycling plants and schedule pickup. |
| RecycleNation | Web and Mobile Application | No | Can locate recycling centers on map,track user contribution to recycling movement. |
| WhatGoesWhere | Web and Mobile Application | No | Guides user for curbside program and drop-off location to maximize recycling. |
| WM | Web and Mobile Application | No | Allows pickup service for residential,business waste by prior scheduling. |

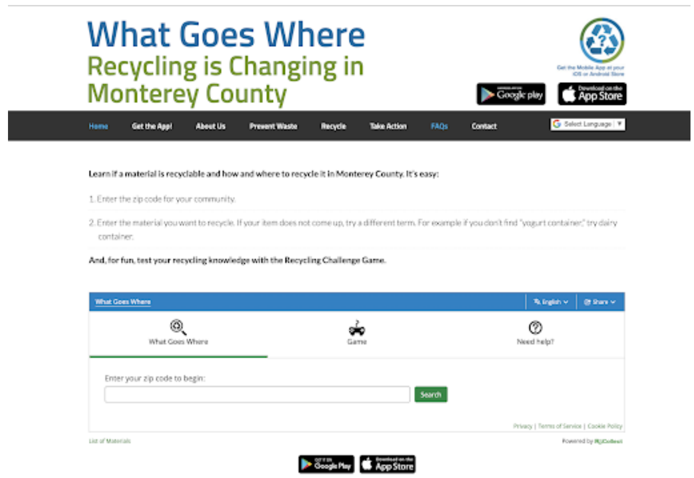
code.After that user can select one of the location in the list which is best feasible and economical. App provides services such as drop-off, curbside program, pickup and Mail-back services.The type of items Recycled by recycle nation includes metal, plastic construction, automotive and many more.From all this Recycle nation provides a way to recycle a particular item to a desired location.




WhatGoes Where app is also a waste management app which guides user for curbside programs and drop-off location to maximize recycling. Its collaborative project in Monterey county helps residents answer the question “Can I recycle this”. It provides a game known as Waste recycle sorting game which helps user to learn material sorting. For example, if we have aluminum foil and paper to recycle than by playing game it teaches us under which category the particular item should belong such as Food,Scraps, Yard Waste, Garbage, Bulky item collection, recycling.

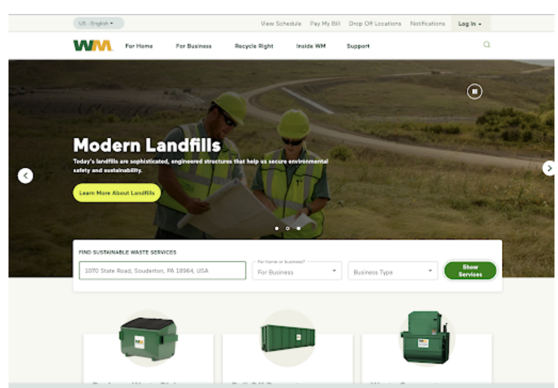
WM app is another app that provides pickup services for residential, business waste.To use this app we have to just enter our location and select from home or business type of waste. Then when the user clicks on show services, the list of services provided by WM will be visible for selections out of which user can choose residential Waste Pickup,Roll-off Dumpster, Bagster Bag. WM usually pro-




vide their container and dumpster for waste storage which is chargeable monthly as per the size of container. We can opt for pickup services and pay bill online monthly which helps us to keep track of activities.

If a user has selected service for business waste, then he has to mention a type of business done.Then it will list out various business types such as construction, arts and entertainment, educational, financial services. User can opt for long term or short-term rental service of roll-off dumpster by mentioning delivery date and removal date.WM app provides a distinguishing platform to separate out residential and business waste and provides dumpster rental facility that is evenly managed by WM app.



## IV. Product Requirements

Our aim is to develop an application that aims to help users organize and plan the disposal of their waste. Our app uses a machine learning algorithm to recognize waste from places such as households, construction sites, and public spaces to enable the user to distinguish recyclable waste and provide the information for proper disposal. Using the information from the machine learning algorithm the application will tell the user which services are closest to handle the classified garbage in the photo. The user will then take information from the application to coordinate the proper retrieval of their garbage.

Overall our application will function as a tool to make garbage disposal more efficient and easy. To make this application these are some key features required:

*1) User Management:* - Users should be able to access the interface of the application to manage the photo input.

*2) Garbage Detection:* - The application should have the functionality to recognize and classify garbage into the following categories: Cardboard, Glass, Metal, Paper, Plastic, and Miscellaneous Trash

*3) Information Retrieval:* - The application should be able to take the data from garbage classification to retrieve the appropriate facilities with the corresponding services to remove the classified garbage

### *A. In addition to these key requirements we have a few requirements that are needed to improve the experience users have with the application:*

*1) Upload Video:* - For ease of use users should eventually be able to send a video instead of taking several images to provide information to the application.

*2) Multiple Recognition:* - Users should also be able to send a picture of garbage and have the application segment and classify all the garbage items in the image. This feature will reduce the number of pictures a user would have to take if they choose to not take a video or the video feature is not available.

*3) Schedule Planning:* - When the user receives information on how to recycle their garbage and who to contact for assistance, it would be a nice feature if the application could schedule the garbage pick up. This would further aid in the organization and planning of garbage retrieval.

*4) Recycle Milestone Tracking:* - We want to make users feel like they are contributing to the cause of creating a greener society. In the application we want to implement a tracker to track the individual's positive impact on the environment; as well as a tracker to track every user's positive impact together.

## V. Methodology

The Squander application follows a decentralized architecturing model of Serverless Application model, which is a revolution in cloud computing[1]. Our application is based upon an open-source framework for building applications that can promise high reliability, low maintenance and abstraction from dependencies. The whole Application infrastructure can be pre-defined and configured in a single YAML configuration file that could be transformed into a formation template and deployed into cloud. The application model can support serverless functions, databases, API gateways and event source mappings.

There are multiple level of the project where different but right technologies have been used. At the user end, we have build native mobile application. At the server side, we have API Gateways to accept incoming HTTP requests and serverless lambda function to process the requests, the lambda functions communicate with machine learning model hosted in sage maker. The API responses from the backend are then fetched by the mobile application and deployed to the user. Next few sections we will go deeper into each level of the application.

### *A. User frontend*

We have chosen to use native mobile application for user frontend as that would enable us to provide more built-in features to users and can leverage a native user experience. The native application is also know to have better performance and security than web applications [2]. Our application is build on Android Studio with UX designs developed on FluidUI. The studio provides in-build best practices for the application and helped improve usability.

### *B. API Gateways*

These fully managed services make it easy for developers to create, publish, maintain, monitor and secure APIs with scalability to any requirement. These APIs allow front-end application to invoke features and custom services from the backend, they also act as access to data and business logic. HTTP and RESTful requests are both supported at the API gateway with custom API mapping to Queue services to distinguish between paid and free user access. Two-way communication is enabled using these APIs and supports containerized and serverless workload and custom access to storage and server endpoints.

API Gateway handles tasks involving acceptance and processing of a highly scalable number of concurrent API calls, including CORS support, traffic management, throttling, access control, monitoring and API Version Management.The APIs call would receive and the amount of data transferred out and with the API Gateway tiered pricing model allows for a pay-per-use model and reduce your cost as API usage scales.

### *C. Serverless Lambda Functions*

The Serverless Application Model (SAM) is an open-source framework that helps to develop features as lambda functions in AWS, along with AWS infrastructure resources they require. It is a CLI that offers structure, automation and best practices out-of-box, sophisticated. event-driven serverless architecture development is comprised of the functions and events developed using this model. Multiple jobs can be performed using lambda functions and allows for a wide range of service access, this allows to perform automated scripts and jobs running on the AWS ecosystem to trigger applications or pipelines. It also allows users to manage a lot of the features and version control them. This model allows for a great use of separation of concern principle during the architectural designs and reduces inter-dependency.

### D. Machine Learning Model

The machine learning model we have developed is focused on the visual analysis of images for recommendation on the recycling products.This system aims to lower the barrier in visual identification of basic elements that could be recycled and the noval machine learning approach we have developed learns visual patterns of the elements from a large corpus of dataset and associated tagging. The train this model then to allow it to predict with high accuracy the similar patterns recognized in the test dataset compared to the baseline models. We have followed the following procedure to ensure the right approach to model building.

*1) Prepare the data:* : The data required for the model training was researching and identified from multiple research papers including TrashNet[4] dataset. The dataset is scanned for any outlier values and normalized for the model to process.

*2) Principal Component Analysis:* : PCA was performed on the dataset to identify features that had the most impact of the model efficiency and accuracy. The PCA allowed the model to ignore processing low impact variables and avoid skews and processing time.

*3) Dataset Split:* : The dataset is then split into training and test dataset in the standard 80-20 ratio and used random shuffling algorithms to increase the probability of unique and distinct values across the dataset, this allows to reduce the dataset to be less biased, increase training parameter's value ranges and allows for a better mix of test sets.

*4) Model Selection:* : The model used is a Keras Sequential Neural Network. There were pre-built models tested from both Google Cloud Vision and IBM Watson Vision.

*5) Training Model:* : The machine learning model was trained with the split train dataset and the weights we initialized at random. The training allowed the model to adjust the weights to fit the model requirement.

*6) Evaluation:* : The model is evaluated on the test dataset and the main metrics for revaluation accuracy, precision and recall are designed using frameworks available.

## VI. Product Results

So far the accuracy of our model is around 64% which is good enough considering the starting point of the project. The model is very good at detecting images that are clear and perfectly in view like the image of the wine bottle, but have a hard time categorizing images that are not clearly in plain view, but are very zoomed in. But the next steps for the model are to improve the training and validation sets with cross validation and we will be going to look for more data to train the model with.Currently we are training the model with about 1300 images, but with only about 250 images per tag. With the tags being cardboard, glass, metal, plastic, paper and misc trash. So we will try to double our volume of data and see how it improves the model. We will also be looking to increase the models layers making the model deeper because right now the model we are using is rather shallow.


```
This image most likely belongs to glass with a 100.00 percent confidence.
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Mock up design of application using fluidUI tool presents various stages through which app undergoes. Fig 1 to 5 shows design implementation.

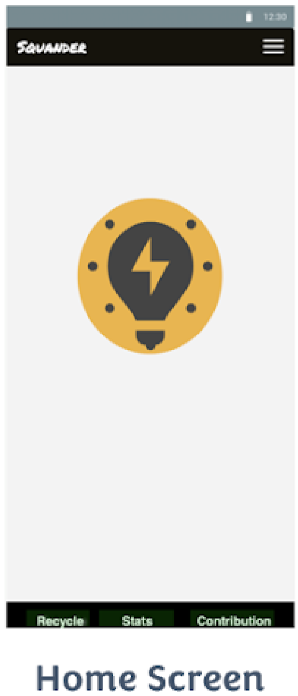


Fig. 1.

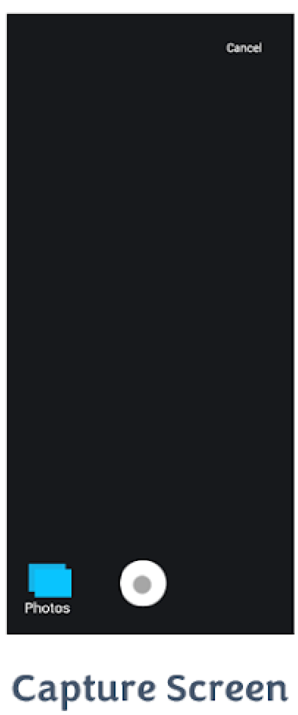


Fig. 2.


Fig. 3.

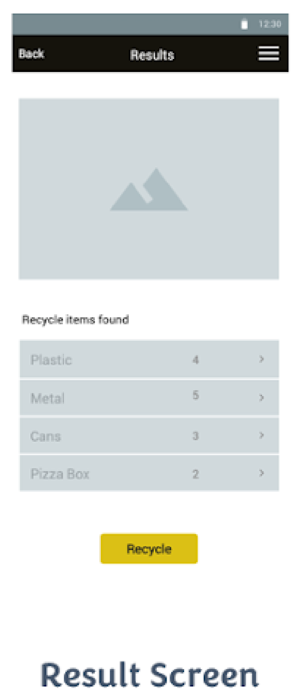


Fig. 4.


Fig. 5.

## VII. Conclusion

Squander is an application that aims to help users organize and plan the disposal of their waste. The application uses Machine Learning algorithm to recognize waste from images taken from places such as households, construction sites, and public places to enable the user to distinguish recyclable waste and provide a way for its proper disposal. The user can analyze what amount of waste he is producing so that they can minimize or recycle the waste in an efficient way. The application also provides a mechanism to know individual contribution to environment protection and how its global impact can save our environment.

Future scopes of this project includes adding capabilities for analyzing the input of waste materials along with image analysis to produce an overall "better" prediction result. Additionally, the integration of Google Maps API is another feature to be considered for inclusion in the future.

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