



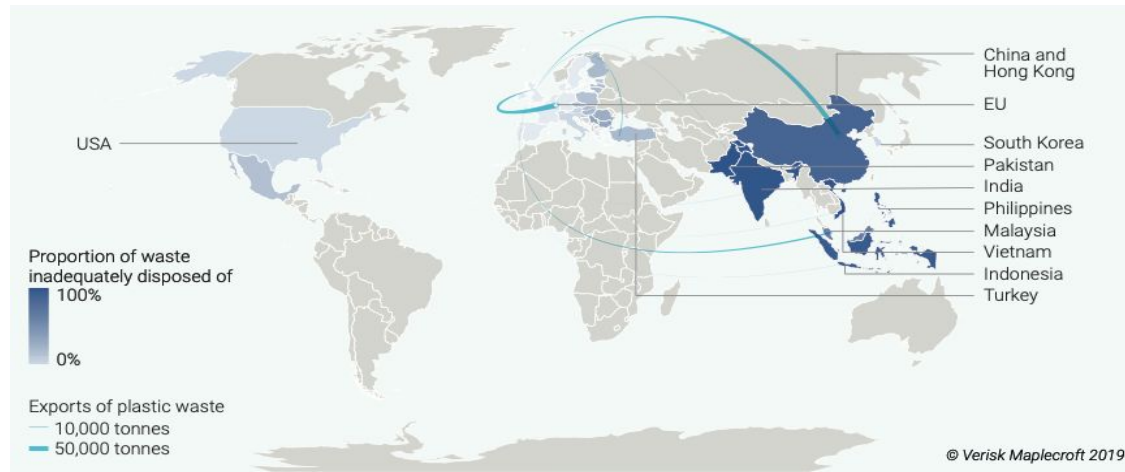
iRefuse

"What the citizens of the UK believe they send for recycling is actually dumped in our country." - Yeo Bee Yin, Malaysia's Environment Minister

*Finn Tan
5th March 2020*

Overview

- In 2016, the UK generated 223 million tonnes of waste equivalent to 482 kg / person
- Landfill space is limited and the pace of build out of alternative waste treatment infrastructure lags behind the YoY growth in waste
- Depressed prices for recycling material have also increased margin pressure in the industry



Source: Verisk Maplecroft, 2019

“Many wealthy countries send their recyclable waste overseas because it is cheap, helps meet recycling targets and reduces domestic landfill” - BBC

Manual Labor vs Machinery



Cost savings from of automation outweighs cost of manual labor in the long run

How Can Data Science Help?

Image Classification using Deep Learning

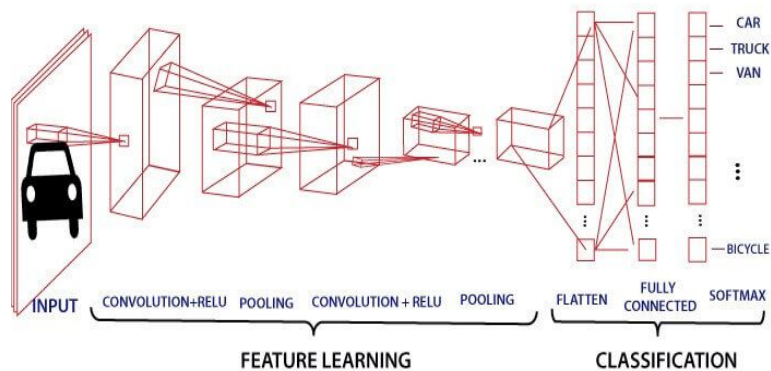
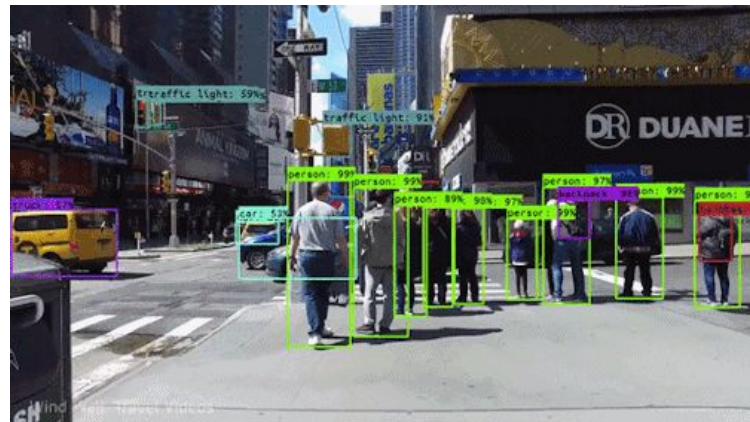


Image classification is the process of taking an input (like a picture) and outputting a class (like "recyclable") or a probability that the input is a particular class ("there's a 90% probability that this input is recyclable")

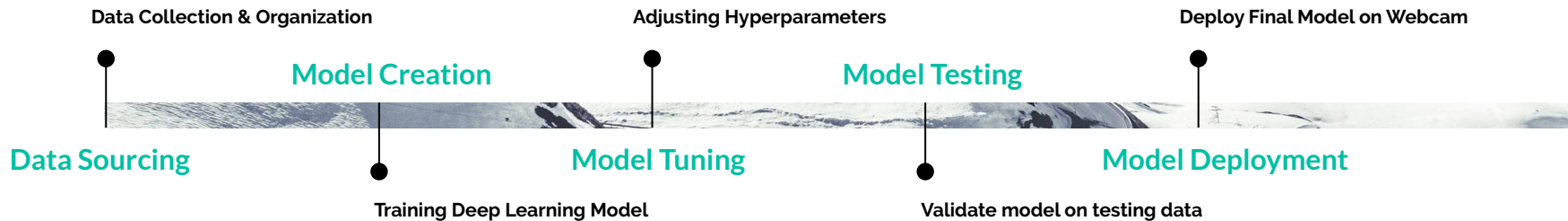
Model Deployment using Computer Vision



Utilizing installed webcam to collect information from digital images or videos and process them to define the attributes

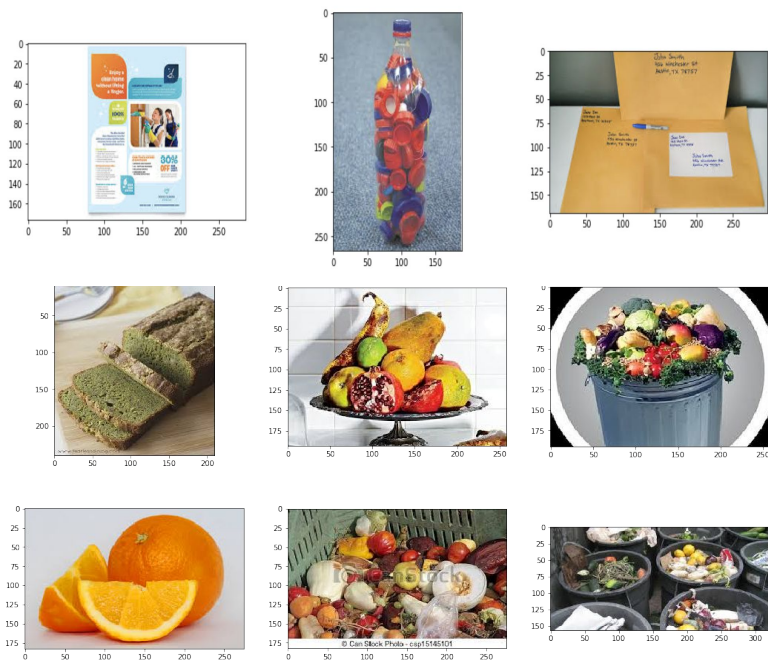


Model Creation

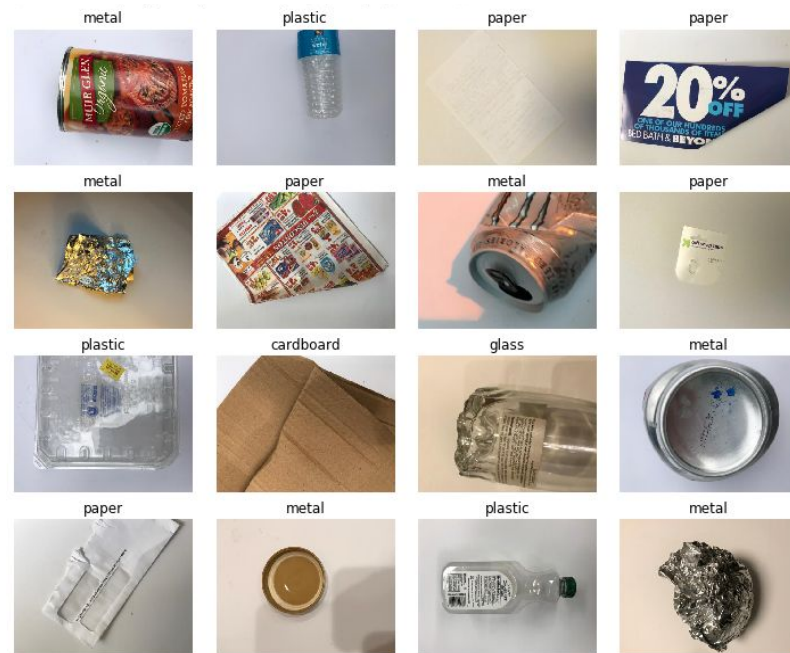


Example Images

Model 1 [Binary Classification]: Recyclable vs Organic



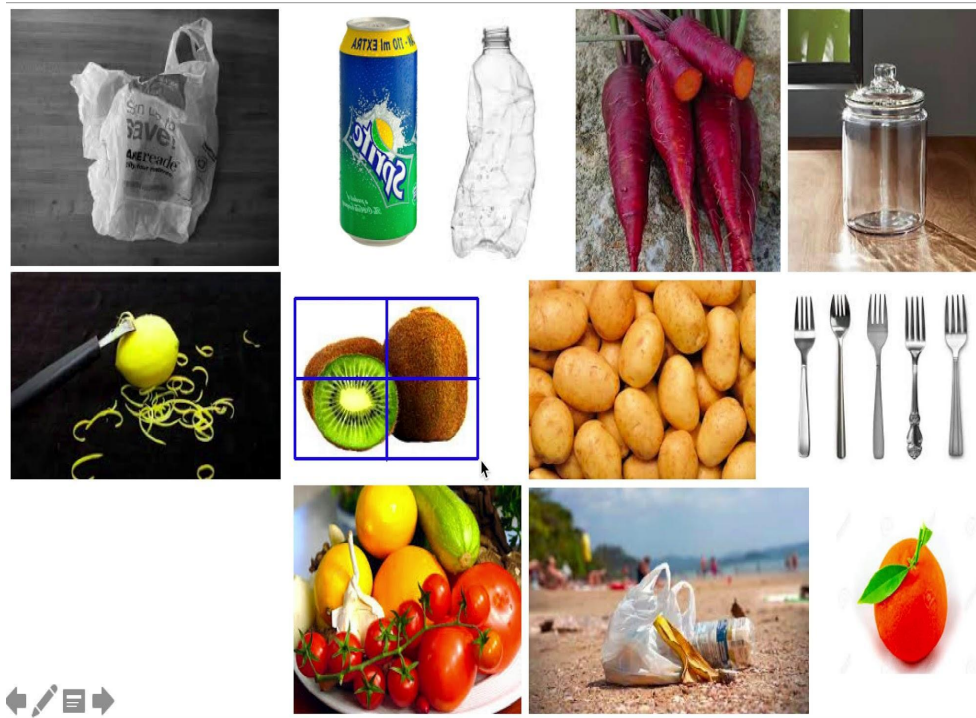
Model 2 [Multi-Classification]: Cardboard, Glass, Metal, Paper, Plastic



Deployment on Still Images - *Single Object*



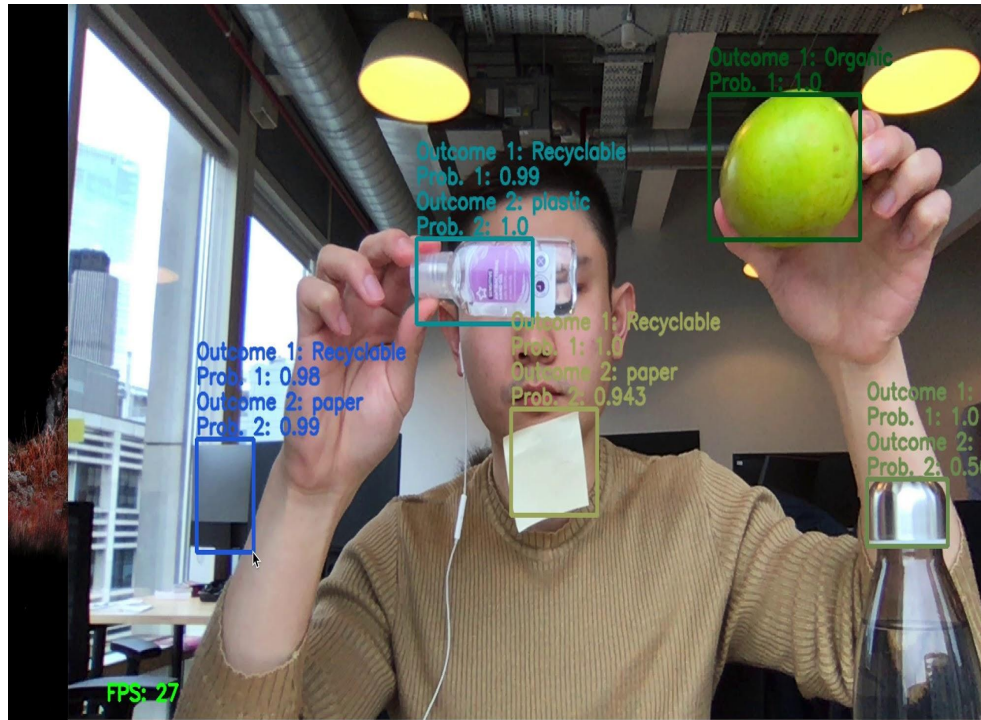
Deployment on Still Images - *Multi Object*



Deployment on Live Video Stream - *Single Object*



Deployment on Live Video Stream - *Multi Object*





LIVE DEMO

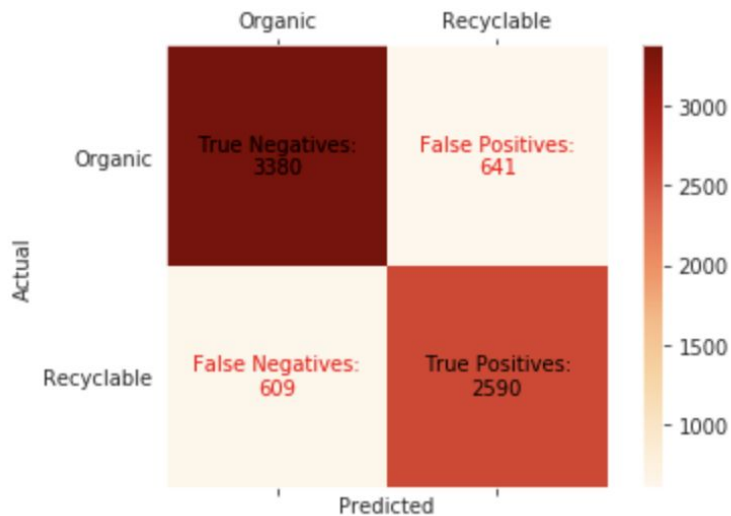


Appendix

Understanding Model Performance, Limitations, Lessons & Future Work

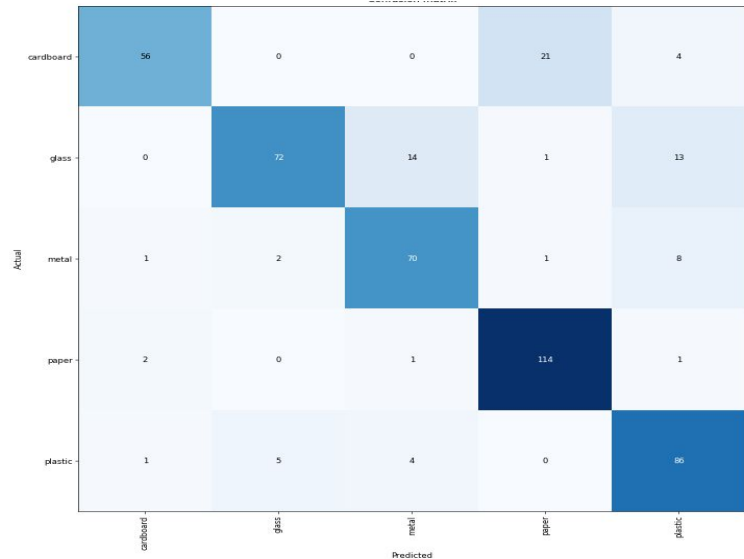
Model Performance using Confusion Matrix

Model 1 [Binary Classification]: Recyclable / Organic



Accuracy: 83%

Model 2 [Multi-Classification]: Cardboard / Glass / Metal / Paper / Plastic



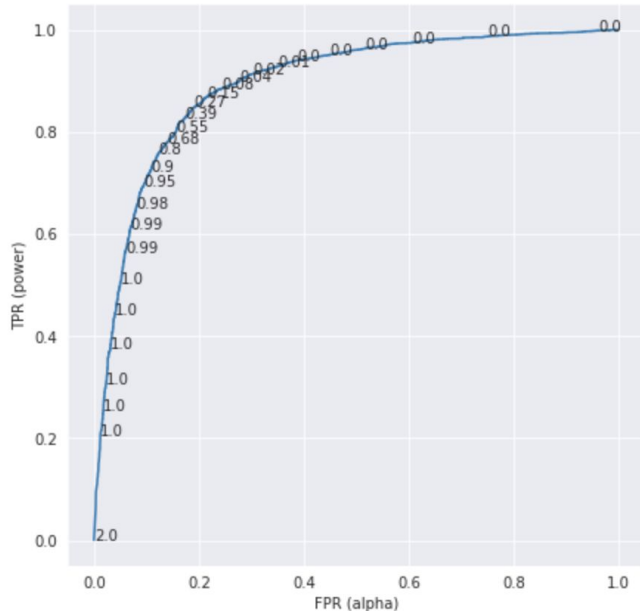
Accuracy: 83%

Model however tends to confuse between:

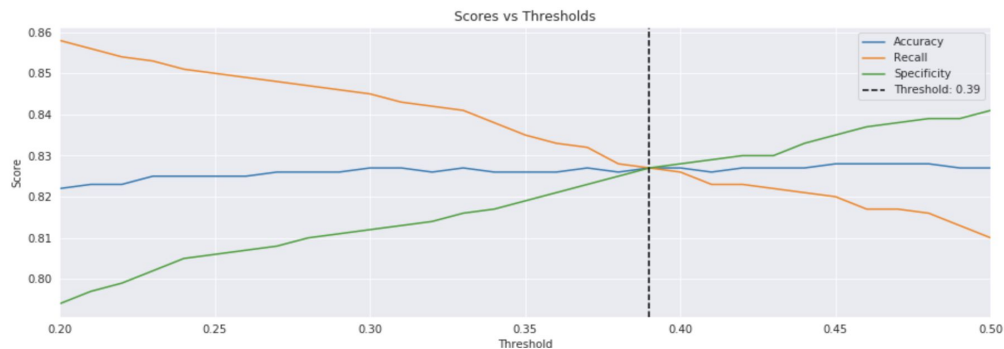
- Glass vs metal vs plastic
- Paper vs Cardboard

Model 1: ROC Curves & Threshold Selection

Receiver Operating Characteristics Curve



Threshold Selection



True Positive Rate: Out of all actual positives [Recyclable], how many were **correctly** classified

False Positive Rate: Out of all actual negatives [Organic], how many were **incorrectly** classified

Threshold %: Anything above this threshold probability will be classified as Recyclable.

Model Limitations

- 01 | Limited training data in second model (only 2.5k images vs 25k for first model)
- 02 | Deployed model is only baseline model with only limited additional tuning
- 03 | Real life deployment not as straightforward given noise in webcam frames
- 04 | Model Performance drops in low light conditions
- 05 | Training and Validation error do not converge, a potential sign of overfitting
- 06 | Some training images not correctly labelled and not good representative of classes



Lessons

Building your own model from scratch can be a tedious and cumbersome process especially with large datasets, higher number of hidden layers and if there are multiple hyperparameters to tune. Progress can also be sluggish without external computing resources. Below is an example of the time taken to tune several hyperparameters using rented computing power on Google Cloud Platform.

8 vCPUs, 30 GB RAM				
NVIDIA Tesla P100				
Tuning 1		Mean CV 3 Accuracy		
		Batch Size		
		300	400	500
Epochs	10	0.66	0.73	0.55
	20	0.73	0.72	0.73
	30	0.82	0.75	0.67
		Total Time Taken		
		Batch Size		
		300	400	500
Epochs	10	6.90	6.90	6.90
	20	13.80	13.50	13.50
	30	20.40	20.40	20.40
Total Time		122.7		

4vCPU, 15GB memory
NVIDIA Tesla P100

Tuning 2	Score
SGD	0.63
RMSProp	0.50
Adagrad	0.68
Adadelat	0.70
Adam	0.64
Adamax	0.64
Nadam	0.55

Tuning 2	Time
SGD	20.3
RMSProp	19.8
Adagrad	19.8
Adadelat	19.9
Adam	19.9
Adamax	19.8
Nadam	13.4

Total Time 132.9

4vCPU, 15GB memory
NVIDIA Tesla P100

Tuning 3	Score
Softmax	0.67
Softplus	0.73
Softsign	0.78
Relu	0.61
Tanh	0.74
Sigmoid	0.74
Hard Sigmoid	0.69
Linear	0.62

Tuning 2	Time
Softmax	27.2
Softplus	20.2
Softsign	16.8
Relu	19.8
Tanh	19.8
Sigmoid	19.8
Hard Sigmoid	23.1
Linear	19.2

Total Time 165.9

* Total time in minutes

Future Work

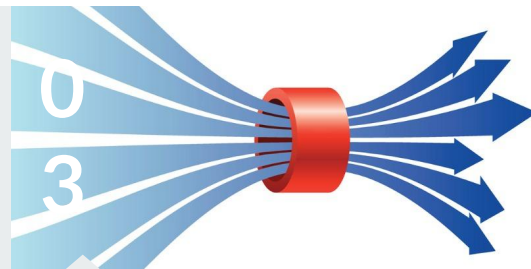
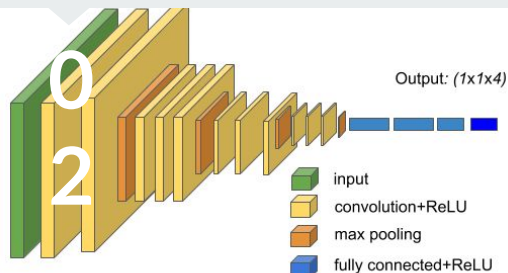


Image Pre-processing & Augmentation

Utilizing Keras' built in function ,
ImageDataGenerator to create image
augmentations including mirroring, rotating,
shearing and color shifting

Transfer Learning - ResNet50

Transfer learning by using weights obtained
from pretrained network. Benefit of ResNet50
is that even if we train deeper networks, the
training error does not increase



Solving for Global Interpreter Lock

Using multithreading to speed up Frame
Processing Rate in light of the bottleneck
caused by Python's Global Interpreter Lock

Thank you

