Wastage Segregation using Convolutional Neural Network Ensemble

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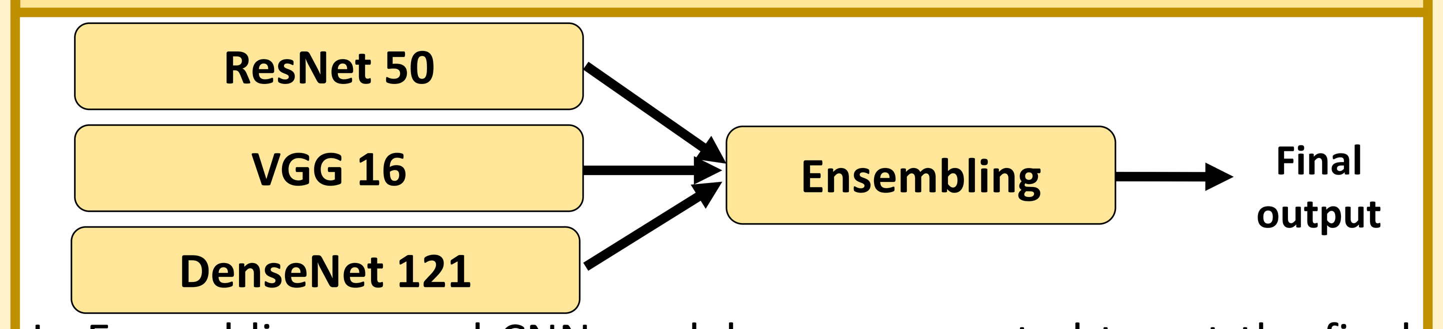
Introduction

Waste management is a global issue that is becoming worse as the globe becomes more urbanized [1]. The precise and effective categorization of solid waste is an essential component of today's waste disposal process. The current manual procedure for wastage segregation is expensive and time consuming. In addition, people involved in this manual procedure are prone to diseases due to harmful substances in the garbage. To overcome this, in this work we propose an automated approach based on an ensemble of Convolutional Neural Networks (CNN) as ensemble classifiers performs better than single classifiers [2]. We investigate different ways of ensembling, such as concatenation-based, averaging-based and weighted averaging-based. Our initial results show that the concatenation-based ensembling gives marginal improvements over a single CNN models. On the public *TrashNet* dataset [3] we report an average F1 score of 0.88.

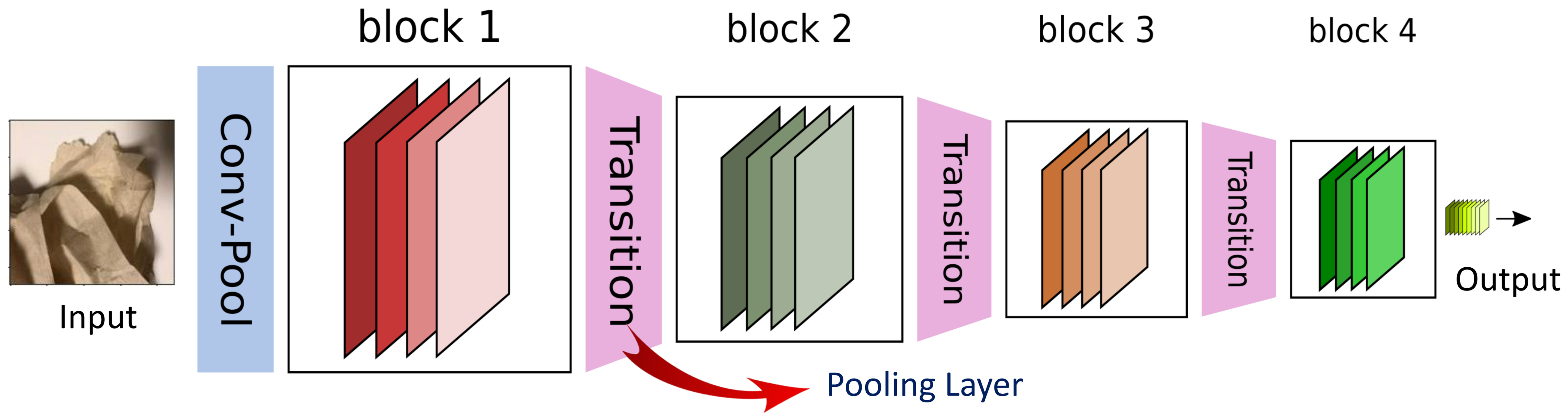
Neural Networks Ensemble



In Ensembling several CNN models are aggregated to get the final prediction. We considered the following ensembling approaches:

- **Concatenation:** the last layer features are concatenated and a classifier is learned on this concatenated representation.
- **Averaging:** The predicated probabilities are simply averaged to get the final prediction.
- **Weighted averaging:** The final prediction is obtained as the weighted average of the probabilities from individual models. The weights are set as trainable parameters and learned in the training procedure which minimizes the Cross Entropy loss of the training samples.

Ensembling using Simple Averaging

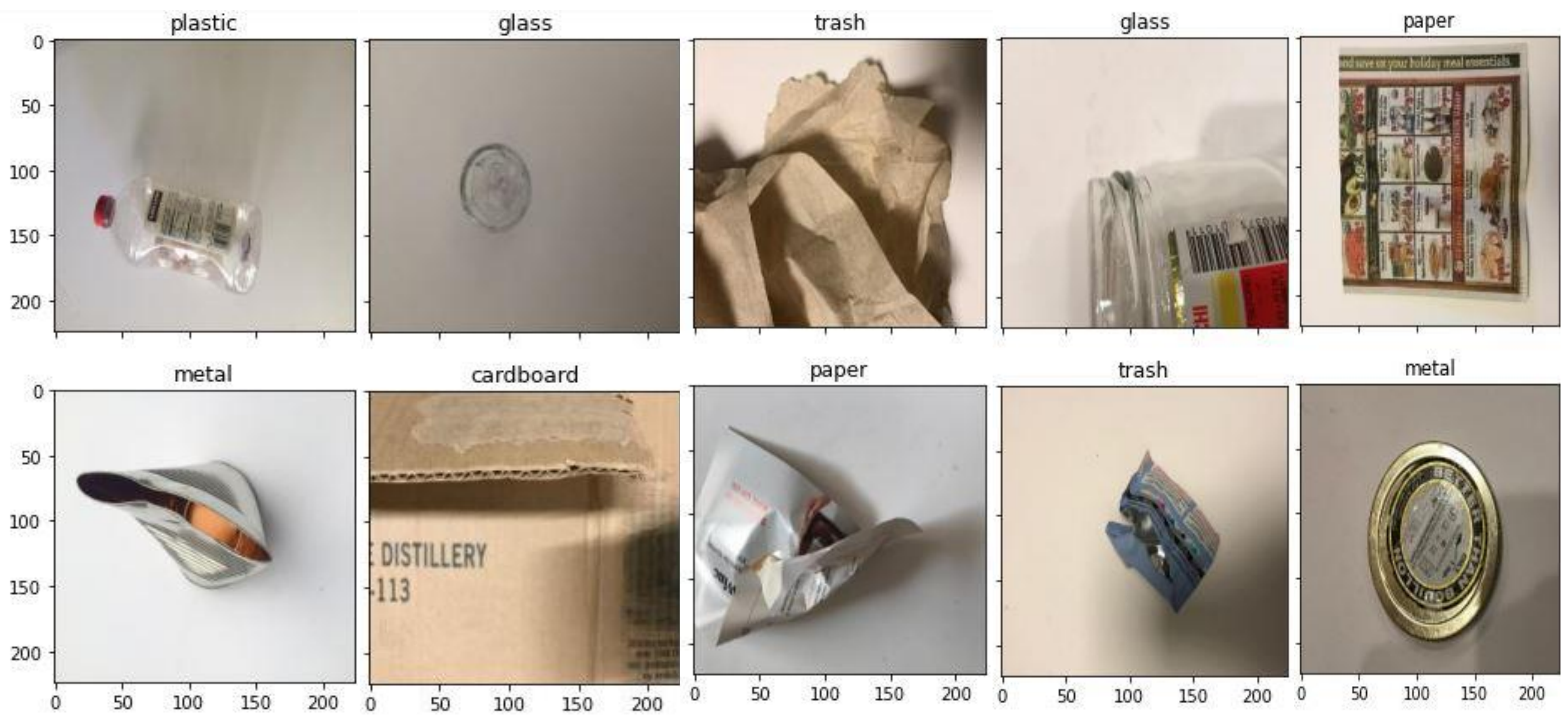


Ensemble output for input *x when using simple averaging*:

$$y^{ensemble}(x) = \frac{1}{N_{networks}} \sum_{net=1}^{N_{networks}} y^{net}(x)$$

Dataset & Experimental Setup

The *TrashNet* dataset [3], consists of 2527 images of waste divided into six categories, namely *glass, paper, plastic, metal, cardboard*, and *trash*. Some sample images are shown in figure below.



To evaluate the proposed framework's capability, the TrashNet dataset was randomly divided into a training set (70%) and a testing set (30%).

Experiments and Results

Class	Concatenation Ensemble Model		Average Ensemble Model		Weighted Average Ensemble Model		DenseNet_121 Model		VGG_16 Model		ResNet_50 Model	
	Recall	F1 Score	Recall	F1 Score	Recall	F1 Score	Recall	F1 Score	Recall	F1 Score	Recall	F1 Score
Glass	0.93	0.92	0.97	0.96	0.90	0.90	0.88	0.91	0.86	0.89	0.86	0.89
Paper	0.51	0.55	0.92	0.94	0.46	0.51	0.63	0.55	0.51	0.53	0.51	0.53
Cardboard	0.79	0.84	0.44	0.46	0.71	0.82	0.81	0.85	0.78	0.84	0.78	0.84
Plastic	0.93	0.96	0.89	0.85	0.93	0.94	0.95	0.94	0.94	0.93	0.94	0.93
Metal	0.97	0.94	0.76	0.82	0.93	0.91	0.94	0.94	0.95	0.91	0.95	0.91
Trash	0.89	0.86	0.96	0.91	1.00	0.86	0.90	0.88	0.92	0.87	0.92	0.87
Macro Average	0.85	**0.85**	0.82	0.82	0.82	0.82	0.84	0.84	0.83	0.83	0.83	0.83
Weighted Average	0.89	**0.89**	0.87	0.87	0.87	0.87	0.88	0.88	0.87	0.87	0.87	0.87

Input image size: 224 x 224x 3. We use ImageNet pretrained models (as finetuning pretrained models show better performance than training from scratch [4]) and fine tune them on the TrashNet dataset.
The following data augmentation were used: horizontal and vertical flip, rotation, and horizontal and vertical shift. The initial learning rate for training was set to 10^{-4}. Adam optimizer was used with a batch size of 18, and the cross-entropy loss was used as the loss function.

Conclusion

In this work we presented an initial work on CNN based wastage segregation. We investigated different ways of ensembling, and our initial results with a small dataset suggests that the concatenation-based ensembling performs marginally better than the best performing individual model. Based on our initial work, we report a weighted F1 score of 0.89. Future work will focus on investigating this ensembling model on a large scale waste classification dataset.

References

1. K. N. Sami, Z. M. A. Amin, and R. Hassan, “Waste management using machine learning and deep learning algorithms,” International Journal on Perceptive and Cognitive Computing, vol. 6, no. 2, pp. 97–106, 2020.
2. Thomas G. Dietterich, Ensemble Methods in Machine Learning, International Workshop on Multiple Classifier Systems, 2000
3. M. Yang and G. Thung, “Classification of trash for recyclability status,” CS229 Project Report, vol. 2016, 2016.
4. F. Zhuang, Z. Qi, K. Duan, D. Xi, Y. Zhu, H. Zhu, H. Xiong, Q. He, A Comprehensive Survey on Transfer Learning, CoRR abs/1911.02685, 2020