



# A Systematic Investigation on end-to-end Deep Recognition of Grocery Products in the Wild

MARCO LEO, PIERLUIGI CARCAGNÌ, COSIMO DISTANTE

NATIONAL RESEARCH COUNCIL OF ITALY, INSTITUTE OF APPLIED SCIENCES AND INTELLIGENT SYSTEMS - LECCE (CNR-ISASI)

EMAIL : {MARCO.LEO, PIERLUIGI.CARCGNI, COSIMO.DISTANTE}@CNR.IT

### INTRODUCTION

Automatic recognition of products on grocery shelf images is a new and attractive topic in computer vision and machine learning since, it can be exploited in different application areas. This paper introduces a pure end-to-end classification to make the task ready to be exploited on data acquired in different contexts and without any constraint.

The proposed pipeline takes as input a raw image containing grocery products (acquired in the wild from the market shelves with multiple products in the scene even under occlusions and viewpoint changes) and gives as output the product class.

Along with the manuscript, a systematic investigation of different CNN architectures is proposed. The architectures are based on convolutional neural networks for addressing the product recognition task exploiting the proposed pipeline on the huge challenging dataset in [1].

[1] M. Klasson, C. Zhang, and H. Kjellstr<sup>•</sup>om, "A hierarchical grocery store image dataset with visual and semantic labels," in IEEE Winter Conference on Applications of Computer Vision (WACV), 2019.

### DATASET

The dataset contains natural images of raw and refrigerated grocery items (fruits, vegetables, and packages).

The dataset consists of 5125 images of raw grocery items, from 81 classes, where the number of images in each class ranges from 30 to 138.

It has a hierarchical structure: it takes into account three categories of items: fruits, packaged food and drinks, and vegetables.



### DATASET

Each of these three category items contains 19, 9, and 15 coarse classes respectively.

Some of the coarse classes have subcategories that lead to their fine classes.

F 11	Name	ID	ID	Packages	Name	ID	ID	1	/	Name	ID	ID Fine
Fruits		Coarse	Fine			Coarse	Fine	v	egetables		Coarse	classes
		classes	classes		luice	classes	classes	1 1	-		classes	
	Apple	ciusses	clusses		Bravo-Apple-Juice	19	28			Acapacity	20	50
	Golden-Delicious	0	0		Bravo-Orange-Juice	19	29			Asparagus	20	29
	Granny-Smith	ő	1		God-Morgon-Apple-Juice	19	30			Aubergine	29	60
	Pink-Lady	ő	2		God-Morgon-Orange-Juice	19	31			Cabbage	30	61
	Red-Delicious	ő	3		God-Morgon-Bed-Grapefruit-Juice	19	33			Carrots	31	62
	Poval-Gala	ő	4		Tropicana-Apple-Juice	19	34			Cucumber	30	63
	hojar cala	Ŭ			Tropicana-Golden-Grapefruit	19	35			Carlia	22	64
	Avocado	1	5		Tropicana-Juice-Smooth	19	36			Garric	55	64
	Banana	2	6		Tropicana-Mandarin-Morning	19	37			Ginger	34	65
	Kiwi	3	7		Milk					Leek	35	66
	Lemon	4	8		Arla-Ecological-Medium-Fat-Milk	20	38			Mushroom/Brown-Cap-Mushroom	36	67
	Lime	5	ğ		Arla-Lactose-Medium-Fat-Milk	20	39			Onion/Vellow-Onion	37	68
	Mango	6	10		Arla-Medium-Fat-Milk	20	40			Onion/Tellow-Onion	37	00
	Wango		10		Arla-Standard-Milk	20	41					
	Melon				Garant-Ecological-Medium-Fat-Milk	20	42			Pepper		
	Cantaloune	7	11		Garant-Ecological-Standard-Wilk	20	43			Green-Bell-Pepper	38	69
	Galia-Melon	7	12		Oat-Milk/Oatly-Oat-Milk	21	44			Orange-Bell-Penner	38	70
	Honeydew-Melon	7	13		Oatghurt/Oatly-Natural-Oatghurt	22	45			Ded Bell Depper	20	71
	Watermelon	7	14							Red-beil-Pepper	20	/1
	Watermelon	· '	14		Sour-Cream	23	46			Yellow-Bell-Pepper	38	72
	Nectarine	8	15		Arla-Sour-Cream	23	47					
	Orange	0	16							Potato		
	Panava	10	17		Sour-Milk/Arla-Sour-Milk	24	48			Floury-Potato	39	73
	Passion-fruit	11	18		Soy-Milk					Calid Datata	20	74
	Peach	12	10		Alpro-Fresh-Soy-Milk	25	49			Solid-Potato	29	/4
	reach	12	15		Alpro-sneit-soy-Milk	25	50			Sweet-Potato	39	75
	Dear				Soyghurt							
	Aniou	13	20		Alpro-Blueberry-Soyghurt	26	51			Red-Beet	40	76
	Conference	12	20		Alpro-Vanilla-Soyghurt	26	52					
	Contelence	12	21		Markan					-		
	Kaisei	15	22		Yognurt Arla-Mild-Vanilla-Voghurt	27	53			Iomato		
	Pineannle	14	23		Arla-Natural-Mild-Low-Fat-Yoghurt	27	54			Beef-Tomato	41	77
	Dum	15	23		Arla-Natural-Yoghurt	27	55			Regular-Tomato	41	78
	Pomegrate	15	24		Valio-Vanilla-Yoghurt	27	56			- Vine-Tomato	41	79
	Ped-grapefruit	17	25		Yoggi-Strawberry-Yoghurt	27	57			the follow		
	Sateumas	10	20		Yoggi-Vanilla-Yoghurt	27	58					
	Jacsumas	10	21							Zucchini	42	80

### RESULTS

TABLE I: Results concerning 81 fine classes classification by using a single model.

Model	Acc	F1-score	Prec.	Rec.
ResNet-18	87.51	88.79	89.97	88.95
ResNet-34	89.10	89.98	90.88	90.11
ResNet-50	90.58	91.75	92.47	91.96
ResNet-101	92.55	93.23	93.68	93.55
ResNet-152	91.68	92.84	93.66	92.84
SE-ResNet-50	90.58	91.47	92.32	91.55
SE-ResNet-101	88.89	89.87	90.96	89.82
EfficientNet-b0	88.94	89.82	90.57	90.11
EfficientNet-b1	88.35	88.89	89.72	88.99
EfficientNet-b2	88.98	90.14	90.60	90.41
EfficientNet-b3	88.68	90.03	90.68	90.29
EfficientNet-b4	89.19	90.61	90.82	91.07
EfficientNet-b5	88.22	89.30	89.88	89.60
EfficientNet-b6	88.73	89.98	90.53	90.27
EfficientNet-b7	89.36	90.55	91.27	90.84
DenseNet-121	91.16	91.74	92.78	92.06
DenseNet-169	91.29	92.47	93.22	92.55
DenseNet-201	92.01	92.99	93.40	93.16

#### TABLE II: Results concerning 43 coarse classes classification by using a single model.

Model	Acc	F1-score	Prec.	Rec.
ResNet-18	91.54	89.02	90.41	88.69
ResNet-34	92.43	89.74	91.12	89.56
ResNet-50	93.61	91.91	92.70	92.05
ResNet-101	94.87	93.35	93.63	93.61
ResNet-152	94.32	92.98	93.80	92.95
SE-ResNet-50	92.97	90.98	91.98	90.86
SE-ResNet-101	92.43	89.77	91.01	89.65
EfficientNet-b0	92.01	89.38	90.00	89.53
EfficientNet-b1	92.85	91.31	92.18	91.07
EfficientNet-b2	92.64	90.75	91.47	90.70
EfficientNet-b3	92.09	90.06	90.82	90.12
EfficientNet-b4	92.43	89.42	90.01	89.68
EfficientNet-b5	92.05	89.90	91.11	89.58
EfficientNet-b6	92.13	89.68	90.74	89.60
EfficientNet-b7	92.38	89.68	91.62	89.04
DenseNet-121	94.66	92.60	92.73	93.11
DenseNet-169	93.94	92.35	93.09	92.46
DenseNet-201	94.95	93.56	94.25	93.49

### RESULTS

### max-voting ensemble approach has been employed

TABLE III: Results concerning 81 fine classes classification with ensembles of models.

Model	Acc	F1-score	Prec.	Rec.
Ensemble A	92.89	93.87	94.46	93.98
Ensemble B	92.47	93.63	94.08	93.62
Ensemble C	93.48	94.46	94.98	94.52
Ensemble D	93.14	94.41	94.88	94.42
Ensemble E	92.68	93.77	94.36	93.80

TABLE IV: Results concerning 43 coarse classes classification with with ensembles of models.

Model	Acc	F1-score	Prec.	Rec.
Ensemble A	95.42	94.41	95.13	94.19
Ensemble B	95.16	93.99	94.79	93.57
Ensemble C	95.84	94.88	95.31	94.78
Ensemble D	95.58	94.81	95.48	94.59
Ensemble E	95.42	94.41	95.13	94.19

## RESULTS

TABLE V: Comparison of the results concerning 81 fine classes and 43 coarse classes classification. Experimental outcomes reported in [1] have been considered for reference.

Net	F1-score fine classes	F1-score coarse classes		
Proposed				
ResNet-101	93.23	89.65		
Ensemble C	94.46	94.88		
DenseNet-201	92.99	93.56		
Previous				
AlexNet + SVM	72.6	78		
VGG16 + SVM	73.3	76.6		
DenseNet-169 + SVM	85	84		
AlexNet	69.3	76.4		
VGG16	73.8	74.9		
DenseNet-169	80.4	82		

[1] M. Klasson, C. Zhang, and H. Kjellstr<sup>o</sup>om, "A hierarchical grocery store image dataset with visual and semantic labels," in IEEE Winter Conference on Applications of Computer Vision (WACV), 2019.

### CONCLUSIONS

Gathered classification results were very encouraging and largely outperformed previous approaches on the same dataset. This could be a useful step towards the implementation of an accurate classification system able to supply support in different assistive applications.

Future works will explore other deep learning models.

Besides, we are being collecting new images in order to extend the dataset, making it even more suitable to be exploited for modern machine learning approaches.

