Food Recognition and Leftover Estimation for **Daily Diet Monitoring**

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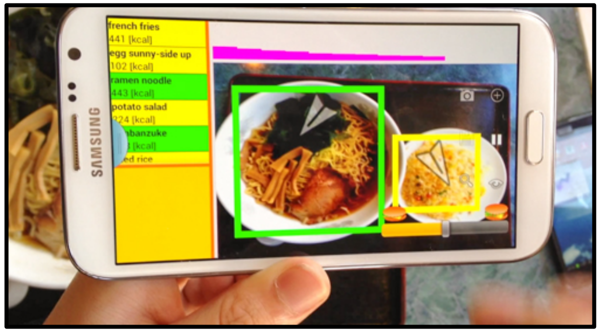
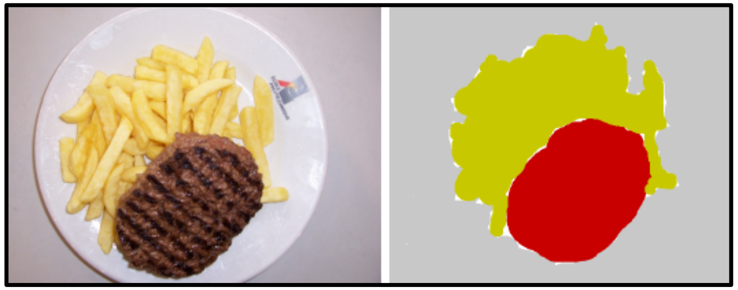
Automatic dietary monitoring

Nowadays, **technology** can support the users in keep tracks of their **food consumption** in a more user friendly way allowing for a more comprehensive **daily dietary monitoring**.;

Recent findings showed that **computer vision** techniques can help to automatically **recognize food** and **estimate its quantity**

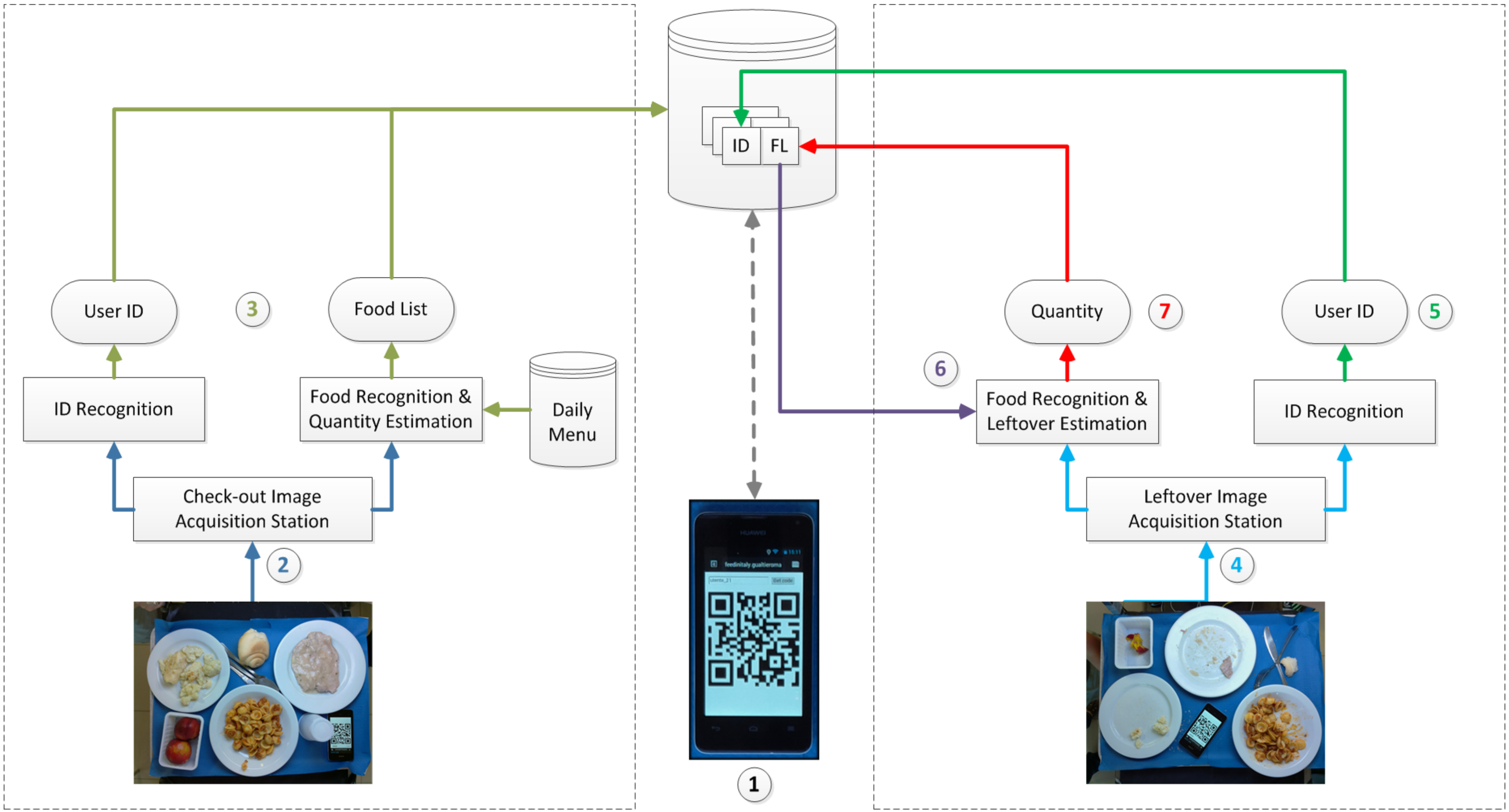




Proposed System // Workflow

Automatic dietary monitoring of canteen customers

(based on robust computer vision techniques for food recognition and leftover estimation)



Proposed System // Food recognition

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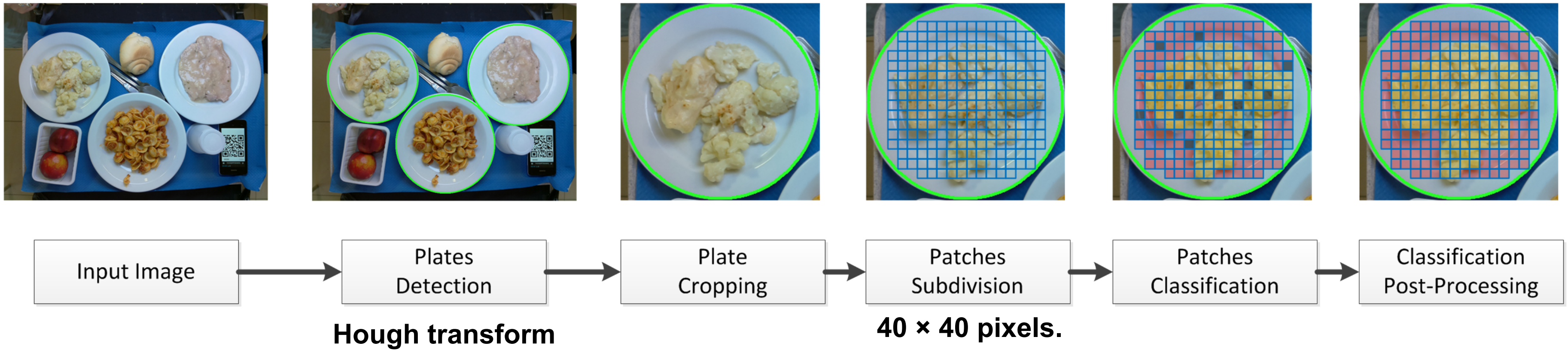

From each patch, a visual descriptor is extracted and submitted to a **pre-trained k-NN** classifier in order to receive a **classification label**.

The labels of the the patches are then **post-processed** to remove spurious labels in order to have more homogeneous groups of labels that correspond to the **food regions**.

Name	Description	Length
CEDD	Color and Edge Directivity Descriptor	144
Gabor	Gabor features. Mean and st.dev. of RGB DFT at $(\theta, f)=(4,4)$	96
OG	Opponent Gabor. Gabor on iter-intra channel combinations	264
LBP	Non-uniform, invariant Local Binary Pattern with (r,n)=(1,8)	54
LCC	Local Color Contrast	499
CM	Two sets of five normalized Chromaticity Moments	10
CWT	Complex Wavelet features. RGB mean and st.dev. at three scales	18

Proposed System // Leftover estimation

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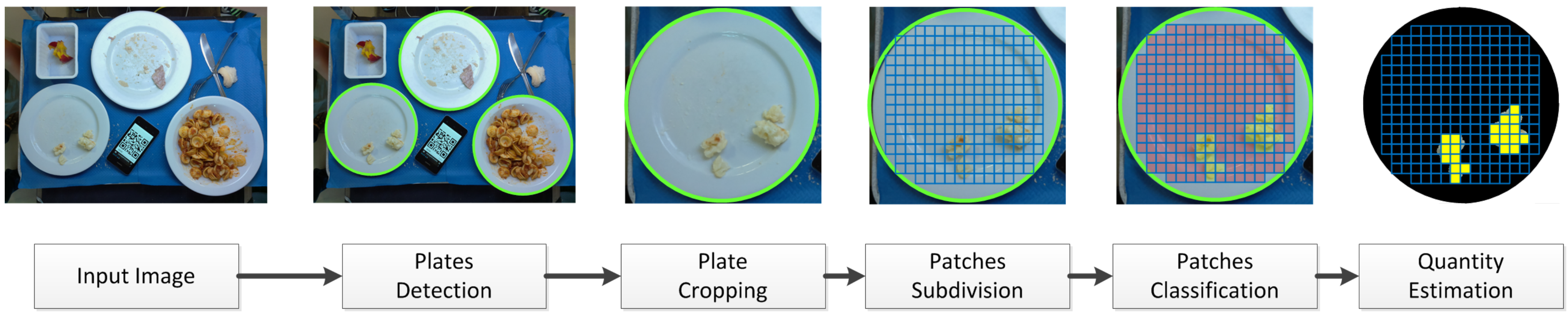


The personnel of the canteen is bounded to follow the regulations provided by nutritionists in the form of nutritional tables, and to serve a specific amount of food (that depends on its calories and nutrients). This somewhat simplifies the problem of the estimation of the food quantity.

$$r_{ic}^{est} = \frac{\#Patches\ leftover}{\#Patches\ before}$$

Once we have identified this ratio, the corresponding amount of calories is deduced by the precompiled nutritional tables.

Experiments // Canteen scenario

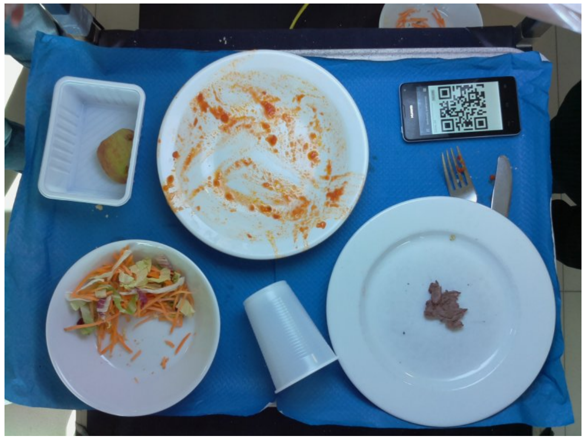
Monitored and recorded the meal of 1000 customers of a real canteen
(1000 customers correspond to 2000 tray images, 1000 before and 1000 after the meal)

- **Customer behavior:** each customer selected 3 dishes from the daily menu that included 15 different dishes;

- **Tray acquisition:** automatic photographic system that includes a raspberry motherboard, an embedded camera and a motion sensor. The system automatically detects when the tray has to be acquired.

- **Ground-truth:** The annotations have been created using the IAT – image annotation tool [2], that permitted to draw a polygon around the food: r_{ic}^{gt}

before



after

Experiments

2 metrics for food recognition:

Standard Accuracy (**SA**) and the **Macro Average Accuracy** (**MAA**)

$$SA = \frac{\sum_{c=1}^{C} TP_c}{\sum_{c=1}^{C} NP_c}; \qquad MAA = \frac{1}{C}\sum_{c=1}^{C} A_c = \frac{1}{C}\sum_{c=1}^{C} \frac{TP_c}{NP_c}$$

Denoting ***NPc*** the number of positives, i.e., the number of times the class ***c*** occurs in the dataset; ***TPc*** the number of true positives for class ***c***, i.e., the number of times that the system recognizes the dish ***c***; ***C*** the number of classes,

leftover estimation:

Error

$$Error = \sum_{c=1}^{C} w_c \sum_{i=1}^{I} |r_{ic}^{gt} - r_{ic}^{est}|$$

where w_c is the class weight and ***I*** is the number of test customers. The class weight is defined as the number of elements of the class divided by the total number of elements.

Experiments

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Classes	w_c(%)		CEDD	OG	Gabor	LBP	LLC	CM	CWT
			visual descriptors						
bistecca	(3.8%)		100.00	100.00	100.00	27.50	97.50	91.25	80.00
carote	(7.6%)		100.00	100.00	100.00	100.00	100.00	98.75	100.00
cavolfiore	(8.6%)		100.00	100.00	98.89	97.22	98.33	97.22	98.33
fagiolini	(7.6%)		100.00	100.00	100.00	99.38	100.00	100.00	96.25
frittata	(7.6%)		100.00	100.00	100.00	81.25	93.75	83.12	100.00
fusilli ragu	(8.6%)		100.00	100.00	100.00	85.56	100.00	97.22	100.00
insalata mista	(2.4%)		100.00	92.00	42.00	58.00	100.00	90.00	32.00
lenticchie	(7.1%)		98.67	99.33	96.67	68.00	94.67	28.67	57.33
minestra	(6.7%)		100.00	100.00	97.86	99.29	97.86	93.57	100.00
pasta cime rapa	(8.6%)		100.00	100.00	100.00	100.00	100.00	100.00	100.00
pasta sugo	(2.4%)		100.00	100.00	100.00	28.00	76.00	100.00	98.00
piselli	(7.1%)		99.33	100.00	98.67	94.67	100.00	88.00	98.00
pollo ferri	(7.6%)		96.86	97.48	67.30	62.26	76.10	93.71	69.18
scaloppina	(8.6%)		98.90	99.45	99.45	13.81	98.34	97.79	98.90
tortino	(5.7%)		91.67	90.83	79.17	22.50	79.17	83.33	80.00
		SA	**99.05**	99.00	94.33	74.14	95.05	89.57	90.38
		MAA	**99.03**	98.61	92.00	69.16	94.11	89.51	87.20

The system is capable of estimating the **relative quantity of eaten food** with an average error of about **15 percentage points**, with the **best** and **worst** cases being **7** and **34 percentage points** respectively.

Conclusions

Results achieved on a real canteen scenario are promising with an average accuracy in recognition of about 99%, and and average error in food estimation of 15 percentage points.

The proposed food recognition and leftover estimation system can serve multiple purposes:

1. at the check-out station, the food recognition allows to keep track the eaten food and the user's dietary habits;
2. using the list of recognized foods, an automatic billing procedure can be activated speeding up the check- out;
3. by evaluation the leftovers, we can better estimate the food intakes in terms of calories ingested.

As a future work,

1. we will experiment the system on large scale food datasets
2. we will experiment CNN based features