Eye Localization Through Multi-scale Sparse Dictionaries

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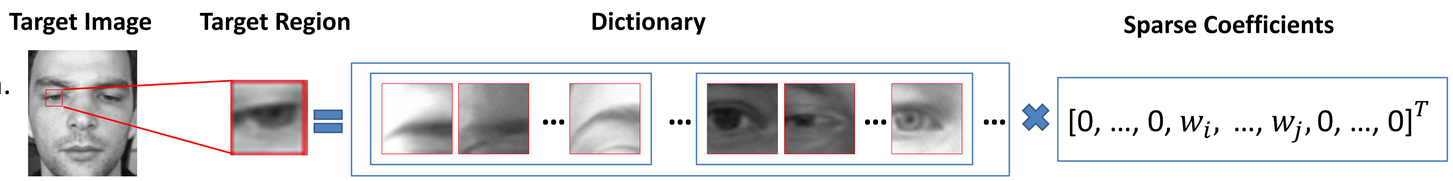
Motivations

- Object localization can be formularized as a sparse fitting problem.
- Contextual information is important to detection and localization.
- Only the most likely locations should be evaluated, rather than sliding a window in the whole image.



Localize a target patch

- A target patch y_p should approximately lie in the linear span of all the training patches $v_{p,i}$ extracted from the same location p

$$y_p = \alpha_{p,1}v_{p,1} + \alpha_{p,2}v_{p,2} + \cdots + \alpha_{p,N}v_{p,N}$$

- Build a dictionary that consists of patches extracted from all the training images and from all possible locations

$$A = [v_{1,1}, \cdots, v_{1,N}, \cdots, v_{P,1}, \cdots, v_{P,N}]$$

- Localize target patch by solving sparse coefficients

$$x = \text{argmin}||Ax - y||^2, \text{subject to } ||x||_0 \leq k$$

- Compute residual for each non-zero coefficient

$$r_i(y) = ||y - Ax_i||_2, (i = 1, \cdots, k)$$

- Estimate the position of the target patch

$$L_y = \underset{i}{\text{argmin}}\, r_i(y)$$

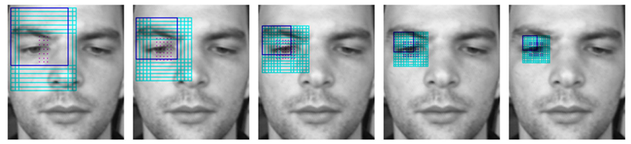
Localize eyes

- From large scale to small scale
- Update the best estimated eye location

$$L_S = L_{S-1} + L_0 - L_y$$

- Combine the estimation of each scale

Build multi-scale dictionaries



Algorithm summary

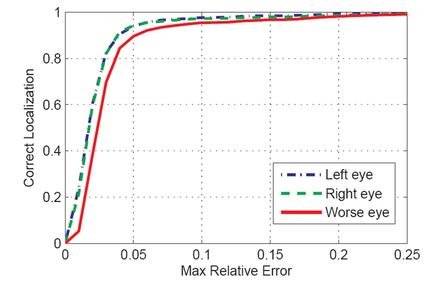
Algorithm 1 *Training sparse dictionaries*

1: Align face images using the positions of two eyes.
2: Expand training set by scaling and rotation.
3: **for** scale $s = 1 : S$ **do**
4: **for** position $p = 1 : P$ **do**
5: Extract image patches at scale s and location p.
$A_{s,p} = [v_{s,p,1}, v_{s,p,2}, \cdots, v_{s,p,N}]$.
6: Normalize columns of $A_{s,p}$ to have unit length.
7: Compress $A_{s,p}$ by K-SVD.
8: **end for**
9: Concatenate all the dictionaries at size s.
$A_s = [A_{s,1}, A_{s,2}, \cdots, A_{s,P}]$
10: **end for**

Algorithm 2 *Eye Localization*

1: Detect and crop face region.
2: Set initial eye position L_0.
3: **for** $s = 1 : S$ **do**
4: Apply OMP algorithm to find k sparse coefficients $j_1, \cdots, j_k$
5: Find minimum residual and estimate the location of current patch following Equation (9) and (10).
6: Update current estimated eye position L_s following Equation (11).
7: **end for**
8: Repeat the above steps for the other eye.

Experiments



BioID	$e < 0.05$	$e < 0.10$	$e < 0.25$
Jesorsky 01 [18]	40.00%	79.00%	91.80%
Hamouz 04 [16]	50.00%	66.00%	70.00%
Hamouz 05 [17]	59.00%	77.00%	93.00%
Cristinacce 04 [12]	56.00%	**96.00%**	98.00%
Asterialdis 06 [2]	74.00%	81.70%	97.40%
Bai 06 [3]	37.00%	64.00%	96.00%
Niu 06 [21]	78.00%	93.00%	95.00%
Campadelli 06 [4]	62.00%	85.20%	96.10%
Campadelli 09 [5]	80.70%	93.20%	95.30%
Valenti 08 [27]	**84.10%**	90.85%	**98.49%**
Ours	**89.60%**	**95.50%**	**99.10%**

COMPARISON OF EYE LOCALIZATION METHODS IN BIOID DATABASE