Object Categorization using Kernels combining Graphs and Histograms of Gradients

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Introduction : object categorization

Pattern recognition process

1. image processing,
2. feature extraction,
3. recognition,
4. post-processing.

Introduction : object categorization

Pattern recognition process

signal processing,

→ feature extraction,

→ recognition,

post-processing.

Idea

⇒ combination of various representations, using kernels and SVM classifier.

Graph representation

- Object representation using a skeleton,
- skeleton comparison $\Leftrightarrow$ graph comparison

Properties

- shape description,
- various information contained into labels.

Graph designing

1. binary mask,
2. morphological skeleton,
3. skeleton to graph :
   2 kinds of pixels : vertices
   - skeleton branch ending,
   - branches intersection.

   and edges
4. graph labeling.

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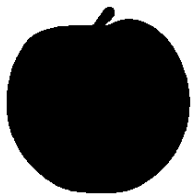

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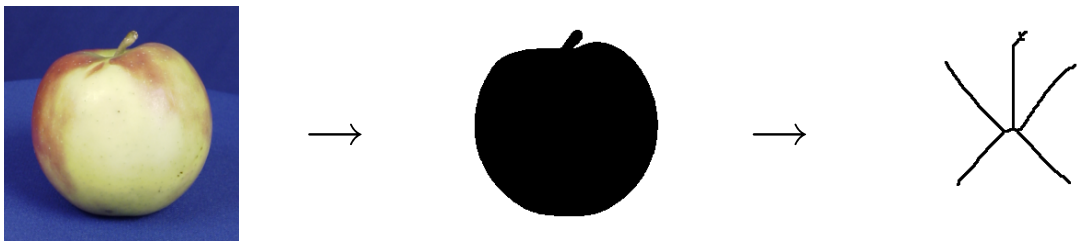

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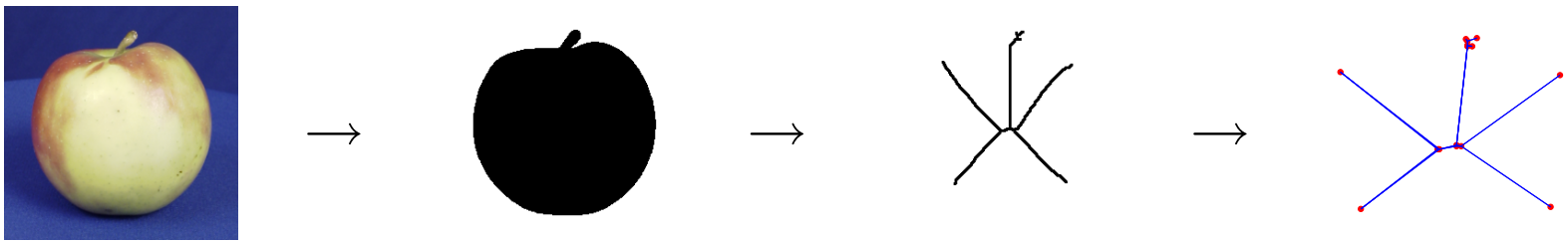

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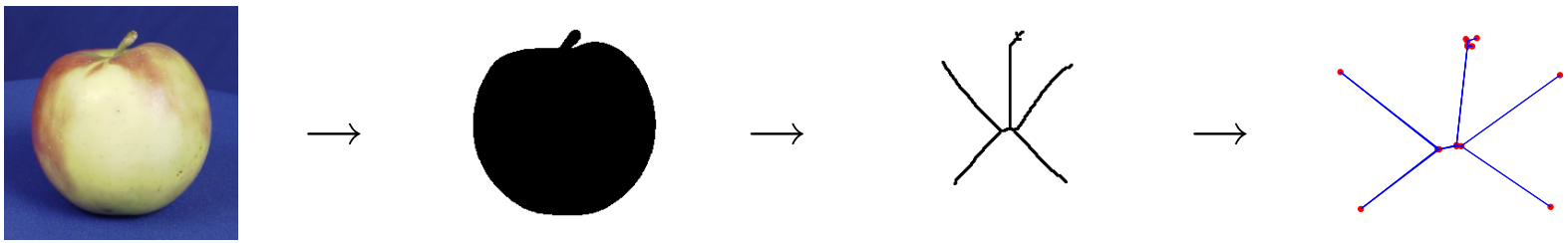


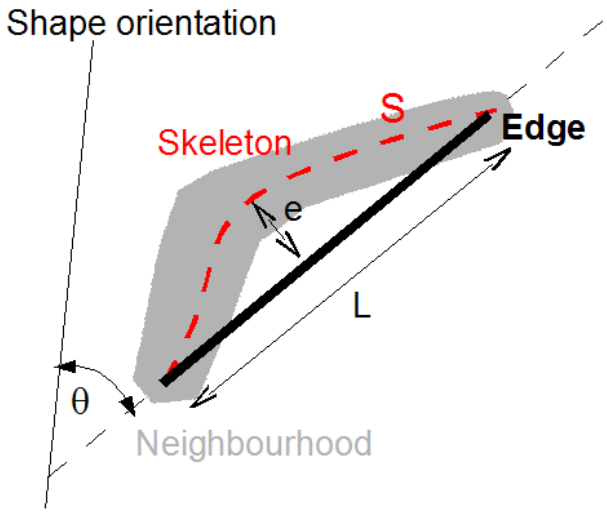
Graph labeling

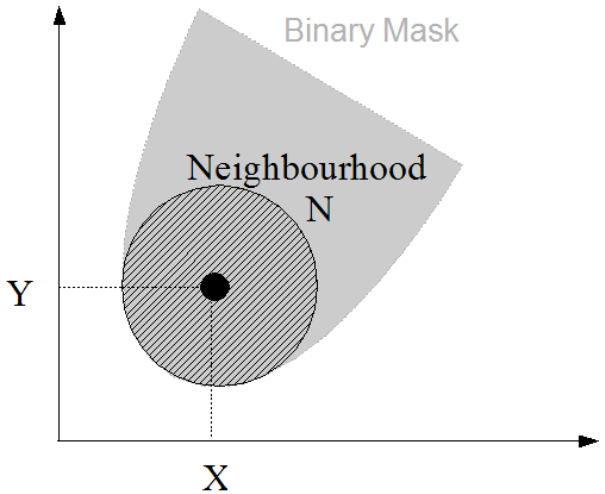
Edge

- length (L),
- skeleton length (s),
- orientation (θ),
- neighbourhood area (A),
- distance between skeleton and edge (e).

Vertex

- coordinates (X,Y),
- neighbourhood area (N).





HOG

Histograms of Oriented Gradients

- Introduced by N. Dalal and B. Triggs [DT05]
- Computation of local gradient histograms.

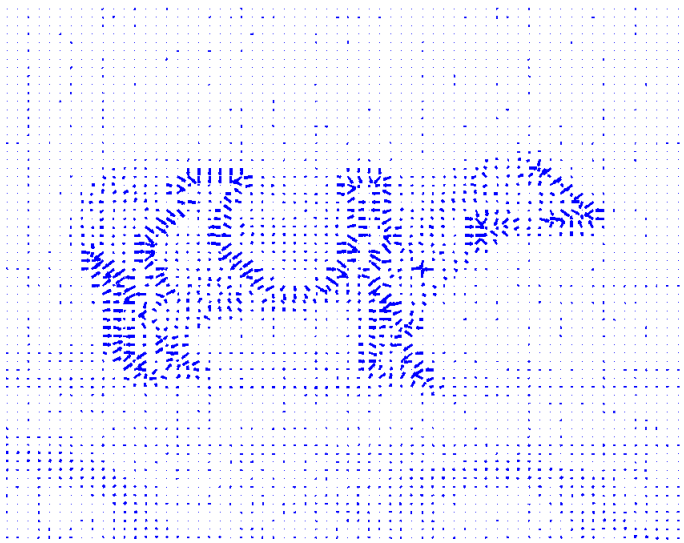
$\Rightarrow$ representing image appearance with a vector of histograms.

HOG computation steps

Original Image :

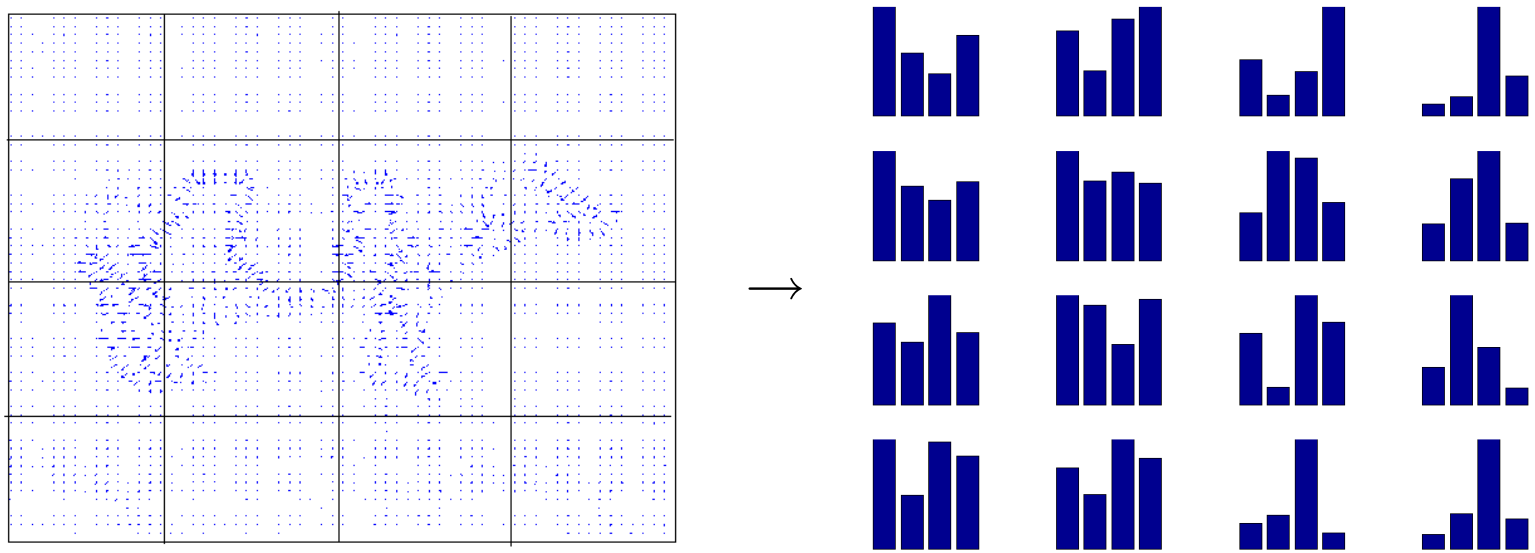
HOG computation steps

Gradient Orientation and Norm:



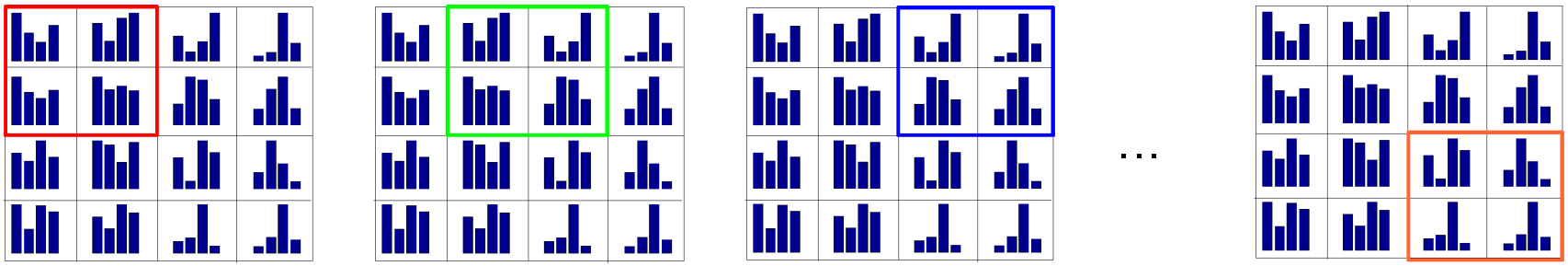
HOG computation steps

Cell Splitting, computaton of gradient orientation histograms:



HOG computation steps

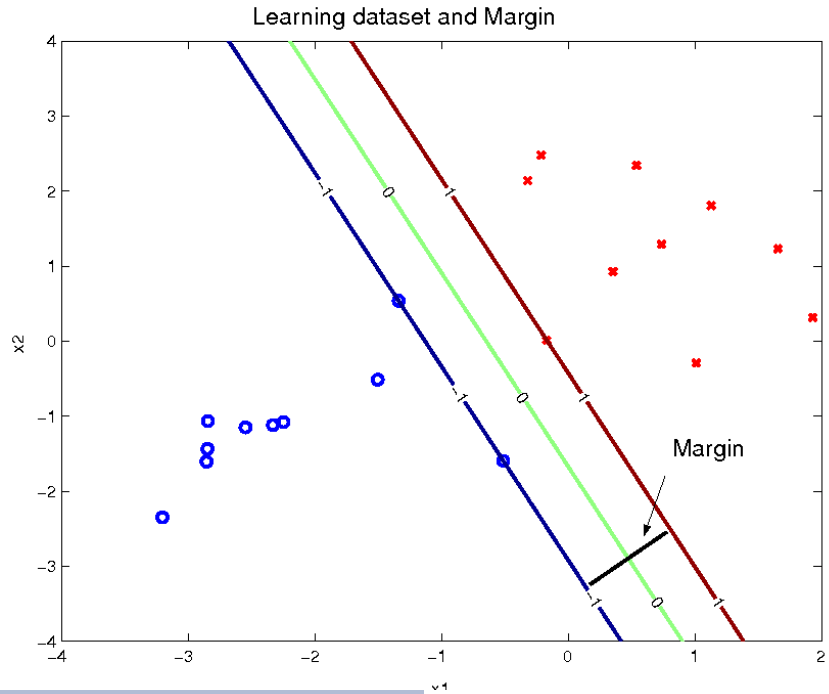
Histogram normalization:



Final descriptor = $[H_{11}, H_{21}, H_{21}, H_{22},\ H_{12}, H_{13}, H_{22}, H_{23},$
$H_{13}, H_{14}, H_{23}, H_{24},\ \ldots\ ,\ H_{33}, H_{34}, H_{43}, H_{44}\ ]$

Support Vector Machine Classifier

- Data $x \in \mathcal{X}$, labels $y \in \{-1, 1\}$
- Class of x = sign of $f(x)$
- Decision function $f(x) = \sum_{i=1}^{m} \alpha_k \cdot y_i \cdot k(x_i, x) + b$



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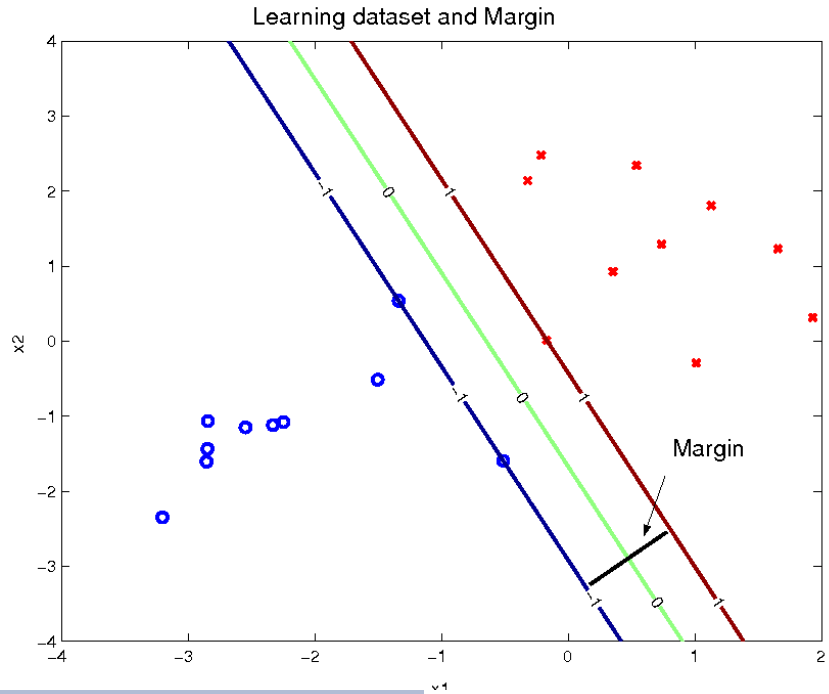

Kernel combination

2 representations

- HOG descriptor
- Graph

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$\Rightarrow$ How to combine kernels ?

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⇒ How to combine kernels ?

k_1, k_2 : kernels over $\mathcal{X} \times \mathcal{X}$, $0 \leq \lambda \leq 1$ and $a \geq 0$

The following functions are kernels [CST00]

- $k(x, y) = \lambda k_1(x, y) + (1 - \lambda) k_2(x, y)$
- $k(x, y) = a \cdot k_1(x, y)$
- $k(x, y) = k_1(x, y) \times k_2(x, y)$

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k_1, k_2 are normalized : $k_n(x,y) = \frac{k(x,y)}{\sqrt{k(x,x) \times k(y,y)}}$

k_1 : kernel for HOG descriptor, inner product between vectors,

k_2 : kernel between graphs.

Graph Kernel

Inner product between graphs [KTI03]

- → random walk,
- → compare labels values.

$$K(G, G') = \sum_{h} \sum_{h'} K_z(h, h') \times p(h, G) \times p(h', G')$$

$$K_z(h, h') = K_v(h_1, h'_1) \prod_{i=2}^{l} K_e(h_{2i-2}, h'_{2i-2}) \times K_v(h_{2i-1}, h'_{2i-1}) \quad (1)$$

$$K_v(h_k, h'_k) = K_e(h, h'_k) = \exp\left(-\frac{\|h_k - h'_k\|^2_{\mathbb{R}^d}}{2\sigma^2}\right) \quad (2)$$

σ : bandwidth.

Process

- ETH database (3280 images):
  - 8 classes,
  - 10 objects/class,
  - 41 views/object
- Kernel combination : product.
- Multiclass 1 vs 1 : vote between $\frac{n(n-1)}{2}$ binary classifiers for n classes.
- Crossvalidation method : leave-one-object-out (41 images).

Graph

T \ P								
	317	0	0	6	0	0	0	87
	0	397	6	0	1	1	5	0
	0	21	310	0	36	43	0	0
	4	1	2	391	3	0	0	9
	0	6	36	0	313	55	0	0
	0	2	55	0	51	302	0	0
	0	3	2	0	0	0	405	0
	88	0	0	9	0	0	0	313

Good Recognition rate : 83,8%

Histograms of Oriented Gradients

T \ P								
	402	0	0	0	0	0	0	8
	0	409	0	0	1	0	0	0
	0	5	323	0	38	43	1	0
	0	0	0	410	0	0	0	0
	0	2	30	0	354	24	0	0
	0	1	59	0	24	326	0	0
	0	0	0	0	0	0	410	0
	5	0	0	0	0	0	0	405

Good Recognition rate : 90,1%

Combination

T \ P								
	403	0	0	0	0	0	0	7
	0	409	1	0	0	0	0	0
	0	1	345	0	37	27	0	0
	0	0	0	410	0	0	0	0
	0	1	31	0	353	25	0	0
	0	0	35	0	21	354	0	0
	0	0	0	0	0	0	410	0
	7	0	0	0	0	0	0	403

Good Recognition rate : 94,1%

Performance improvement

Recognition rate

- Graph : 83,8%
- HOG : 90,1%
- **HOG+Graph : 94,1%**

Graph	0	21	310	0	36	43	0	0
HOG	0	5	323	0	38	43	1	0
Combination	0	1	**345**	0	37	**27**	0	0

Conclusion and perspectives

+

- Various kinds of representation,
- improve performance,
- combination done in the classifier.

−

- graph kernel : complexity,
- skeleton method,
- region segmentation.

Perspectives

- Try other combinations, multiple kernels,
- define kernel for histogram.

References

N. Cristianini and J. Shawe-Taylor.
Introduction to Support Vector Machines.
Cambridge Univeristy Press, 2000.

Navneet Dalal and Bill Triggs.
Histograms of oriented gradients for human detection.
In Cordelia Schmid, Stefano Soatto, and Carlo Tomasi, editors, *International Conference on Computer Vision and Pattern Recognition*, volume 2, pages 886–893, INRIA Rhone-Alpes, ZIRST-655, av. de l'Europe, Montbonnot-38334, June 2005.

H. Kashima, K. Tsuda, and A. Inokuchi.
Marginalized kernels between labeled graphs.
In *Proceedings of the Twentieh International Conference on Machine Learning*, 2003.