An Efficient, High Quality Object Recognition System

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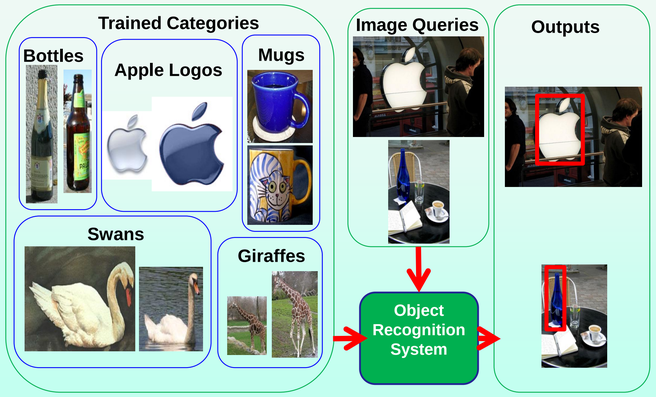
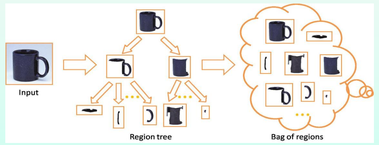
Object Recognition

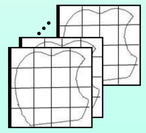


Feature Extraction

- Construct a region tree by clustering regions together recursively
- Generate a bag of regions by collecting all nodes from the region tree



- Collect contour features by accumulating gPb value on 4 by 4 grids and 8 orientations
  - Each regions is represented by a 128-bin histogram



Key Parallelization Strategies

BFS Graph Traversal

- Local Minimum Extraction
- Node and Edge Extraction
- Label Assignment
- Edge Linearization
- Watershed Propagation
- Edge Reweighting

→ Structured Grids → Data Parallelism

- Key idea: Introduce redundant work to increase the amount of parallelism

Histogram Accumulation

- Feature Extraction

→ Map Reduce → Geometric Decompo-sition

- Key idea: Deal with different regions in parallel, and deal with each histogram bin in parallel.

Dense Linear Algebra

- Hough Voting
- χ^2Distance Computation
- Weight Learning

→ Dense Linear Algebra → Data Parallelism

- Key idea: Integrate a set of small problems into a large problem, and solve the large problem in parallel

Object Recognition Using Regions

C. Gu, J. Lim, P. Arbelaez, and J. Malik, "Recognition Using Regions," Conference on Computer Vision and Pattern Recognition (CVPR'09), Miami, FL, 2009.

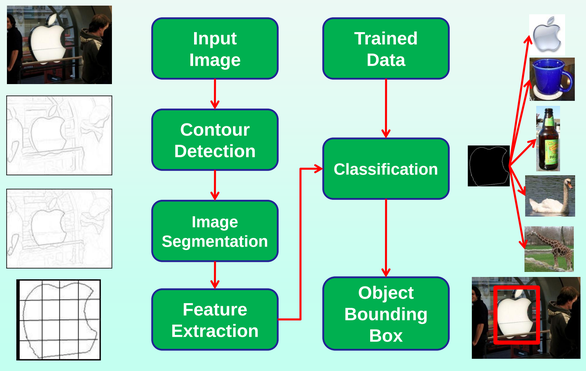
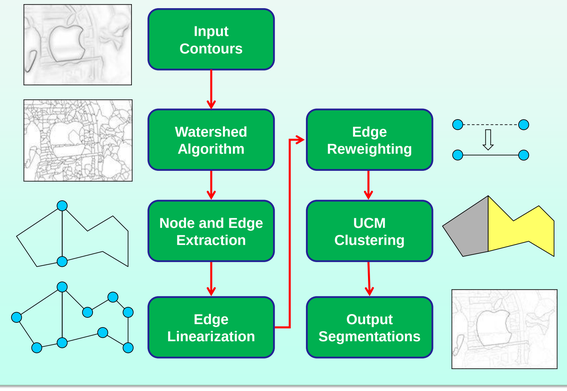


Image Segmentation

P. Arbelaez, M. Maire, and J. Malik, "From contours to regions: An empirical evaluation," Conference on Computer Vision and Pattern Recognition (CVPR'09), Miami, FL, 2009.



Training and Classification

Training

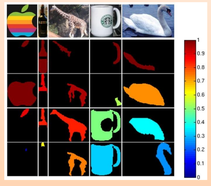
- Distance computation
  - Image I has regions $r_1^I, r_2^I, \ldots, r_m^I$
  - Image J has regions $r_1^J, r_2^J, \ldots, r_n^J$
  - $D(I \to J) = w_1 d_1 + w_2 d_2 + \ldots + w_m d_m$
    - w_i: the weight of r_i^I; $d_i = min_j\, d(r_i^I, r_j^J)$
- Weight learning
  - Formulate to a large-margin opt. problem
  - Identify representative regions in an image

$$\min_{w,\xi} \frac{1}{2}\sum_{i=1}^{N_I}(w_i^I)^2 + C\sum_{t=1}^{T}\xi_t$$

$$s.t. \sum_{i=1}^{N_I} w_i^I (d_i^{IK_t} - d_i^{IJ_t}) \geq 1 - \xi_t, \forall t = 1,2,\ldots,T$$

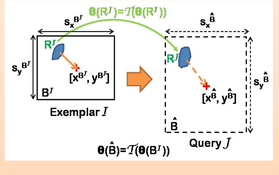
$$w_i^I \geq 0, \forall i = 1,2,\ldots,N_I$$

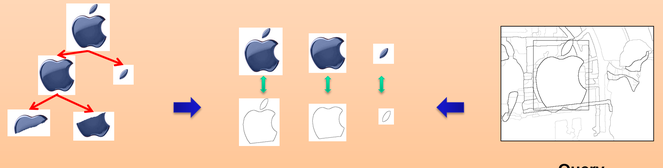
$$\xi_t \geq 0, \forall t = 1,2,\ldots,T$$



Classification

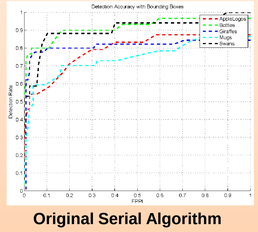
- Hough Voting
  - Consider the weights of regions of exemplars
  - Generate hypotheses of bounding boxes and possible categories
  - Cluster the bounding box guesses by the mean shift algorithm



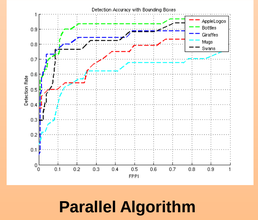


Experimental Results

Detection Quality



Original Serial Algorithm



Parallel Algorithm

Speedup by Parallel Implementation

Computation	Computation time (s)		Speedup
	Core i7	Tesla	
Contour	236.7	2.243	106x
Segmentation	2.27	0.357	6.36x
Feature	7.97	0.279	28.6x
Hough Voting	84.13	1.688	49.8x
Classification	331	4.567	72.5x

Classification

Computation	Computation time (s)		Speedup
	Core i7	Tesla	
Feature	543	24.9	21.8x
Distance	1732	2.9	597x
Weight	57	2.16	26.4x
Training	2332	29.96	77.8x

Training on 127 images