Contour Detection and Hierarchical Image Segmentation

P. Arbelaez, M. Maire, C. Fowlkes, and J. Malik. IEEE TPAMI 2011.

Islam Beltagy

Original slides from: Hsin-Min Cheng http://archer.ee.nctu.edu.tw/powerpoint/GM_1024.pptx

Outline

- Introduction
- Contour Detection
- Hierarchical Segmentation
- Results and Evaluation
- Discussion

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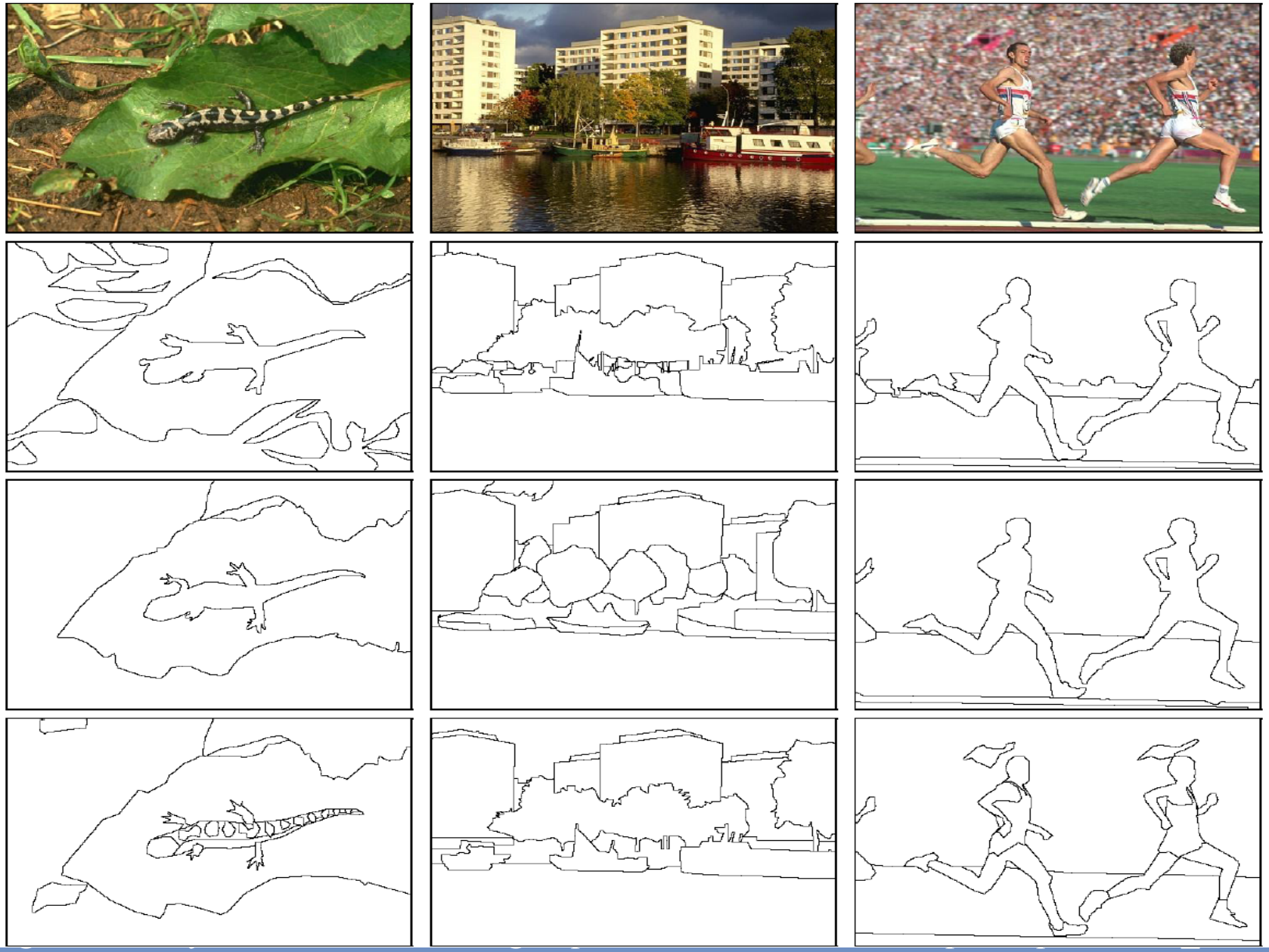
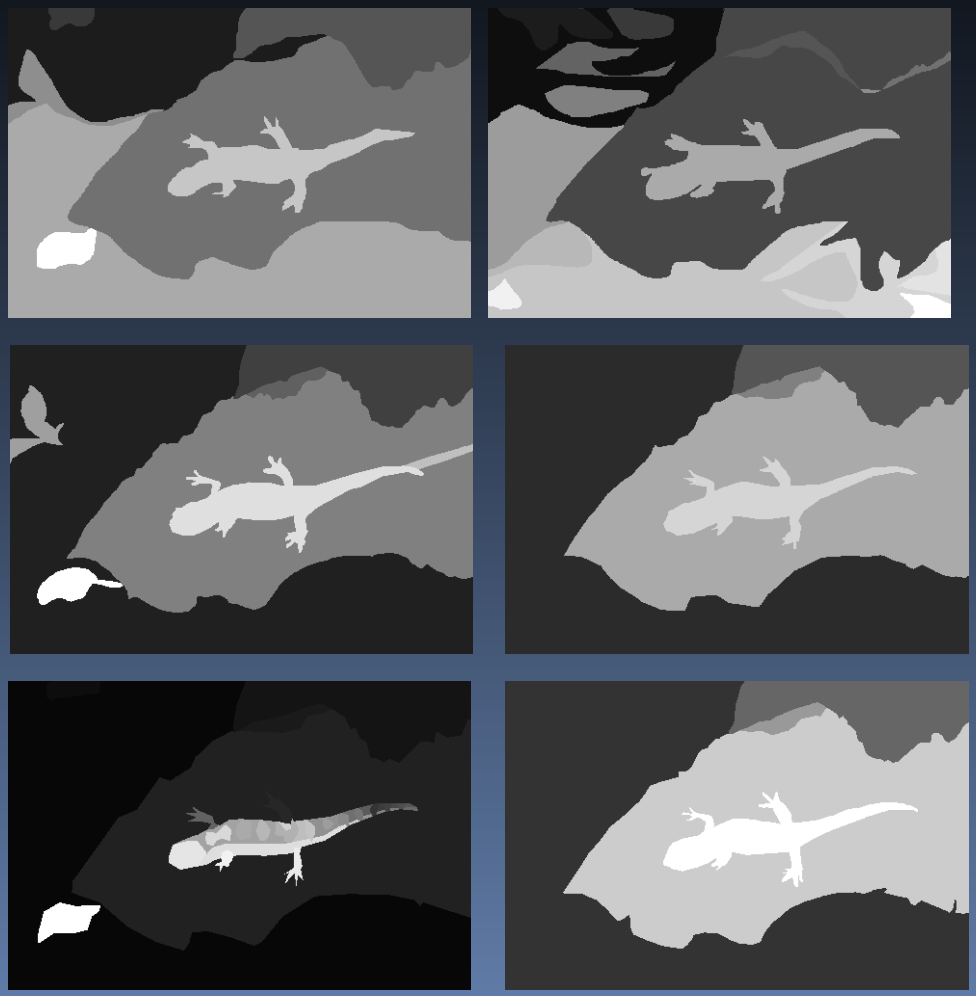
Contours (Ground Truth BSDS500)



Segmentation (Ground Truth-BSDS500)



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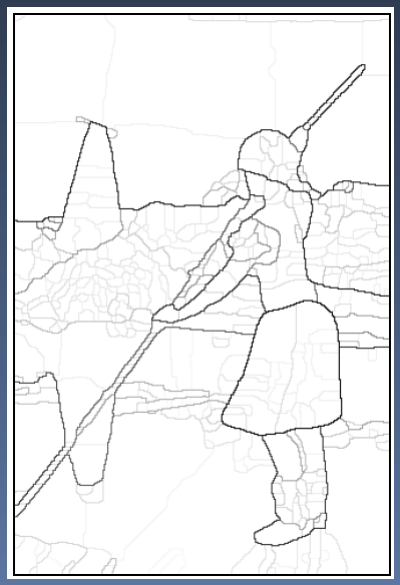
Goal

- Contour Detection
- Segmentation from Contours

Original Image

Contour



Segmentation

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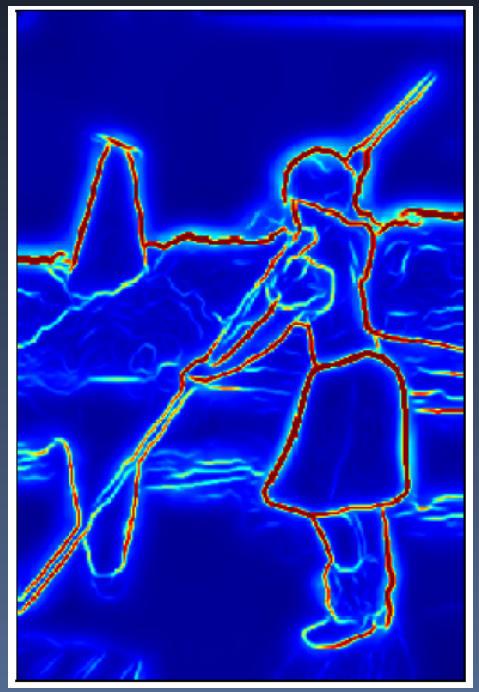
Contours Detection

Original Image



Contour = Pr(x, y, O)

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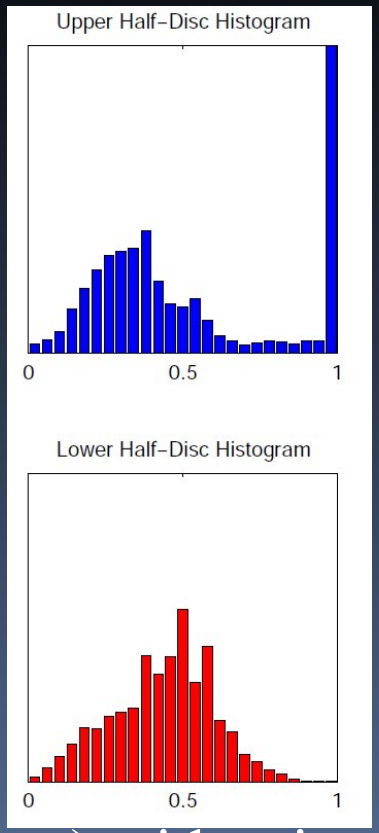
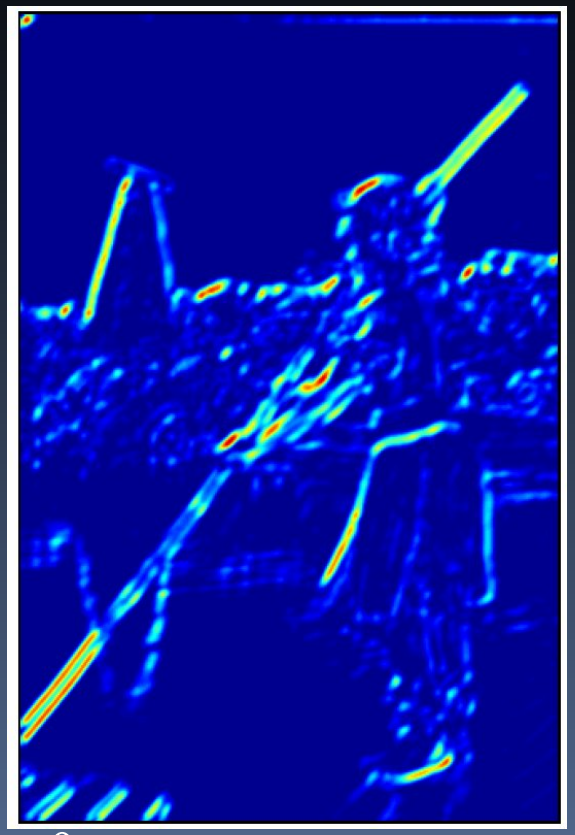
Contour Detection-Oriented gradient of histograms





- Circular disk around (x, y) with orientation θ
- Histograms of **Intensities** in both halves
- Chi Square distance between the two histograms
- Three scales of r and eight values for θ

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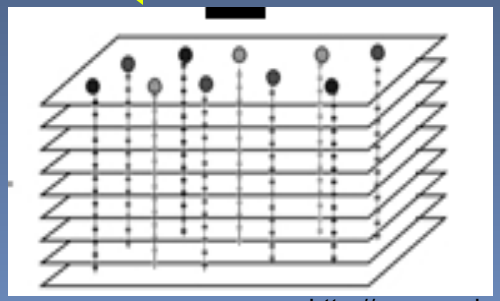
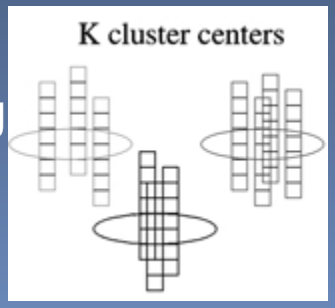
Contour Detection

- Extract different channels
  - Brightness L, Color a, Color b
    - Components of CIE Lab colorspace
  - Texture

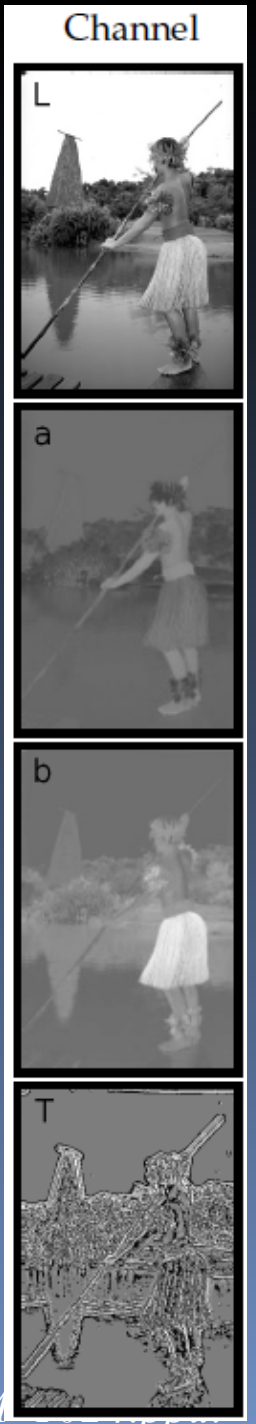
Convolve



K-mean clustering



Replace pixel with cluster index



http://www.cs.berkeley.edu/~malik/papers/LM-3dtexton.pdf

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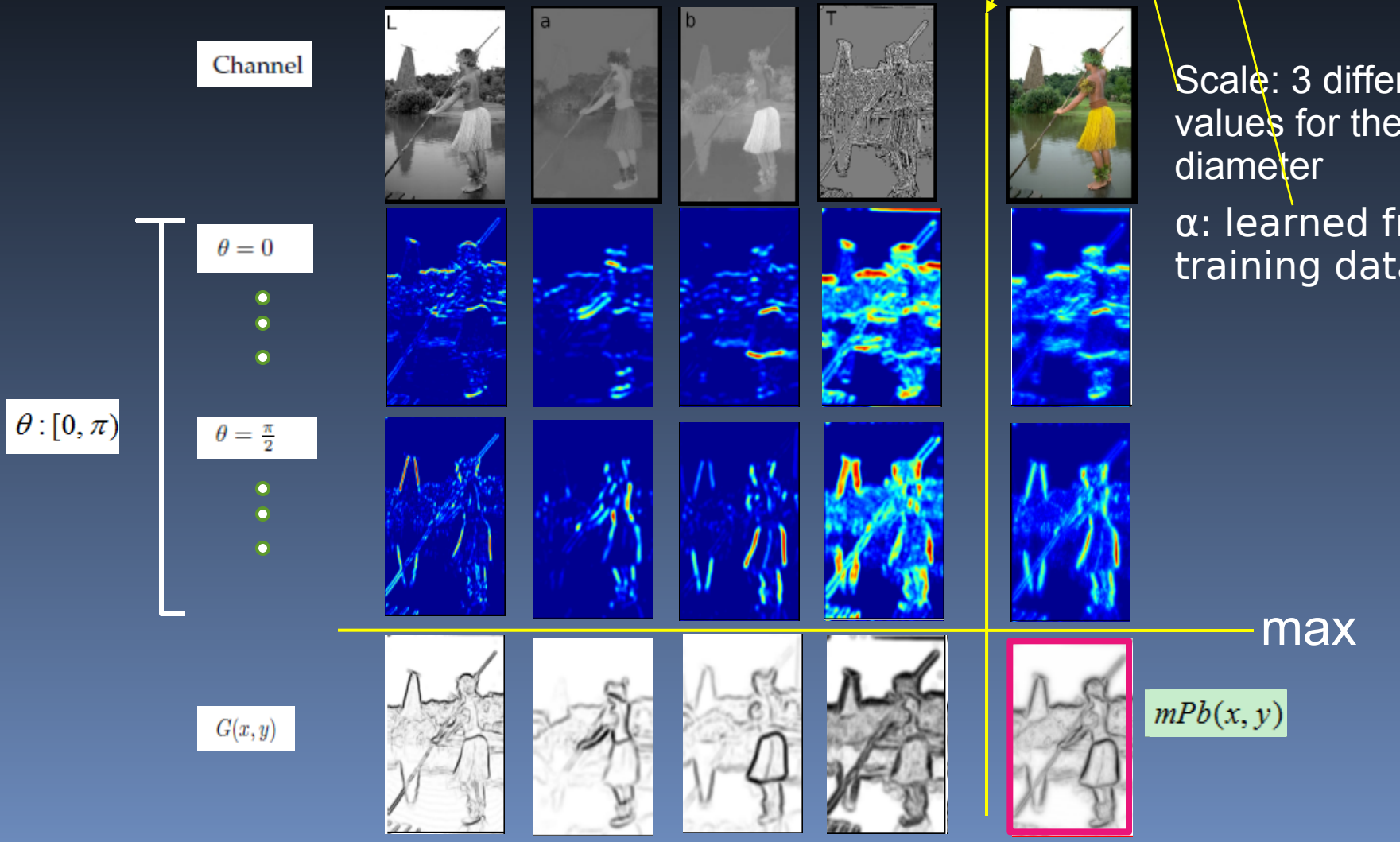
Contour Detection

- Local Cues Combination

$$mPb(x, y, \theta) = \sum_s \sum_i \alpha_{i,s} G_{i,\sigma(i,s)}(x, y, \theta)$$



Scale: 3 different values for the disc diameter

α: learned from training data

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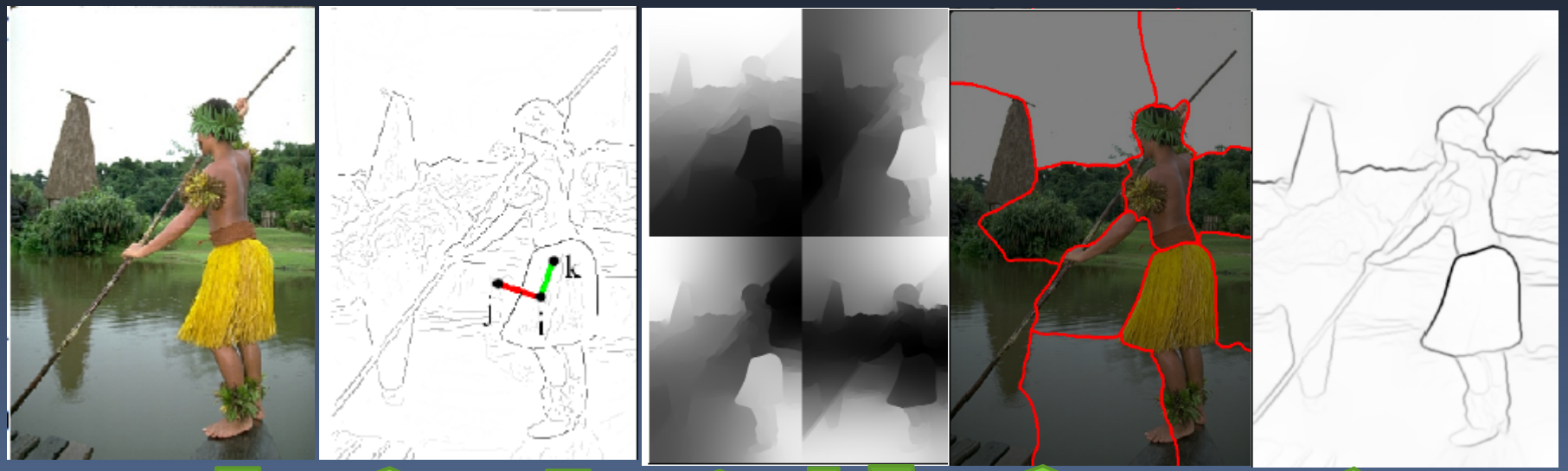
Contour Detection

- Globalization



Affinity Matrix

Eigen Values

Normalized Cuts

Apply filters then sum

$$W_{ij} = \exp\left(-\max_{p \in \overline{ij}}\{mPb(p)\}/\rho\right)$$

$$D_{ii} = \sum_j W_{ij}$$

$$sPb(x, y, \theta) = \sum_{k=1}^{n} \frac{1}{\sqrt{\lambda_k}} \cdot \nabla_\theta \mathbf{v_k}(x, y)$$

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Uncertainty in Segmentation

Hierarchical Segmentation

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Hierarchical Segmentation

- Oriented Watershed Transform
- Ultrametric Contour Map

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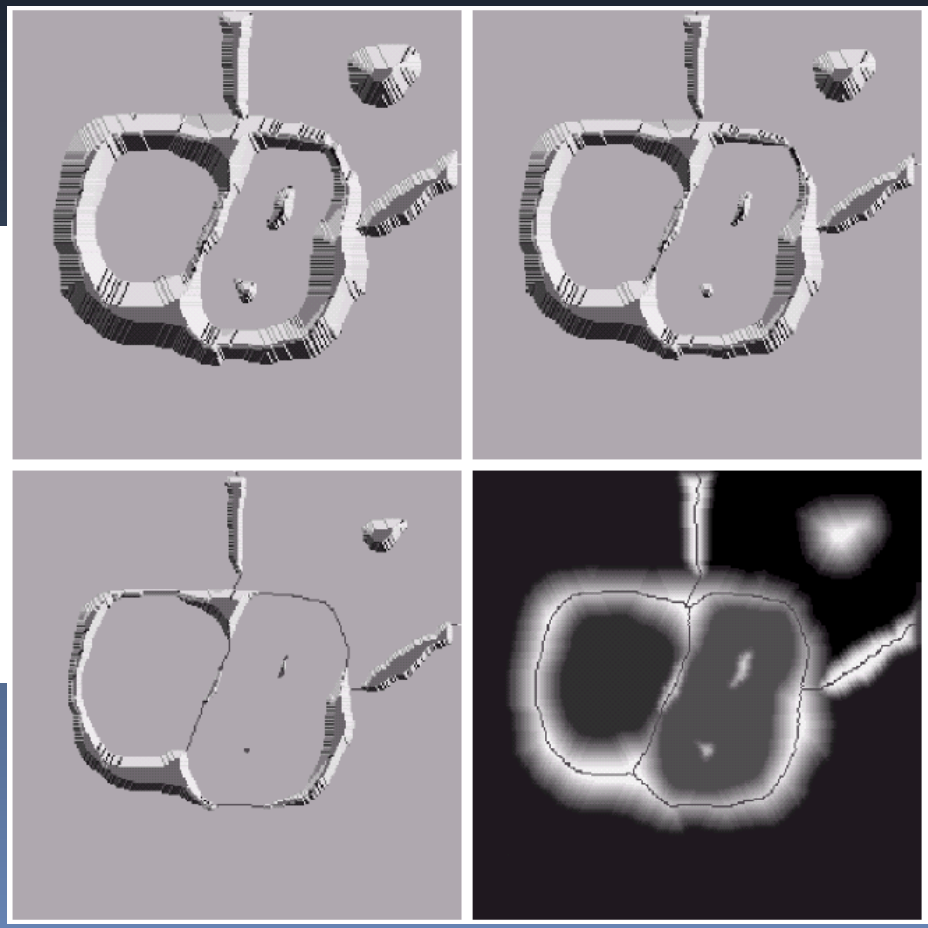
Oriented Watershed Transform

- Watershed Transform



http://cmm.ensmp.fr/~beucher/wtshed.html

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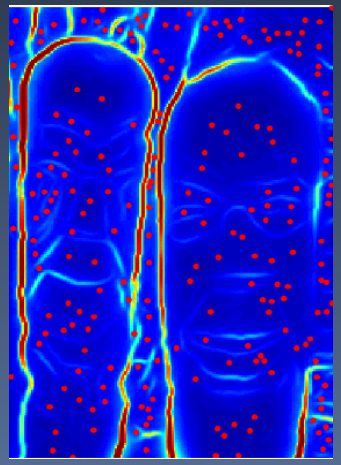
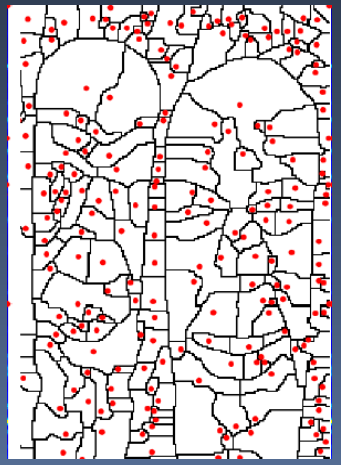
Oriented Watershed Transform

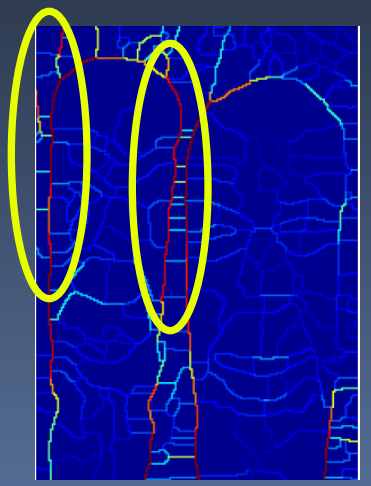
- Watershed Transform





Weight each arc

Artifacts



$$E(x,y) = \max_\theta E(x,y,\theta)$$

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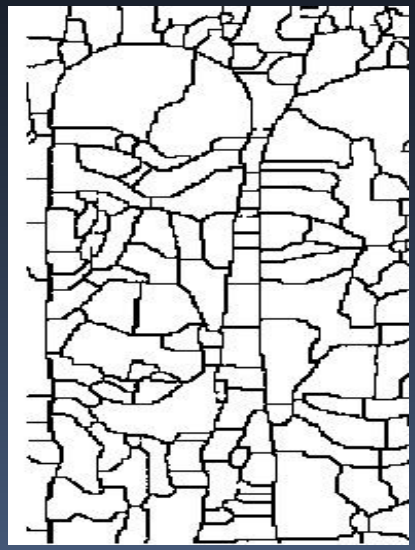
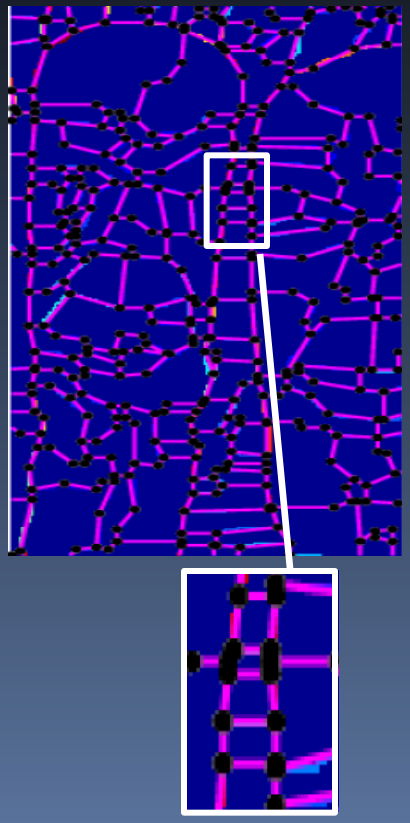
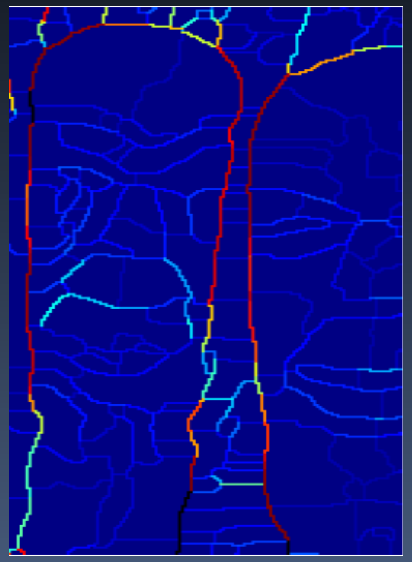
Oriented Watershed Transform





Fitting lines



OWT

Weight arcs according to orientation

WT

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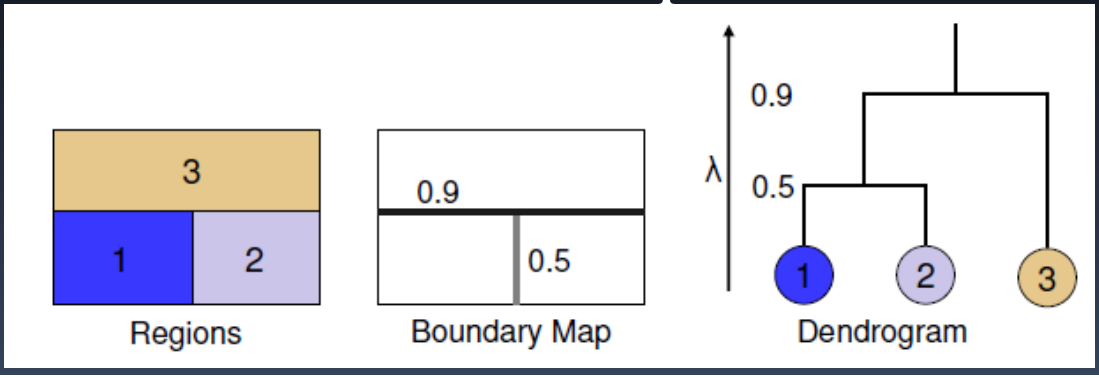
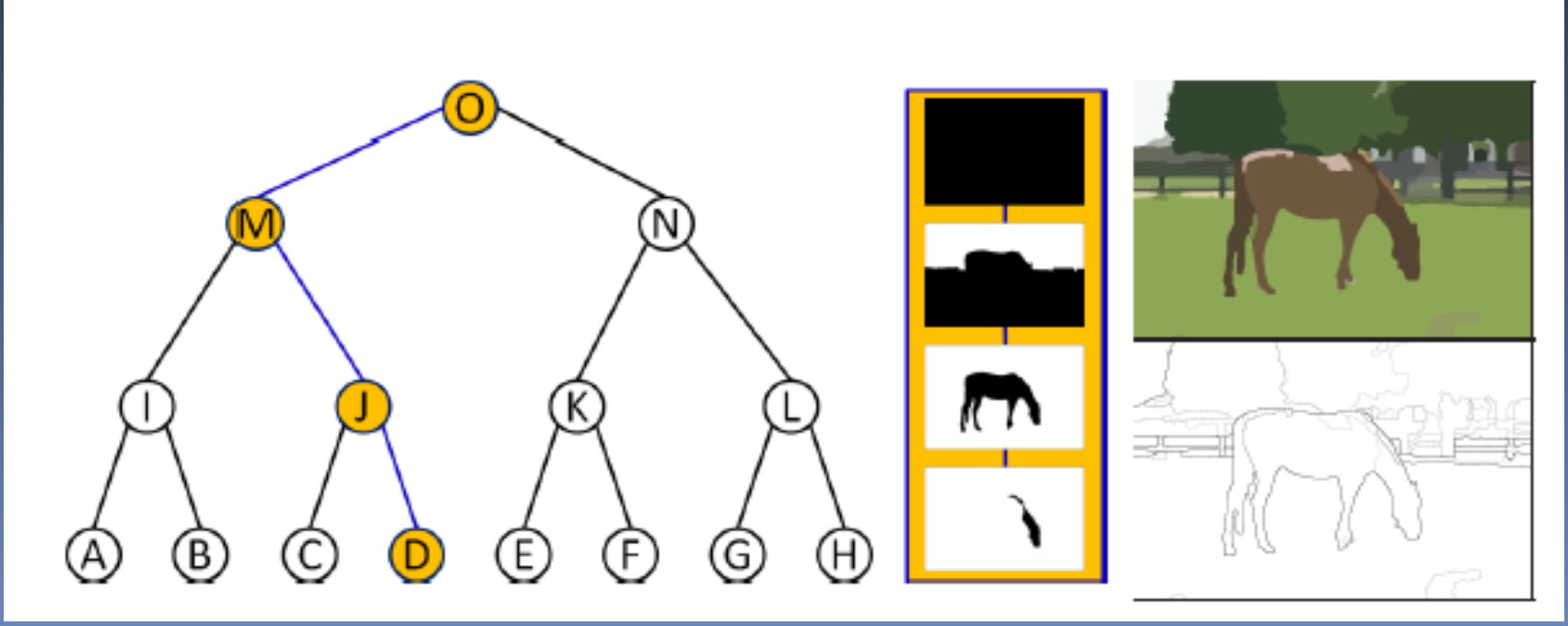
Hierarchical Segmentation

- Ultrametric Contour Map - Iterative Merging





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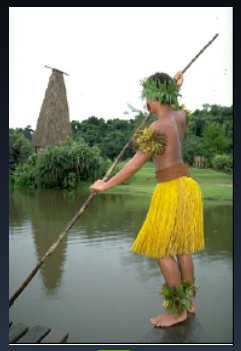
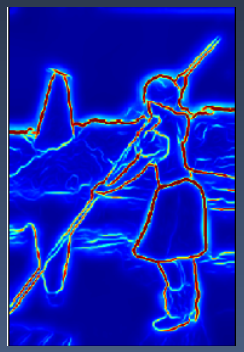
Brief Summary



Original Image

Oriented Gradient
of histograms



Contour

Hierarchical Segmentation

Oriented Watershed Transform
Ultrametric Contour Map

Threshold

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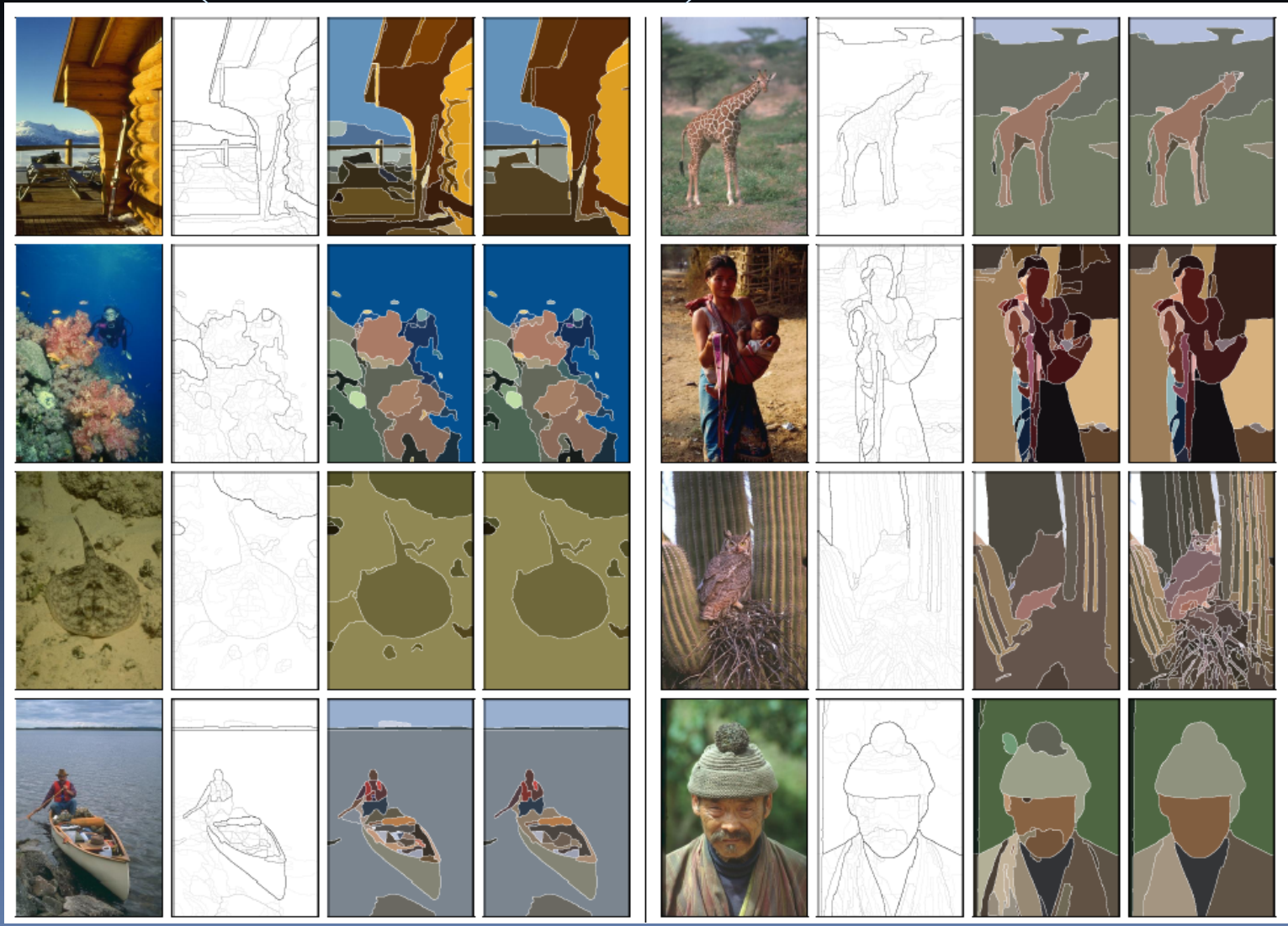
Result (BSDS500 dataset)



Left to Right: Image, gPb-owt-ucm, threshold = optimal dataset scale, threshold = optimal picture scale

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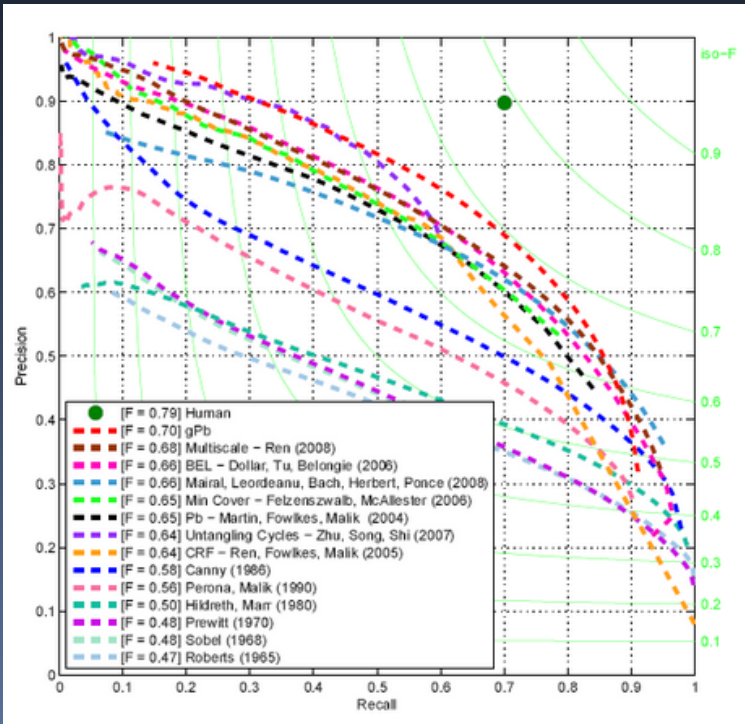
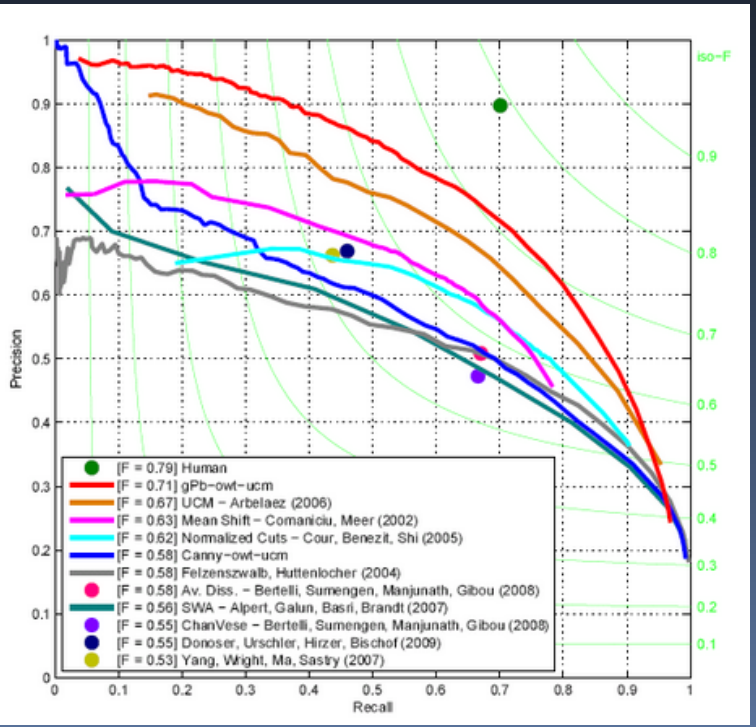
Result

- BSDS300 Dataset



Evaluation of contour detector



Evaluation of segmentation algorithms

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Region benchmarks(2)

Covering **Rand Index** **Variation of Information**

	BSDS300						
	Covering			PRI		VI	
	ODS	OIS	Best	ODS	OIS	ODS	OIS
Human	0.73	0.73	–	0.87	0.87	1.16	1.16
gPb-owt-ucm	**0.59**	**0.65**	**0.75**	**0.81**	**0.85**	**1.65**	**1.47**
[34] Mean Shift	0.54	0.58	0.66	0.78	0.80	1.83	1.63
[32] Felz-Hutt	0.51	0.58	0.68	0.77	0.82	2.15	1.79
Canny-owt-ucm	0.48	0.56	0.66	0.77	0.82	2.11	1.81
[33] NCuts	0.44	0.53	0.66	0.75	0.79	2.18	1.84
[31] SWA	0.47	0.55	0.66	0.75	0.80	2.06	1.75
[29] Total Var.	0.57	–	–	0.78	–	1.81	–
[70] T+B Encode	0.54	–	–	0.78	–	1.86	–
[30] Av. Diss.	0.47	–	–	0.76	–	2.62	–
[30] ChanVese	0.49	–	–	0.75	–	2.54	–
Quad-Tree	0.33	0.39	0.47	0.71	0.75	2.34	2.22

	BSDS500						
	Covering			PRI		VI	
	ODS	OIS	Best	ODS	OIS	ODS	OIS
Human	0.72	0.72	–	0.88	0.88	1.17	1.17
gPb-owt-ucm	**0.59**	**0.65**	**0.74**	**0.83**	**0.86**	**1.69**	**1.48**
[34] Mean Shift	0.54	0.58	0.66	0.79	0.81	1.85	1.64
[32] Felz-Hutt	0.52	0.57	0.69	0.80	0.82	2.21	1.87
Canny-owt-ucm	0.49	0.55	0.66	0.79	0.83	2.19	1.89
[33] NCuts	0.45	0.53	0.67	0.78	0.80	2.23	1.89
Quad-Tree	0.32	0.37	0.46	0.73	0.74	2.46	2.32

-ODS: optimal dataset scale

-OIS: optimal image scale

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Discussion

- What enforces closure in OWT-UCM for all possible thresholds?

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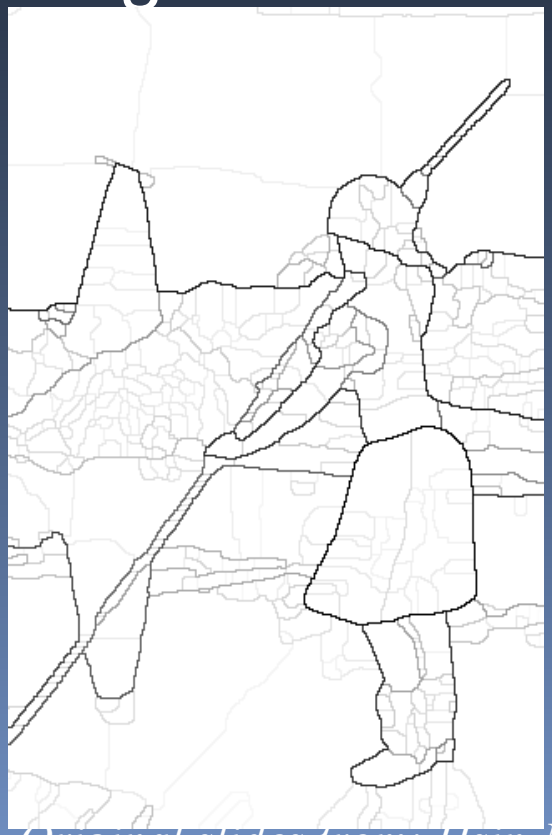
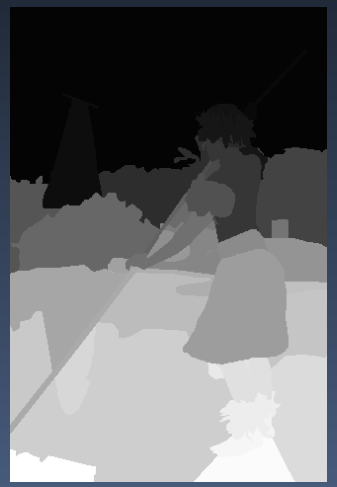
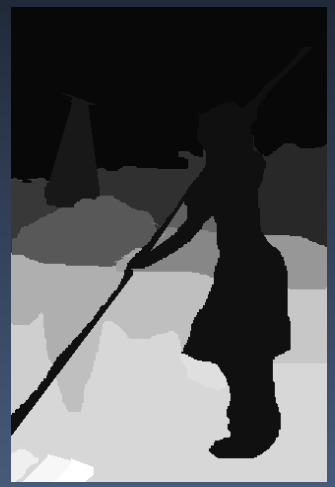
Discussion

- How to define ground truth ?

Can we use Hierarchal segmentation ?







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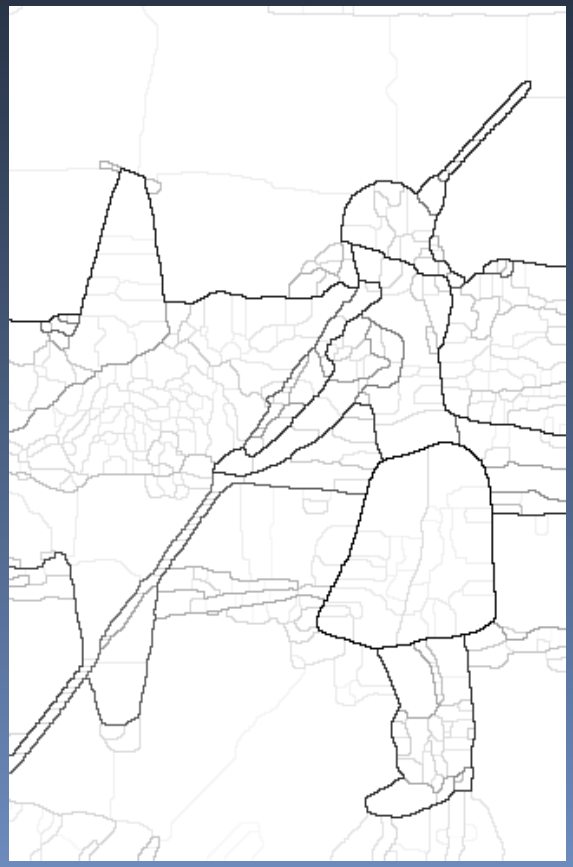
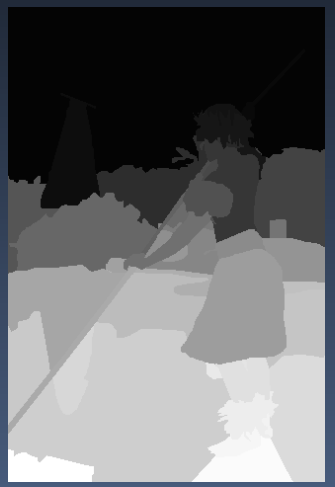
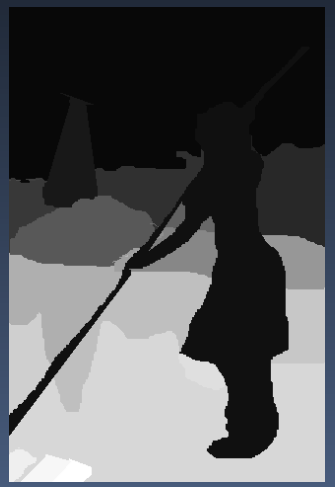
Discussion

- OIS and the different possible segmentations below, what do they suggest ?







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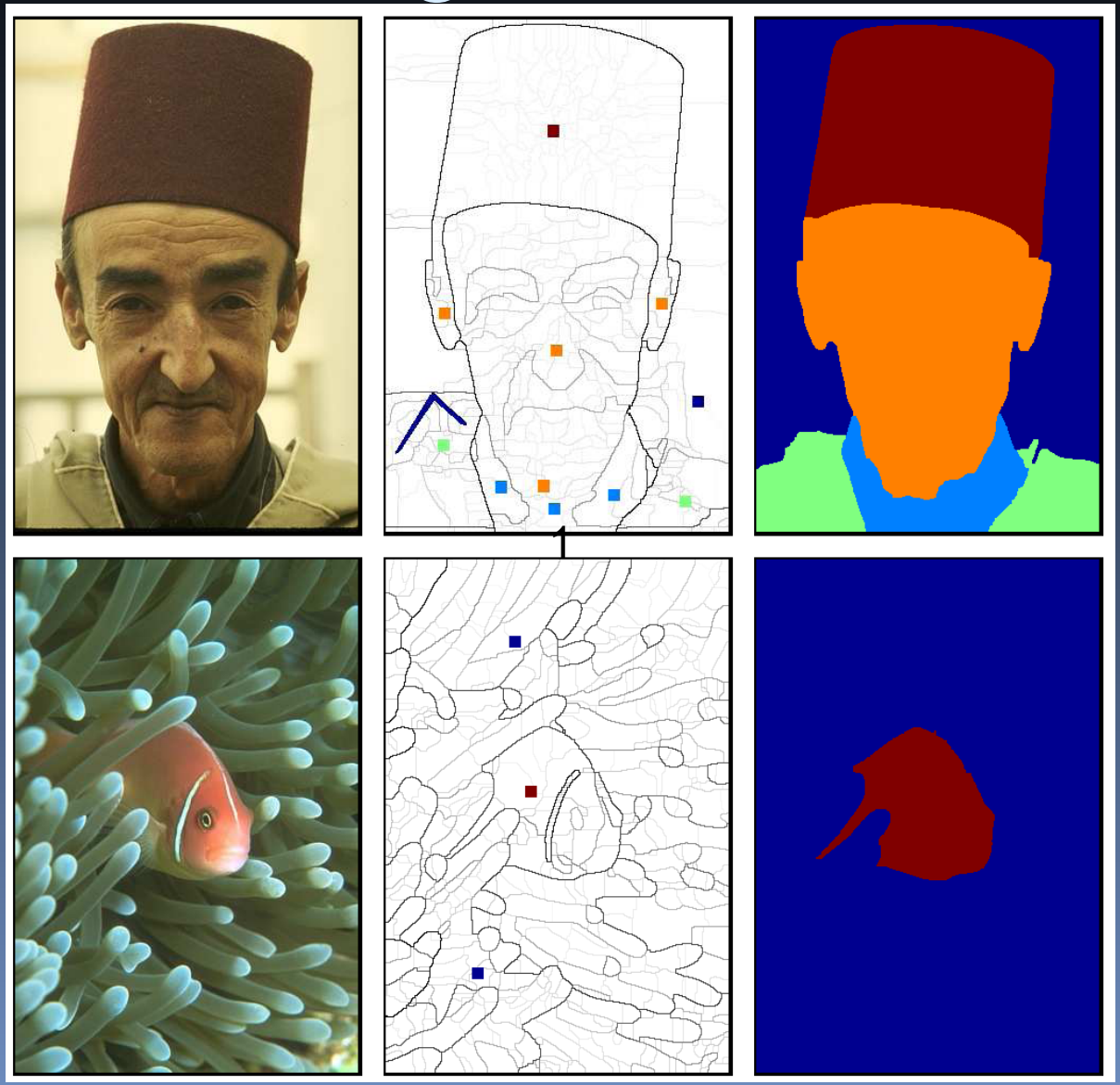
Interactive Segmentation



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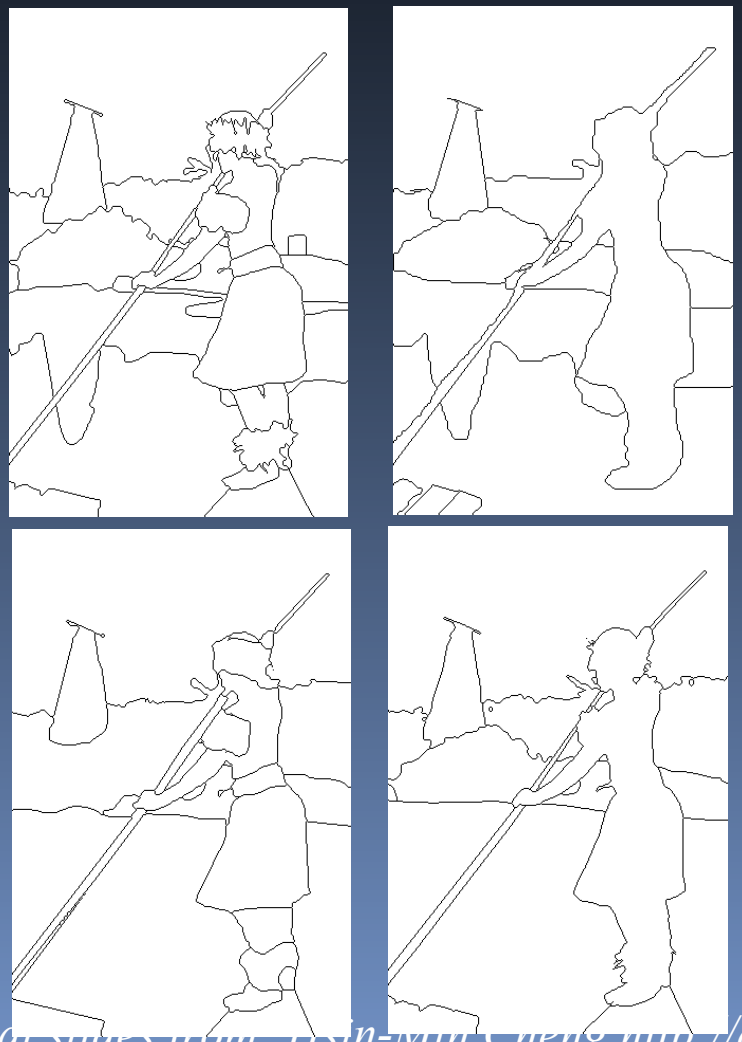
Discussion

- Contours vs Segments.



Reference

- P. Arbelaez, M. Maire, C. Fowlkes and J. Malik. *Contour Detection and Hierarchical Image Segmentation*. IEEE TPAMI, Vol. 33, No. 5, pp. 898-916, May 2011
- P. Arbelaez, M. Maire, C. Fowlkes and J. Malik. From Contours to Regions: An Empirical Evaluation. In CVPR 2009.
- P. Arbelaez and L. Cohen. Constrained Image Segmentation from Hierarchical Boundaries. In CVPR 2008.

Thanks

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