Paper Seminar Presentation

Image Processing for Video-CT Registration in Sinus Surgery

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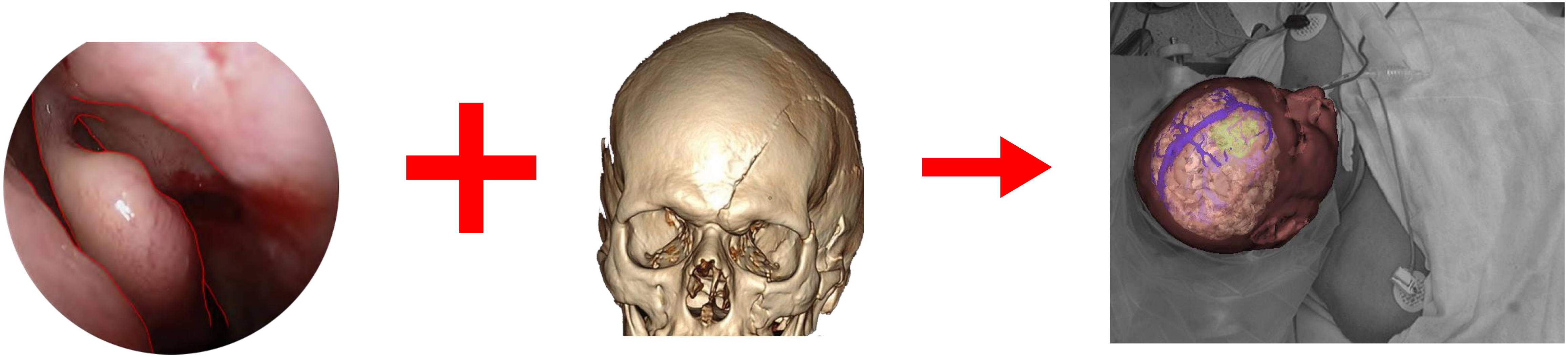
Project Review

The goal of this project is to be able to enhance magnetic tracker registration and surgical tool position by utilizing CT data with occluding contours extracted from the endoscopic video feed.



Paper Selection

Contour Detection and Hierarchical Image Segmentation

University of California at Berkeley

Arbelaez, P., Maire M., Fowlkes C., Malik, J., Contour Detection and Hierarchical Image Segmentation. IEEE Transactions on Pattern Analysis and Machine Intelligence, 2011

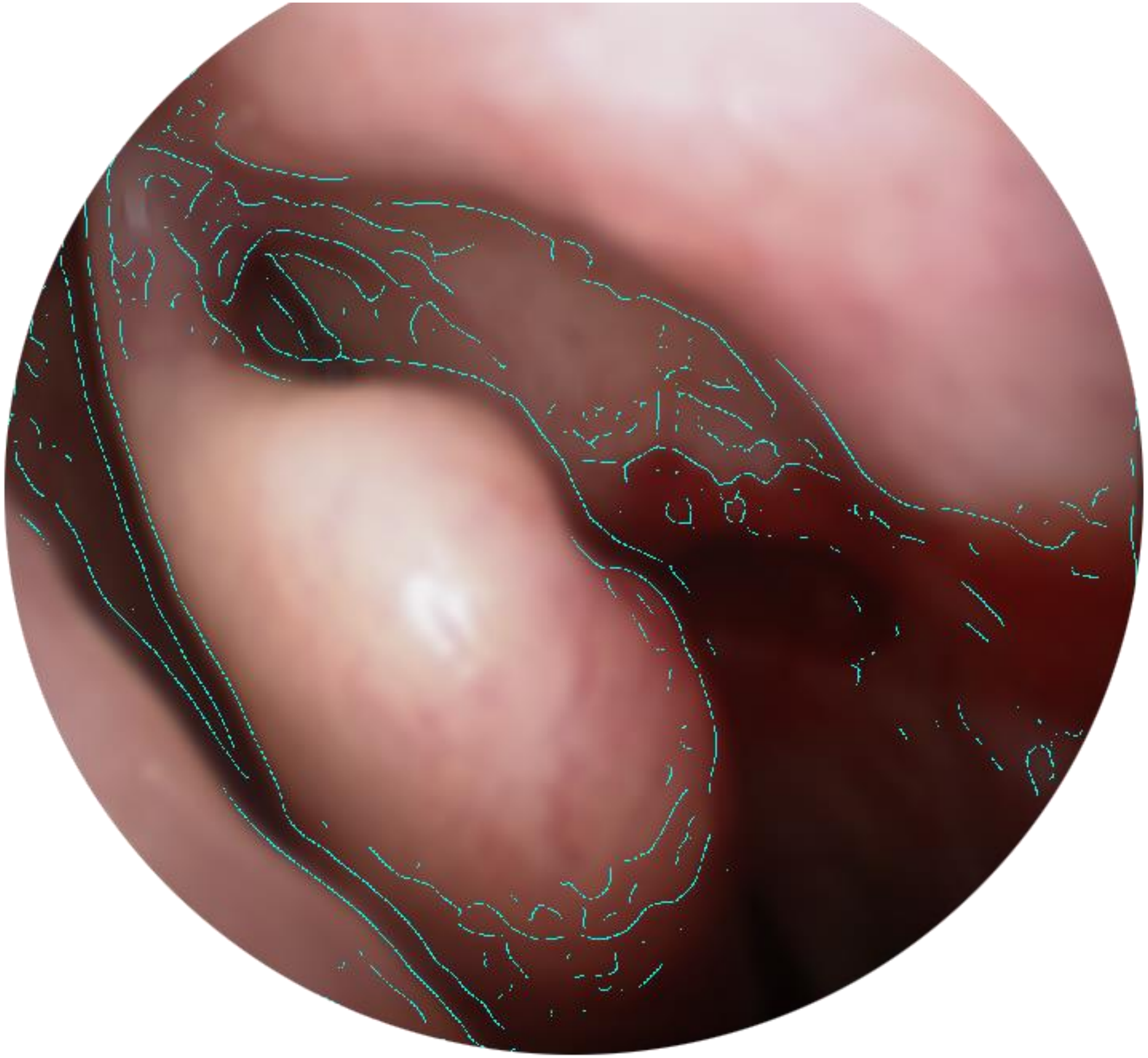
Paper Relevance

Canny Edge Detection

1. Gaussian filter
2. Discontinuities in Brightness
3. Nonmaximum suppression
4. Double Threshold
5. Hysteresis thresholding

Weaknesses:

- High noise



Results

“This paper…Provides a means of coupling our system to recognition applications”

Key Advantages

- More refined contour detection based off directional gradient
- Examines the picture globally for patterns
- Segmentation provides guaranteed closed contours

Paper Structure

- Previous Work
  - Overview of Contour Detection
  - Overview of Segmentation
- Benchmarks
- Their Work
  - Contour detection
  - Image segmentation
- Final Results

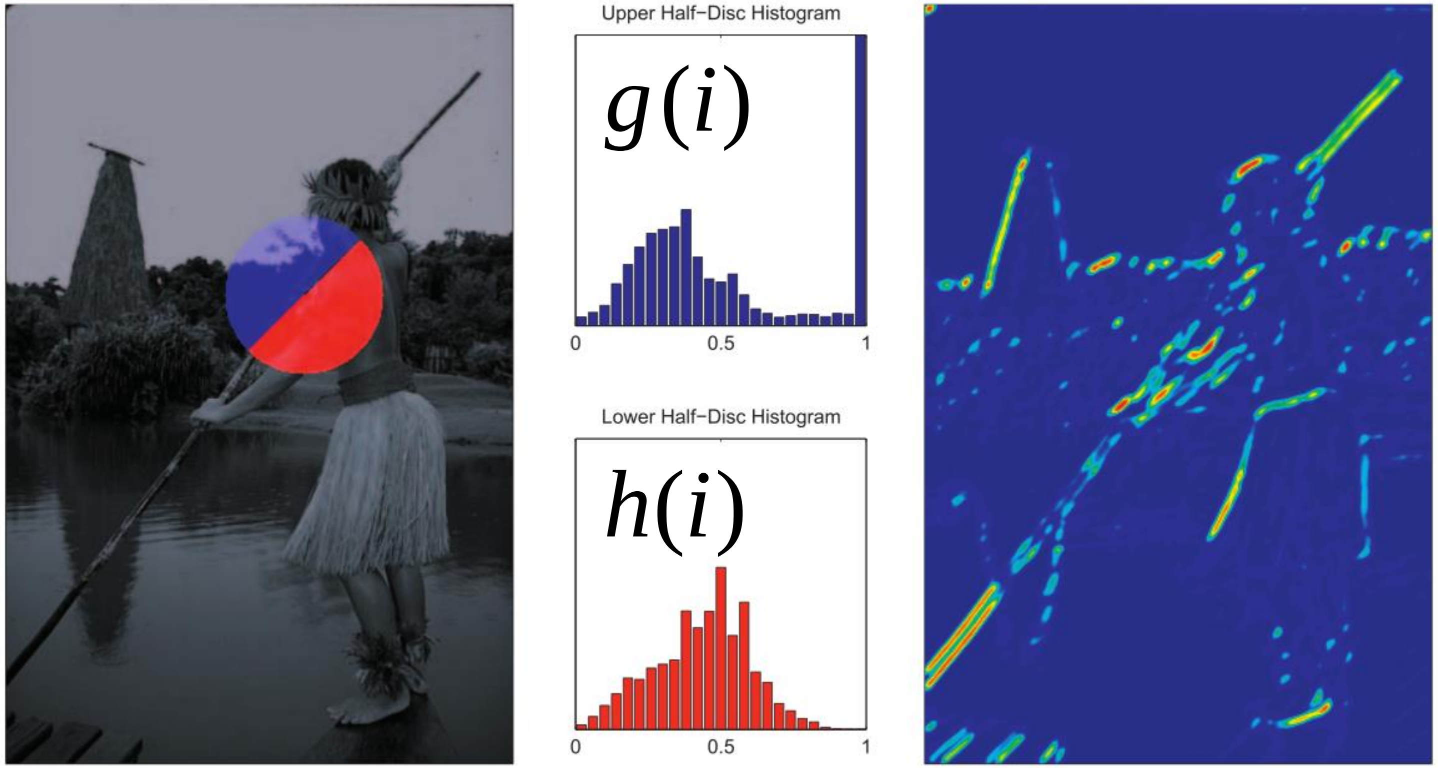
Probability of Boundary (Pb)

- Oriented Gradient Signal:

$$G(x, y, \theta)$$

- Gradient Magnitude:

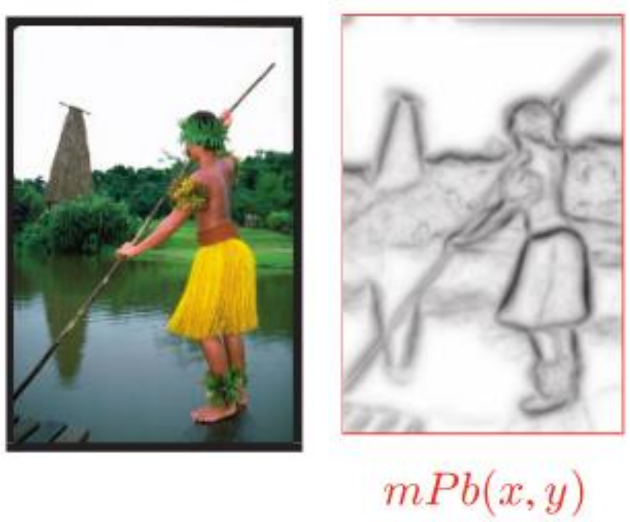
$$\chi^2(g,h) = \frac{1}{2}\sum_i \frac{(g(i)-h(i))^2}{g(i)+h(i)}$$

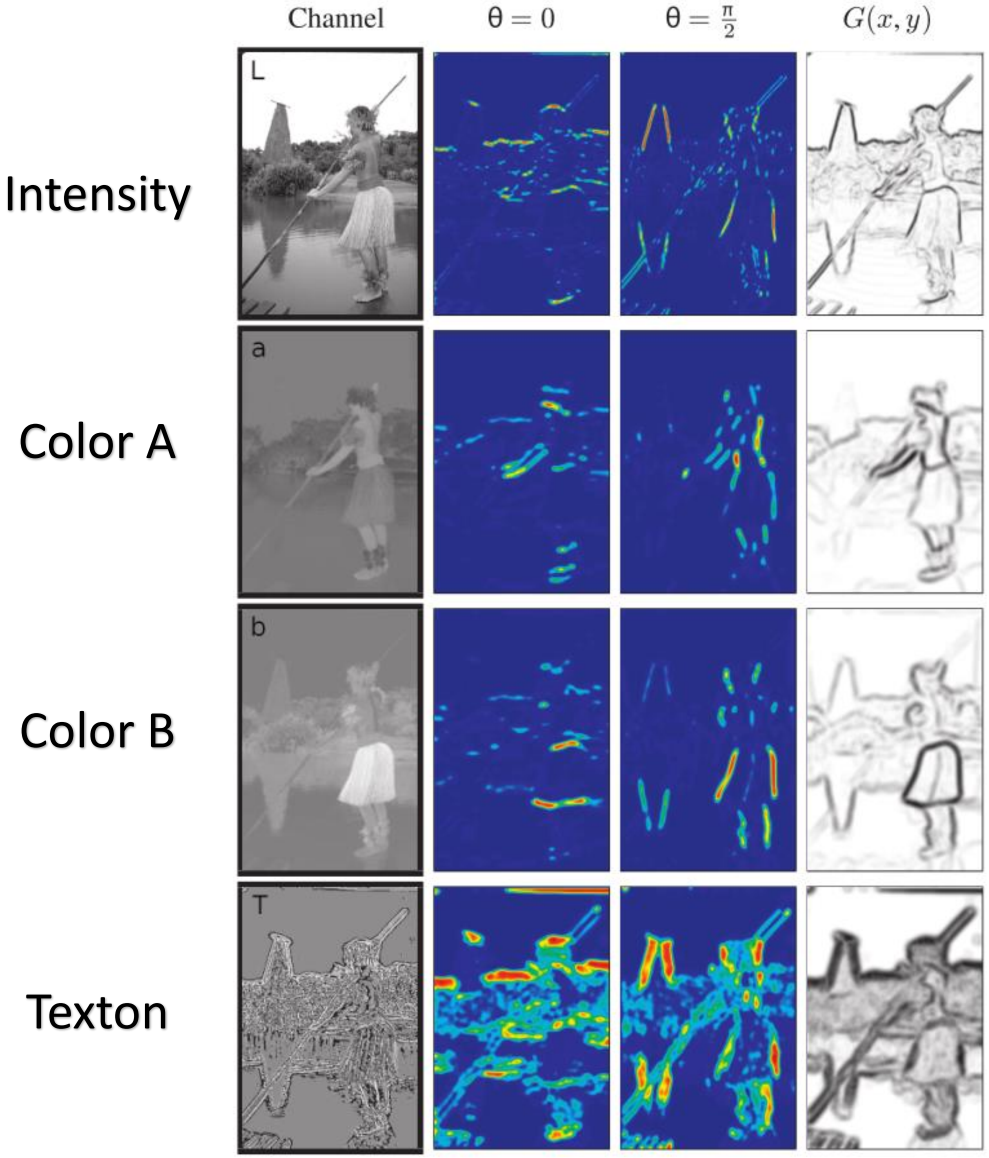


(a) (b) (c)

Multiscale Pb (*mPb*)

- 8 Pb samples from 4 categories with θ in $[0, \pi)$
- $mPb(x, y, \theta) = \sum_s \sum_i \alpha_{i,s} G_{i,\alpha(i,s)}(x, y, \theta)$
- $mPb(x, y) = \max_\theta \{mPb(x, y, \theta)\}$





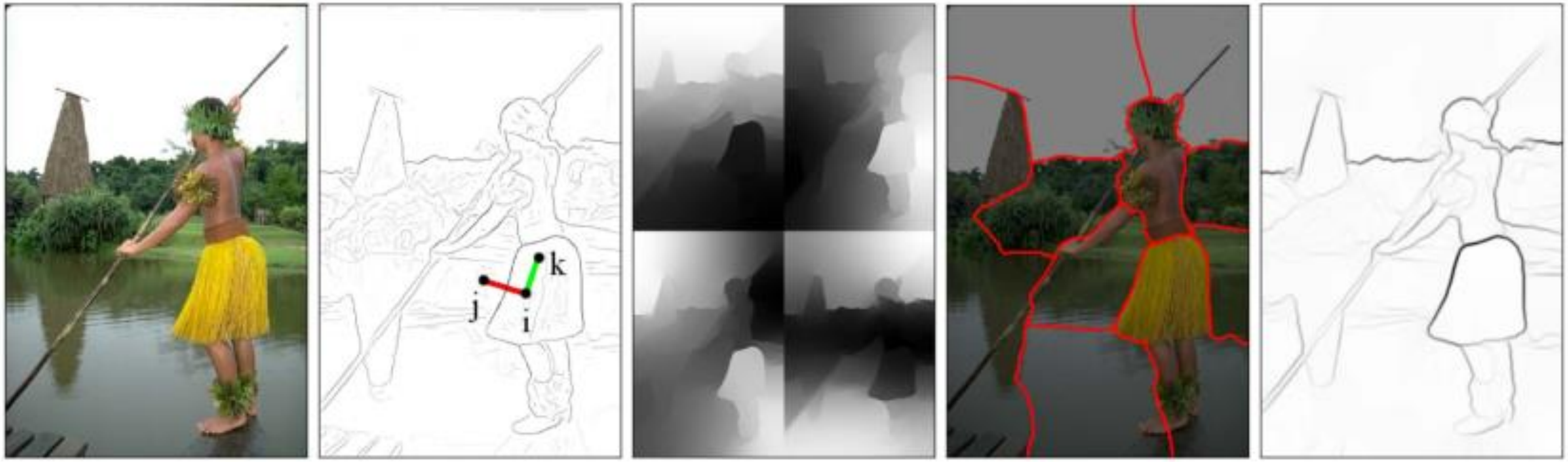
Spectral Pb (sPb)

- Connect all pixels i and j within a radius r to each other

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

- Define $D_{ii} = \sum_j W_{ij}$ and solve $(D - W)v = \lambda D v$
- Partition image using K-means

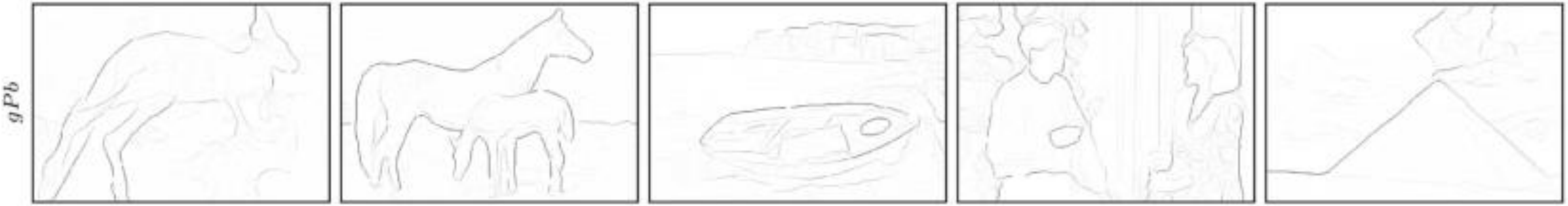
$$sPb(x, y, \theta) = \sum_{k=1}^{n} \frac{1}{\sqrt{\lambda_k}} \nabla_\theta v_k(x, y)$$



Global Pb (sPb)

- sPb highlights most salient curves
- mPb tries to find all edges

- $gPb(x, \mathrm{y}, \theta) = \sum_s \sum_i \beta_{i,s} G_{i,\sigma(i,s)}(x, y, \theta) + \gamma * sPb(x, y, \theta)$

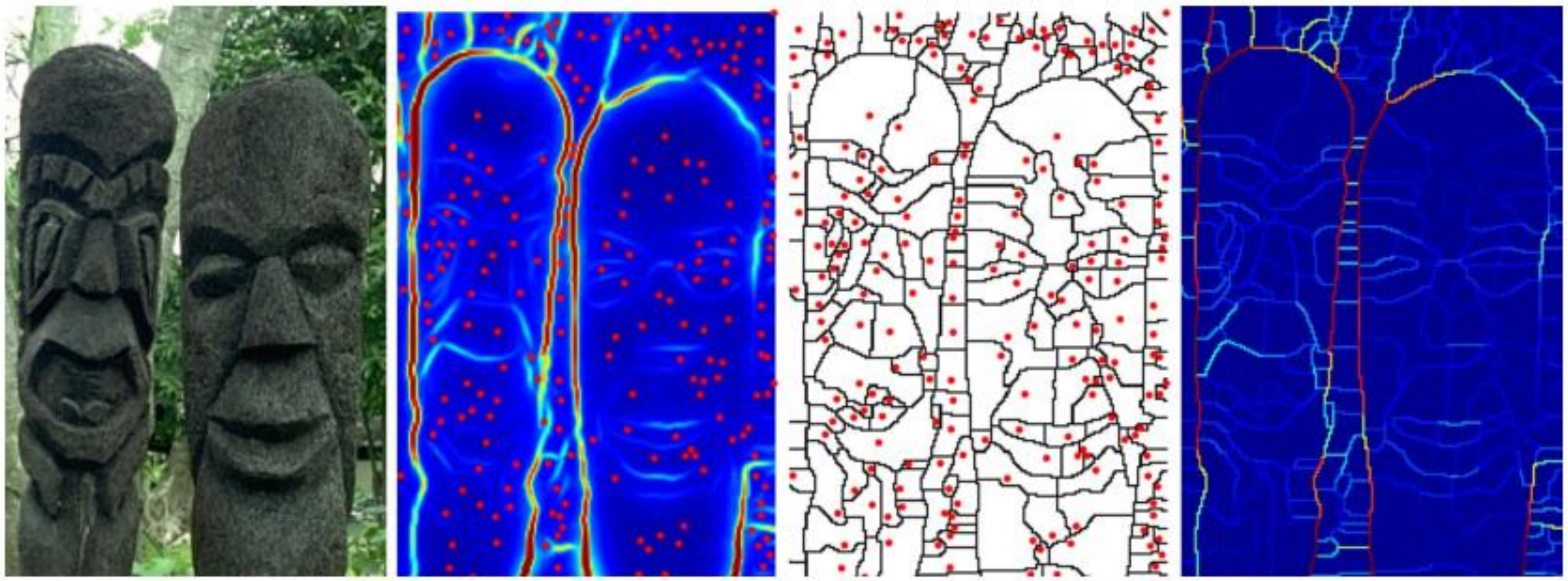


Segmentation

- Maximal response of a contour detector for each pixel:

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

- Oriented Watershed Transform is performed



Segmentation

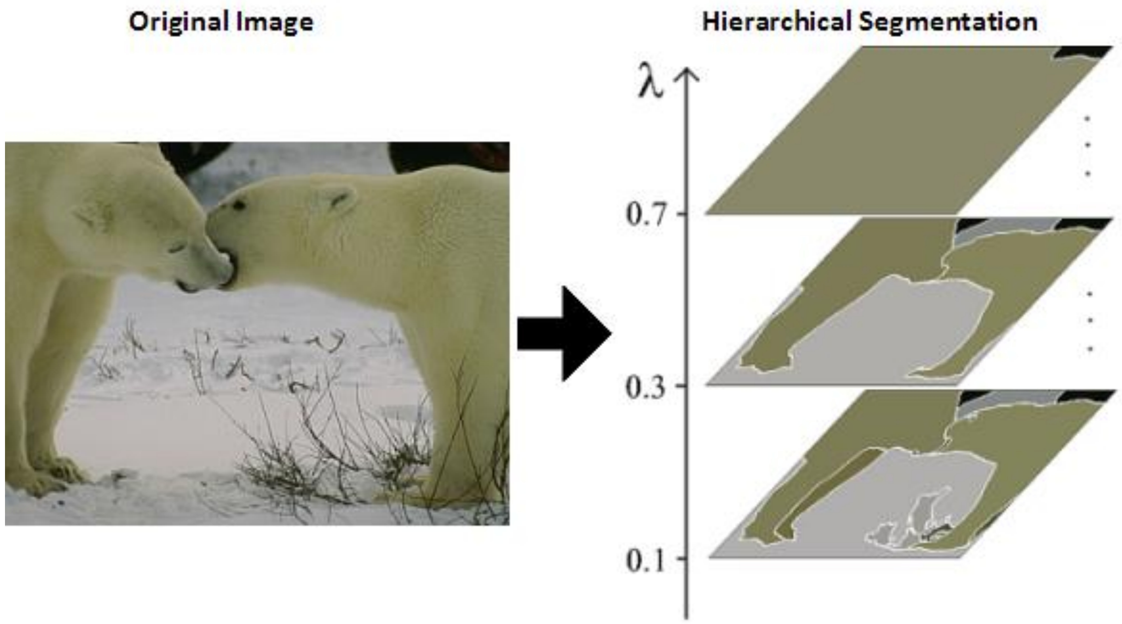
1. Select minimum weight contour:

$$C^* = \arg\min_{C \in \mathcal{K}_0} W(C).$$

2. Let $R_1, R_2 \in \mathcal{P}_0$ be the regions separated by C^*.
3. Set $R = R_1 \cup R_2$, and update:

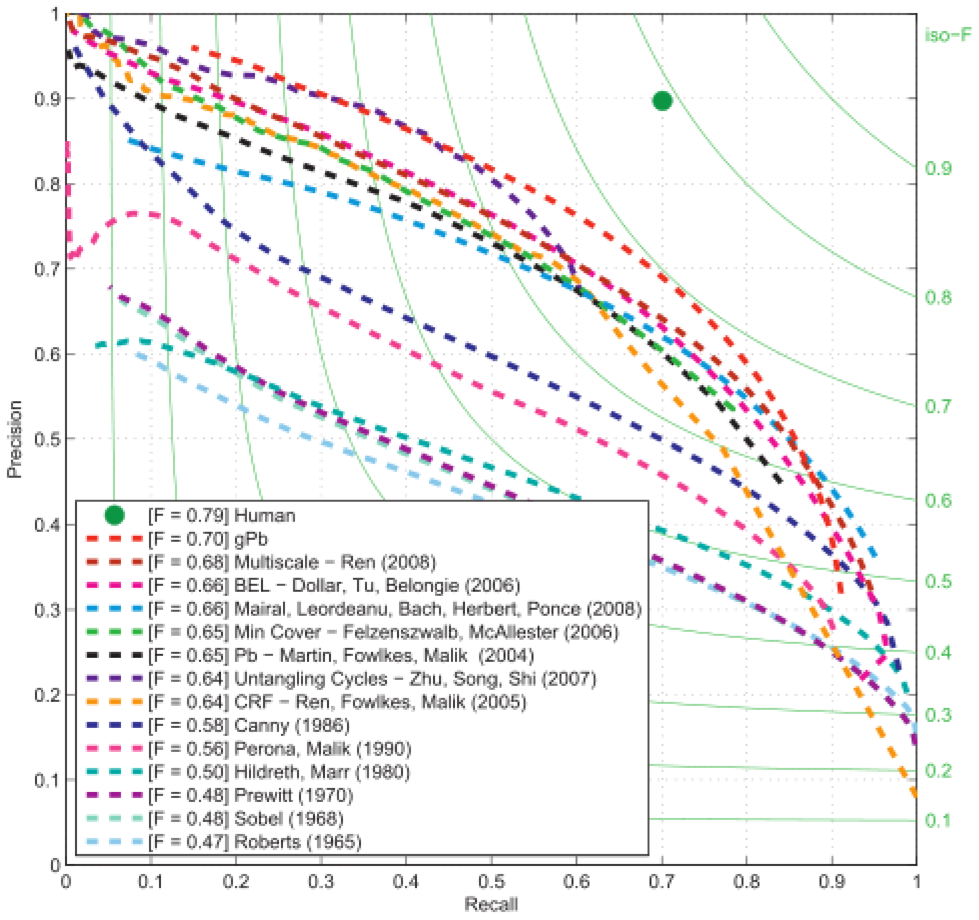
$$\mathcal{P}_0 \leftarrow \mathcal{P}_0 \backslash \{R_1, R_2\} \cup \{R\} \quad \text{and} \quad \mathcal{K}_0 \leftarrow \mathcal{K}_0 \backslash \{C^*\}.$$

4. Stop if $\mathcal{K}_0$ is empty.
   Otherwise, update weights $W(\mathcal{K}_0)$ and repeat.

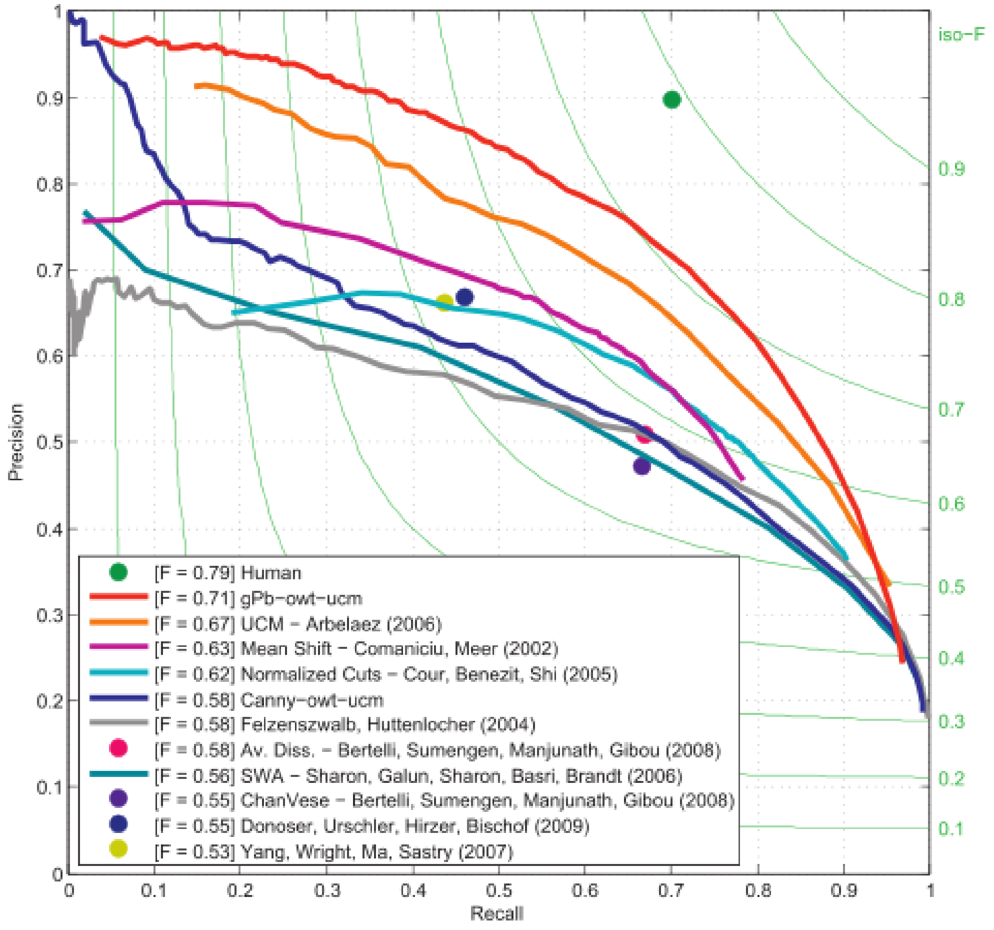


Benchmarks

Contour:



Segmentation

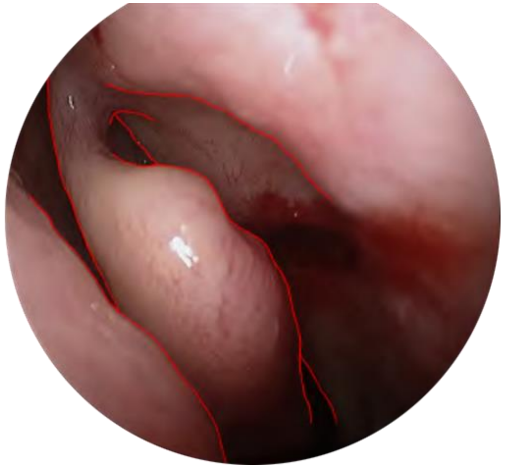


Issues/Critique

- Terminology not clearly defined
  - sPb, mPb, Pb, etc.
- Tedious introduction and background overview
- Insufficient explanations
  - Texton Gaussian convolutions
  - sPb equation rationale
- Segmentation and Contour detection segments were disjoint

Conclusion

- Paper showed a clear advantage and was well proven on large data sets
- However, contour detection algorithm is very slow
  - Computation of eigenvalues and vectors
  - Multiple θ
- We can incorporate their segmentation algorithms into our project to eliminate noise
- However, our images may not have clear closed boundaries
- Our images are mostly monochromatic, eliminating key mPb categories



Appendix

- Textons:
  - Image is convolved with:

  - Pixels are clustered using K-means
  - Each pixel is assigned to closest cluster [1,K]
- K-means:
  - Where k is number of clusters, x is observations, μ is mean of points in a cluster

$$\arg\min \sum_{i=1}^{k} \sum_{x \in S_i} \left\| x - \mu_i \right\|^2$$