

Reflection Symmetry Integrated Image Segmentation

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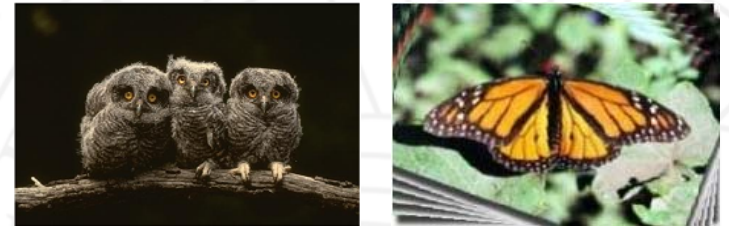
University of California, Riverside

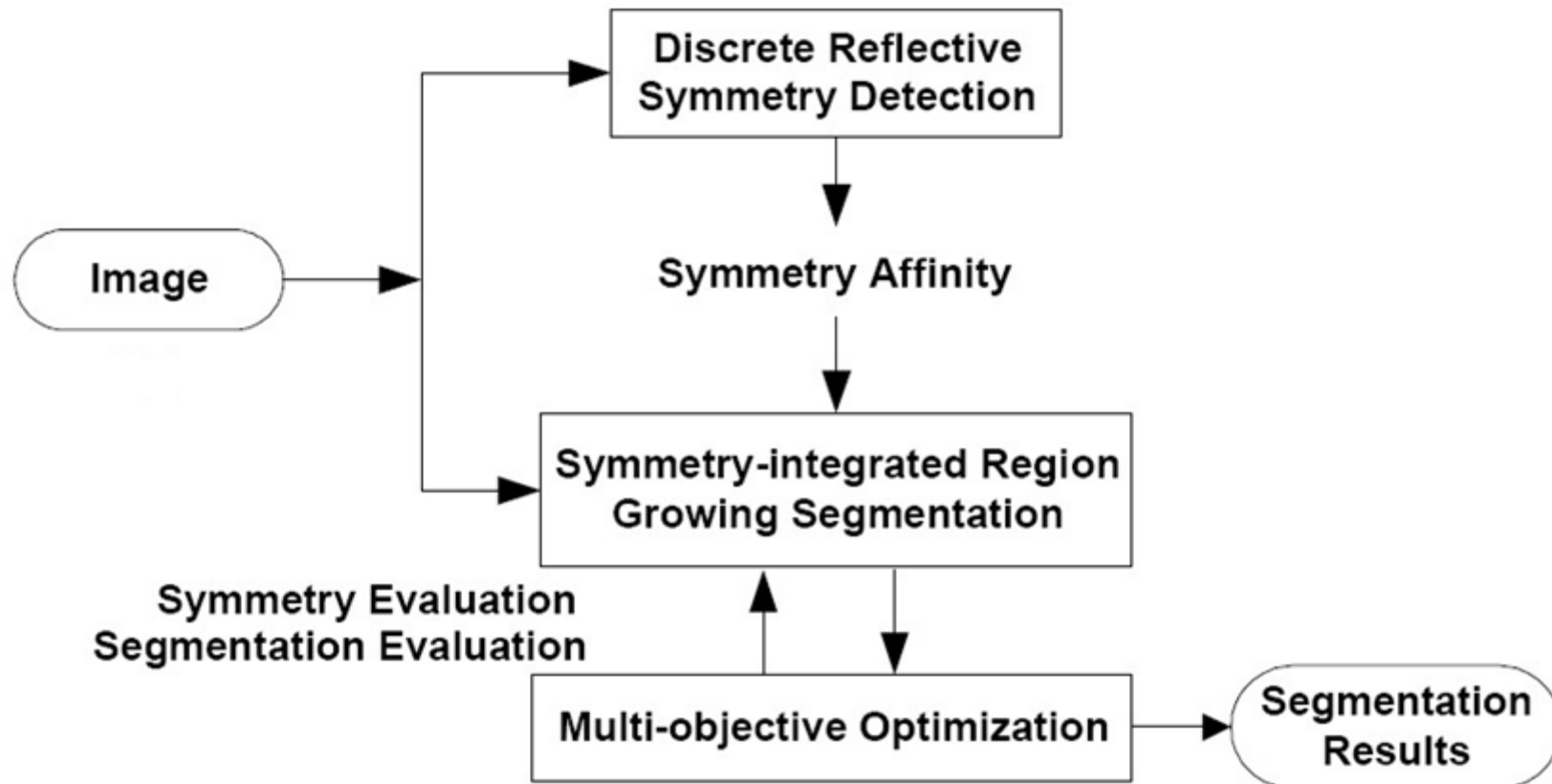
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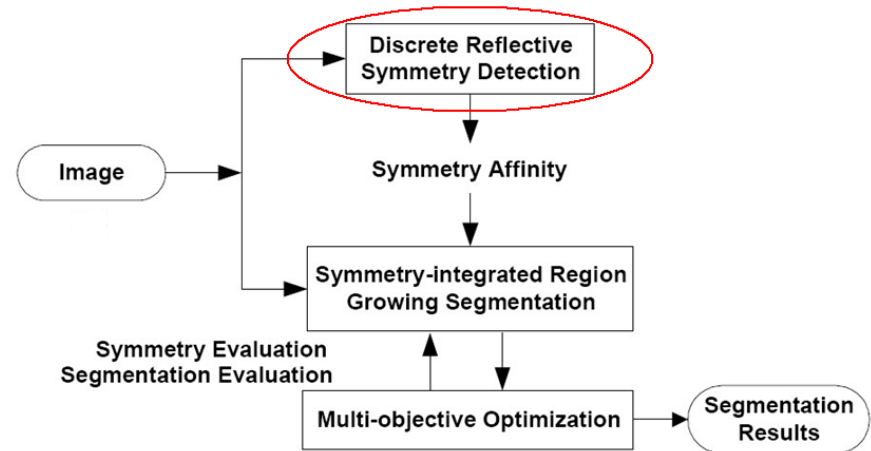
June 24, 2011

- Symmetry is a **high level concept** present in natural and manmade objects.
- **Challenge:**
How a high level concept of symmetry can be used for low level (pixel-based) segmentation?
- **Solution:**
Symmetry is integrated through affinity in a region growing segmentation approach
- **Contributions:**
First work to use symmetry for the segmentation of an ENTIRE image





Global symmetry axis detection:
using Constellations of Features
(Loy et al., ECCV 06')



SIFT points

local symmetric pairs

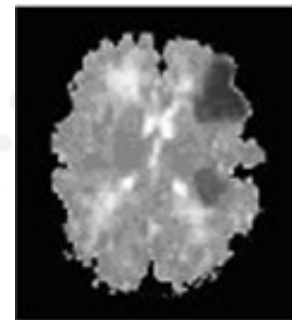
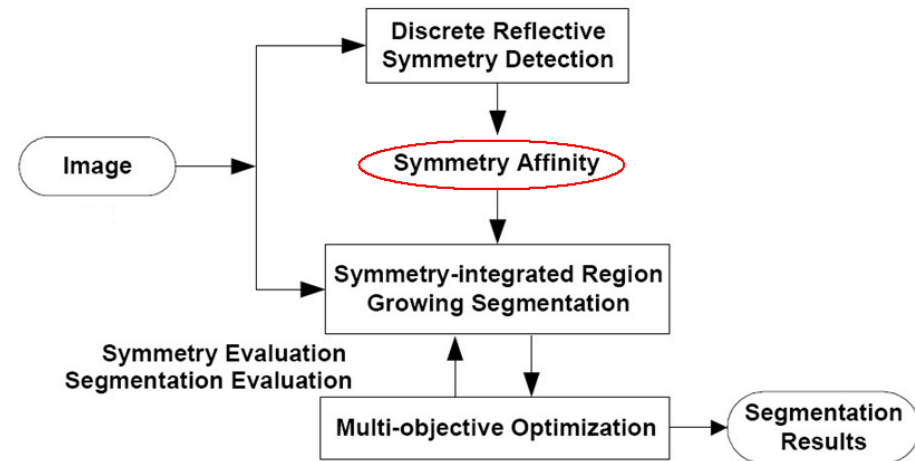
vote for global
symmetry axis

Symmetry Affinity:

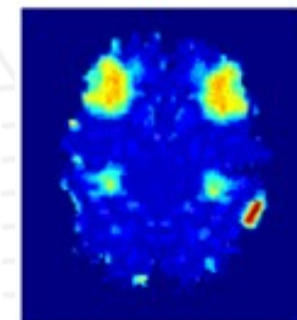
$$C_i = |Curv_i - Curv_j|$$

(Prasad et al., IEEE TIP 04')

- Pixel i and its symmetric counterpart j reflected by the axis
- $Curv_x$: Pixel's curvature of gradient vector flow (CGVF)
- Pixel i and j : Closer CGVFs \rightarrow lower affinity \rightarrow higher symmetry

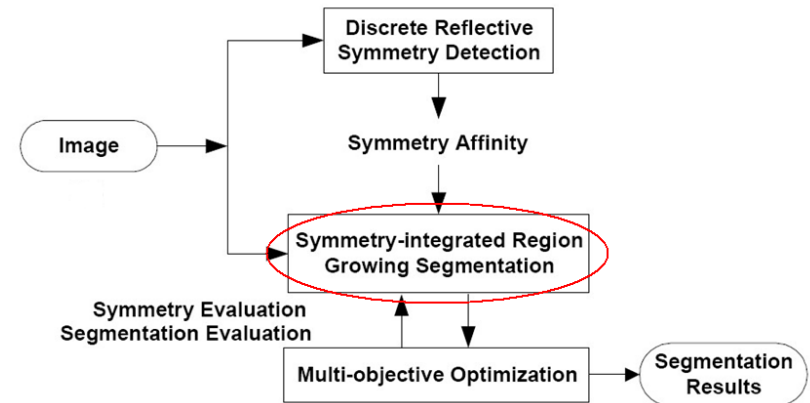


original



symmetry affinity

- **Region growing:** pixel i is grown into neighboring region j if their **similarity cue**: $\delta(i, j) < \delta_m$



- **Traditional region Growing**

- $\delta(i, j) = \delta_R(i, j) = \delta_{Color}(i, j) + \delta_{Texture}(i, j)$
- $\delta_{Color}(i, j) = \|F_{Color}(i) - F_{Color}(j)\|$: color similarity cue (HSV)
- $\delta_{Texture}(i, j)$: texture similarity cue (Gabor features)

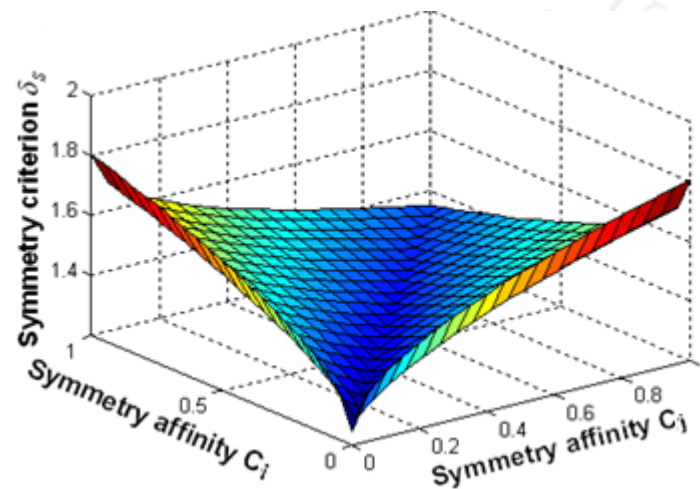
- **Symmetry-integrated Region Growing**

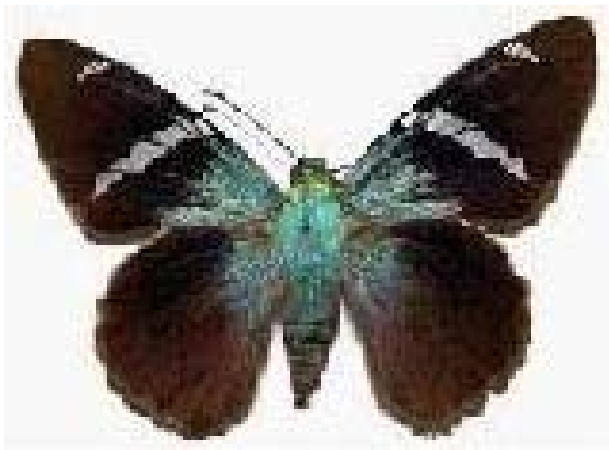
- $\delta(i, j) = \delta_R(i, j) \cdot \delta_S(i, j)$

The symmetry cue:

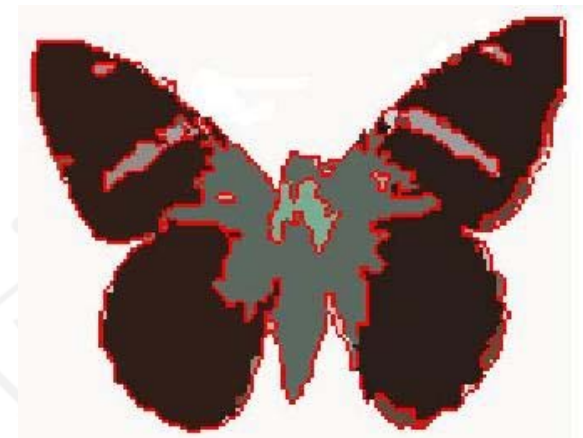
$$\delta_s(i, j) = \frac{\frac{\pi}{2} + \arctan(\sqrt{(1+C_i)(1+C_j)})}{\pi} + \frac{1 + |\sqrt{C_i} - \sqrt{C_j}|}{2}$$

- C_i and C_j : symmetry affinities of pixel i and neighboring region j
- **High level** symmetry concept is used as a **low level (pixel-based)** cue
- Smaller/closer affinities -> smaller cue > pass the threshold -> complete symmetric region





Segmentation using
symmetry cue



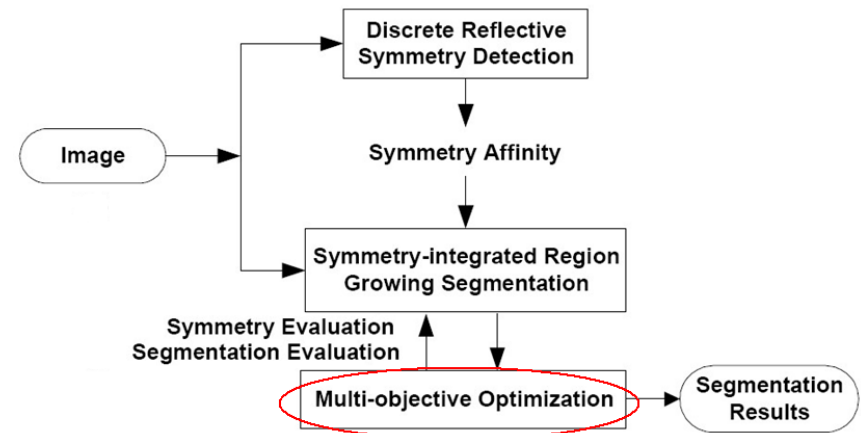
segmentation without
symmetry cue

■ Performance Evaluations

- **Supervised Segmentation Evaluation:** pixel-based region overlap with ground-truth segmentation [Hafiane et al., ACIVS 07']

- **Unsupervised Segmentation Evaluation:** pixel-based inter- and intra-region contrast [Borsotti et al., PR Letters 98']

- **Symmetry Evaluation:** region's symmetry level in segmented image

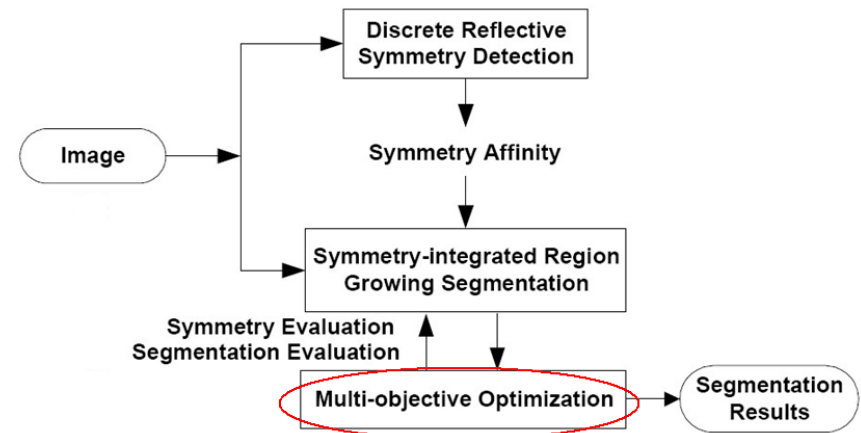


Multi-objective Optimization:

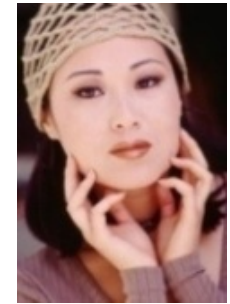
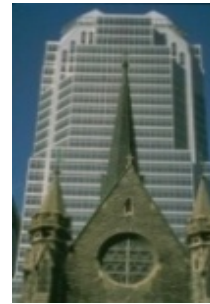
NSGA-II

















[Kodali et al., ICETET 08']

- Objective functions: segmentation and symmetry evaluations
- Search space: thresholds for pixel agglomeration and region merging

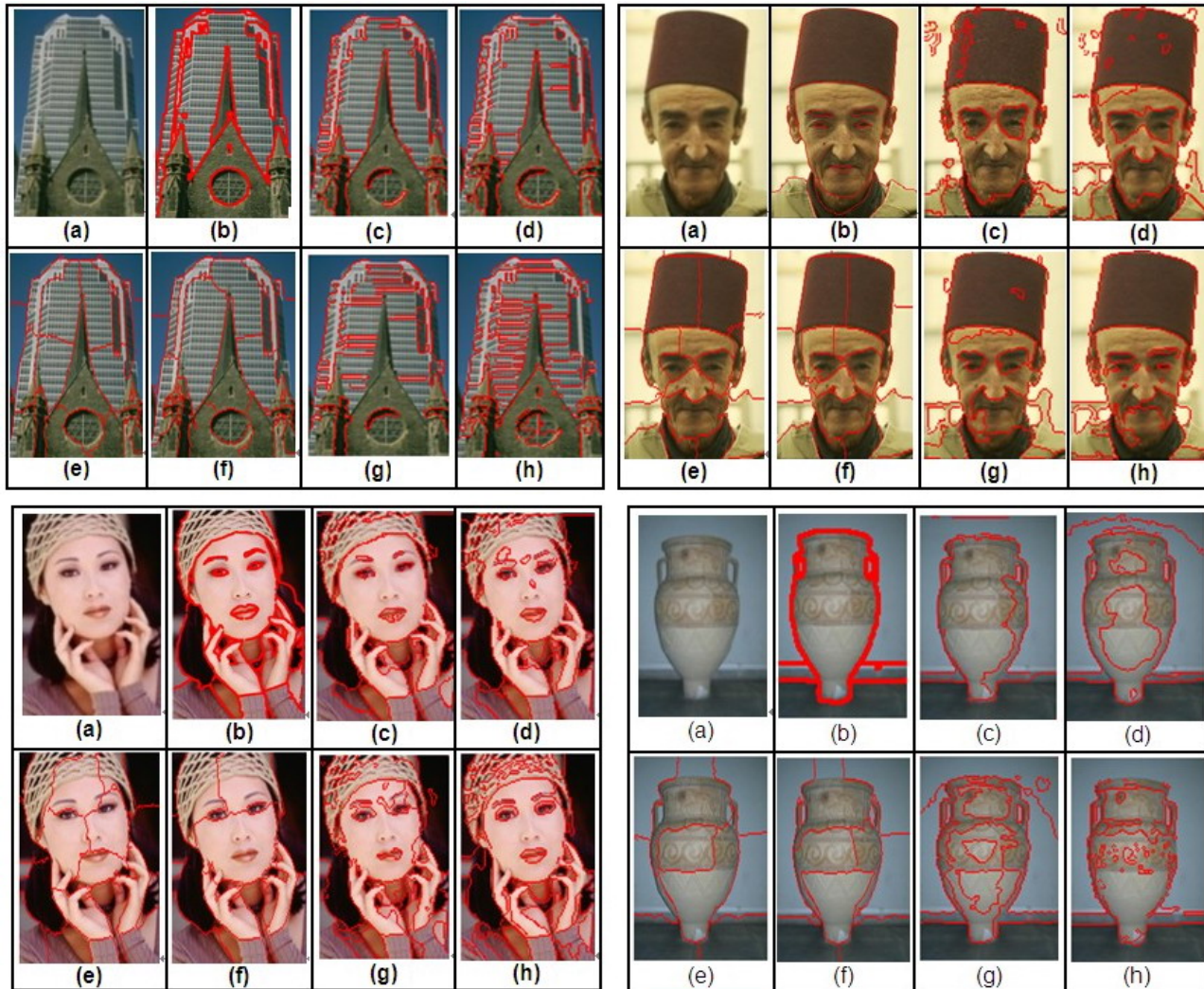


- UC-Berkeley Segmentation Benchmark:**
 - 36 images with full and partial symmetric objects
 - Ground-truth segmentation: publicly available
- Caltech-101 Database:**
 - 127 images with full and partial symmetric objects
 - Ground-truth segmentation: extracted manually



Original (UC-Berkeley)	Ground-truth	Region growing - no symmetry	Region growing - symmetry	% improvement
				+2.60%
				+1.23%
				+5.37%
				+3.70%





(a) Original
(b) Ground-truth

(c) Region growing - symmetry
(d) Region growing - no symmetry

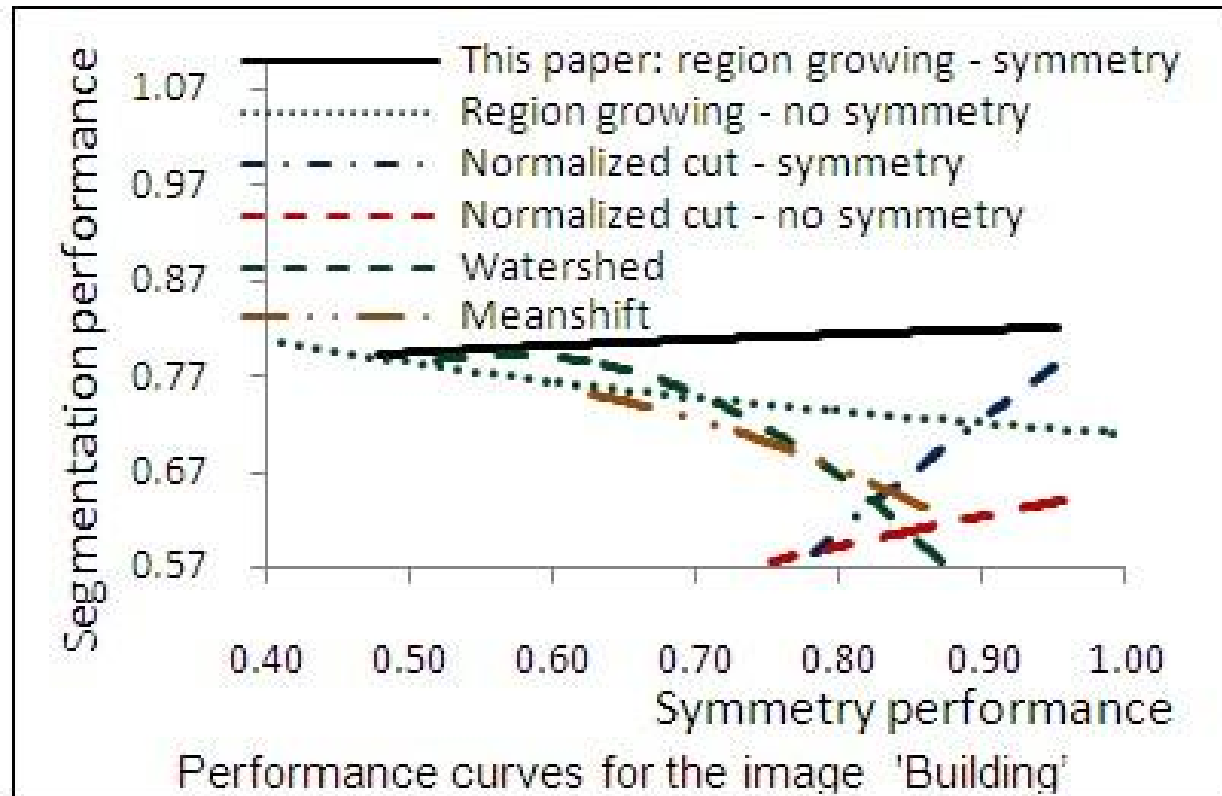
(e) Normalized cut - symmetry [Gupta et al., ICIP 05']
(f) Normalized cut - no symmetry










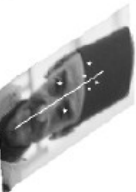

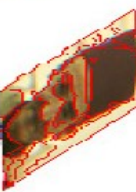







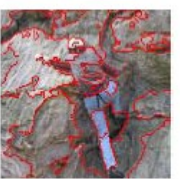
(g) Watershed
(h) Meanshift

Images in UCB dataset	Comparison: proposed method		
	With symmetry	No symmetry	% improvement
Building	75.48%	73.57%	+2.60%
Man	72.58%	71.67%	+1.27%
Woman	71.44%	70.57%	+1.23%
Vase	76.70%	76.42%	+0.37%

Images in UCB dataset	Comparison: symmetry-based normalized cut		
	With symmetry	No symmetry	% improvement
Building	69.99%	68.36%	+2.38%
Man	66.42%	65.01%	-2.48%
Woman	68.76%	68.13%	+0.92%
Vase	69.13%	69.01%	+0.17%

Images in UCB dataset	Watershed	Meanshift
Building	74.62%	63.37%
Man	67.29%	62.83%
Woman	66.52%	61.28%
Vase	68.34%	61.03%



Distortions	Original	Axis	Segmentation - symmetry	Segmentation - no symmetry	% improvement
Occlusion					+0.16%
Perspective					+1.21%
Affine					+1.19%
Multiple					+4.66%
Articulation					+1.79%

1. We use symmetry as a new cue in region-based image segmentation, along with other cues like color and texture.
2. With the symmetry cue enforced, both the symmetry and segmentation are improved with the amount of 1%-9%.
3. Our method has better performance compared to several other well known region-based segmentation methods.
4. If no symmetry axis is detected, our method is equal to the traditional region growing without symmetry.

THANKS!