On Measuring* the Ecological Validity of Local Figure-Ground Cues

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* "When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of the meager and unsatisfactory kind." --Lord Kelvin

Cues to Figure-Ground Assignment

- Size
- Surroundedness
- Convexity
- Lower-Region
- Symmetry
- Parallelism
- Meaningfulness

Photo by Wei-Chung Lee

Ecological Statistics of Figure-Ground Cues

- Hypothesis: Perceptual organization reflects the statistics of the natural world in which the visual system evolved.

- In the context of grouping, this has been explored by:
  - Brunswik/Kamiya 1953 : proximity of similars
  - Geisler et. al. 2001 : good continuation
  - Martin/Fowlkes/Malik 2001 : proximity, similarity in color/texture

- In this work we measure, in a probabilistic sense, the power of size, convexity and lower-region in determining figure-ground assignment

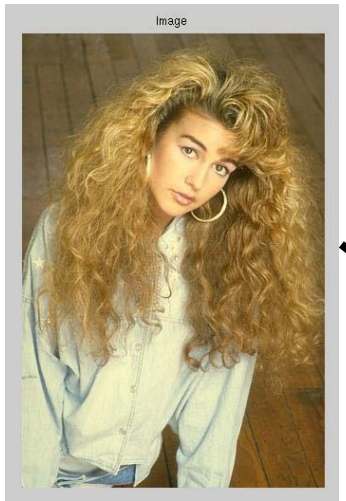
Overview

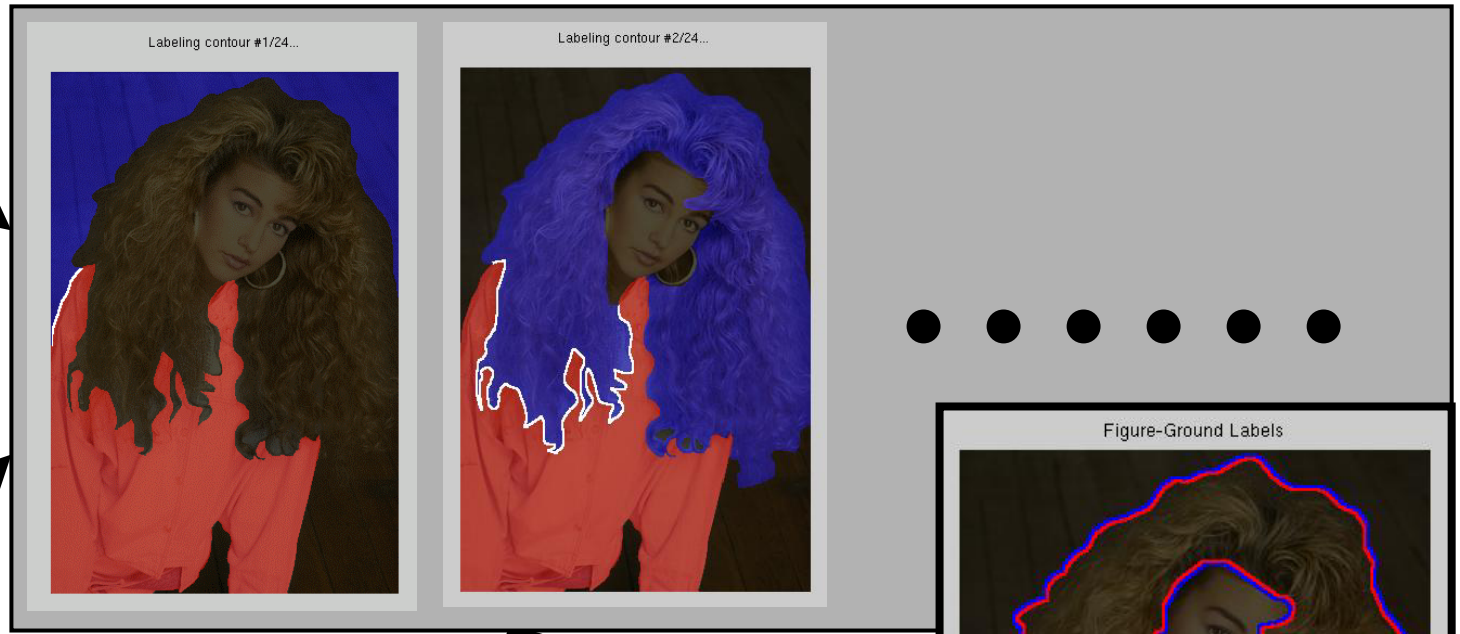
1. Human observers assign figure-ground labels to every boundary in a collection of natural images.
2. The cues of size, convexity, and lower-region are measured locally at each boundary point.
3. The extent to which these local cues are able to predict the ground-truth labeling is quantified.

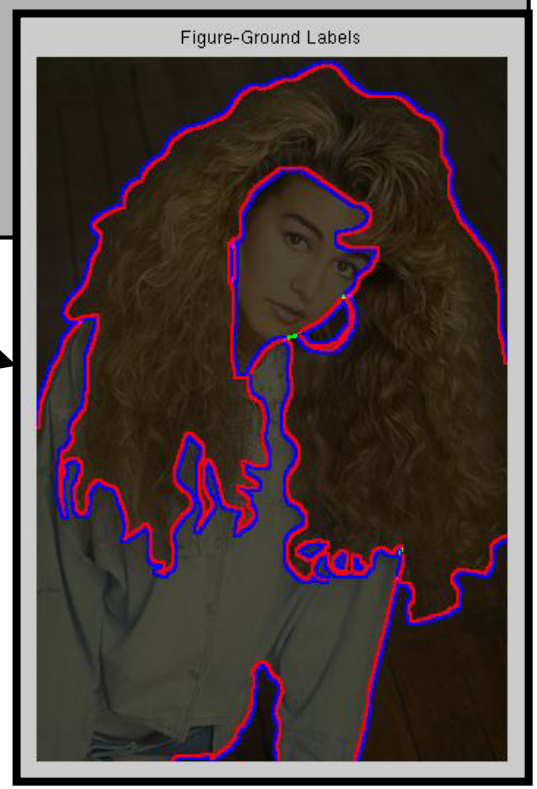
Berkeley Segmentation Dataset

1000 images each segmented by 10 different subjects
http://www.cs.berkeley.edu/projects/vision/grouping/segbench

Figure-Ground Labeling



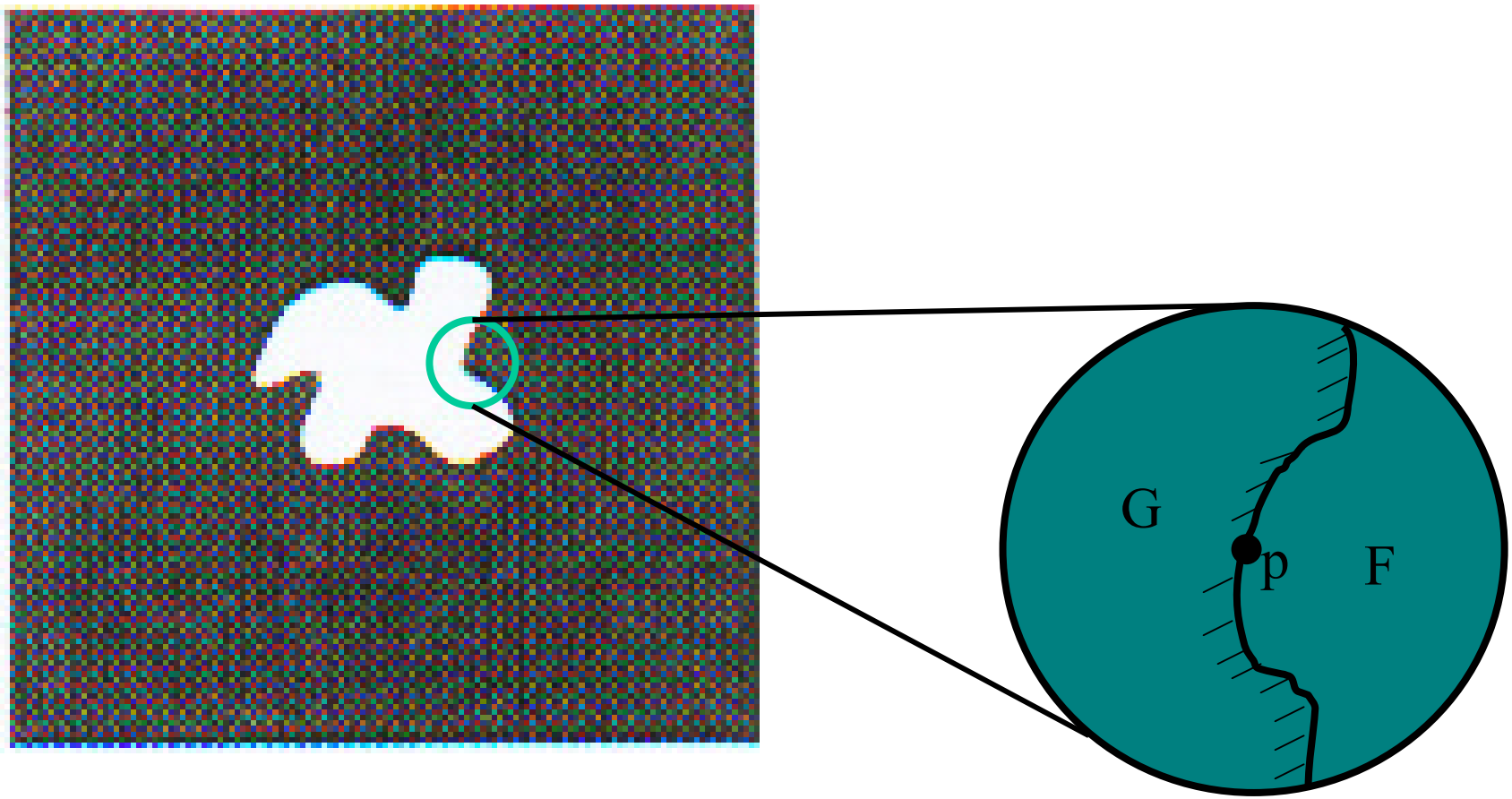




- 200 segmented images of natural scenes
- boundaries labeled by at least 2 different human subjects
- subjects agree on 88% of contours labeled

Size and Surroundedness

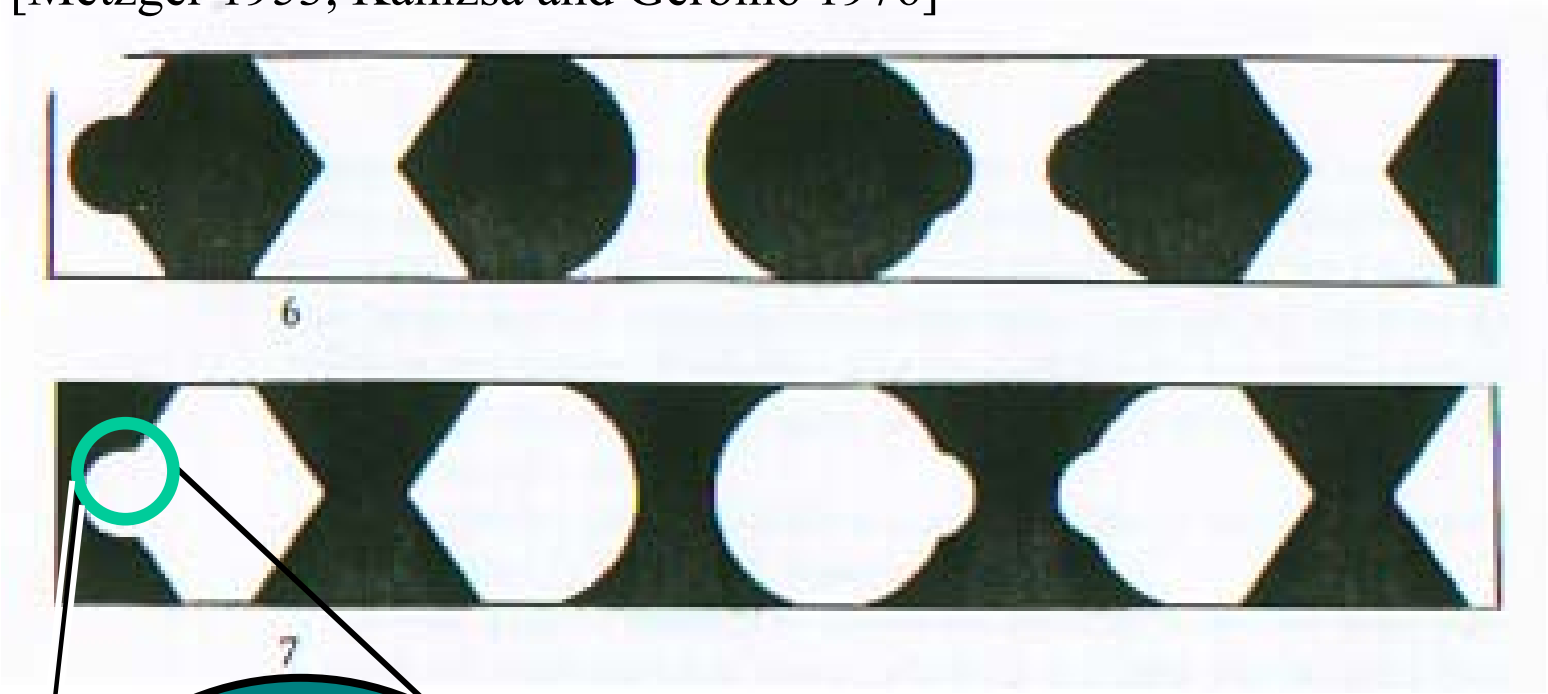
[Rubin 1921]

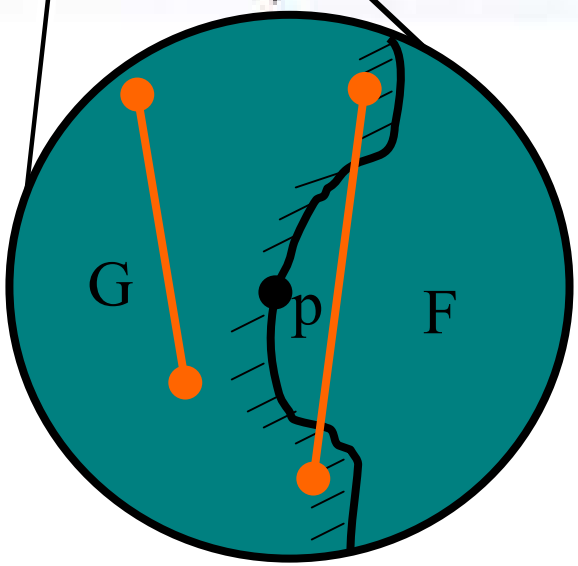


$$\text{Size}(p) = \log(\text{Area}_F / \text{Area}_G)$$

Convexity

[Metzger 1953, Kanizsa and Gerbino 1976]



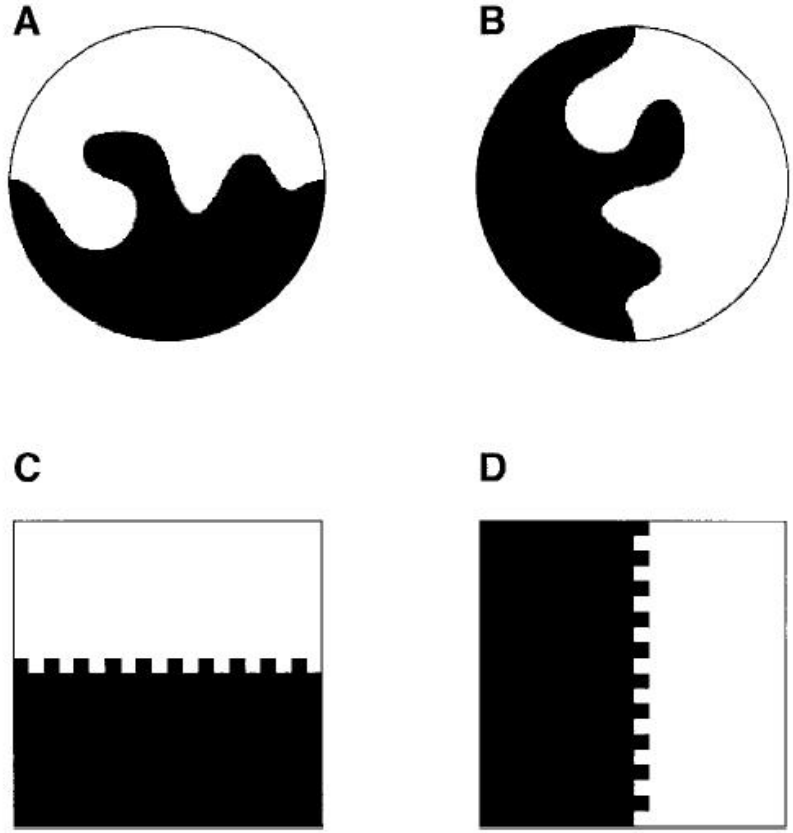


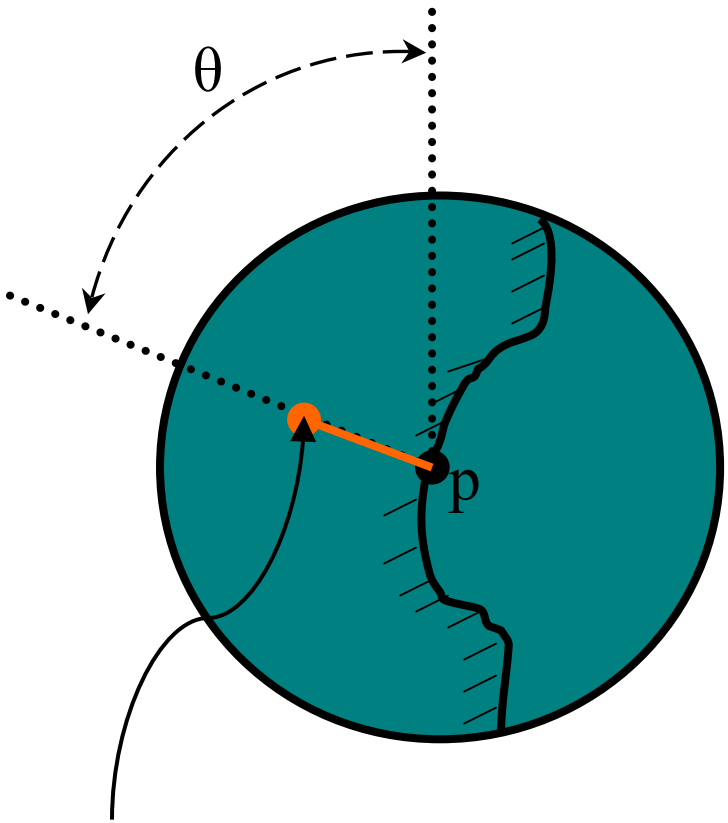
$Conv_G$ = percentage of straight lines that lie completely within region G

$$Convexity(p) = \log(Conv_F / Conv_G)$$

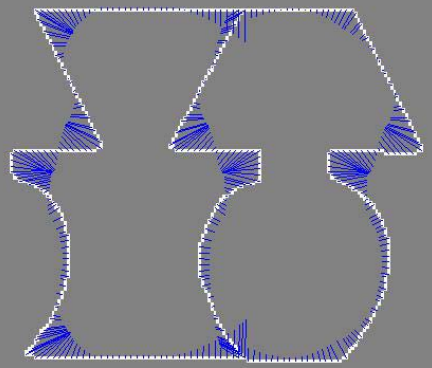
Lower Region

[Vecera, Vogel & Woodman 2002]

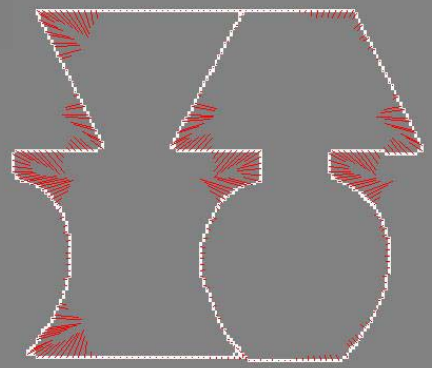




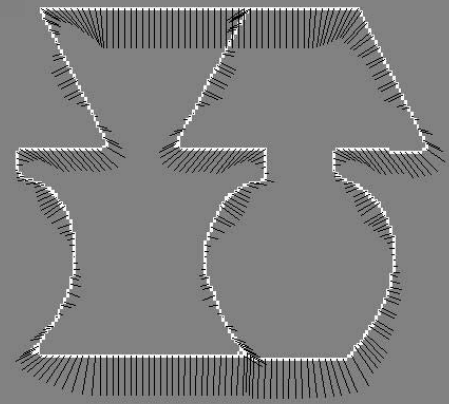
$$\text{LowerRegion}(p) = \theta_G$$



size



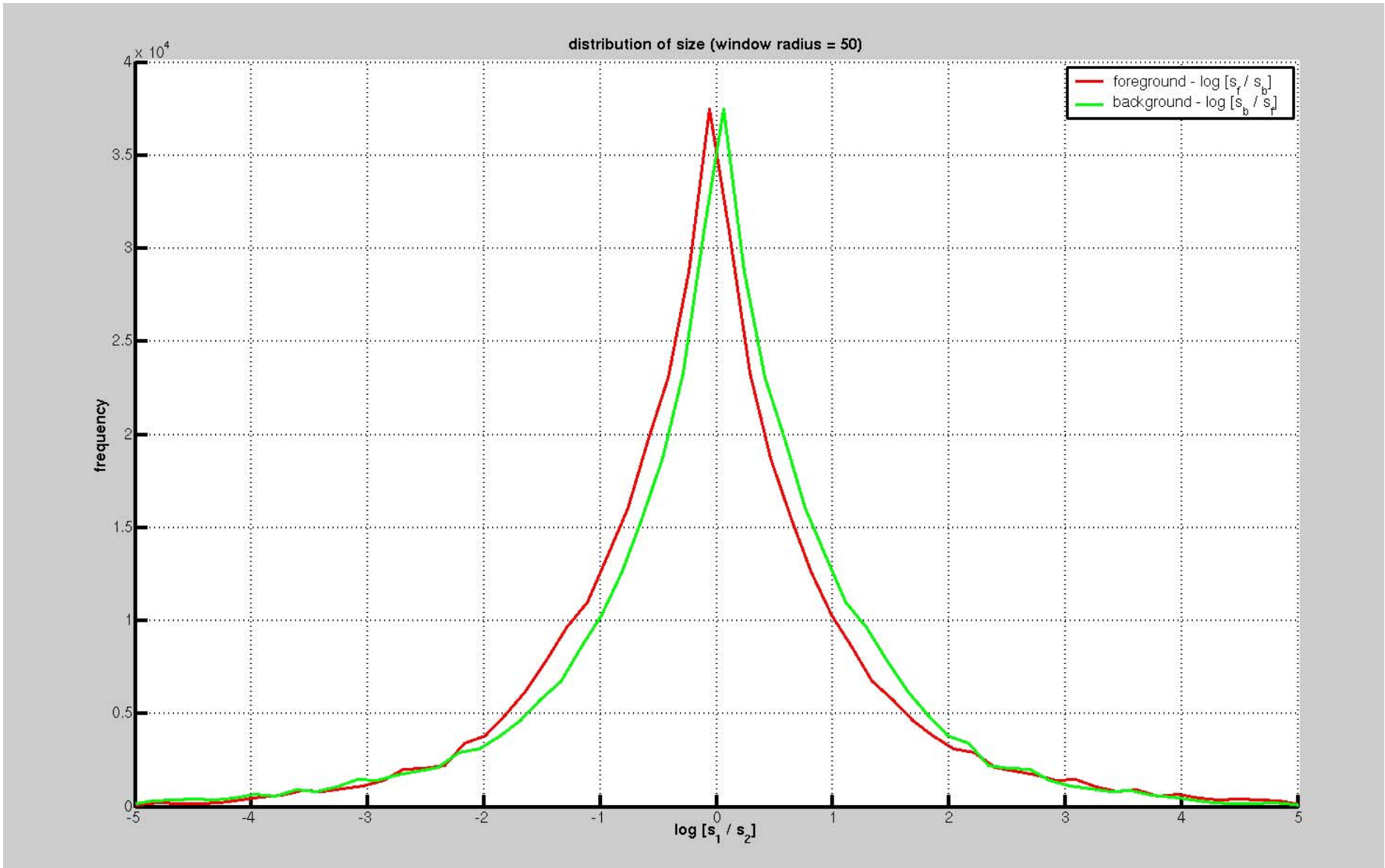
convexity



lower region

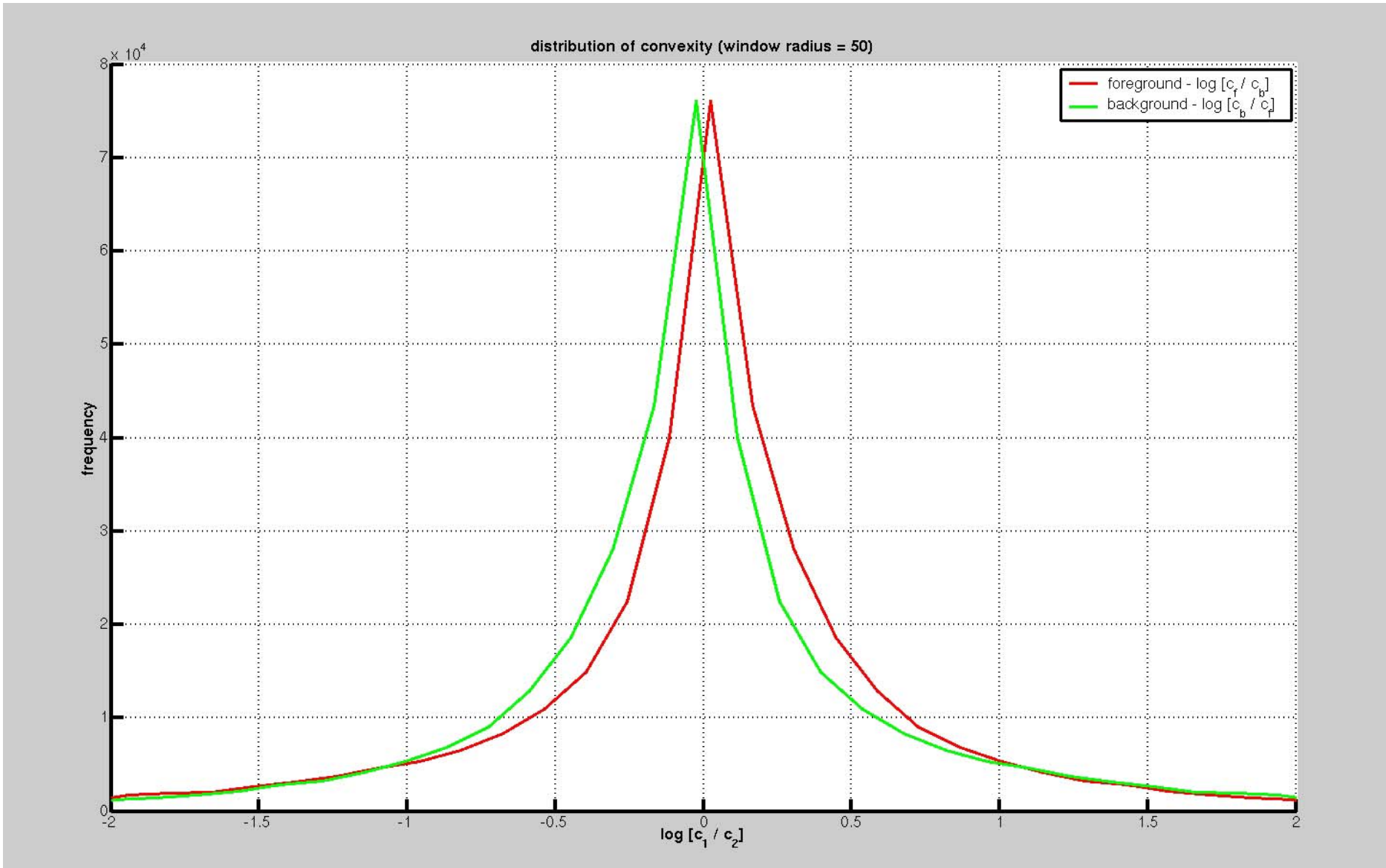
-Sample 350,000 boundary points from 200 images
-Intersect with circular window of chosen radius r
-Compute size, convexity and lower-region cues
and compare to ground truth labeling

Figural regions tend to be smaller



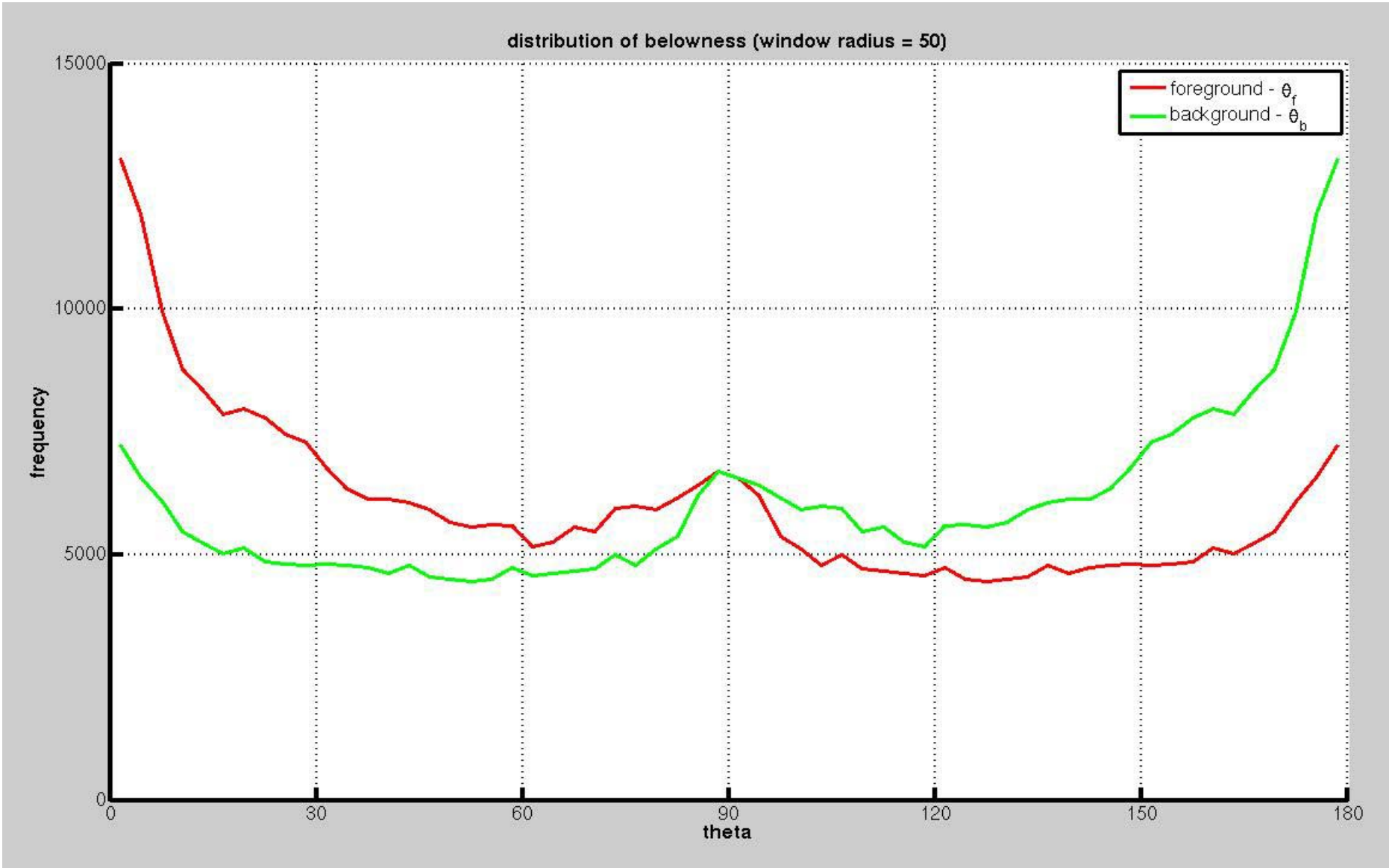
mean is zero with $p < 10^{-16}$

Figural regions tend to be convex



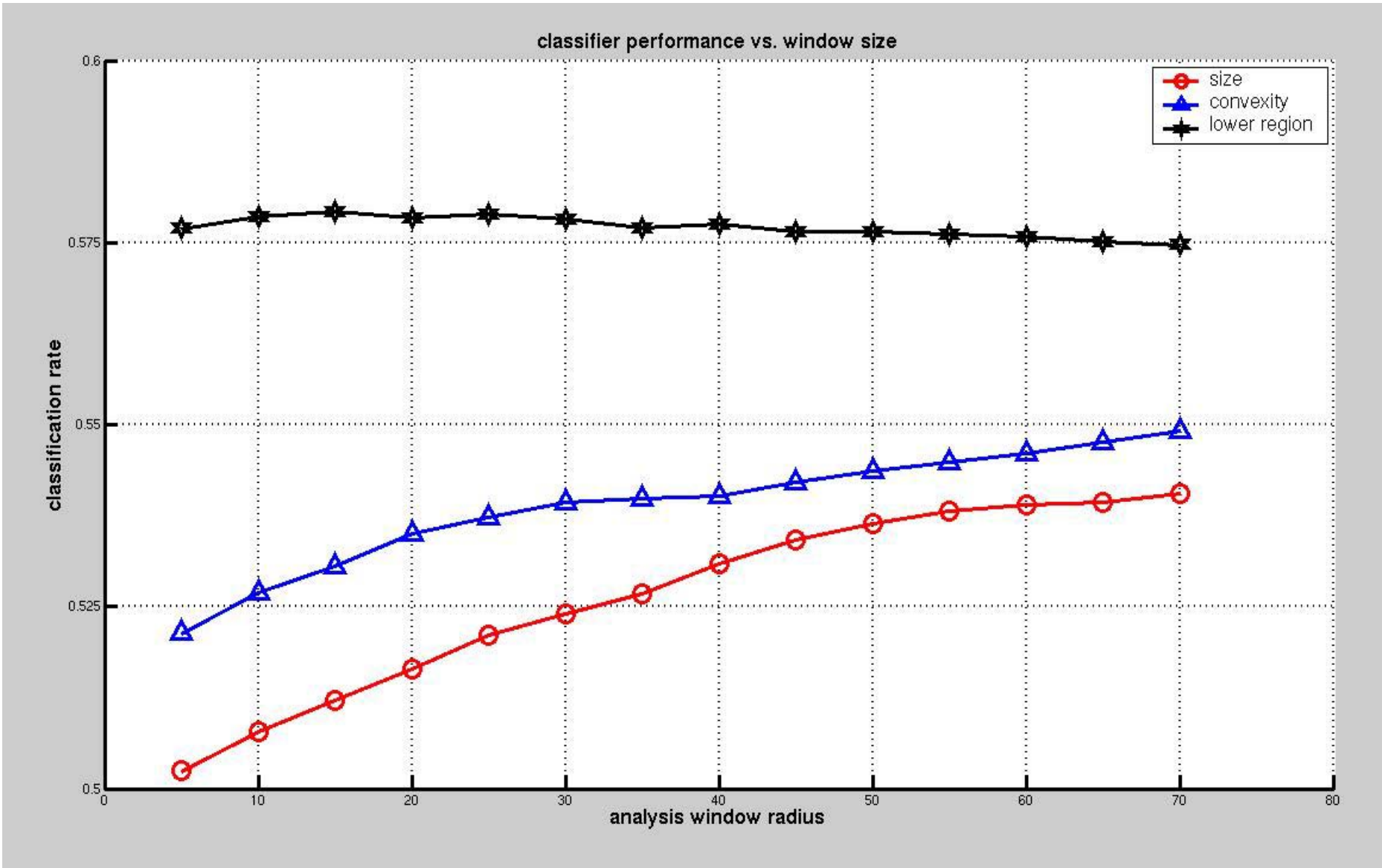
mean is zero with p = 0.021 (less at other radii)

Figural regions tend to lie below ground regions



mean is 90 with $p < 10^{-16}$

Power of cue depends on support of the analysis window.



Conclusion

- Figural regions are smaller, more convex and below ground regions in natural images