Natural image statistics differ for fixated vs. non-fixated regions

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PERCEPT

Problem statement

Why do we direct our gaze to particular locations in an image?

Image

Fixation map

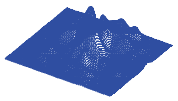


Image redrawn with areas receiving higher numbers of fixations appearing brighter.

Previous work suggests that the edge distribution is important in human fixations [1]. We are interested in the difference between the edge distribution of fixated versus non-fixated regions.

Eye-tracking data

- National Geographic images – 49 images of size 800x540 pixels
- Free viewing condition – 18 subjects, 5 seconds per image
- EyeLink II, SR Research Ltd. Eye-tracker

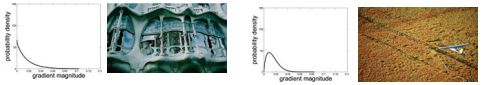
Edge distribution

- The edge distribution of natural images is captured by the two parameter Weibull distribution [2].

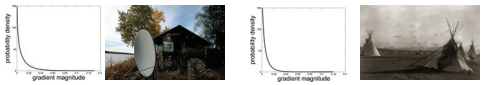
$$pdf(x) = \frac{\gamma}{\beta}\left(\frac{x}{\beta}\right)^{\gamma-1} \exp^{-(\frac{x}{\beta})^{\gamma}}$$

where $x > 0$ is the value of the gradient magnitude, $\beta > 0$ is the shape parameter and $\gamma > 0$ is the scale parameter of the distribution.

- The scale parameter β represents the width of the distribution and reflects the local contrast. A wide distribution indicates a texture with high contrast.
- The shape parameter γ represents the slope of the distribution and is sensitive to the local edge frequency.



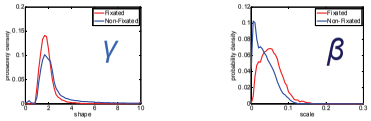
Images with overall similar contrast variation (β = 4.11 left image and 4.12 right image), but moderate and high frequency edges (γ = 0.95 left image and 1.59 right image).



Higher and lower contrast images (β = 2.01 left image and 1.58 right image) with overall moderate frequency edges (γ = 0.701 left image and 0.702 right image).

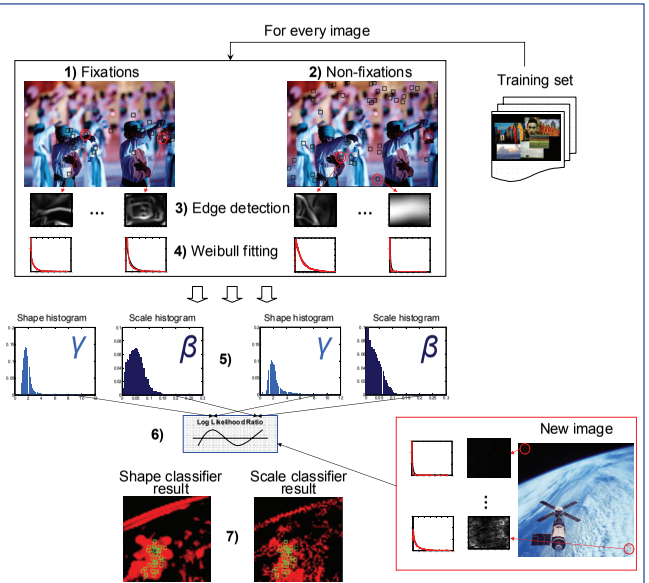
Experimental setup

Difference between probability density functions of Weibull parameters over fixated and non-fixated region for the entire subject set. The t-test showed a highly significant difference between fixated and non-fixated regions ($p < 10^{-5}$).



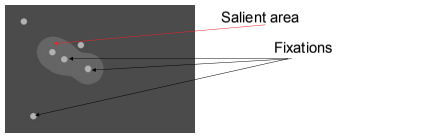
Methods

1) Extraction fovea sized regions around fixations based on eye-tracking data (fixated regions).
2) Extraction fovea sized regions around non-fixations which are taken as fixations from other images (non-fixated regions).
3) Edge detection with colour gradient magnitude over fixated and non-fixated regions.
   Scale in edge detection varying according to minimal reliable scale method [3].
4) Parameterisation of edge distribution with Weibull model.
5) Histogram estimation for Weibull parameters over fixated and non-fixated regions.
6) Log-likelihood ratio classifier.
7) Determination of the conditional probability of fixation given the Weibull parameters based on log-likelihood ratio.



Evaluation method

For evaluation, we determine the Receiver Operating Characteristic (ROC) curve which is a plot of *True Positive* rate vs. *False Alarm* rate for a log-likelihood ratio as its discrimination threshold is varied.



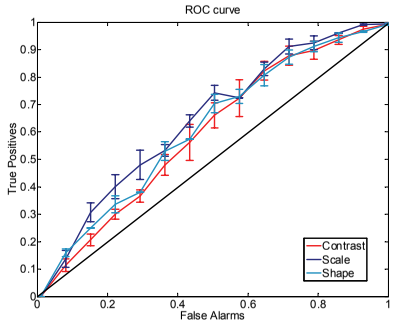
True Positives = Positives correctly classified (white area) / Total positives (white area)

With respect to

False Alarms = Negatives incorrectly classified (white area) / Total negatives (black area)

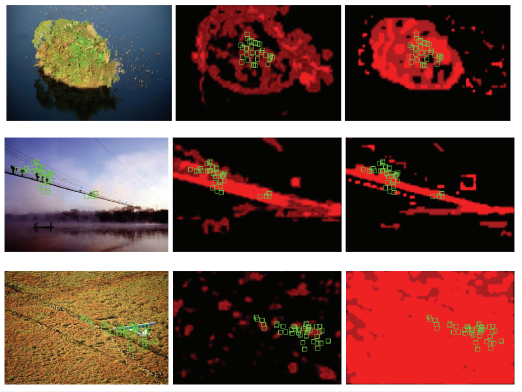
With respect to

Results



- 29 images for training
- 20 images for testing
- Average over 15 runs

Both classifiers based on Weibull parameters perform better than the traditional contrast (colour gradient magnitude).



Conclusions

- Our results demonstrate significantly different distributions of Weibull parameters for fixated and non-fixated image regions.
- We identify both contrast and edge frequency to be cues for attention.
- Natural image statistics as captured by the two-parameter Weibull distribution could play a role in determining where we direct our first few saccades.

Acknowledgements

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References

[1] R.J. Baddeley and B.W. Tatler. High frequency edges (but not contrast) predict where we fixate: A Bayesian system identification analysis. Vision Res., 46(18):2824–2833, 2006.

[2] J. M. Geusebroek and A. W. M. Smeulders. A six-stimulus theory for stochastic texture. Int. J. Comput. Vision, 62(1):7–16, 2005.

[3] J. H. Elder and S. W. Zucker. Local Scale Control for Edge Detection and Blur Estimation. IEEE Trans. Pattern Anal. Machine Intell., 20(7):699–716, 1998.