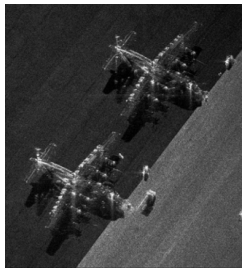
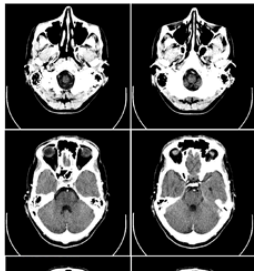
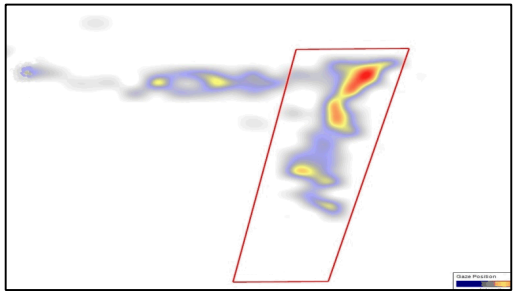
SAND2015-6562C







Saliency Estimation for Advanced Imaging Scenes Using Pixel Statistics

Michael J. Haass, Laura E. Matzen, Laura A. McNamara, Kristina R. Czuchlewski

European Conference on Eye Movements
17-August-2015

Sandia National Laboratories

Exceptional service in the national interest

U.S. DEPARTMENT OF ENERGY

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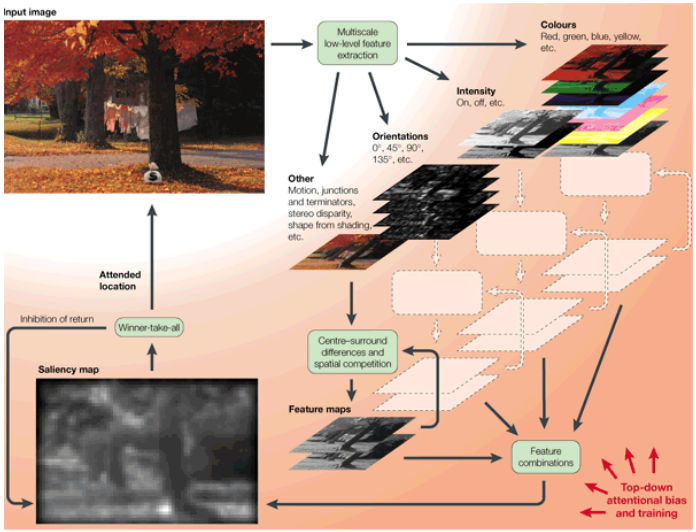
Background

- Large body of work on estimating visual saliency of natural scene imagery
- "Standard" models readily available for downloading



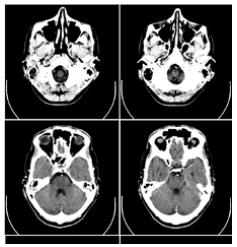
Itti & Koch, 2001

- Some efforts to continue making improvements
  - "Large-scale Scene Understanding Challenge" - http://lsun.cs.princeton.edu/

Advanced Imaging Sensors

- But many of today's advanced sensors produce image products with novel visual characteristics

X-ray



- Shadowing
- Orientation

IR & Thermal

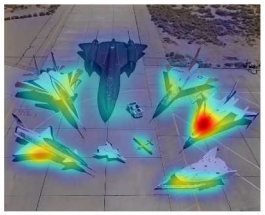
- Saturation
- Resolution
- False color

Radar

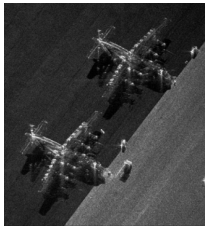
- Layover
- Shadowing
- Noise

Challenge/Problem

- Data from advanced sensor systems are ultimately interpreted by human analysts - traditional saliency models will have some applicability
  - Information still encoded and displayed using standard visualization parameters such as contrast and color



- Developing technologies will continue to provide challenging imagery
  - *"While dual-energy imaging is now a reality in medical practice, **multienergy** is still in its early stage, but a promising research activity."*[1]



[1]Pacella, D., Reports in Medical Imaging, Vol. 8, 2015

Study Overview

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- How well does existing model (Itti & Koch) predict saliency in synthetic aperture radar (SAR) imagery?
- How can standard saliency estimation be improved to better predict gaze patterns of sensor-knowledgeable viewers?

- Study task - change detection in SAR imagery
- Participants
  - 3 with no SAR experience (“novices”)
  - 6 radar engineers familiar with SAR (“engineers”)
  - 3 professional SAR imagery analysts (“experienced IAs”)

SAR Example – Saliency vs. Actual Gaze

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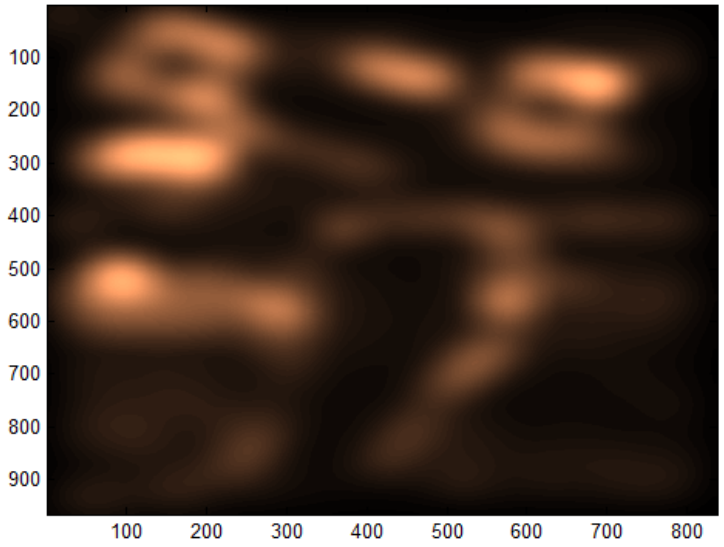
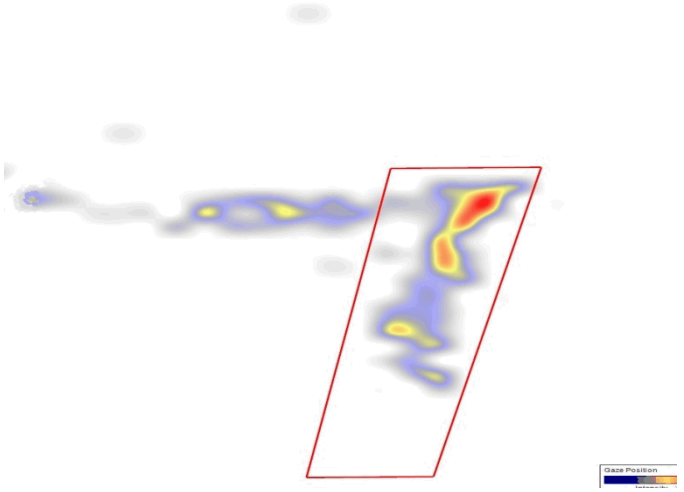
Salience Map



Gaze Map



Saliency Comparison Metrics*

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1. Linear Correlation Coefficient (CC)
   - Measure of the strength of a linear relationship between fixation map (G) and saliency map (S)
     - $CC(G,S) = \frac{cov(G,S)}{\sigma_G \sigma_S}$ When CC is close to ± 1, there is almost a perfectly linear relationship
2. Normalized Scanpath Saliency (NSS)
   - Average of saliency values at human gaze positions (saliency normalized to have zero mean and unit standard deviation)
     - NSS = 1 indicates that the subjects' gaze positions fall in a region whose predicted saliency is one standard deviation above average
     - When NSS ≥ 1, the saliency map exhibits significantly higher saliency values at human gaze locations compared to other locations
     - NSS ≤ 0 indicates the saliency model performs no better than picking a random position
3. Area Under Curve (AUC)
     - Human gaze positions are considered positive set, other points are negative set
     - Saliency map is treated as binary classifier to separate positive and negative sets

*Borji, A., et al. (2013). "Quantitative Analysis of Human-Model Agreement in Visual Saliency Modeling: A Comparative Study." IEEE Transactions on Image Processing **22(1): 55-69.**

Example Gaze Maps By Expertise

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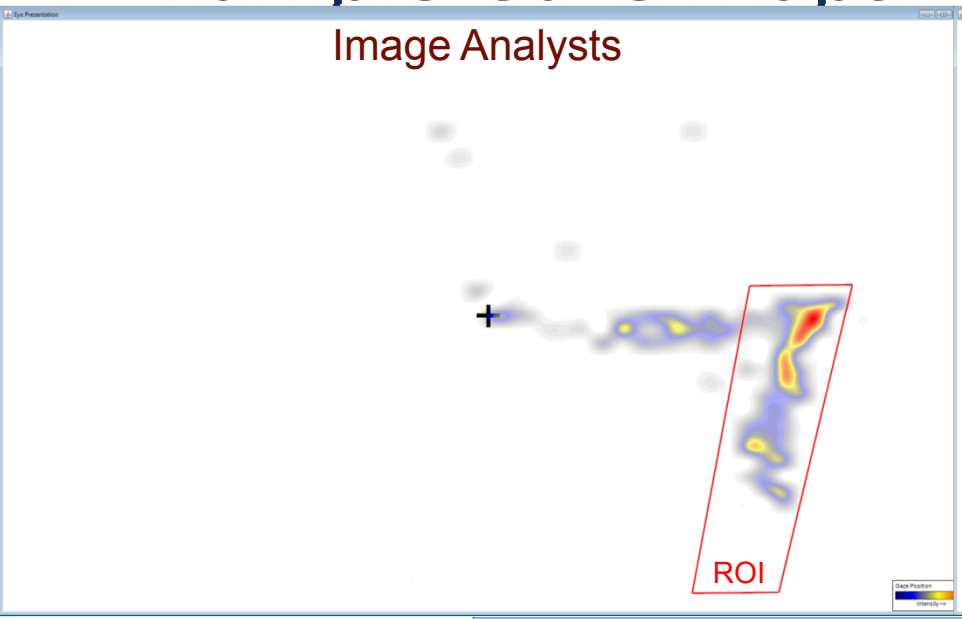

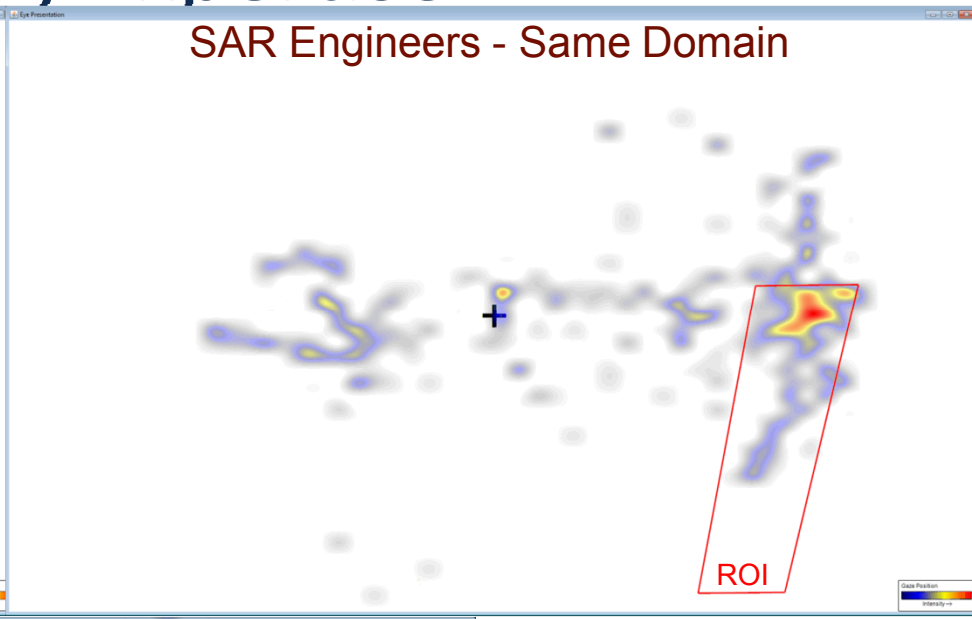

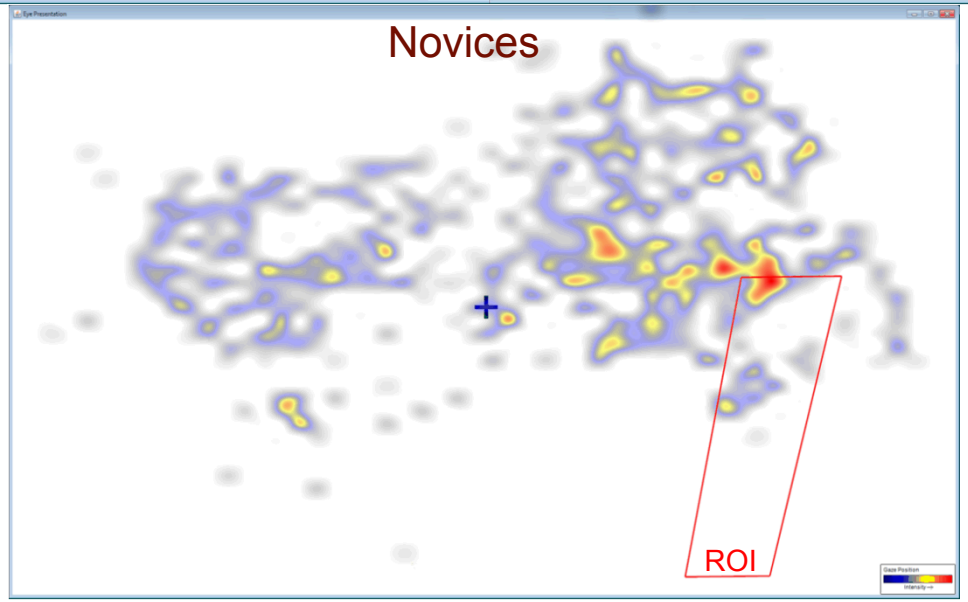

Standard Saliency Estimation Applied to SAR Imagery

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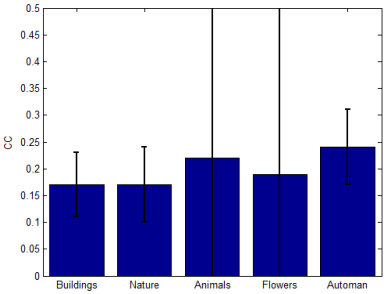
Image Type*

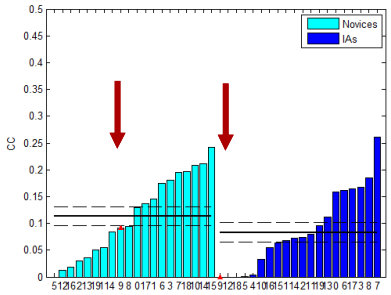
Kootstra & Shomacker Image Set

SAR Images

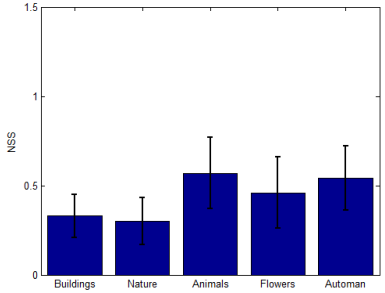
Metric

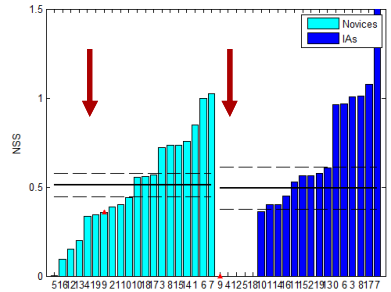
CC



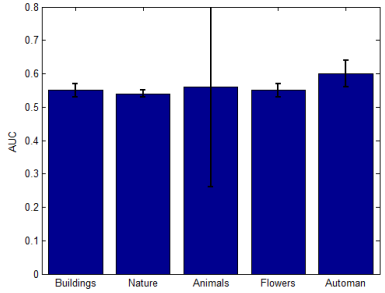


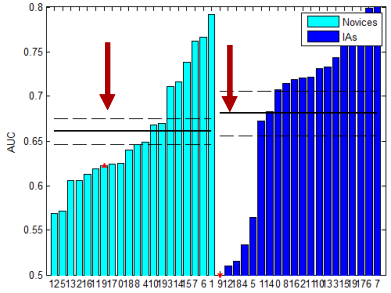
NSS





AUC





Buildings - Nature – Animals – Flowers - Automan

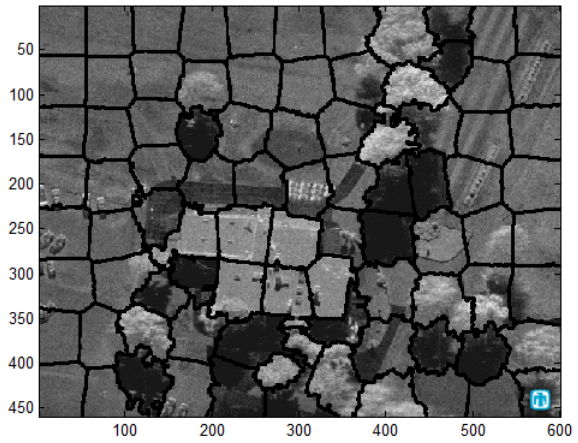
Itti COI2 Used for all SAR Images

*Borji, A., et al. (2013). "Quantitative Analysis of Human-Model Agreement in Visual Saliency Modeling: A Comparative Study." IEEE Transactions on Image Processing **22(1): 55-69.**

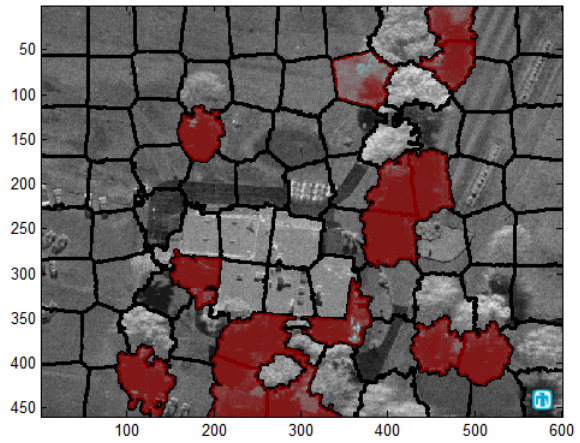
Reducing Salience Estimates in Shadow Regions

- Pixel-statistical methods used to segment[1] the scene and characterize the segment properties[2]
- These properties can serve as filters to modulate traditional saliency estimates
  - SAR Phenomenology - shadow regions have low coherence

Segment



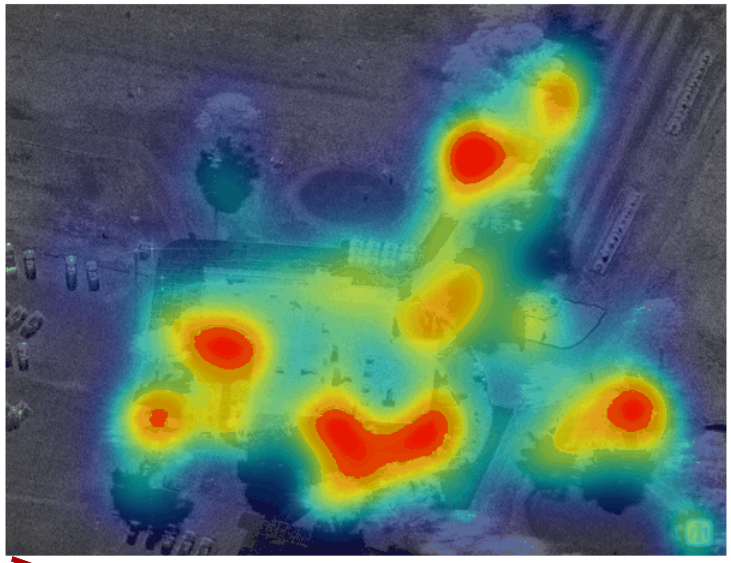
Classify

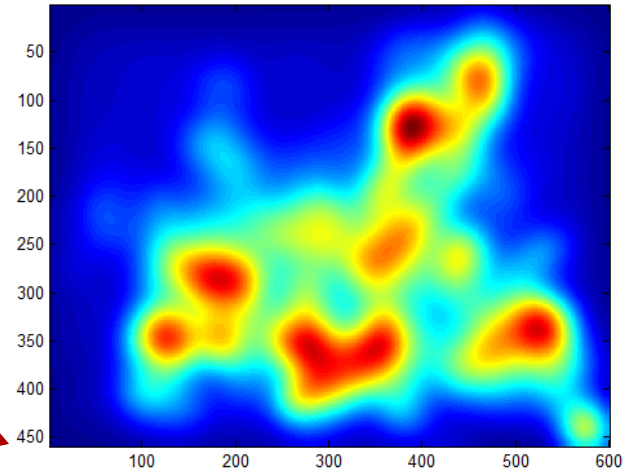


[1] M. M. Moya, et al, "Superpixel segmentation using multiple SAR image products" RADAR SENSOR TECHNOLOGY XVIII, Proceedings of SPIE VOL 9077, Conference on Radar Sensor Technology XVIII, MAY 05-07, 2014, Baltimore, MD

[2] M.M. Moya, et al., "Superpixel Classification for Signature Search in Synthetic Aperture Radar Imagery," Conference on Data Analysis (CoDA), March, 2014, Santa Fe, NM.

Method (1): Natural Scene Saliency Map





[1] Itti citation

Method (2): Select and Filter Based on Superpixel Characteristics

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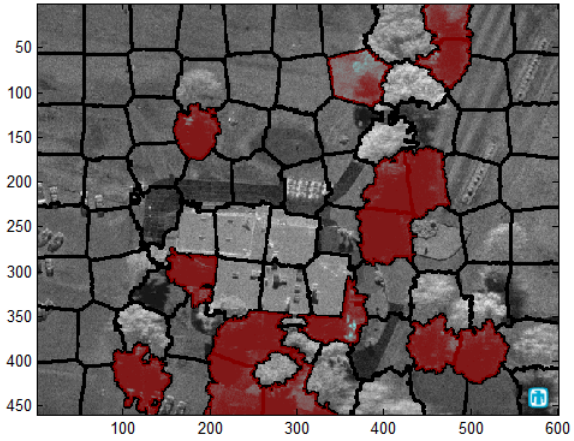
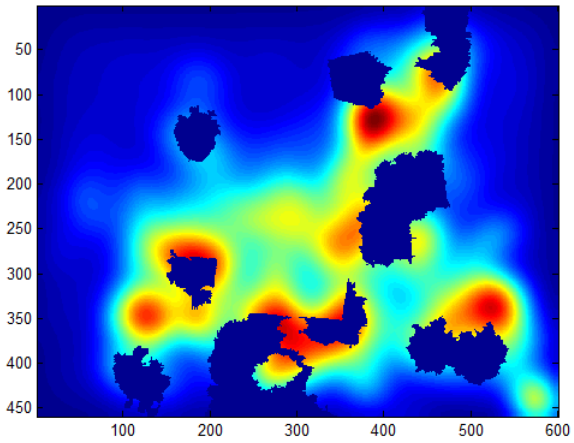
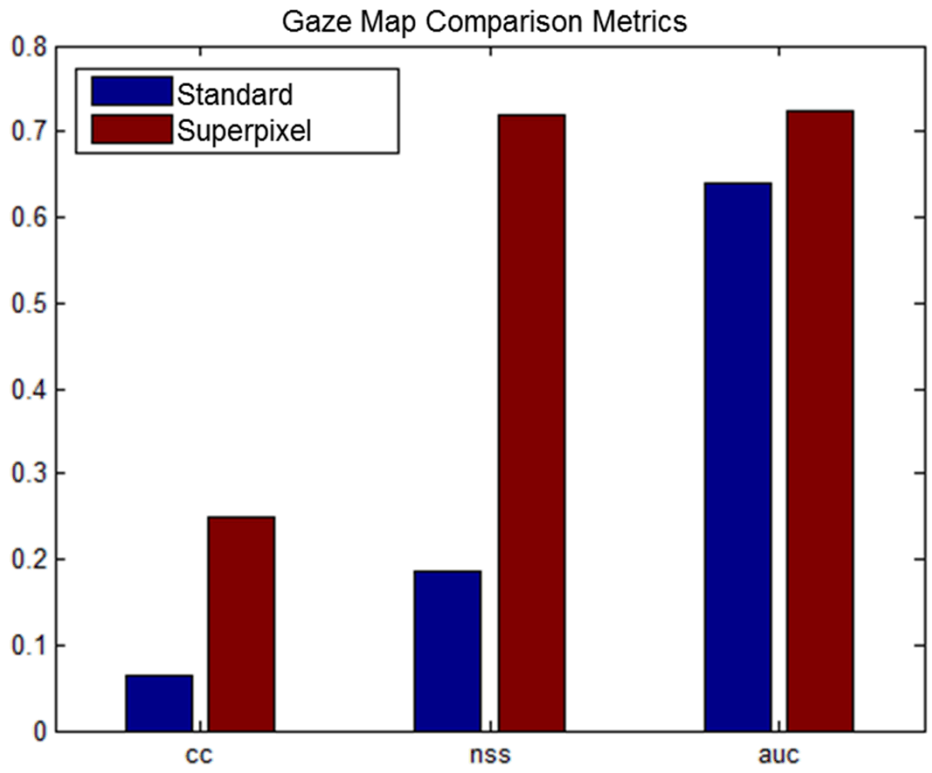
- Select superpixels with certain characteristics (i.e. shadows)
  - Classify using pixel statistics within each superpixel



- Apply mask to original saliency map
  - Can add Gaussian, or other smoothing to reduce discontinuities



Study Results



Saliency map modulated by superpixel characteristics is more similar to analyst fixation maps

- Linear correlation (cc) improvement factor is 3.8X
- Normalized scan path saliency (nss) improvement factor is 3.9X
- Area under receiver-operator curve (auc) improvement factor is 1.1X

Conclusion

- Saliency estimates from “standard” model have high variance in agreement with gaze maps
- Modulating standard model using superpixel segmentation and classification based on sensor phenomenology can improve salience – gaze agreement
- Using eye tracking technology to explore relationships between traditional saliency models and pixel-statistical properties we can understand eye movements of domain experts interacting with imagery from today’s most advanced sensors