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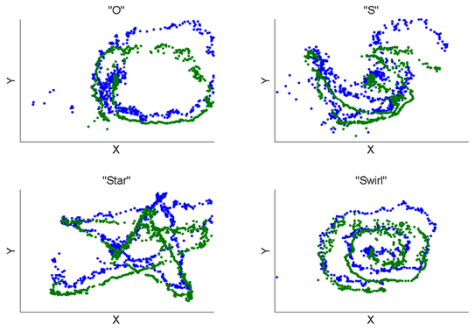

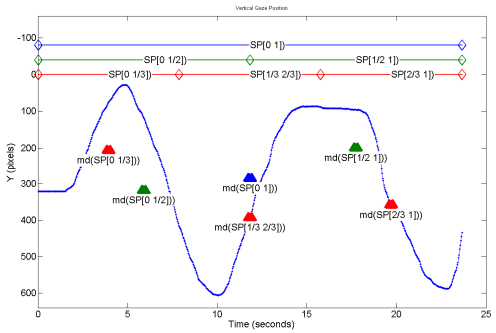

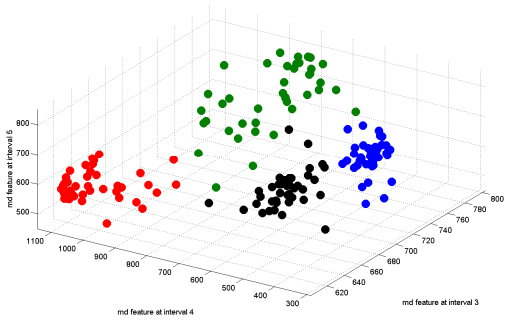

GazeAppraise

A New Method for Categorizing Gaze Trajectories

Michael J. Haass, Laura E. Matzen, Karin M. Butler, Mika Armenta

2016 Symposium on Eye Tracking Research and Applications
Charleston, SC, March 14 -17

U.S. DEPARTMENT OF ENERGY | National Nuclear Security Administration | CCR Center for Computing Research

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Visual Cognition at SNL: Core Scientific Questions

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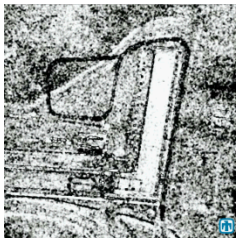
What features capture attention in non-optical imagery?
How does domain experience influence visual search/inspection?
How can top-down visual attention be modeled?
Do people with expertise in one domain perform differently on domain-general tasks?

Radar

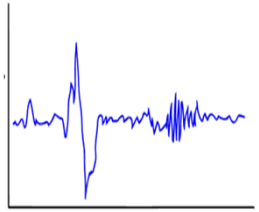


Intended to make important features more salient

False color X-rays

Intended to make important features more salient

Waveforms

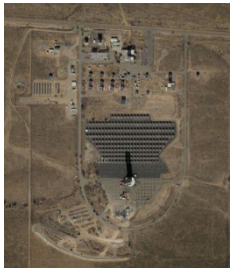


Visualizations of raw data

Log Files

Raw data

Satellite Imagery



Similar to optical imagery

Novices

Experienced with optical imagery only

Example Gaze Maps By Expertise

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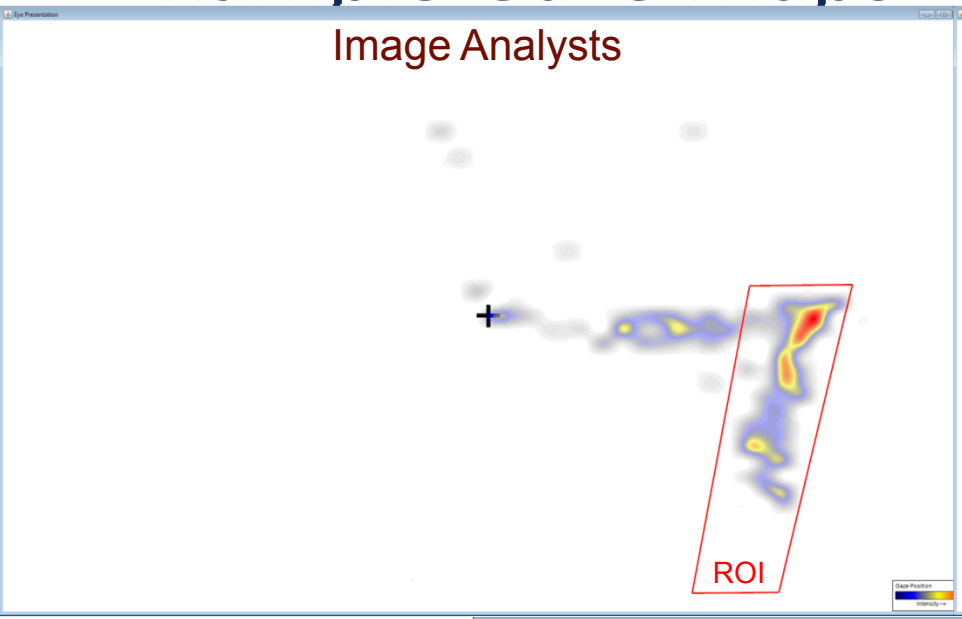

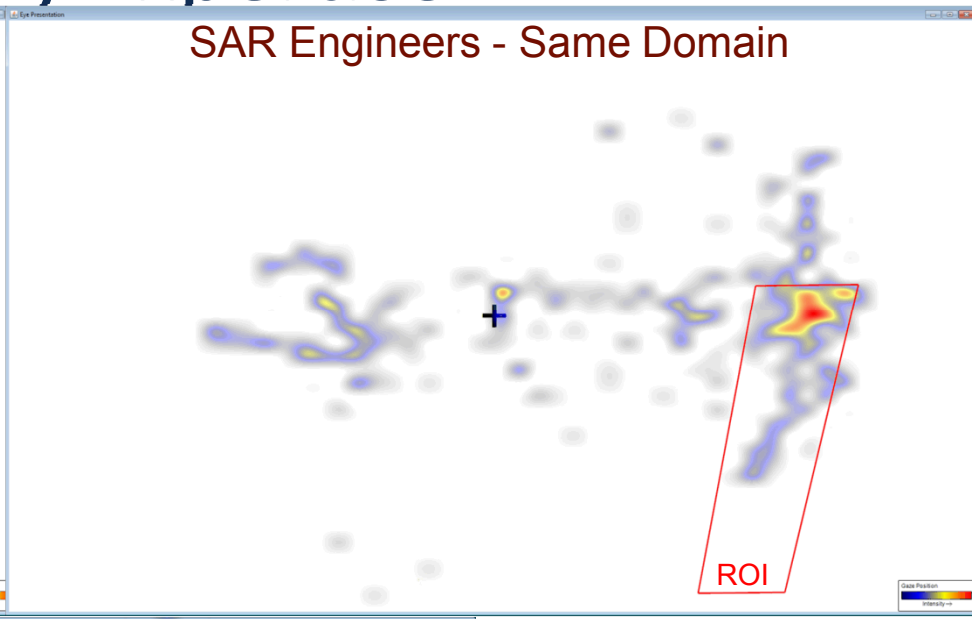

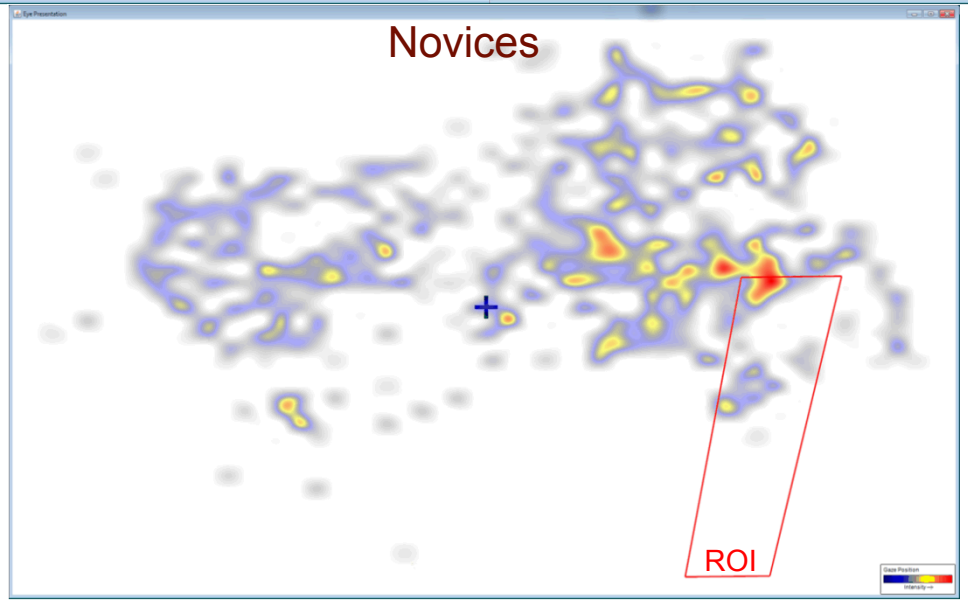

Motivation, Challenges, Goals

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- Why Scanpaths?
  - Anecdotal reports of search strategies from expert image analysts
  - Observed differences in image analyst performance (accuracy and speed)
- Analysis of the sequential dependencies between eye positions (scanpath analysis) is complex
  - Incorporating influence of stimuli (defining AOI's)
  - Preprocessing raw eye movement data (defining fixation parameters)
  - Analysis algorithms that are sensitive to both spatial and temporal characteristics of eye movements
- Sensitivity to several scanpath characteristics is desirable (Holmqvist et al.2011*)
  - overall shape comparison
  - similar shape that differs in scale
  - Differences in spatial extent
  - similarity in position but reversal of order
  - differences in the speed of execution of a scanpath
  - Differences in fixation durations even if position and sequence are the same
  - Similarity between sub-segments of scanpaths
- We sought a method of extracting eye movement trajectory information that could be
  - Applied to minimally-processed eye movement data
  - Applied without specifying areas of interest a priori
  - Is sensitive to multiple scanpath characteristics
- The research we present here represents a proof-of concept that this new approach can be used with unprocessed eye tracking data

*HOLMQVIST, K., NYSTR¨O M, M., ANDERSSON, R., DEWHURST, R., JARODZKA, H., AND VAN DE WEIJER, J. 2011. Eye Tracking: A Comprehensive Guide to Methods and Measures. Oxford University Press.

Inspired by Flight Trajectory Analysis

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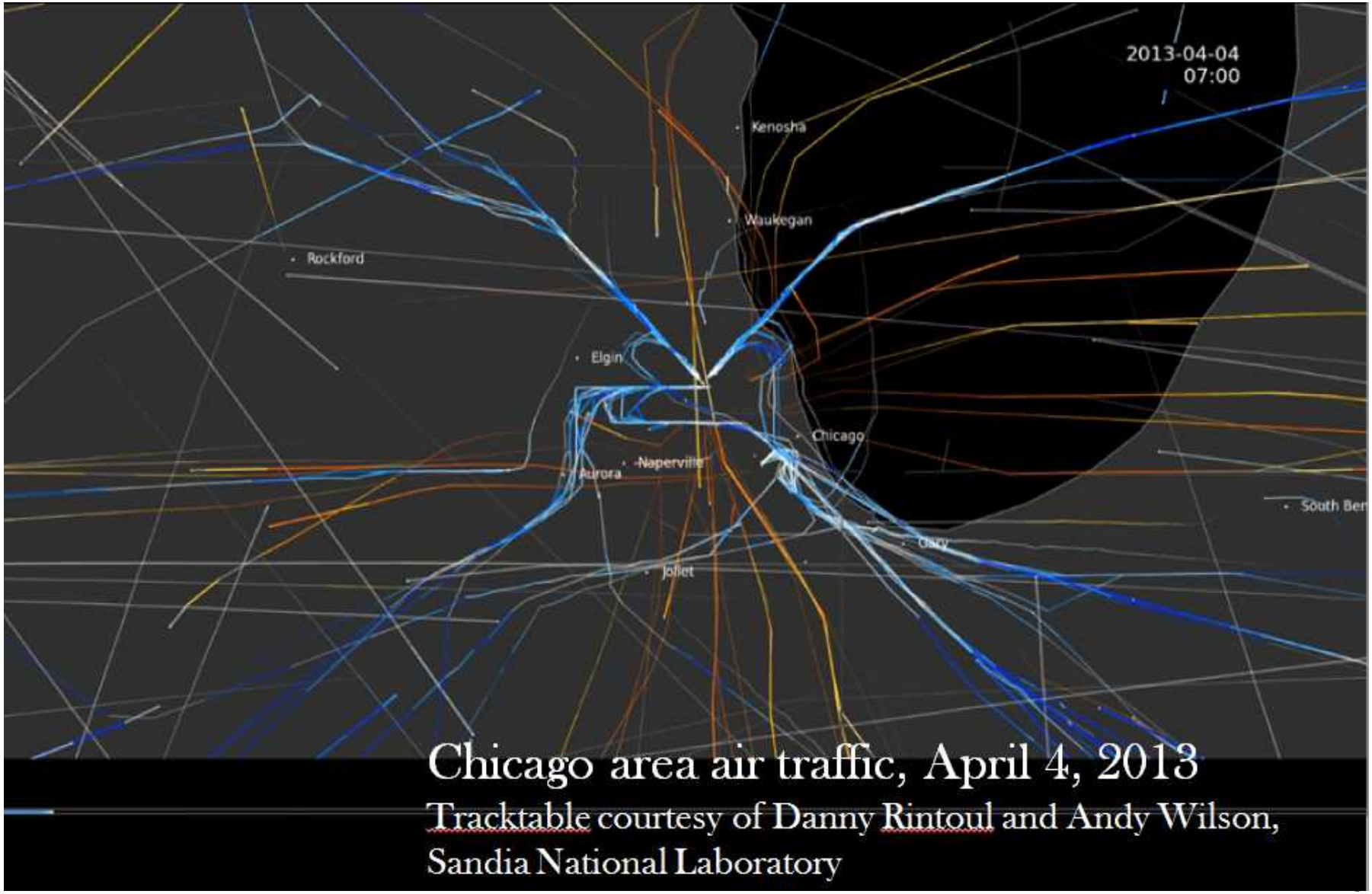

GazeAppraise Method (1)

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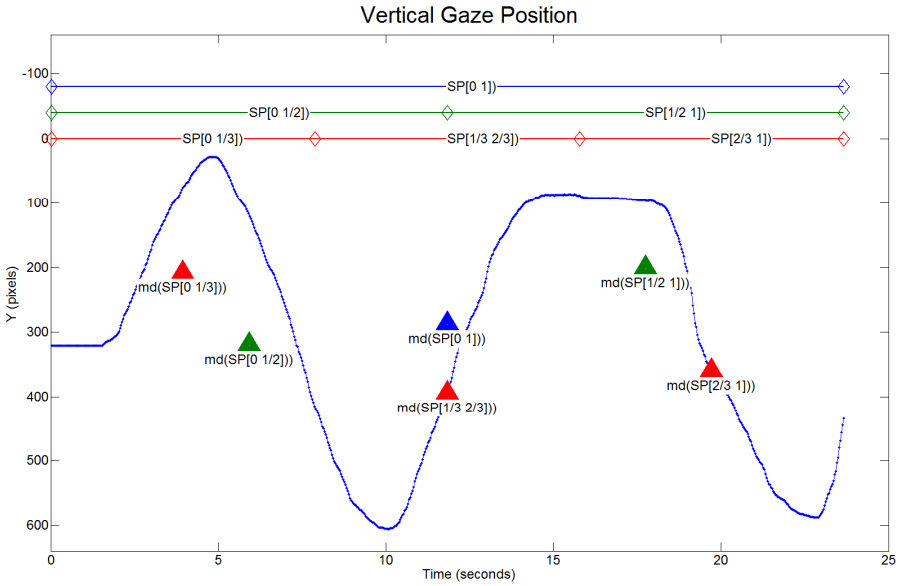
Calculate geometric features at multiple scales

Scale	Temporal Interval	Scanpath Fraction
1	1	0 - 1
2	2	0 - ½
	3	½ - 1
3	4	0 - ⅓
	5	⅓ - ⅔
	6	⅔ - 1
4	7	0 - ¼
	8	¼ - ½
	9	½ - ¾
	10	¾ - 1



Feature metrics can use any quantity calculable from samples in each interval

- This study used median x and median y positions of raw gaze data

GazeAppraise Method (2)

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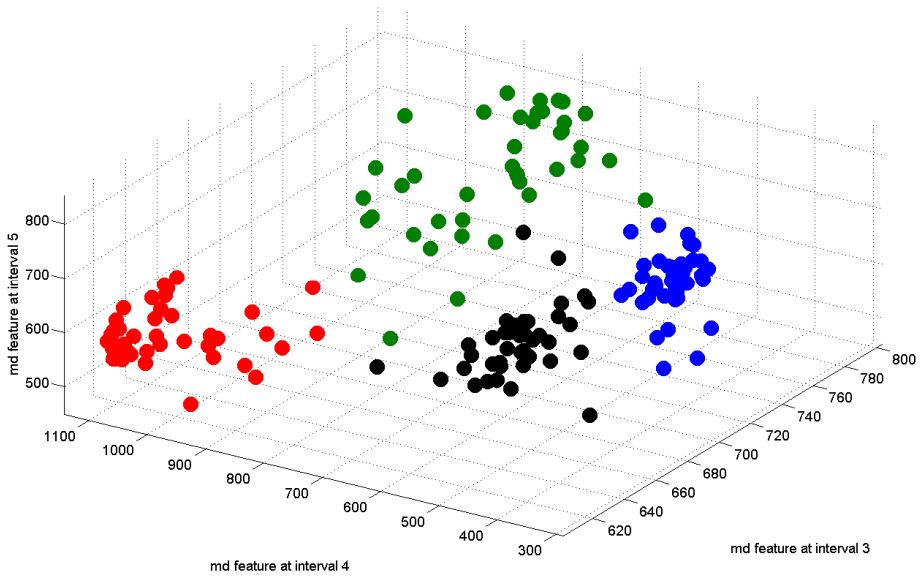
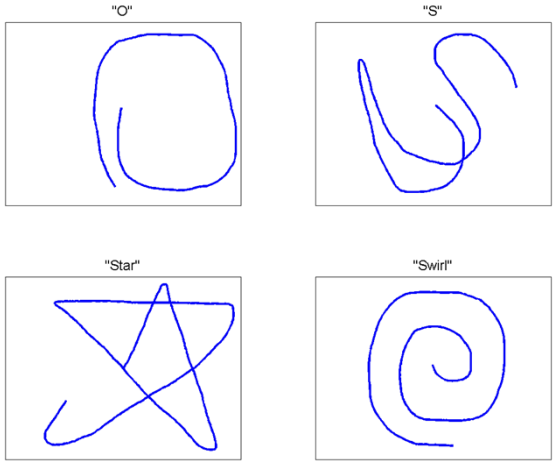
Cluster multidimensional scanpath features

- GazeAppraise uses a density based clustering algorithm (DBSCAN) which does not require a priori knowledge of number of clusters
  - minPts: minimum # of members to form a cluster
  - Eps: neighborhood radius



Study

- Participants: Forty-one subjects
- Apparatus: Seeing Machines FOVIO running at 60 Hz
- Task: Smooth pursuit eye movements constrained by stimulus characteristics
- The 41 participants generated 164 scanpaths
- In our analysis, we chose four temporal scales, resulting in 10 temporal intervals



Results

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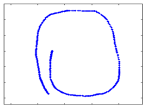
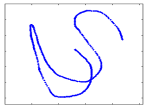
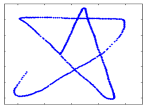
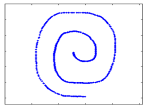
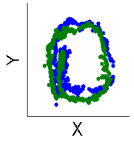
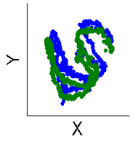
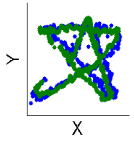
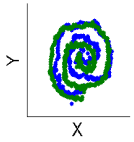
	Stimuli			
				
Cluster	O'	S'	Star	Swirl
 1	40			
 2	0	41		
 3	0	0	40	
 4	0	0	0	41
Outlier	1	0	1	0

98.8% recall/sensitivity and 100% precision

Current State & Future Assessments

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- GazeAppraise
  - Performs unsupervised cluster analysis on spatiotemporal sequences
  - Requires zero-to-minimal preprocessing
  - Does not require a priori specification of areas of interest
- This study represents a proof-of concept: GazeAppraise successfully categorized raw eye tracking samples into distinct scanpaths that reflected the stimulus constraints, but in the absence of stimulus information to constrain the categorization
  - Even when those data include samples collected with variations in calibration precision, tracking consistency, and viewer performance
- Future work will need to explore how much and in what ways shapes can differ yet still be categorized together
  - For example, it is expected that there would be more temporal variation across individuals in eye movement samples collected during cognitively guided viewing than during saliency guided viewing

Acknowledgement

- We wish to thank Danny Rintoul and Andy Wilson of Sandia National Laboratories, Albuquerque, NM, USA, for their assistance adapting Tracktable to eye tracking data.

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NOTES

Notes (1)

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- Although this application of GazeAppraise used the median x and y position as features, the metrics used for each feature are flexible. In fact, each feature can have a different units scale, i.e. one feature measured in degrees of visual angle, another measured in milliseconds and another measured in pixels. Thus, features can be any quantity calculable from the eye tracking samples in each temporal interval. Other features that may be useful for scanpath categorization include, but are not limited to, mean and variance of point-to-point distances, mean nearest neighbor distance (randomness of points), total length of scanpath, area and centroid of the convex hull encompassing scanpath points, etc. For example, metrics based on point-to-point distances would implicitly encode the proportion of fixation to saccade activity over the temporal interval. Total scanpath length could measure the amount of the visual display that was viewed which may be important for assessing systematic search processes like visual inspection. Convex hull metrics could measure the amount of the peripheral visual display that is viewed.
- The application of GazeAppraise to eye movement analysis is nascent; the eye tracking samples were collected under highly constrained viewing conditions (smooth pursuit eye movements constrained by the stimulus characteristics) not typical of everyday eye movement patterns. It remains to be demonstrated that more typical eye movement trajectories with fixations and saccades, that are influenced to a greater extent by top-down processes, can be categorized. The contribution of this research is to demonstrate the application of a new set of spatiotemporal trajectory libraries to raw eye tracking data, an application we refer to as GazeAppraise. Categorization of eye tracking data collected while viewing four different, but constraining, stimuli was highly successful. Future work will validate the usefulness of this approach by applying the algorithm to eye tracking data from systematic search tasks.