Proposal for a full day Eurographics 2015 Tutorial
Eye Tracking Visualization

Keywords
Eye Tracking, Visualization, Cognition, Visual Analytics, User Studies, Evaluation, Eye Tracking Metrics, Information Visualization, Visualization Systems, Study Design, Human-Computer Interaction, Statistics

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Introduction and Motivation
Eye tracking has become a widely used method to analyze user behavior in marketing, neuroscience, human-computer interaction, and visualization research. Apart from measuring completion times and recording accuracy rates of correctly given answers during the performance of visual tasks in classical controlled user experiments, eye tracking-based evaluations provide additional information on how visual attention is distributed and changing for a presented stimulus. Due to the wide field of applications of eye tracking and various kinds of research questions, different approaches have been developed to analyze eye tracking data such as statistical algorithms (either descriptive or inferential), string editing algorithms, visualization-related techniques, and visual analytics techniques. Regardless of whether statistical or visual methods are used for eye tracking data analysis, a large amount of data generated during eye tracking experiments has to be handled.

Where statistical analysis mainly provides quantitative results, visualization techniques allow researchers to analyze different levels and aspects of the recorded eye tracking data in an explorative and qualitative way. Visualization techniques help to analyze the spatio-temporal aspect of eye tracking data and the complex relationships within the data. This more qualitative exploration aims at finding hypotheses that can be investigated with statistical methods later on.

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Due to the increasing complexity of tasks and stimuli in eye tracking experiments, we believe that visualization will play an increasingly important role in future eye tracking analysis.

Evaluation has become an important step in the development of new visualization techniques. Eye tracking is one means of evaluating those newly developed approaches. Thus, analyzing eye tracking data with visualization techniques is just a logical step that followed. However, in most cases only state of the art visualization techniques are used, such as scan path or attention map visualizations.

In this tutorial we will present an overview on further existing visualization techniques for eye tracking data and demonstrate their application in different user experiments and use cases. The tutorial will present three topics of eye tracking visualization:

1.) Visualization for supporting the general analysis process of a user experiment.
2.) Visualization for static and dynamic stimuli.
3.) Visualization for understanding cognitive and perceptual processes and refining parameters for cognition and perception simulations.

Outline (full day tutorial, 4x90 minutes)

1. Introduction (15 min., presenter Tanja Blascheck) ▪ Introduction of speakers ▪ Organization of the tutorial ▪ Motivation of attendees to participate in tutorial
2. Fundamental Concepts of Eye Tracking (40+5 min., presenter Tanja Blascheck) ▪ Historical overview ▪ Eye tracking ▪ Taxonomy
3. Eye Tracking and Visualization (25+5 min., presenter Kuno Kurzhals) ▪ Point-based visualizations ▪ AOI-based visualizations
coffee break
4. Eye Tracking Metrics (25+5 min., presenter Michael Burch) ▪ Classical metrics ▪ Scan path comparison algorithms ▪ Example eye tracking study
5. Eye Tracking and Visual Analytics (25+5 min., presenter Daniel Weiskopf) ▪ Current approaches ▪ Future directions
6. eTaddy (25+5 min., presenter Tanja Blascheck) ▪ Questionnaire ▪ Study ▪ Circular attention map transition diagram
lunch break
7. Static Visualization of Dynamic Stimuli (25+5 min., presenter Michael Burch) ▪ AOI rivers ▪ Saccade plots
8. Dynamic Stimuli (25+5 min., presenter Kuno Kurzhals)

▪ ISeeCube
9. Simulation of eye movements (25+5 min., presenter Hermann Pflüger) ▪ Simulating process ▪ Training and evaluation data ▪ Results
coffee break
10. Cognition (25+5 min., presenter Michael Raschke) ▪ Cognitive simulation ▪ Ontology based visualization methods ▪ Eye tracking data visualization
11. Discussion (30 min.)
12. Summary and Future Challenges (30 min., presenter Michael Burch)

Target Audience and Necessary Background

The tutorial is designed for the general audience of Eurographics, and is especially suitable for PhD students. Eye tracking and eye tracking visualizations is becoming a new approach and research area. PhD students and researchers will benefit from this tutorial by finding a new and exciting topic and broaden their research horizon. The tutorial requires a minimal level of pre-requisites. Fundamental concepts of eye tracking and visualization will be explained during the tutorial.

Course Notes and Material

Large parts of our tutorial will be based on a recent publication at EuroVis 2014:
Blascheck, Tanja; Kurzhals, Kuno; Raschke, Michael; Burch, Michael; Weiskopf, Daniel; Ertl, Thomas: State-of-the-Art of Visualization for Eye Tracking Data. In: *EuroVis STAR*, S. 63-82, 2014.
We will try to make the publication available to the attendees, however we first have to make sure the copyright is upheld.

Brief Resumes of Presenters

Tanja Blascheck graduated in Computer Science (Diplom-Informatiker) at the University of Stuttgart, Germany in 2012. As a research assistant she is working at the Institute for Visualization and Interactive Systems (VSI) at the University of Stuttgart. Her main research interests are eye tracking, visualization, visual analytics, and digital humanities. A specific focus of her research is on developing new methods to analyze eye movement data from interactive stimuli.

Kuno Kurzhals graduated in Computer Science (Diplom-Informatiker) at the University of Stuttgart, Germany in 2012. As a research assistant he is working at the Visualization Research Center (VISUS) at the University of Stuttgart. His main research interests are eye tracking, video visualization, visual analytics, and computer vision. A specific focus of his research is on developing new visualization methods to analyze eye movement data from dynamic stimuli.

Hermann Pflüger graduated in Engineering and Computer Science (Diplom-Ingenieur, Diplom-Informatiker) at the University of Stuttgart, Germany in 1984 and 2012. As a high school teacher he teaches the subjects computer sciences and media/product design. In addition, he works as a research assistant at the Institute for Visualization and Interactive Systems (VSI) at the University of Stuttgart. His main research interests are digital humanities, visualization of large sets of pictures of Visual Arts, and visual perception in general.

Michael Raschke graduated in Physics (Diplom-Physiker) at the Ruprecht-Karls-University Heidelberg, Germany in 2009. As a research assistant he is working at the Institute for Visualization and Interactive Systems (VIS) at the University of Stuttgart. His main research interests are human centric visualization, cognition simulations, human-computer interaction, and philosophical questions of visualization and cognition.

Michael Burch is a postdoctoral researcher the Visualization Research Center (VISUS) at the University of Stuttgart, Germany. He received his Dr. rer. nat. (PhD) degree in computer science from the University of Trier in 2010. His main research interests are in information visualization, in particular, visualizing dynamic directed and weighted graphs with an additional hierarchical organization of the nodes in a static diagram. Other areas of expertise are the large-scale visualization of hierarchical data, eye-tracking evaluation of information visualization techniques, and the visualization of eye tracking data.

Daniel Weiskopf is a full professor at the Visualization Research Center (VISUS) at the University of Stuttgart, Germany. He received his Dr. rer. nat. (PhD) degree in physics from the University of Tübingen, and the Habilitation degree in computer science at the University of Stuttgart. His research interests include all areas of visualization, visual analytics, GPU methods, perception-oriented computer graphics, and special and general relativity.

Previous Tutorials

The tutorial was previously held at the **12th Biannual Conference of the German Cognitive Science Society** (KogWis: http://www.uni-tuebingen.de/en/faculties/faculty-of-science/departments/interdepartmental-centres/cognitive-science-in-tuebingen/kogwis-2014.html) in Tübingen, Germany from September 29th until October 2nd. It was a half day tutorial (2x90 min) with about 40 attendees. Most of the audience had either a psychology or cognition background. The idea of the tutorial was to give the attendees an overview about eye tracking visualizations as an alternative to classical statistical evaluation of eye movement data. The Eurographics tutorial will have a different audience and the focus will be more on specific visualizations techniques with demonstration of different tools developed at our institute. We will add a session on eye tracking metrics and eye tracking in combination with a visual analytics approach for a more domain specific tutorial.

Appendix A: Selection of References (presenters highlighted)

Kurzhals, Kuno; Fisher, Brian; **Burch, Michael**; **Weiskopf, Daniel**: Evaluating Visual Analytics with Eye Tracking. In: Proc. of Wksp. on Beyond Time And Errors: Novel Eval. Meth. for Vis., to appear, 2014.

Blascheck, Tanja; Kurzhals, Kuno; Raschke, Michael; Burch, Michael; Weiskopf, Daniel; Ertl, Thomas: State-of-the-Art of Visualization for Eye Tracking Data. In: *EuroVis STAR*, S. 63-82, 2014.

Raschke, Michael; Blascheck, Tanja; Ertl, Thomas: Cognitive Ergonomics in Visualization. In: Ebert, Achim and van der Veer, Gerrit C. and Domik, Gitta and Gershon, Nahum D. and Scheler, Inga: *Building Bridges: HCI, Visualization, and Non-formal Modeling*. Berlin/Heidelberg: Springer-Verlag, 2014.

Kurzhals, Kuno; Heimerl, Florian; **Weiskopf, Daniel**: ISeeCube - Visual Analysis of Gaze Data for Video. In: *Proceedings of the 2014 Symposium on Eye Tracking Research and Applications (ETRA)*, S. 43--50, 2014.

Burch, Michael; Beck, Fabian; **Raschke, Michael; Blascheck, Tanja; Weiskopf, Daniel**: A Dynamic Graph Visualization Perspective on Eye Movement Data.

Raschke, Michael; Blascheck, Tanja; Richter, Marianne; Agapkin, Tanja; Ertl, Thomas: Visual Analysis of Perceptual and Cognitive Processes. In: *Proceedings of the International Joint Proceedings of the 5th International Conference on Information Visualization Theory and Applications, IVAPP '14*, S. 284-291, 2014.

Raschke, Michael; Herr, Dominik; **Blascheck, Tanja; Burch, Michael;** Schrauf, Michael; Willmann, Sven; Ertl, Thomas: A Visual Approach for Scan Path Comparison. In: *Proceedings of the Symposium on Eye Tracking Research and Applications, ETRA '14*, S. 135-142, 2014.

Burch, Michael; Schmauder, Hansjörg; **Raschke, Michael; Weiskopf, Daniel**: Saccade Plots. In: *Proceedings of Symposium on Eye Tracking Research and Applications*, S. 307-310, 2014.

Pflüger, **Hermann**: "Computer, Sehen, Bilder", 2014, ISBN 978-3844282900

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Raschke, Michael; Blascheck, Tanja; Burch, Michael: Visual Analysis of Eye Tracking Data. In: Weidong Huang: *Handbook of Human Centric Visualization*. New York, NY, USA: Springer-Verlag, 2013.

Burch, Michael; Kull, Andreas; **Weiskopf, Daniel**: AOI Rivers for Visualizing Dynamic Eye Gaze Frequencies. In: Computer Graphics Forum, EuroVis; Leipzig, Germany, 2013.

Kurzhals, Kuno; Weiskopf, Daniel: Space-Time Visual Analytics of Eye-Tracking Data for Dynamic Stimuli. In: *IEEE Transactions on Visualization and Computer Graphics (TVCG)*: Ausgabe 12, Nr. 19 (2013), S. 2129-2138.

Burch, Michael; Andrienko, Gennady L.; Andrienko, Natalia V.; Höferlin, Markus; **Raschke, Michael; Weiskopf, Daniel**: Visual Task Solution Strategies in Tree Diagrams. In: *Proceedings of the IEEE PacificVIS 2013*, S. 169-176, 2013.

Blascheck, Tanja; Raschke, Michael; Ertl, Thomas: Circular Heat Map Transition Diagram. In: *Proceedings of the 2013 conference on Eye Tracking South Africa, ETSA '13* , S. 58-61, 2013.

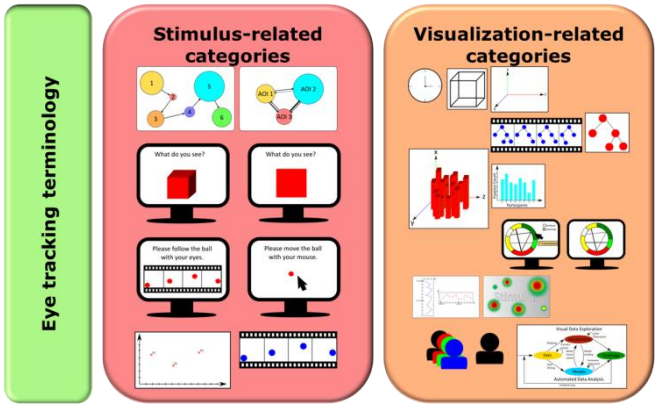
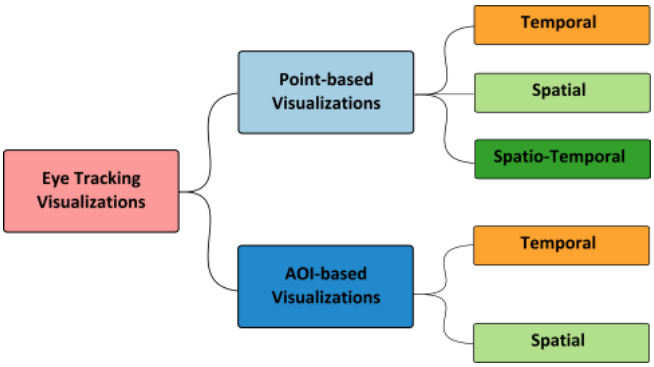
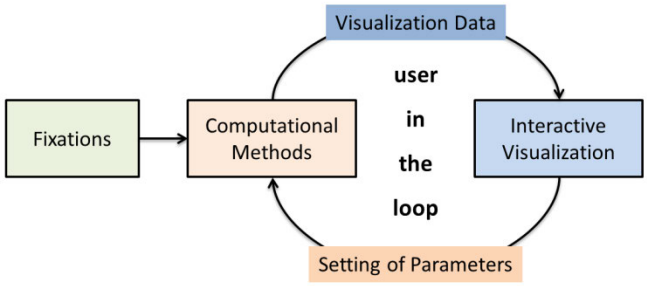
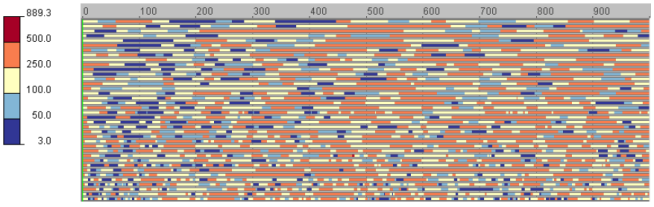
Blascheck, Tanja; Raschke, Michael; Ertl, Thomas: eTaddy - Ein intergratives Framework für die Erstellung, Durchführung und Analyse von Eyetracking-Daten. In: *GI-Edition Lecture Notes in Informatics, Informatiktage 2013*, S. 111-114, 2013.

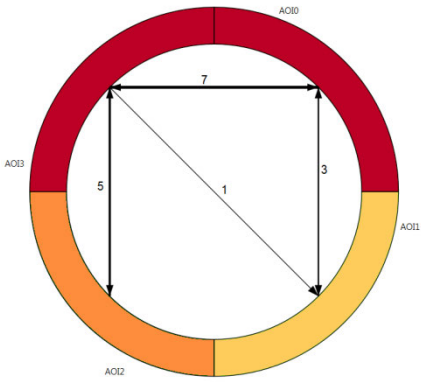
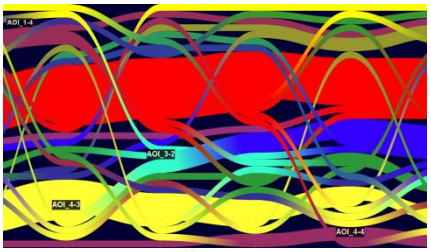
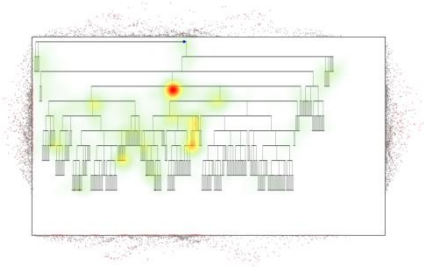
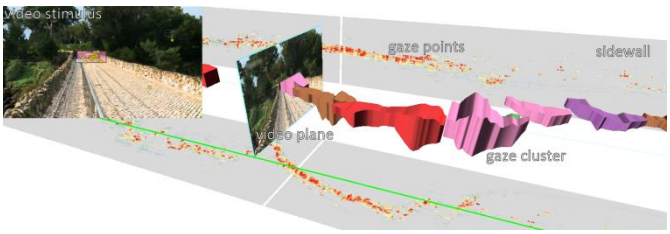
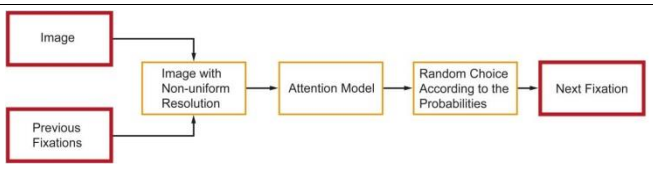
Andrienko, Natalia V.; Andrienko, Gennady L.; **Burch, Michael; Weiskopf, Daniel**: Visual Analytics Methodology for Eye Movement Studies. In: *IEEE Conference on Visual Analytics Science and Technology (VAST)*, 2012.

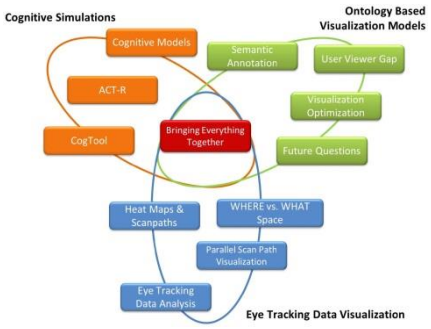
Raschke, Michael; Chen, Xuemei; Ertl, Thomas: Parallel Scan-Path Visualization. In: *Proceedings of the 2012 Symposium on Eye-Tracking Research and Applications*, S. 165-168, 2012.

Höferlin, Benjamin; **Pflüger**, **Hermann;** Höferlin, Markus; Heidemann, Gunther; **Weiskopf, Daniel**: 2012. Learning a Visual Attention Model for Adaptive Fast-forward in Video Surveillance. In ICPRAM (2)'12. 25–32.

Appendix B: Detailed version of outline

1. Introduction (15 min., presenter Tanja Blascheck) ▪ Introduction of speakers ▪ Organization of the tutorial ▪ Motivation of attendees to participate in tutorial	
2. Fundamental Concepts of Eye Tracking (40+5 min., presenter Tanja Blascheck) ▪ Historical overview ▪ Eye tracking o Applications o Hardware o Study Process ▪ Taxonomy o Terminology o Stimulus-related categories o Visualization-related categories	
3. Eye Tracking and Visualization (25+5 min., presenter Kuno Kurzhals) ▪ Point-based visualizations o Timeline visualization o Attention map visualization o Scan path visualization ▪ AOI-based visualizations o Definition of AOIs o Timeline visualization o Relational visualization	
coffee break	
4. Eye Tracking Metrics (25+5 min., presenter Michael Burch) ▪ Classical metrics ▪ Scan path comparison algorithms o Levenshtein distance o Needleman-Wunsch algorithm ▪ Example eye tracking study o Metro maps o Node link diagrams	
5. Eye Tracking and Visual Analytics (25+5 min., presenter Daniel Weiskopf) ▪ Current approaches o Parallel scan path visualization ▪ Future directions	

6. eTaddy (25+5 min., presenter Tanja Blascheck) ▪ Questionnaire ▪ Study ▪ Circular attention map transition diagram	
lunch break	
7. Static Visualization of Dynamic Stimuli (25+5 min., presenter Michael Burch) ▪ AOI rivers ▪ Saccade plots	 
8. Dynamic Stimuli (25+5 min., presenter Kuno Kurzhals) ▪ ISeeCube o Point-based analysis ▪ Gaze points ▪ Clustering o AOI-based analysis ▪ AOI timeline ▪ Scarf plot ▪ Scan path comparison	
9. Simulation of eye movements (25+5 min., presenter Hermann Pflüger) ▪ Simulating process ▪ Training and evaluation data o Eye tracking study ▪ Results o Improvements	
coffee break	

10. Cognition (25+5 min., presenter Michael Raschke) ▪ Cognitive simulation o Framework o Tool ▪ Ontology based visualization methods o Semantic model o Semantic annotation of visualizations ▪ Eye tracking data visualization o Parallel scan path visualization	
11. Discussion (30 min.)	
12. Summary and Future Challenges (30 min., presenter Michael Burch)	