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Innovative analysis methods for eye-tracking data from dynamic, interactive and multi-component maps and interfaces

In the cartographic community there has been an increase in the number of projects reporting on use of eye-tracking for user testing. The major part of the projects using eye-tracking uses static stimuli (Fabrikant et al. 2008, Brodersen et al. 2009, Garlandini et al. 2009 and Fabrikant et al. 2010). Investigations with interactive or animated stimulus are surprisingly rare (Cöltekin et al. 2009). Most eye-tracking software is geared towards static stimuli and thus, the provided analysis tools and methods are also focused on static stimuli.

Static stimuli are not always desired in cartographic research. Digital maps and map systems are becoming more and more interactive and dynamic. Contemporary examples are map animations, multi component map interfaces, web maps and virtual globes. Neither one have a single static representation that represents typical user behaviour. Thus the current methods of performing and analyzing eye-tracking experiments are ill-suited for these kinds of maps.

Eye-tracking produces an enormous amount of data; recording fixation points in addition to the stimuli and video recording of the participants. Traditional methods for eye-tracking analysis include density maps of fixation points, defining “areas of interest”, calculating statistics such as “time to first fixation”, “fixation counts” and similar. These methods do not take into account *changing* stimuli, such as for instance an animation or a dynamic interface. When the stimuli change over time the areas of interest changes, thus, pre-defining static areas of interests is not suitable. Neither is it appropriate to cluster fixation points without taking into account the temporal changes in the stimuli. To account for this we propose several different methods which pay attention to the temporal change of the stimuli for easier analysis of these kinds of data.

The data and the stimuli are inherently related to the temporal dimension as well as the spatial dimension. Thus it is natural to investigate further spatio-temporal analysis methods (Peuquet 2002). The first method we suggest is to analyse eye-tracking data in a multi component interface which consists of the eye-tracking data visualized in a space-time cube (Hägerstrand 1967) interlinked with other visualizations such as fixation plots, density maps and similar. This approach is directly inspired by the work of Li et al. (2010). The authors use the space-time-cube to visualize eye movement data in three dimensions as well as linking the view with other visualisations of data or stimuli. Investigations on different stimuli were, however, not in focus. We extend the work of Li et al. (2010) by focusing on applicability of the approach on animated stimuli. As well we aim at investigating different linked views specialized towards animated stimuli. We hypothesize that this analysis method is suitable for discovering patterns in the temporal dimension which could not previously be discovered due to the tradition of aggregating without respect to this dimension.

When increasing the group of participants the number of trajectories becomes large. As a result the visualization in a space-time-cube may not necessarily be useful due to overlapping trajectories causing visual clutter. We propose that temporal clustering should be employed in order to cluster the eye-tracking trajectories based on similarity of for instance nearness in space in relation to the time. Several clustering algorithms are suitable for this (Vieira 2009). However, the results will need to be visually appealing while at the same time not aggregating too much, as mentioned by Li et al. (2010) as an issue of traditional methods. This could reveal patterns across participants. Particularly interesting could be the patterns which do *not* get clustered in the temporal dimension. This could for instance reveal where and when users are changing their fixation points drastically. In our work we aim primarily at investigating the visual representation of such clustering methods as well as explore which aggregation methods could be useful to implement in further work.

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