Gaze-Enabled Data Recommendations In Visualization: First Considerations

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MultimodalVis '18 Workshop at AVI 2018, May 29, 2018, Grosseto, Italy.
https://multimodalvis.github.io

Abstract
Cheaper and better eye-trackers now make it possible to use this technology to determine users' data interests in real-time, as they visually explore large and heterogeneous data spaces. Data visualizations could use such knowledge to continuously adapt and show data that is well aligned with users' interests and goals. Recommendation systems based on logging and interpreting manual interactions have been studied already. However, integrating eye-tracking into the recommendation process is important in the visualization domain given the medium's inherently visual nature and it poses unique challenges and questions. We introduce and discuss these aspects as they arose from an informal, exploratory investigation.

Author Keywords
Visualization; recommendation systems; eye-tracking; gaze-enabled; multi-modal

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

Introduction
As data becomes increasingly large and heterogeneous so does the need for visualization systems to intelligently curate the data they show to their analysts.

Eye-tracking, a technology that is quickly becoming cheap enough to be part of regular workstations [2], may help tackle this problem. The eye-mind hypothesis posits that where a user looks on a computer screen says much about the interests of that user [1]. Thus, tracking a users' gazing behavior, in addition to traditional logging of manual interactions, could help a visual analytics system more reliably learn a user's data interests in real-time and use that knowledge to adjust the data it shows.

The idea is relatively novel. Steichen et al. and Conati et al. explored the possibility of adapting visualizations to users' viewing particularities (e.g., average fixation time) [3,4], but not to their data viewing interests. Visual systems that recommend data of interest based on users' manual interactions have been studied [5] but integrating eye-tracking into the recommendation process has received less attention and poses unique challenges. Since users interpret visualizations visually, using eye-tracking to understand users' data interests may be a promising research avenue.

We explored the feasibility of gaze enabled data recommendations in a preliminary investigation and in the process identified several challenges. These are the abstract's contributions.

Methodological details

We created a simple visualization of Internet Movie Database (IMDB) data consisting of movie glyphs laid out in 2D so that their proximity reflected similarities between movies. We considered two movies to be similar if they had similar genres, were from similar time periods, had similar ratings, and shared actors. Glyphs were designed to include information about a movie's genre, production date, and rating (Fig 1).

A Tobii EyeX eye-tracker enabled the visualization to match a viewer's gazes to movie glyphs and record a history of fixated movies. The visualization used this history to slowly and unobtrusively change the data shown to more closely match the users' interests. Specifically, it gradually pulled in data similar to that already fixated and filtered out data which was ignored.

The setup was tested informally by the author, who solved simple, well-defined browsing tasks such as "Find a well rated, old, comedy you'd like to watch tonight." We plotted the value properties of the data our visualization showed an tracked how it changed over time to more closely support the explored task.

This allowed us to consider challenges and questions related to gaze-enabled data recommendations in visualization.

Challenges

Dealing with eye-tracking reliability and uncertainty

Reliability is an inherent eye-tracking problem. The more dense a visualization, the less precisely gaze data can pinpoint which visual elements a user is looking at. We proposed methods to increase the accuracy of identifying fixated visuals by leveraging visualization properties [2] and accuracy can likely be increased further by tracking gaze and manual interactions together. Perfect solutions do not exist however, as the lack in accuracy can be traced to the size of the foveated region [1]. As such, we need to develop gaze-enabled recommendation methods that are robust to uncertainty.

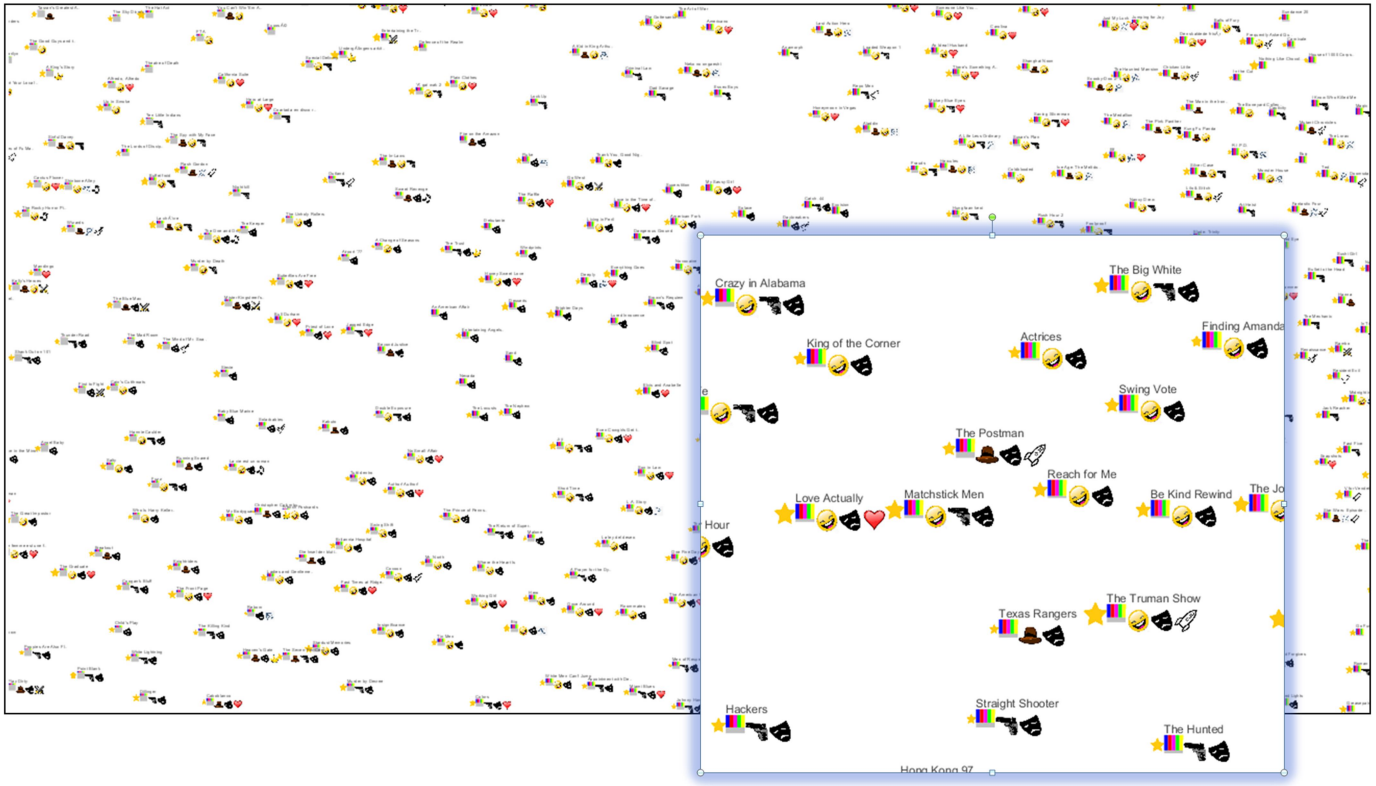

Figure 1. A simple visualization of IMDB data shows movies as glyphs in 2D space. Similar movies are grouped together and depict movie title, genre, rating, and production year. Via an eye-tracker the visualization was able to track in real-time movies that users were viewing often or longer and pull in additional movies with similar attributes. Developing and testing this simple experimental setup allowed us to explore questions and challenges surrounding gaze-enabled visual data recommendations.

Not stifling exploration

Visual systems that gradually remove data categories that don't match users' current interests need to leave room for users to eventually return to such data if their interests change. As such, elements of currently unattended data categories should be kept in the visualization, giving users the possibility to eventually redirect their attention to them.

Unobtrusive changes
While manual interactions are deliberate, eye-movements are not. Sudden changes in an interface in response to users' gazing behavior can thus be extremely disruptive as users cannot link such changes to their gazing. We thus need to investigate gaze-adaptive visualizations that change gradually and unobtrusively.

Visualizations amenable to gaze adaptive techniques
The benefits of adding eye-tracking to the recommendation process may differ significantly based on a visualization's encoding and interactions. Visualizations that rely heavily on user interaction may derive enough information about data interests from manual interactions alone. Conversely, visualizations from which users can gain insight by visual inspection may benefit from eye-tracking significantly. There may be other factors that make a visualization more or less amenable to eye-tracking instrumentation. Developing an understanding of these factors is non-trivial.

Time frames
An important question is how fast a visualization should adapt. If it changes too slow we might not reap any benefits but if it changes to fast it may be perceived as chaotic. Moreover, different data interests exist at different temporal scales. For example, a user's interests may different between a short-term, specific data question or a project spanning multiple days. Building gaze-enable recommendation systems that can be effective at multiple temporal scales is challenging.

What is interesting?
Consider a user fixating on a romantic comedy in our point-cloud visualization. Should we take this to automatically mean that the user is interested in romantic comedies, or at least that they are interested to an equal degree in comedies and romantic movies? Our interpretation needs to take into account the visual context in which that movie was viewed. If the movie is the only romantic comedy in a visualization section otherwise dominated by comedies, it's likely that its romantic nature was more important. If it was instead a comedy surrounded by romantic movies, it's likely that the former attribute counts for more. Finally, if all movies visually available to the user were romantic comedies, it's likely that something other than genre caught the users' interest.

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