A visual analytics approach to evaluate inference affordance from animated map displays

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Extended abstract

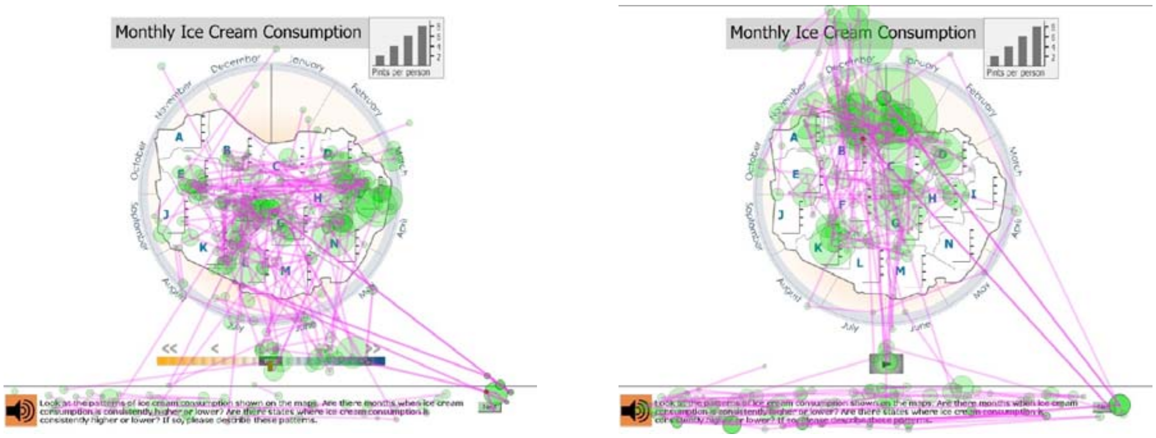
Highly interactive and dynamic visual analytics tools for supporting effective spatio-temporal analytical reasoning and decision-making have become extremely popular recently, fuelled by latest location-based technology developments (i.e., GPS enabled mobile devices, sensor networks, etc.) and the increasing availability of massive spatio-temporal data sets at highest resolution (e.g., GPS tracks of various moving entities). The popularity and use of such VA tools rests on the convincing assumption that humans are generally graphically enabled, and that they will better comprehend multidimensional dynamic spatial processes and phenomena that are congruently depicted with multivariate and dynamic displays. This line of reasoning is also reflected in the rising popularity of map animations that show the passage of time congruently with changing displays over time. Map animations are increasingly used on televised news and the World Wide Web to explain complex spatio-temporal processes to a larger non-expert audience or decision-makers (i.e., Google Earth fly throughs, weather animations, interactive election result maps, animated tsunami events, etc.)

This paper reports on ongoing data analysis of an empirical study on animated map displays where the effects of animation design principles and human-map interaction design choices for depicting spatio-temporal phenomena are systematically assessed for spatial inference and decision

making. For example, visual transitions (i.e. fades, wipes, etc.) are one example where dynamic variables are manipulated to generate a specific visual effect in a dynamic display. We are considering transitions in our research, as Rensink and colleagues (e.g., Rensink et al., 1997) have demonstrated that observers have great difficulty noticing even large (abrupt) changes between two successive scenes in an animation, for example, when blank images are shown in between scenes (e.g., simulating a flicker). Change-blindness is particularly problematic when using complex VA-tools, for example, when users have to keep track of various events occurring simultaneously that require them to split their visual attention between multiple linked, and dynamic views.

We are also interested in how various levels of interactivity in map animations may affect spatial inference making and knowledge discovery. Non-interactive animations, for instance, have a pre-determined sequence and pacing, which may significantly viewer's cognitive load thus hinder effective inference making. Using the eye-movement data collection method we investigate the empirical question whether combining dynamic variables (i.e., display transitions) with different levels of interactivity may help reduce cognitive load, including perceptual problems (e.g., attentional blindness) when having to make inferences from dynamic map displays.

In a mixed two-by-two factorial experiment we ask novice participants (N = 84) to study map animations showing monthly ice cream consumption for an average year for different states in a fictitious country. The first factor (between-subject independent variable) distinguishes two interaction levels (i.e., non-interactive vs. interactive), whereas the second factor (between-subject independent variable) considers the dynamic variable "rate of change" (i.e., abrupt vs. gradual display transitions). The participants answer a number of questions about these animated maps. The test questions (within-subject independent variable) vary in type and complexity. We prompt viewers to verbalize their thought process when performing complex spatial inference tasks with the dynamic displays. Digital audio recordings of their verbal statements while answering the test questions permit joint analyses with accuracy of response, and participants' eye movement recordings (dependent variables).



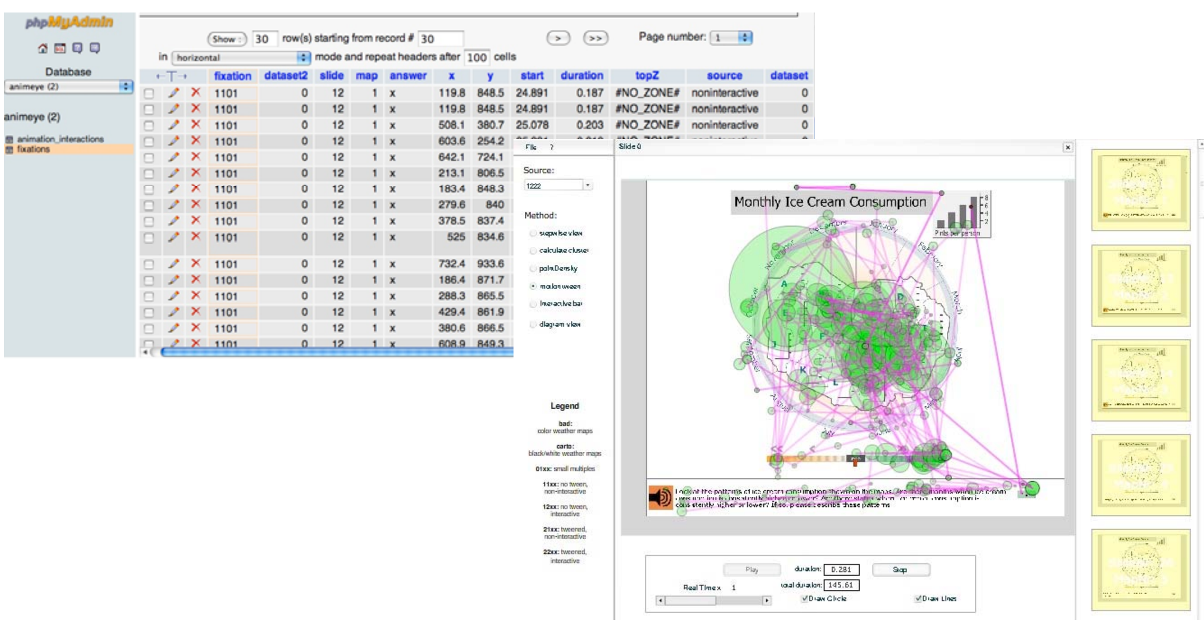
(a) interactive map animation (b) non-interactive map animation

Fig 1. Map animation stimuli with a participant's gaze plot overlaid

Spatial visual analytics of evaluated animated map displays

Ironically, the sheer amount and complexity of the collected spatio-temporal eye movement recordings on map animations required us to develop a new approach on how to analyze these massive empirical spatio-temporal data sets. Elsewhere we have proposed a novel visual analytics method to measure inference affordance from dynamic processes depicted with static small-multiple maps (Fabrikant et al., 2008). We now apply this methodology to dynamic map displays.

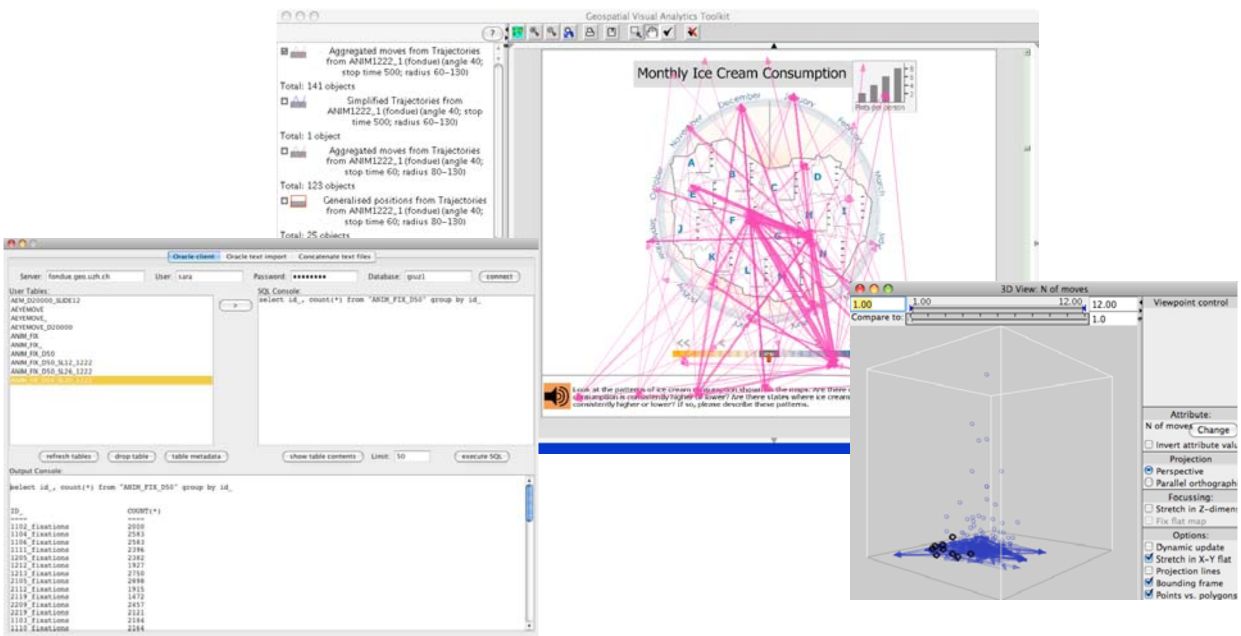
For this study, we collected over 173,000 records of eye movement data from 60 study participants, including the x- and y- coordinates of participants' eye fixations locations, eye fixation duration, and other relevant eye movement data (approximately 10 MB of data). Figure 1 depicts an example of one participant's gaze plot including eye fixations (graduated circles) and saccades (connecting lines) between fixations. This spatio-temporal dataset is complemented by another set of 8,000 records of participants' mouse interaction data, their responses to test questions, including data from background questionnaires (approx. 1 MB of data). Typically for experimental studies like this one, collected records are kept in flat text files, to be later used as input to statistical software for further analysis. The anticipated data size problem prompted us to fully automate testing procedures using Adobe Flash/HTML and Java Script for not only presenting test stimuli—linked to a MySQL database running PHP—but also to automatically collect and store responses in a database. Once the participant records are stored in an online accessible database, it can be queried from anywhere with an Internet connection. This is just one advantage of this approach, as data collection was carried out at the University of California Santa Barbara (USA) while data analysis is performed at Zurich University, Switzerland. A second advantage of this distributed data setup is that experimental results can be "played back" (i.e., visualized) on the fly with a lightweight Flash-based visual analytics interface we developed and coined *eyeview* (Grossmann, 2007). This tool (shown in Figure 2) allows us to visually explore the eye movement data stored in the MYSQL database, as to gain first qualitative insights before running any statistical analyses.



(a) stored gaze data in MYSQL database (b) *eyeview* gaze data visualization tool

Fig. 2. database base driven gaze plot visualization and analysis

Due to severe graphic overplotting—already when viewing data for one single subject—it soon became clear that a new solution had to be found to analyze subject data overall. For this reason, gaze data were additionally ingested into an Oracle database in order to serve as a source for more advanced visual analytics methods offered by a powerful geovisual analytics toolkit specifically targeted for the analysis of movement data (Andrienko et al., 2007). Details of the software and provided analysis routines can be found in Andrienko et al. (2007). We additionally developed a Java-based Oracle data loader including an SQL query tool to facilitate data query and preprocessing for the geoVA toolkit.

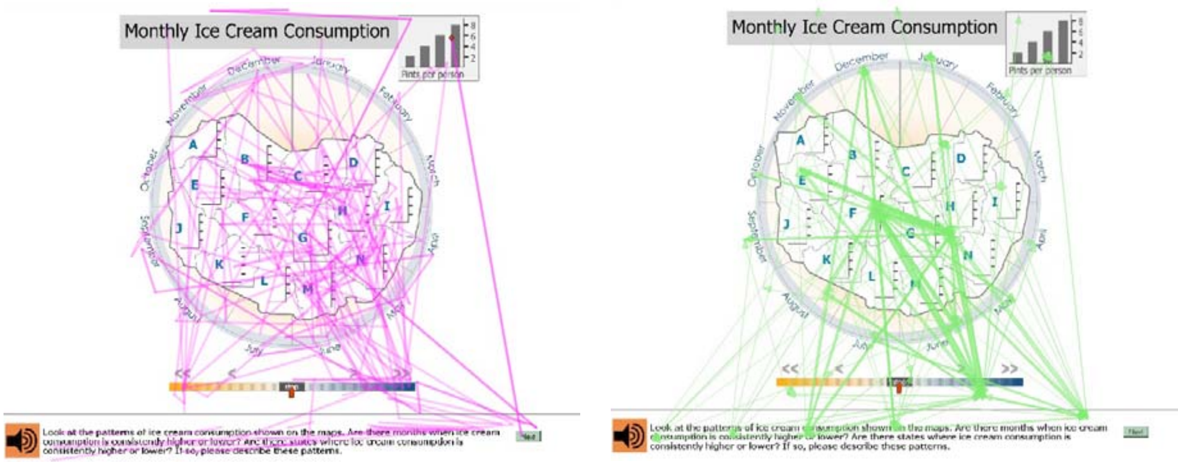


(b) 2D trajectory summarization map

(a) Oracle data loader and query tool (c) perspective view of gaze data

Fig. 3. Visual analytics set up for gaze data analysis

In this workshop we will discuss examples of the spatio-temporal data generalization and gaze plot summarization approach we applied using the geoVA toolkit (Andrienko et al., 2007) in order to facilitate sense making of our large empirical eye movement data sets. A data summarization example is shown in Figure 4 below.



(a) original gaze plot (b) summarized gaze plot

Fig. 4. Effects of spatio-temporal gaze data generalization

One participant's original gaze data is shown in panel 4a). Panel 4b) depicts the resulting dominant movement pattern after applying a gaze-plot generalization based on space-time clustering with the VA toolkit.

With this study we hope to provide a sound visual analytics methodology for better understanding of how people use dynamic map displays to explore dynamic geographic phenomena, and how people make inferences from dynamic visualizations to construct knowledge in a geographical context.

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