Universität Münster

Department of Geoscience

Modeling the performance of interaction techniques for the comparison of spatial entities in the context of geo-dashboards

Bachelorthesis

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Abstract

Contents

1 Introduction

The growing usage of dashboards to represent data across a range of different fields suggests a need for research on layout and design features of dashboards and their influence on the user experience. Previous research has shown that there is no one-fits-all solution for the design of dashboards [19, 15].

This existing agreement that general design recommendations for dashboards are not sufficient and/or possible ask for a breakdown of components that constitute dashboards. One approach is to identify user interactions that are possible when visualized data is explored or analysed. The field of geovisualizations and geodashboards is enriched with many different perspectives that all try to define taxonomies and or classifications models for possible user interactions [1, 6]. Many have their reasonable own application for spatial-temporal information visualization. But the minority of these classifications and taxonomies are empirically-derived. The proposed framework of Roth represents an exception. He has shown that a functional taxonomy of interaction primitives can be empirically derived. He identified general tasks users want to accomplish (objective primitives) [14]. Besides narrowing down the scope to one of Roths derived objective primitives this work will also look at this topic from the perspective of different interaction techniques.

An interaction technique as broadly defined in the Computer Science Handbook from 2004 is "the fusion of input and output, consisting of all hardware and software elements, that provides a way for the user to accomplish a task." [9]. Input describes all sensed information about the physical environment to the computer. Output from computers on the other hand include any emission or modification to the physical environment. In the context of geovisualizations and geodashboards, interaction techniques have been researched [10, 12, 16]. Roth also describes an interaction technique in the context of geovisualizations as the functionality of an given interface and the procedures of manipulating its visualizations [14].

This work will deal with the derived objective primitive of *comparison* from Roth's work. But not only Roth writes about comparison. Wehrend describes *compare* as a seperate operation class in visualization problem [18] and Brehmer et al. speak of comparison as a low level visualization task [3]. In the scope of geovisualizations Crampton identified *compare* as an interactivity task [6] and Gorte and Degbelo argue that *comparison* is a basic task that is relevant in exploratoy and confirmatory analysis [8]. Buja distingiushes between two dimensions of comparison. The first describes the goal of comparing different variables or projections of the whoel dataset. The second describes the goal of comparing subsets of the whole dataset against each other [4]. This work will only focus on the latter.

We will examine two broadly used interaction techniques: *filtering* and *highlighting* [10, 14]. Keim et al. describe *filtering* as a combination of selection and view enhancement and Roth attributes filtering to identifying matches from user-defined conditions. The literature often use the term *brushing* to describe *highlighting*. They can be considered synonymous in the scope of interaction techniques as both describe the process of visualy emphasizing a subset from the whole dataset. Historically to define the subset the process started by drawing a rectangle directly in the view with the mouse which was called *brush*. Which explains the term *brushing*. For the rest of this work we will use the term *highlighting*. Keim et al. state that *highlighting* is often combined with linking which describes the process of selected data beeing communicated to other views of the data. They follow one of the proposed user strategies *Select Subset* from Gleichner [7].

In this work we will investigate how these interaction techniques influence user performance in the context of comparing subsets in geodashboards. Because the interaction technique is by far not the only variable that can be changed, we also want to observe the influence of different variables on the user performance. To provide a starting point backed with emperical data we want to derive a mathematical model that should display user performance in dependence from different variables which are described later. Therefore we can infer two research questions for this work:

1. Which mathematical models best describe user performance during the comparison of spatial entities in the context of geodashboards?
2. Which interaction technique best supports the task of comparison in the context of geodashboards?

To answer these questions we conducted a user study in which participants try to answer questions with the goal of finding differences and/or similarities of subsets of spatial-/temporal datasets. To answer the questions they are using a specially builded digital web-prototype with six different dashboard variants. The dashboards vary in their interaction technique and some render additional views utilizing *explicit encoding* as it is defined as one of the basic designs for visual comparison [7]. The goal of the experiment is to collect data about the user performance. We have defined user performance to include the time it takes to answer questions and the accuracy of that answer. After that we want to use that data to derive mathematical models that best approximate answer time and accuracy during the comparison of features in geodashboards. With special interest for the differences between the selected interaction techniques. We want to learn about the different factors we have included and how they influence answer time and accuracy in this setting.

To get an overview of the current state of research, chapter 2 will provide information about scientific contributions on interaction techniques in geo-dashboards and comparison. We will also give an short introduction to multiple coordinated because we are utilizing such a system in our prototype. Section 3 will describe key concepts of the mathematical models and what constitues them. In Section 4 details about the digital web-prototype and how it was built are presented. How the experiment was designed and what factors that possibly influence comparison performance were considered are covered in section 5. Section 6 will present the results of the experiment and propose our found mathematical models that showed the best testing results. As this experiment only covers a selection of possible factors that possible influence difficulty and accuracy during the comparison of features in geodashboards, this work should be a starting point for further research. Because comparison can be of many different kinds and cover different scopes this work also opens the door for more reseach in different comparison settings. Section 7 discusses such limitations in depth, how our research questions can be answered and how our findings can be transferred to other domains. Lastly we will sumarize our key-learnings and propose future work that has to be done in section 8.

2 Related Work

2.1 Geo-dashboards

2.2 Multiple coordinated views

Multiple Coordinated Views (MCV) is a specifc exploratory visualization technique that allow users to explore data. It consists of multiple views that all encode the same data in different representations. Interactions and operations of the user are managed and synchronised between views [13].

Because of its popularity 20-30 years ago much of previous research in the field of MCV focused on scatterplot matrices [5, 2]. Lawrence et al. used a specfic tool for the exploratory analysis of systems biology data and showed how *highlighting* is an effective technique for discovering outliers [11]. Carr et al. argue that *highlighting* is the most common interaction technique in scatterplot matrices when working with subsets [5, 2]. On the other hand they argue that if the subsets becomes larger another approach may be more suitable. They called it *specify, then compute.* The idea is that a selection region is defined, similar to the highlighting procedure, then the subset is computed and finally a new display is rendered that only contains the subset. This describes our more modern idea of *filtering.*

Some contributions on interaction techniques in MCV systems define *filtering* as a type of *highlighting* or *brushing* [17].

2.3 Comparison

Gleichner writes about four considerations when visualizing comparison [7]. At first we have to identify our comparison elements. Because every comparison task in our study focuses on comparing two or three features of the dataset we can descibe our targets as 'explicit targets' as every item is known and already available. From Gleichners proposed actions on relationships between targets our comparison task fall into the *Identify* and *Measure/Quantify/Summarize* categories. Second we have to identify comparitive challenges. The number of targets should not add much complexity as we are only using two or three targets. Because we are using timeseries with only one observed variable the complexity of each individual item is also fairly low. As we are only identifying and measuring direct differences or differences between differences of targets the complexity of the relationships is low to moderate. Gleichner next proposes to deal with a scalability strategie. To reduce scale challenges the strategies of *Select Subset* and *Summarize Somehow* are utilized. In all dashboard variants either *filtering* or *highlighting* as an interaction technique is used which help with scale because subsets are created. In some variants additional views are rendered that already encode the difference of two targets which summarize a relation. Lastly we have to consider design visualizations. Across all dashboard variants all three basic visual designs for comparison are utilized as each have their benefits and drawbacks. Because we deal with temporal data all graph views are utilizing *superposition*. To reduce scalability problems either *filtering* or *highlighting* are utilized as already mentioned. Our table views use a combination of *super* - and *juxtapostion* as showing each datapoint in the same place would hinder readability. Finally because our actions on the targets include comparing differences between targets we included *explicit encoding* in some dashboard variants.

3 Mathematical models

$F_{difficulty} = \frac{1}{n_{views}} + \frac{n_{targets}}{1} + Difficulty_{question-type} + Difficulty_{interaction-technique}$

4 Digital Web-prototype

4.1 Non-/Functionl requirements

Nr.	Requirement	Type
01	The app should visualize one spatial-temporal dataset with polygons on a map. Each polygon should represent a spatial entity	Functional
02	The app should allow the user to read the exact attribute value for every spatial entity over the whole time period in a separate view	Functional
03	The app should visualize the temporal evolution for the attribute values of all spatial entities at a glance in a separate view	Functional
04	The app eases the process of comparing two (or three) spatial entities through a comparison mode that can be switched on/off	Functional
05	The app should provide six different dashboard versions that differ in their interaction technique and number of rendered views for comparing spatial entities	Functional
06	The app consists of version 1 where in comparison mode only the selected entities are filtered and shown in all views. It represents a 'filtering' interaction technique	Functional
07	The app consists of version 2 where in comparison mode the selected entities are visually emphasized using one color. It represents a 'highlighting' interaction technique	Functional
08	The app consists of version 3 where in comparison mode the selected entities are visually emphasized using multiple colors. One for each entity. It represents a 'highlighting' interaction technique	Functional

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Nr.	Requirement	Type
09	The app consists of version 4 which is a copy of version 1 described in requirement 06. In addition, one more view that meets requirement 02 and one more view that meets requirement 03 are displayed in comparison mode. These additional views encode the subtracted values of the selected entities forming views that encode 'differences'. For every combination of the selected entities one additional data series is displayed.	Functional
10	The app consists of version 5 which is a copy of version 2 described in requirement 07. In addition, one more view that meets requirement 02 and one more view that meets requirement 03 are displayed in comparison mode. These additional views encode the subtracted values of the selected entities forming views that encode 'differences'. For every combination of the selected entities one additional data series is displayed.	Functional
11	The app consists of version 6 which is a copy of version 3 described in requirement 06. In addition, one more view that meets requirement 02 and one more view that meets requirement 03 are displayed in comparison mode. These additional views encode the subtracted values of the selected entities forming views that encode 'differences'. For every combination of the selected entities one additional data series is displayed. In line with version 6, which represents a highlighting interaction technique with individual colors, the rendered differences are also visually highlighted in different colors.	Functional
12	In all six versions in comparison mode all selected spatial entities are highlighted on the map.	Functional
13	The app enables the user to switch between four selected datasets which all have the same spatial-temporal dimensions	Functional
14	The app should be available over a website	Non-Functional
15	The app should be user-friendly and have fast loading times	Non-Functional
16	The app should use multi-coordinated views appropriately by paying attention to common guidelines to reduce cognitive overhead.	Non-Functional

Table 4.1: This table describes all functional- and nonfunctional requirements of the web-prototype

5 User Study

6 Evaluation

7 Discussion

8 Conclusion

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