A Design Space for Visual Data Mapping for Low-Color Displays

Abstract/Summary

This PhD project will establish guidelines for data visualization on displays with no or only few color hues. Typical examples of these displays are electronic paper or e-ink displays that have, by design, a severely limited color resolution (typically black-and-white, black-white-red, black-white-yellow, or 16 levels of gray. Such displays yet are becoming increasingly popular on devices such as smart and fitness watches, electronic shelf labels and price tags in stores, secondary displays for cell phones, and e-book readers—but we cannot readily use color hue as a categorical color encoding and similarly the encoding of ordered data by brightness/saturation-based color scales is extremely limited. In this project the PhD student will investigate the design space for visual mapping of categorical, ordinal, and quantitative data for effective data representation on low-color displays, build a prototype system to test such mappings, conduct an experiment to better understand the different design choices in the design space, and experiment with practical e-ink hardware to test the results.

Topic

On e-ink displays we do not have a full color hue or brightness channel, and often others such as density are limited by display resolution and the lack of antialiasing and transparency. Yet, these types of displays are becoming more popular and important targets for data representations such as in wearable devices, e-readers, or in the retail domain.

The project centers around the question of how we can use data representations on low-color devices such as e-ink displays. In particular, the question of how we can best encode ordinal and categorical data without color needs to be addressed. The work will build heavily on the important past work by Jacques Bertin [1] who first established a set of visual variables and theoretically discussed their appropriateness for different data types. His work will be influential because it was developed at a time where color was similarly limited due to the cost and mechanisms of paper printing. We will take similar inspiration from old techniques used in print but expand it with the capabilities offered by modern computers. The work will also be influenced by Cleveland and McGill's studies [2] on the effectiveness of visual variables for quantitative data and Mackinlay [4] conjectures on the effectiveness for ordinal and categorical data, repeated by others and most textbooks in Visualization (e.g., Munzner [5]).

Domain

The topic is situated in the domain of Visualization and focuses specifically on the use of specific data encoding channels. As such, it is fundamental research with an applied component linked to the end-use on electronic paper.

Objectives

The main objectives of the thesis are:

1. Develop a design space for low-color data encodings,
2. Conduct user studies to compare different types of data encodings for ordinal and categorical data encodings, and
3. Develop a prototype or toolkit for e-ink displays.

Context

The work will be conducted in the AVIZ team at Université Paris/Saclay/LISN/Inria and supervised by Tobias Isenberg. The student will work as part of a team that engages in Visualization and Visual Analytics research.

Methods

To address this challenge, we will investigate, in particular, the use of texture patterns to replace color as a visual variable. Here, we start by investigating abstract patterns to associate them with data values. For these patterns, we need to understand what patterns work on e-ink displays and which ones do not. In particular, we will study parameters such as shape type, shape size, shape orientation, shape frequency/density for both linear structures and for area fills. The suitability of these patterns with respect to their parameters will depend on the e-ink color and spatial resolution. In addition to abstract shapes we will also study iconic shapes for their use in patterns. This decision is motivated by past work that studied iconic colors and their intuitive association to data elements such as company names and fruits [3]. With patterns we have a much wider design space than with color hues, yet we are also limited by the constraints that icons need specific sizes and spatial resolutions to be recognizable.

Expected Results

The expected results include:

- Fundamental research results on a design space for low-color data encodings published in a scientific paper.
- Results from 2–3 user studies that compare the effectiveness of different encodings chosen from the design space.
- A prototype toolkit or encoding for e-ink displays

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