Interactive Multi-Criteria Optimization of 2D Color Maps

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Abstract

Two-dimensional color maps are used in various application domains. Different color maps have been proposed with different goals in mind. We propose an automatic approach to create color maps based on different quality criteria. The quality criteria and their weightings may be defined interactively by the user. The color maps are defined as parametric surfaces in an arbitrary color space. Automatic non-linear optimizers modify the control points of these surfaces so that the desired quality criteria are met. As a result, the user can interactively create a color map that fits nicely for a given task.

Categories and Subject Descriptors (according to ACM CCS): Information Systems [H.5.2]: User Interfaces—

1. Introduction

Color is one of the most important visual encodings for data elements in information visualization. One prominent example is to use similar colors to indicate to the user that two items are considered to be similar. Another one is to use the same color in different views of the same data elements to show that two different visual representations actually refer to the same element.

With an increasing number of elements the choice of colors becomes more and more important. It also strongly depends on the task. In those cases where a single variable is encoded, a one-dimensional color gradient can be used. For two variables, the data items can be mapped directly into a 2D color map. For more variables, the data items can be transformed and projected into the 2D space of a color map.

In order to faithfully reproduce the original data as close as possible, such a color map should preserve the notion of perceived similarity in terms of color. A similar color should imply a low geometric distance. Some tasks also require a certain contrast against the background color so that the visual elements can be clearly identified as such. Others try to exploit the given color space in order to achieve a maximum number of distinguishable colors.

This is why many different color maps have been proposed in the literature, each finding its own trade-off between the aforementioned quality criteria.

2. Approach

We propose an approach to optimize a color map automatically. The optimization goal may be described with an objective function. One example could be a function that aims at maximizing the number of distinguishable colors. The optimization may also be subject to a set of constraints. Such constraints can be to keep a certain minimum distance to black and white. The user can define constraints and weights for different objectives in an interactive manner. The system then tries to find an optimal color map based on the given criteria.

The color map is defined by a rectangular grid of control points in an arbitrary color space. We interpolate the area between control points using parametric surfaces (e.g., based on Bézier splines or Catmull-Rom). These control points are then moved in space by an optimization approach to maximize the objective function.

3. Discussion

The approach we present is highly modular and therefore flexible, meaning that most components can be replaced transparently. This allows us to use different color spaces, different interpolation schemes and different optimizers. We plan to extend the system to better support the iterative nature of the optimization process.

Figure 1: A Bézier surface of a 2D color map