

# Color Crafting:

## Automating the Construction of Designer Quality Color Ramps

Stephen Smart, Keke Wu, and Danielle Albers Szafir, IEEE Transactions on Visualization and Computer Graphics, 2019.

CPSC 547  
Frances Sin

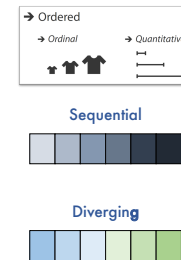
Background  
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Background

## Color Ramps

- Used to encode **ordered** data
- Can be **sequential** or **diverging**
- Properties of **effective** ramps:
  - Discriminable colors
  - Well-aligned with the data
  - Aesthetically pleasing

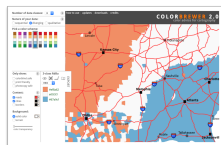


[Visualization Analysis and Design. Tamara Munzner, A K Peters Visualization Series, CRC Press, 2014.]

Background

## Existing Approaches

- Use (limited) **intuition**
- Choose from **predefined** set
- Select colors (control points) and **interpolate**



[colorbrewer2.org]

## Existing Approaches

- Choose from predefined ramps designed by color experts
- How can designers of **all levels** craft **high-quality color ramps**?
- Select colors (control points) and interpolate
- Problem: quality interpolated ramps are not very good



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Algorithm

## Modeling Designer Practice

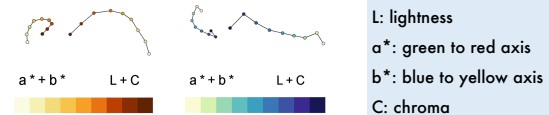
- Goal**: construct high-quality color ramps that reflect **experts' design practices**
- Method**: utilize **clustering algorithms** to learn patterns from designer color ramps

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Algorithm

## Color ramps can be modelled as curves

- Curves have salient **structural properties**
- Common **structural patterns** occur across subsets of ramps

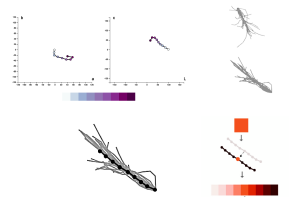


[Fig 2. Color Crafting: Automating the Construction of Designer Quality Color Ramps. Stephen Smart, Keke Wu, Danielle Albers Szafir, IEEE Trans. Visualization and Computer Graphics, 2019.]

Algorithm

## Method Overview

- Transform designer ramps into curves
- Cluster the curves
- Model the curves
- Seed the curves



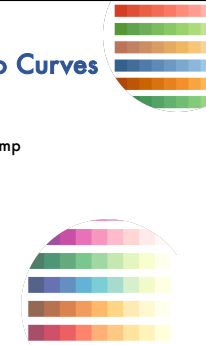
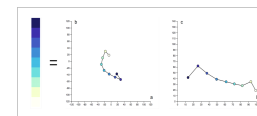
[Fig 3. Color Crafting: Automating the Construction of Designer Quality Color Ramps. Stephen Smart, Keke Wu, Danielle Albers Szafir, IEEE Trans. Visualization and Computer Graphics, 2019.]

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Algorithm

## [Step 1] Transform Ramps Into Curves

- Raw data: 222 designer-quality color ramps
- Fit **interpolating curve** through colors of each ramp
- Normalize** curves to nine points



[cmci.colorado.edu/visualab/ColorCrafting/visualization/]

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## [Step 2] Curve Clustering

- Use **two** unsupervised clustering techniques to capture patterns in expert-crafted ramps
  - Bayesian
  - K-means
- Clustering is based on curve **structure** (not color)

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Algorithm

## [Step 2] Curve Clustering

- Method 1: **Bayesian Clustering**
  - Group curves based on **overall shape**
    - Elastic shape metric** = invariant to affine transformations



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Algorithm

## [Step 2] Curve Clustering

- Method 2: **K-means Clustering**
  - Group curves based on **color ramp structure**
  - Compute 255-dimension feature vector for each curve
    - Explicitly consider features related to structure of ramp
    - E.g. Rate of change between adjacent colors

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## [Step 3] Model Construction

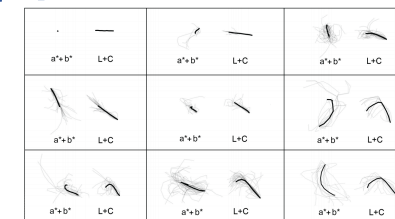
- Within each cluster...
  - Align** each curve to common starting point
  - Orient** each curve to same direction
  - Construct a **representative curve**



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## [Step 3] Model Construction



[Fig 4. Color Crafting: Automating the Construction of Designer Quality Color Ramps. Stephen Smart, Keke Wu, Danielle Albers Szafir, IEEE Trans. Visualization and Computer Graphics, 2019.]

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### [Step 4] Seeding

$L^* = 27$

- User specifies **seed color**
- Compute  $\Delta L^*$  between seed and control points
- Translate curve
- Compute other colors based on relative positions of control points

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Algorithm

### What-Why-How Summary

What	Why	How
<ul style="list-style-type: none"> <li>• <b>In</b> Multiple items, multiple attributes</li> <li>• <b>Out</b> Geometry (curve interpolating 9 points)</li> </ul>	<ul style="list-style-type: none"> <li>• Derive (transform colors into curves)</li> </ul>	<ul style="list-style-type: none"> <li>• Encode position (scatterplot)</li> </ul>

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### What-Why-How Summary

What	Why	How
<ul style="list-style-type: none"> <li>• <b>In</b> Multiple items, multiple attributes</li> <li>• <b>Out</b> Clusters, geometry (representative curves)</li> </ul>	<ul style="list-style-type: none"> <li>• Discover (structural patterns)</li> <li>• Derive (construct representative curve)</li> </ul>	<ul style="list-style-type: none"> <li>• Superimpose (curves)</li> <li>• Encode position (scatterplot)</li> </ul>

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Algorithm

### What-Why-How Summary

What	Why	How
<ul style="list-style-type: none"> <li>• <b>In</b> Geometry (curve, seed color)</li> <li>• <b>Out</b> Geometry (curve interpolating 9 points)</li> </ul>	<ul style="list-style-type: none"> <li>• Produce</li> </ul>	<ul style="list-style-type: none"> <li>• Encode position (scatterplot)</li> <li>• Encode color</li> </ul>

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Evaluation

### Three Methods of Evaluation

1. Lab study/expert review
2. Replication study
3. Use case evaluation

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Evaluation

### Lab Study/Expert Review

- **Goal:** Compare **accuracy** and **subjective preference** between ramps generated from different techniques
- Bayesian clustering
- K-means clustering
- Linear interpolation
- Hand-crafted by designer

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Evaluation

### Lab Study/Expert Review

- 35 design practitioners
- Identify mark that encodes target value, rate "pleasantness"

[Fig 7. Color Crafting: Automating the Construction of Designer Quality Color Ramps. Stephen Smart, Keke Wu, Danielle Albers Szafir, IEEE Trans. Visualization and Computer Graphics, 2019.]

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Evaluation

### Lab Study/Expert Review

**Accuracy**

**Subjective Preference**

[Fig 8 & 9. Color Crafting: Automating the Construction of Designer Quality Color Ramps. Stephen Smart, Keke Wu, Danielle Albers Szafir, IEEE Trans. Visualization and Computer Graphics, 2019.]

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Evaluation

### Replication Study

- **Goal:** Replicate expert ramps
- Representative curves may aggregate away details
- **Method:** Use random seed color from designer ramp as input

[Fig 10. Color Crafting: Automating the Construction of Designer Quality Color Ramps. Stephen Smart, Keke Wu, Danielle Albers Szafir, IEEE Trans. Visualization and Computer Graphics, 2019.]

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Evaluation

### Use Case

- **Goal:** Generate aesthetically pleasing color ramps from "ugly" colors
- Algorithm should be robust to poor seed selection
- **Method:** Use "ugly" seed colors as input to algorithm

[Fig 11. Color Crafting: Automating the Construction of Designer Quality Color Ramps. Stephen Smart, Keke Wu, Danielle Albers Szafir, IEEE Trans. Visualization and Computer Graphics, 2019.]

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Discussion

### Critique: Strengths

- Robust evaluation methods
- Great example how algorithm/techniques from different studies can be combined
  - E.g. Bayesian clustering approach was from a different paper
- Algorithm has very high utility
  - Color ramps are used all the time!

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Discussion

### Critique: Weaknesses

- Restrictive input/output
  - E.g. Can only specify **one** seed color, generated ramp has **nine** colors
- Clustering techniques difficult to understand without prior ML knowledge

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<https://cmci.colorado.edu/visualab/ColorCrafting/>

## Thank you!

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