Slides adapted from: https://cmci.colorado.edu/visualab/ColorCrafting/19-vis-colorcrafting.pdf

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

Algorithm

Evaluation

Critique

Background

Algorithm

Evaluation

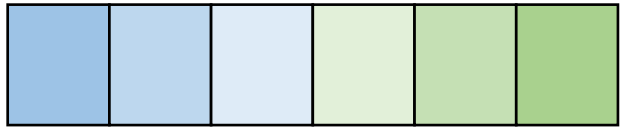
Critique

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

Sequential

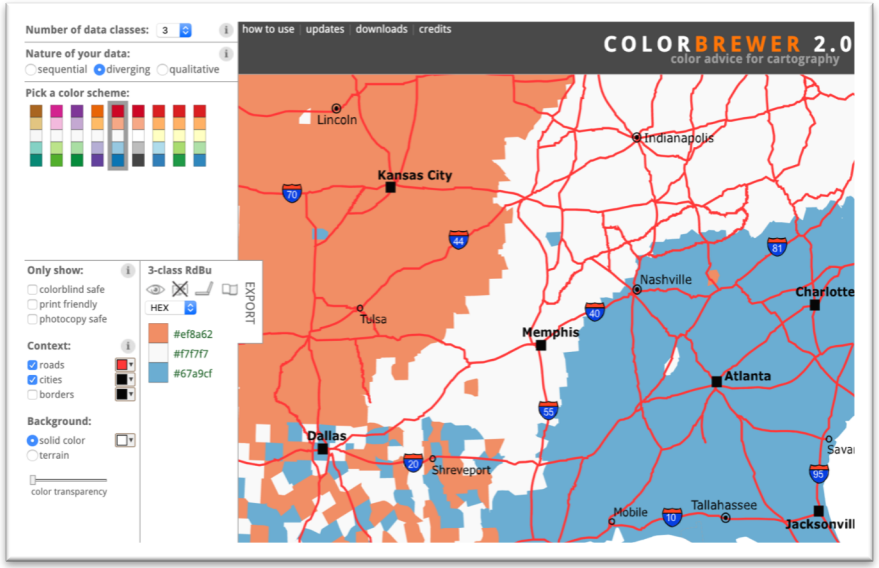
Diverging



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

Existing Approaches

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



Hand designed

Interpolating endpoints

[colorbrewer2.org]

Existing Approaches

- Choose from predefined ramps designed by color experts
  - Problem: choices are limited
- Select colors (control points) and interpolate
  - Problem: quality of interpolated colors are not very good

How can designers of *all* levels craft high-quality color ramps?

Hand designed

Interpolating endpoints

Background

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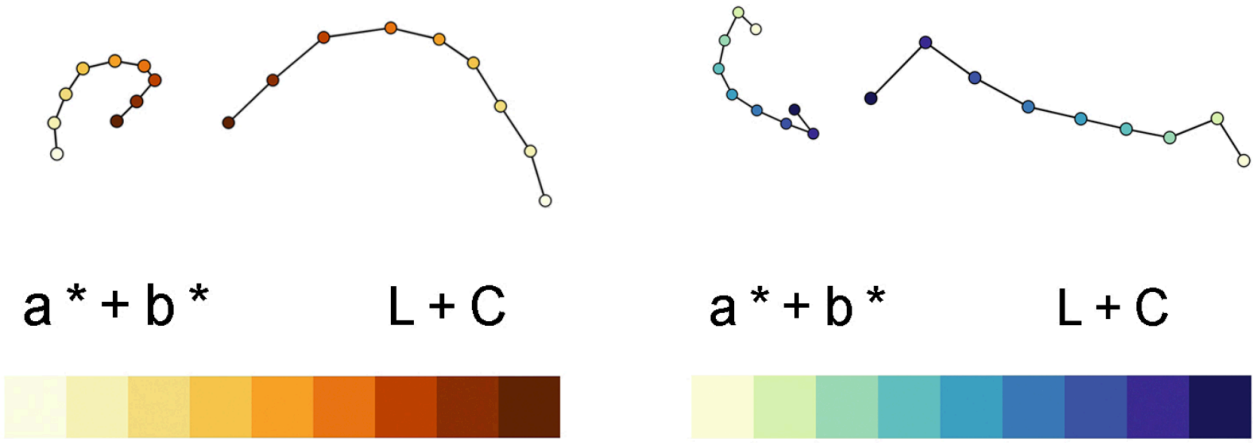
Modeling Designer Practice

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

Color ramps can be modelled as *curves*

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



L: lightness

a*: green to red axis

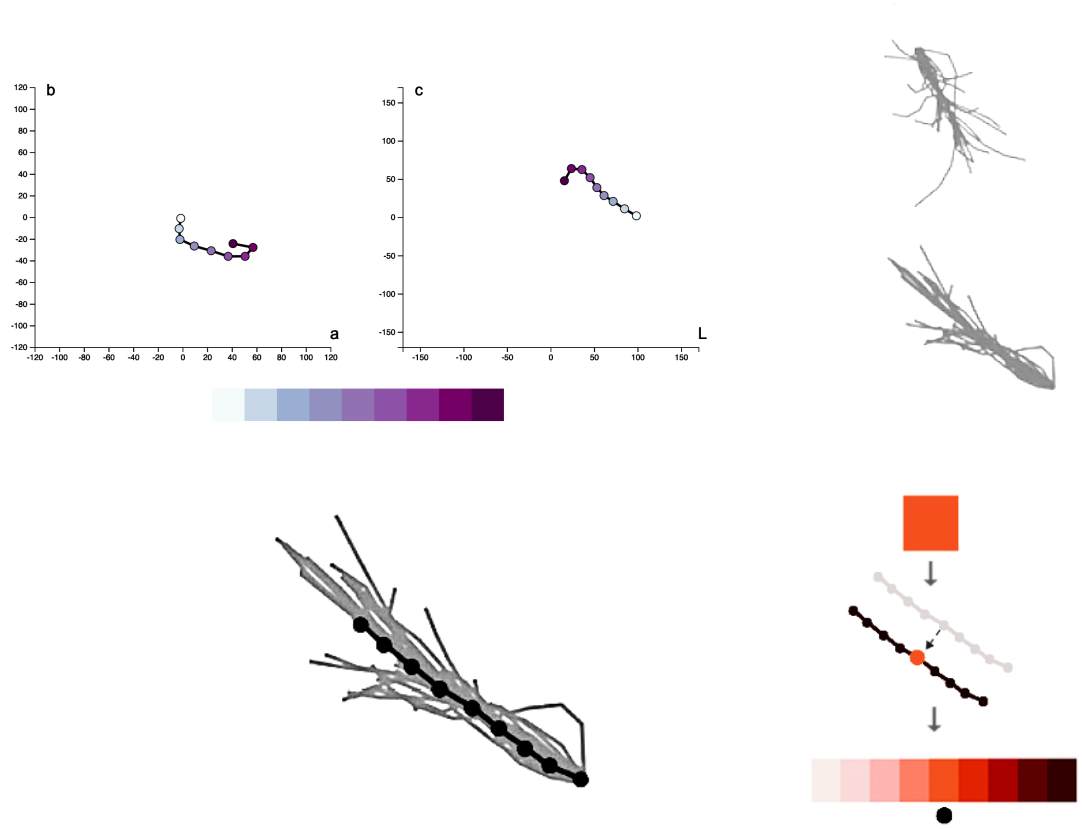
b*: blue to yellow axis

C: chroma

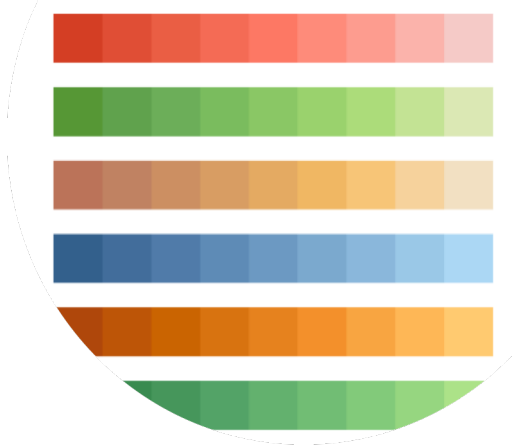
[Fig 2. Color Crafting: Automating the Construction of Designer Quality Color Ramps. Stephen Smart, Keke Wu, Danielle Albers Szafir, IEEE Trans. Visualization and Computer Graphics, 2019.]

Method Overview

1. Transform designer ramps into curves
2. Cluster the curves
3. Model the curves
4. Seed the curves

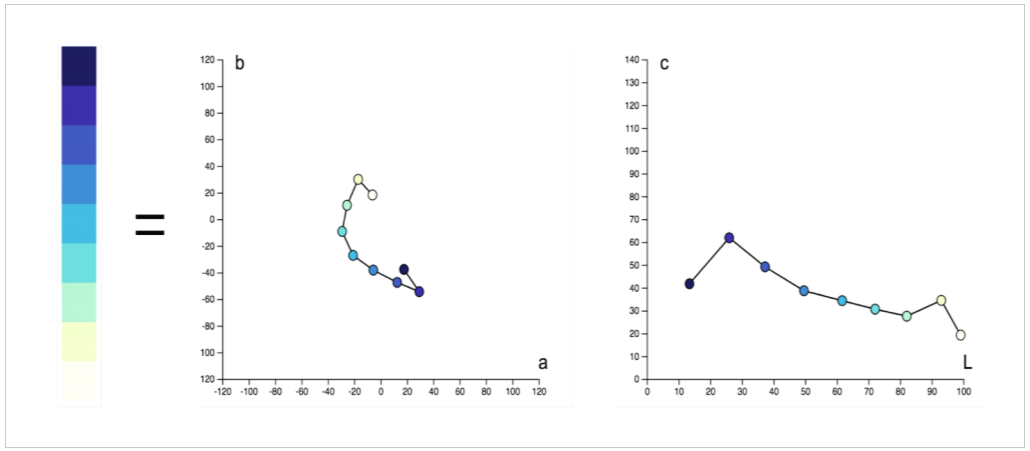


[Fig 3. Color Crafting: Automating the Construction of Designer Quality Color Ramps. Stephen Smart, Keke Wu, Danielle Albers Szafir, IEEE Trans. Visualization and Computer Graphics, 2019.]



[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



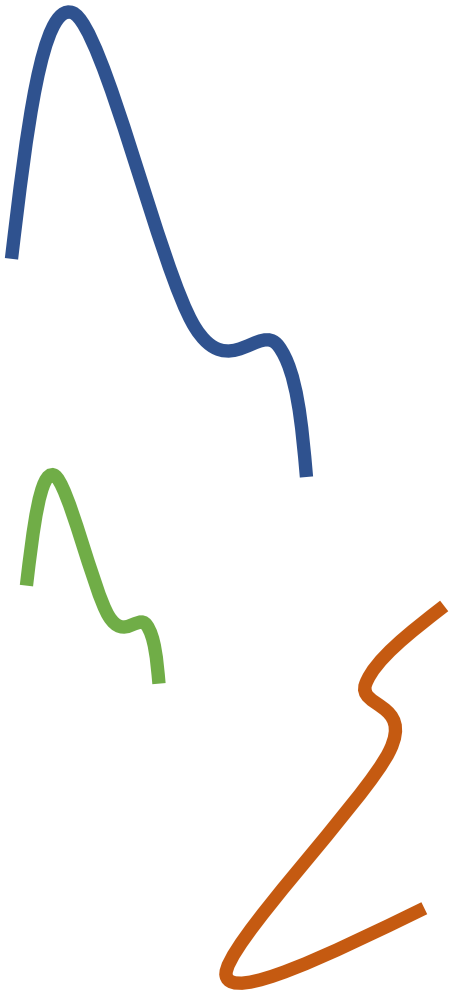
[cmci.colorado.edu/visualab/ColorCrafting/visualization/]

[Step 2] Curve Clustering

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

[Step 2] Curve Clustering

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

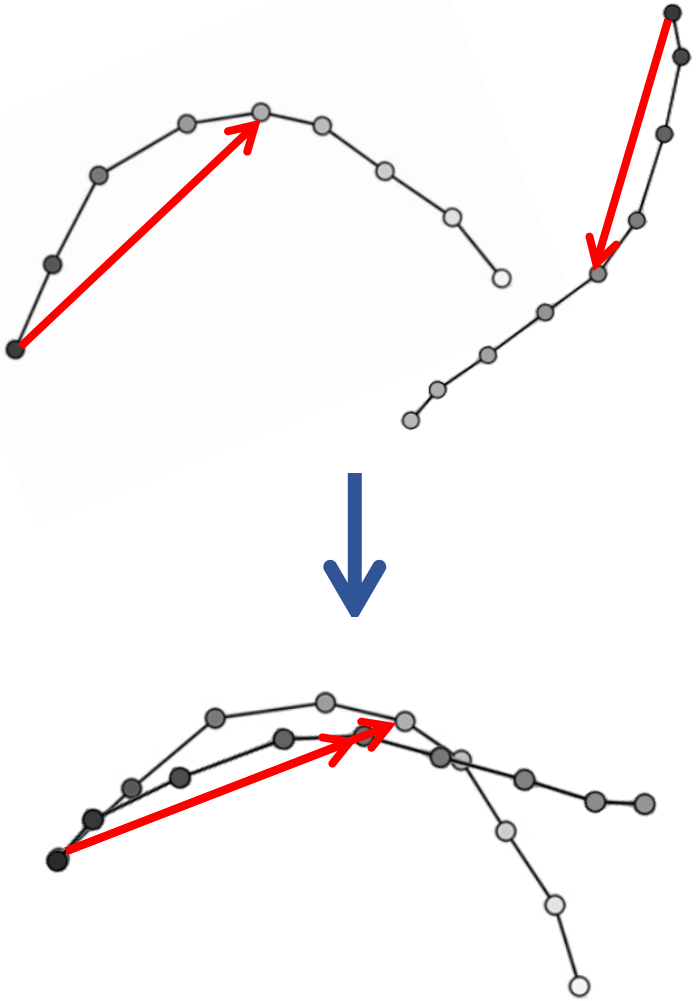


[Step 2] Curve Clustering

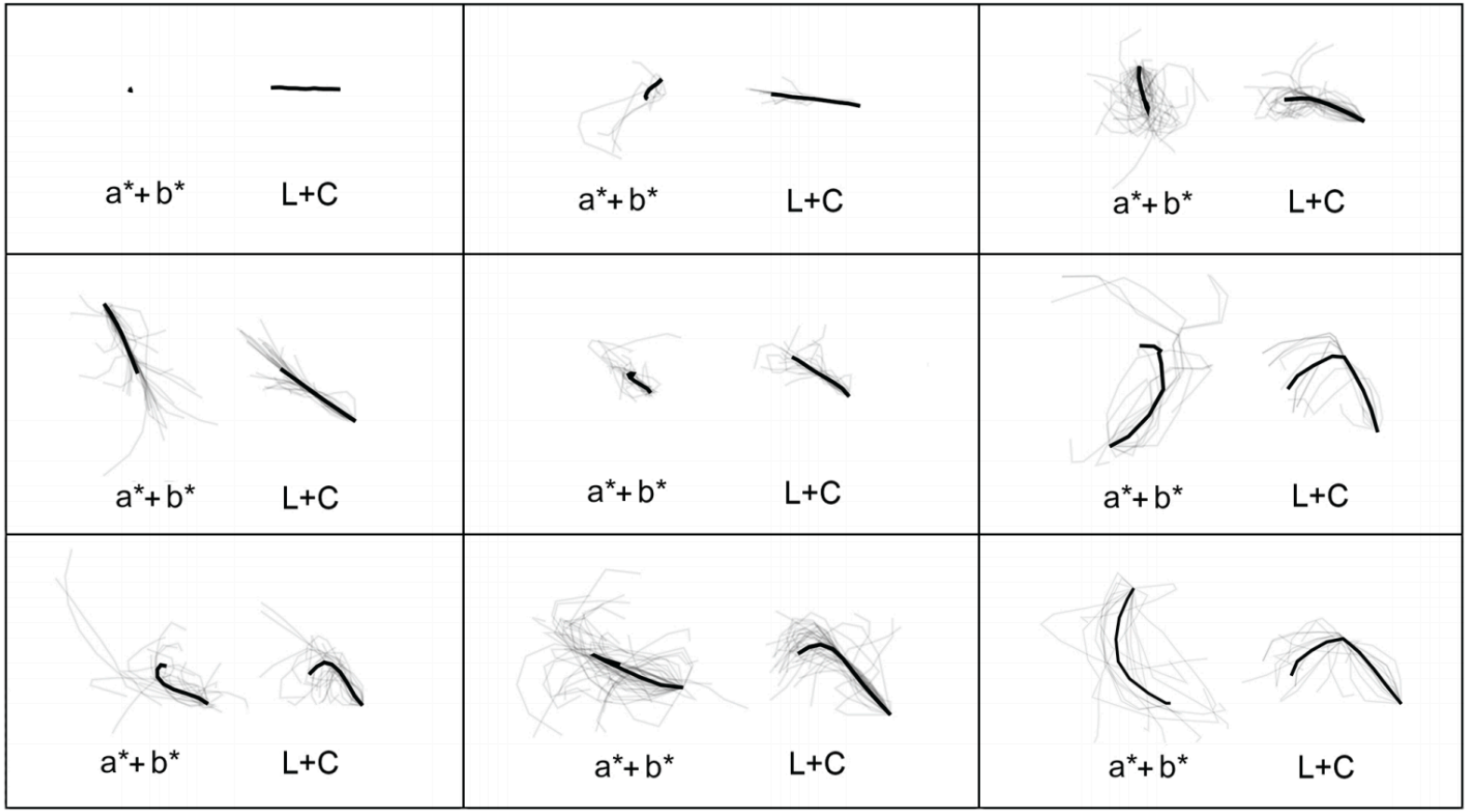
- Method 2: **K-means Clustering**
  - Group curves based on **color ramp structure**
  - Compute 255-dimension feature vector for each curve
    - Explicitly consider features related to structure of ramp
    - E.g. Rate of change between adjacent colors

[Step 3] Model Construction

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



[Step 3] Model Construction

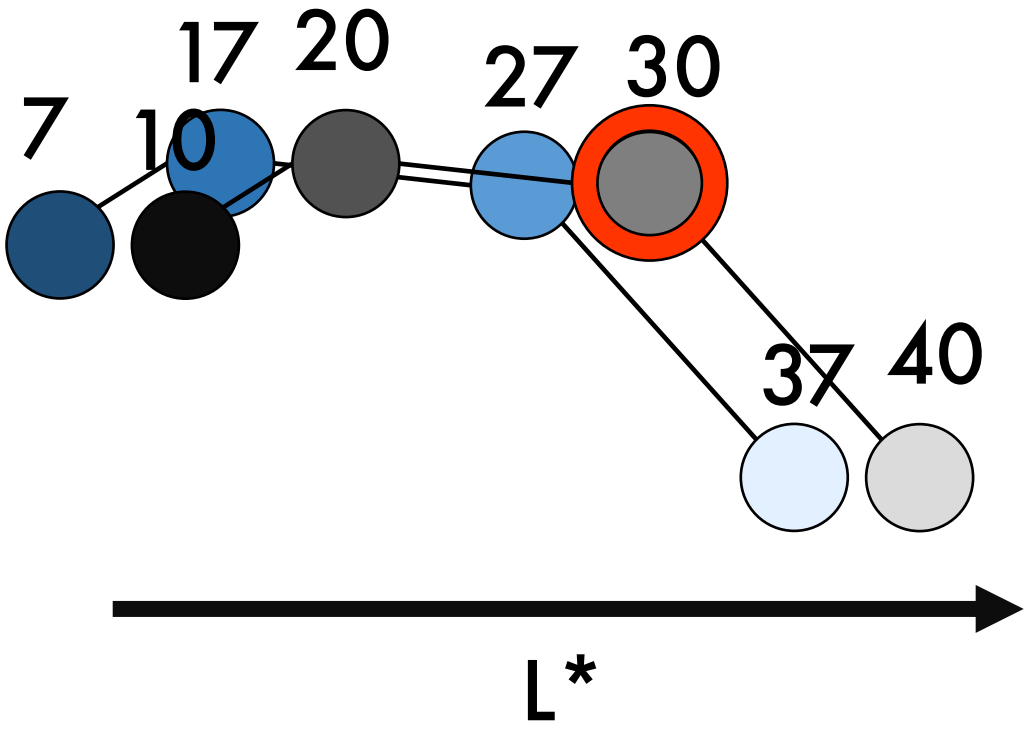


[Fig 4. Color Crafting: Automating the Construction of Designer Quality Color Ramps. Stephen Smart, Keke Wu, Danielle Albers Szafir, IEEE Trans. Visualization and Computer Graphics, 2019.]

[Step 4] Seeding

L* = 27

- User specifies **seed color**
- Compute ΔL* between seed and control points
- Translate curve
- Compute other colors based on relative positions of control points



What-Why-How Summary

What

- In Multiple items, multiple attributes
- Out Geometry (curve interpolating 9 points)

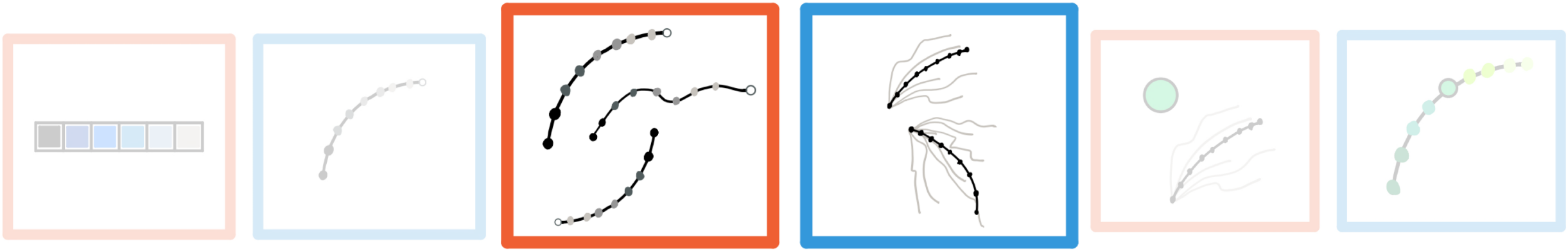
Why

- Derive (transform colors into curves)

How

- Encode position (scatterplot)

What-Why-How Summary



What

- In Multiple items, multiple attributes
- Out Clusters, geometry (representative curves)

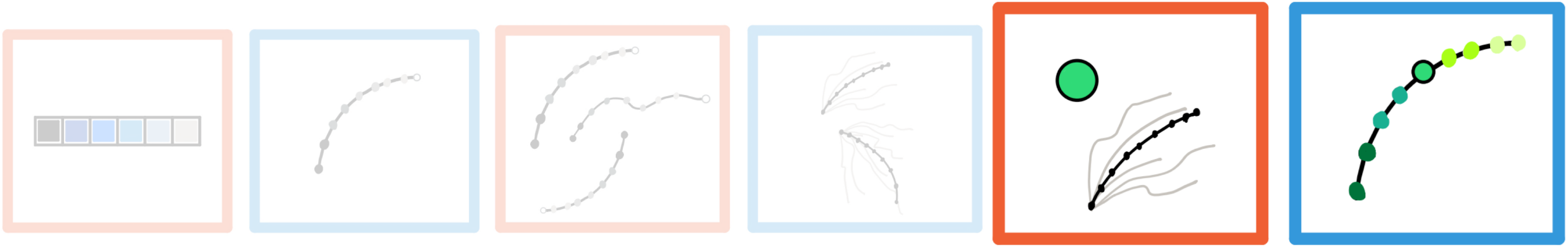
Why

- Discover (structural patterns)
- Derive (construct representative curve)

How

- Superimpose (curves)
- Encode position (scatterplot)

What-Why-How Summary



What

- In Geometry (curve, seed color)
- Out Geometry (curve interpolating 9 points)

Why

- Produce

How

- Encode position (scatterplot)
- Encode color

Background

Algorithm

Evaluation

Critique

Three Methods of Evaluation

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

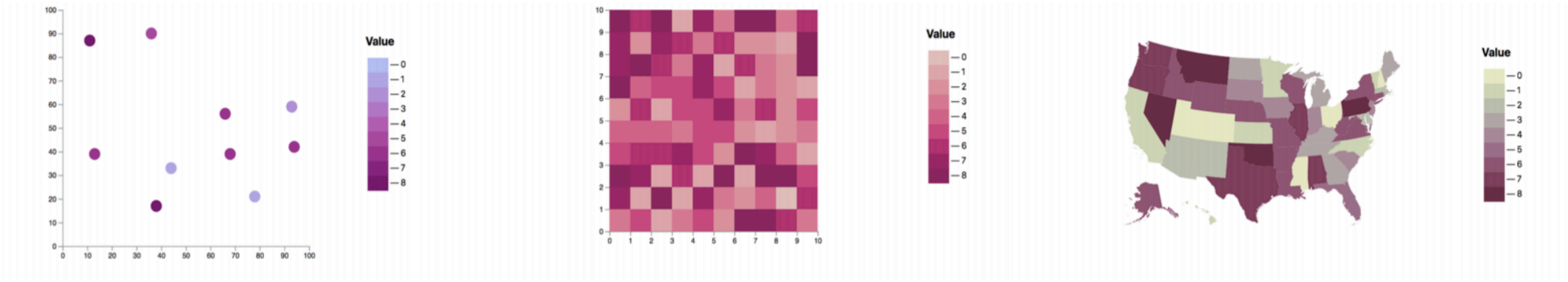
Lab Study/Expert Review

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

Evaluation

Lab Study/Expert Review

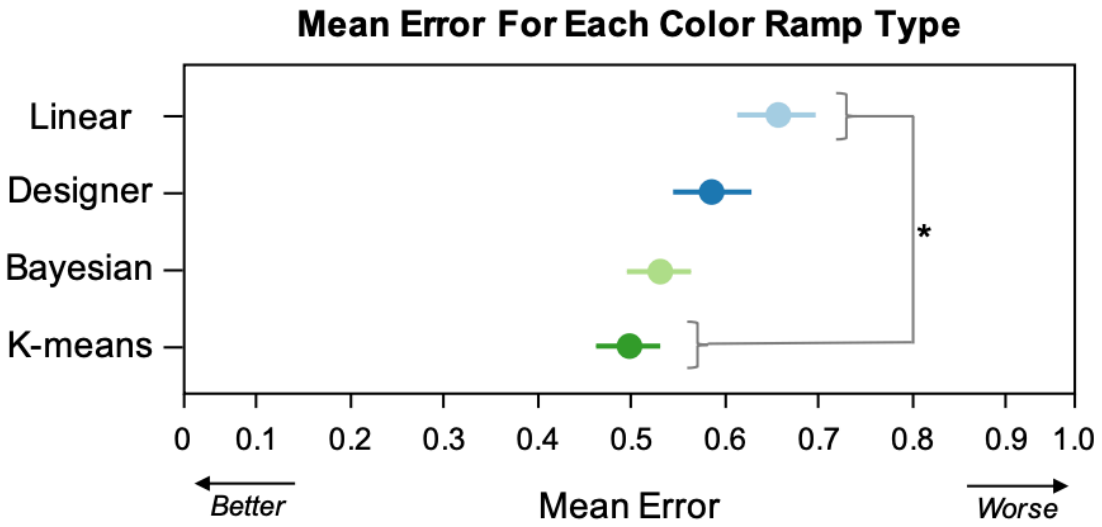
- 35 design practitioners
- Identify mark that encodes target value, rate "pleasantness"



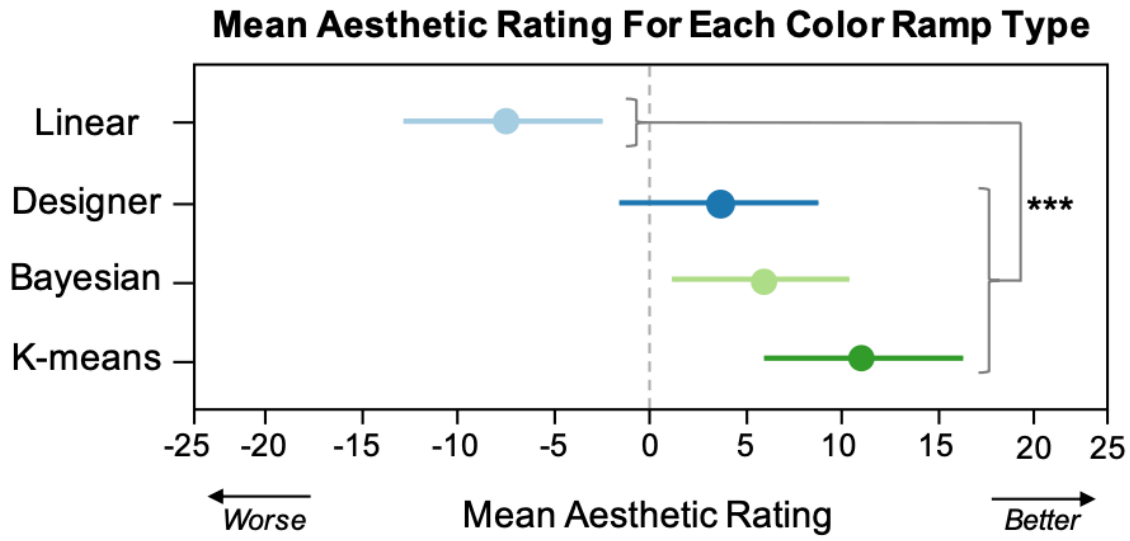
[Fig 7. Color Crafting: Automating the Construction of Designer Quality Color Ramps. Stephen Smart, Keke Wu, Danielle Albers Szafir, IEEE Trans. Visualization and Computer Graphics, 2019.]

Lab Study/Expert Review

Accuracy



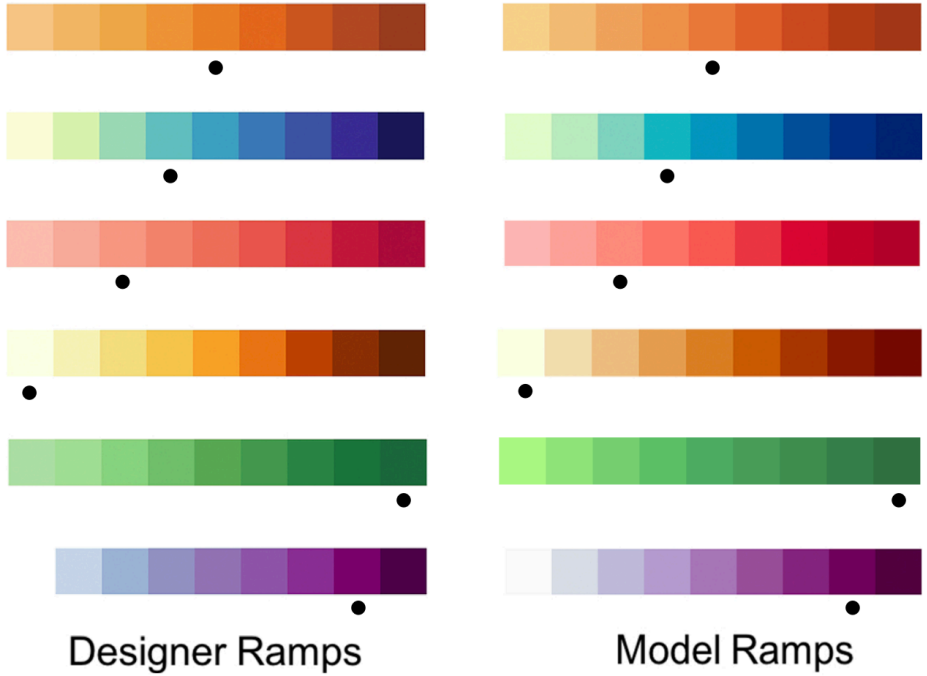
Subjective Preference



[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.]

Replication Study

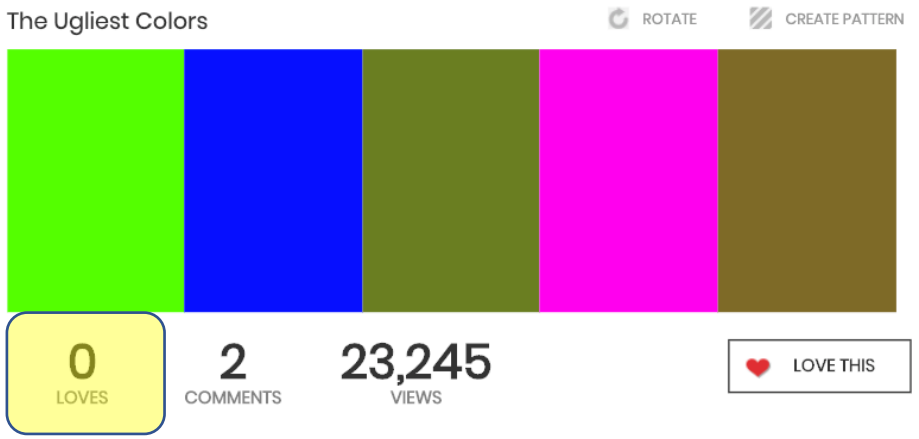
- Goal: Replicate expert ramps
  - Representative curves may aggregate away details
- Method: Use random seed color from designer ramp as input

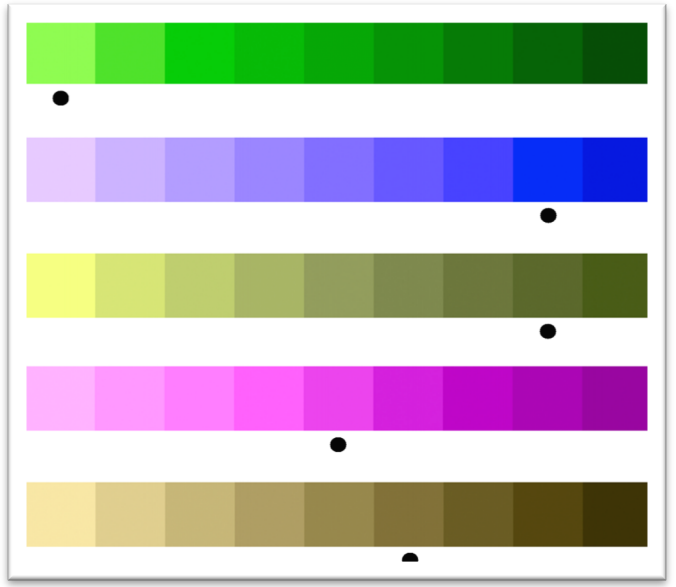


[Fig 10. Color Crafting: Automating the Construction of Designer Quality Color Ramps. Stephen Smart, Keke Wu, Danielle Albers Szafir, IEEE Trans. Visualization and Computer Graphics, 2019.]

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.]

Background

Algorithm

Evaluation

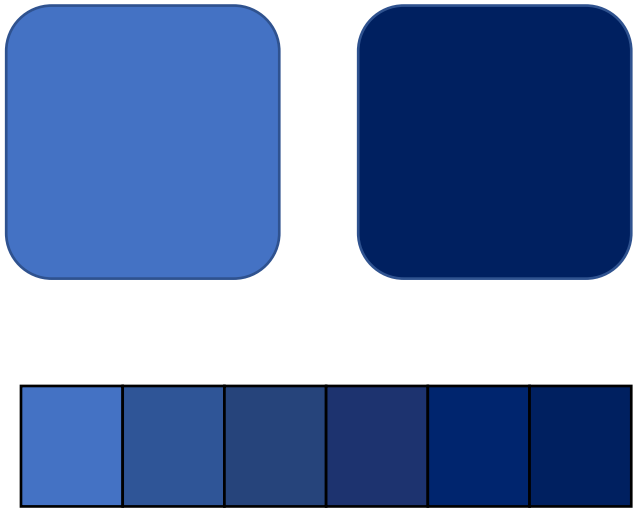
Critique

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!

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



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

Thank you!