## Phan\_ColorOrchestraOrderingColorPalettesForInterpolationAndPrediction

Highlighted – relevant for thesis

Color = at intersection of art and science

Focus: framework for real-time palette interpolation (need for separate work/study on photo colorization) and enriched photo recolorization

Discipline: color transfer, color harmony, grey-scale photo colorization, color picking interfaces

Tasks: photo recolorization (with multiple local palettes) (see Huang et al.) ; data-driven discovery of harmonious color combinations from existing color themes (color harmony); enhance color themes (see Wang et al.), image colorization; color palette sorting

Keywords: palette density estimation, palette interpolation

Core: model density of palette data to know how frequently a certain palette appears in the data

Target: user can obtain beautiful recolorized photos with the dedicated style of particular artist; predict missing colors of a palette given a number of observed colors in the palettes, predict the remaining colors of a 5-color palette, + useful for color learning from own painting collection

Goal: estimate density of color palettes to interpolate new palettes

Benefit: instead choosing from a few predefined themes, surf a continuous space for preferred themes

Advantages: more accurate prediction, fast enough to make real-time apps possible

Challenge: unnatural recolorization to more realistic colors; palettes are a set of unordered colors

Method: Gaussian process latent variable models (GPLVM) – a dimensionality reduction method to 2-D; interpolation (when the number is limited, interpolation helps extending the range of available choices);

Application: Photo-style Explorer

Terminology: palette = color theme

Rules of color use in fine art: warm colors for illuminating regions and color colors for shaded regions; artists use their favorite color combinations over the actual colors of the objects being painted

* Psychological experiments on human perception to derive laws of color compatibility
* Tasks: from color harmony to …
  + Harmony templates (Cohen Or et al.)
  + Assess quality of photographs (Nishiyama et al.)
  + Segmented photo colorization (Sauvaget et al.)
  + Predict color ratings (O’Donovan et al.)
  + Color suggestion
  + Theme extraction
  + Theme optimization
  + Collaborative filtering (?) to know about user preference of color combinations
  + Harmonious colors assigned to 2D patterns (Lin et al.) based on rating regression model in factor graph based on Markov chain Monte Carlo method (too expensive for real-time apps), only pairwise palette color combinations, no global training
  + Interpolate color palette on demand using *manifold learning* on palette data to provide a wider range of color choices for image recolorization – modeling the manifold of color palettes rather than colors (Phan et al.), based on a data-driven probability density function of color themes and recommendations to the user based on their probabilities for color compatibility prediction and color suggestion
  + Map color distribution from a reference image to a given image using histograms = color transfer
  + Automatic discovery of styles in a collection of images via clustering (Lin et al.)
  + Image recolorization by manual modification to the image’s global color palette (Chang et al.)
  + Grey-scale image colorization by retrieving semantically similar photographs (Chia et al.)
  + Change colors of an object: color manifold and dimred (Nguyen et al.)
  + Browse possible appearance of an image (Shapira et al.)
* Application: selecting colors
  + Color picker (wheel-like interface vs. slider-like interface) (see Adobe Color CC, Coolorus)
  + Color mixer pads (see Corel Painter, MyPaint)
  + Gradient mixer – gradients between colors
  + Palette breeder – generate new palettes with an algorithm
  + Curves of color harmony parameters (see Wijffelaars et al.)
  + Color names
* Palette (object) arrangement
  + Arrange objects into locations so that the pairwise distances between objects are preserved as much as possible after being aligned into the new location
  + Methods: kernelized sorting technique = kernels and centering matrix to make distances comparable
  + Method: IsoMatch = match objects with a layout
* Steps of this paper:
  + Data collection and processing: images of fine art artists, extract color themes methods:
    - Palette extraction from painting as a whole
    - Palette extraction from local patches from the paintings: use sliding window over painting of step-size 100 pixels to extract color patches, randomly sample 1000 pixels from each patch, apply k-means in CIE\*Lab space to cluster pixels obtaining K=5 (7 or 10) clusters, one color palette per patch, per artist randomly select 400 palettes and aggregate to a dataset of color palettes
  + Palette ordering:
    - with Binary Palette Sort algorithm to get sorted palette features, distance metric for two palettes of different lengths the Hausdorff distance (no Euclidean distance) is used
      * partitioning
      * merging
    - with Brightness Sort algorithm
  + Learning and inference: apply density estimation techniques GPLVM/PCA interpolation on palette data, unsupervised learning over min. 10 example paintings for consistent color themes
    - Palette interpolation: did not choose neural networks or latent Dirichlet allocation, but Gaussian process latent variable models, manifold learning
    - Density estimation: GPLVM vs. PCA+GMM
    - Color prediction: recover missing colors by projecting the partially observed palette onto the latent space using GPLVM
  + Applications:
    - Photo Recolorization (color transfer method): summarize color characteristics of a set of source photos, infers set of colors for each region of the destination photo(vs. only one color for an image region), + local shades are preserved
    - Photo-style Explorer : surf through an infinite space of color styles and refine the result, cache intermediate values for real-time use, color picking “SmartPalette” interface (add-in for MyPaint), palette prediction is instantly (<.5 sec) presented to the user for each stroke in the original image
  + Evaluation:
    - Palette Sort Comparisons: Hue Sort and Brightness Sort fail – if no strong constrast or hue, vs. BPS; ordering performance = mean distance between the colors in two consecutive palettes, averaged over all palettes in a dataset
    - Context localization: BPS preserves the painting context of each color locally embedded in a palette dataset; similar palettes should describe similar objects or regions
    - Recolorization technique: colors with the same indices across color palettes applied to the same regions in the source image
    - Color prediction: learning approaches are better, Brightness is the most important factor in visual data
  + Limitation:
    - No perfect alignment with distant palettes – replace MHD kernel in KPCA sorting with a more advanced kernel
    - No evaluation of photo-style exploration with user studies
  + Future:
    - Context-specific photo recolorization: train on similar scenes such as beach, mountain, summer, to recolorize novel images;
    - How different image segmentation results affect recolorization results