Web-based Learning of Naturalized Color Models for Human-Machine Interaction

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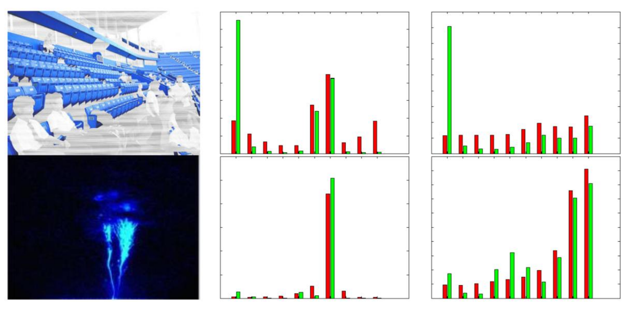
Overview

Motivation

- Recognizing and naming attributes is essential for HRI
- Large annotated data sets required to learn robust models
- Use Internet queries to retrieve training data and learn natural, robust models for HRI (different domain!)

Summary

- Smaller model trained on raw data provides equal/better performance
- Probabilistic HSL model for domain adaptation combined with X² ranking



Model

Probabilistic HSL Color Observation Model

- Images retrieved through Internet image search engines are often **synthetic or highly** processed
- Improve quality with a transformation that adds noise to **approach natural distributions** for artificial images

1) Probabilistic Hue-Saturation-Lightness color model to **reflect degree of randomness** of "measured" colors

$$l_d = l$$

$$f_{\mathcal{VM}}(x;\mu,\kappa) = \frac{1}{2\pi I_0(\kappa)} e^{\kappa\cos(x-\mu)}\Big|_{\mu=h_d}$$

$$f_{\mathcal{TN}}(x;\mu,\sigma,a,b) = \frac{\frac{1}{\sigma} f_{\mathcal{N}}(\frac{x-\mu}{\sigma})}{F_{\mathcal{N}}(\frac{b-\mu}{\sigma}) - F_{\mathcal{N}}(\frac{a-\mu}{\sigma})}\Bigg|_{\substack{\mu=s_d\\ a=0\\ b=1}}$$

2) κ and σ define the degree of randomness and the **randomized HSL transform resamples** data for training

$$\kappa = (1-s)^{-p_s}(1-b)^{-p_b} - 1 \qquad \sigma = \kappa^{-1/2}$$

$$b = 2\min(l, 1-l) \in [0,1]$$

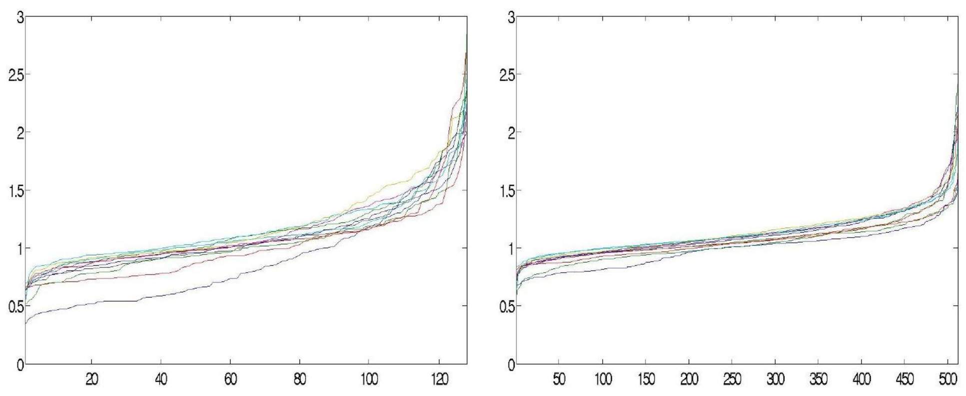
Learning Color Terms

- 11 basic color terms in English (other colors are derived)
- Train color term models on randomized training data

1) Train initial models and use **X² ranking to remove outliers** and images degraded by a huge amount of background

$$d^{zd}_{\chi^2}(P'(\cdot|z), P(\cdot|d)) = \sum_{w\in W} \frac{(P(w|d)-m)^2}{m} \quad m = \frac{P'(w|z)+P(w|d)}{2}$$

$$R^{zd}_{\chi^2} = \frac{d^{zd}_{\chi^2}}{\min_{z'\neq z} d^{z'd}_{\chi^2}}$$



2) Probabilistic latent semantic analysis with a latent background topic to learn the color models

$$P(w|d, l_d = z) = \alpha_d P(w|l_d = z) + (1-\alpha_d) P(w|bg)$$

3) Assign color term with highest likelihood (uniform prior)

Evaluation

Data

- Training with 512 Google images for each color term

- Evaluation with E-Bay data set (10 images per term)
- E-Bay data set extended with labels assigned by 5 persons

- 32x8x8 HSL histogram bins; no preprocessing of images (Weijer et al.: 10x20x20 L*a*b*; foreground segmentation)

Results

Method	Space	Cars	Shoes	Dresses	Pottery	Total
Randomized						
X² rank	**HSL**	**73.63**	**92.73**	**88.18**	**79.01**	**83.41**
pLSA-bg	HSL	69.18	87.36	87.36	77.36	81.32
Deterministic						
X² rank	HSL	68.18	91.81	87.27	76.36	80.90
pLSA-bg	HSL	66.36	90.00	85.45	73.63	79.31
Reference						
Weijer	L*a*b*	71.82	92.73	86.36	83.64	83.64
Human	Brain	92.73	90.18	91.99	87.82	90.64

- X² rank color **labeling behavior closer to human**, i.e distance between confusion matrices is 0.57 and 0.73, resp.