Perceptual Evaluation of Color-to-Grayscale Image Conversions

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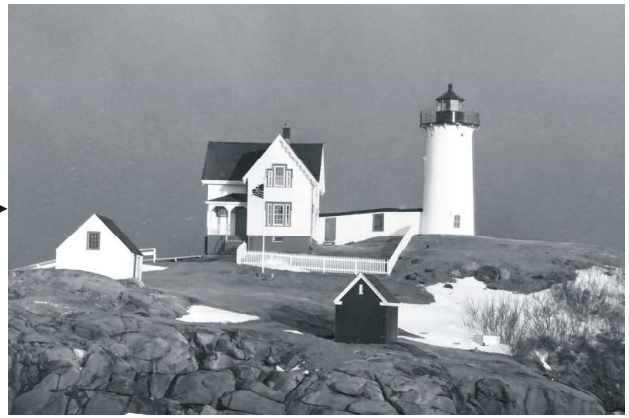
Content

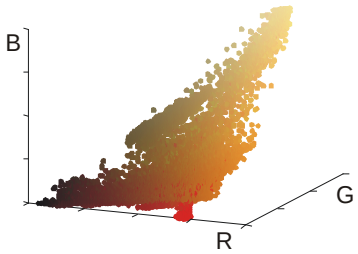
- Color-to-Grayscale Conversion, Motivation
- Related Work
- Conducted Experiments
- Results
- Conclusions

Color-to-Grayscale Conversion

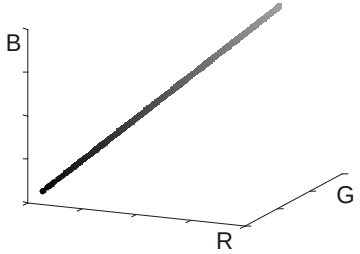
- 3D data → 1D data

Color-to-grayscale





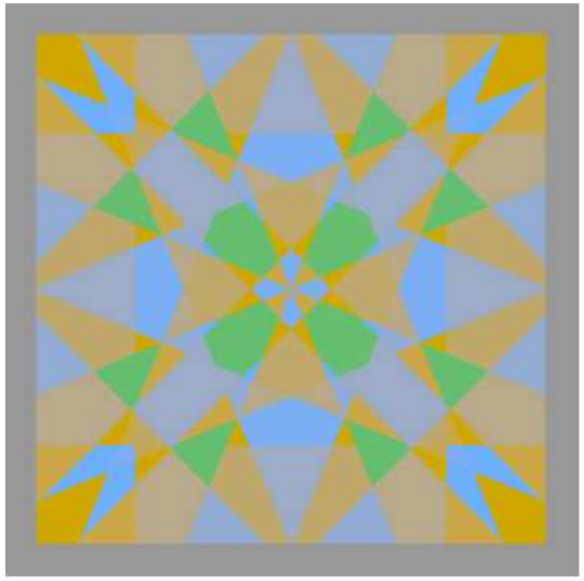
Color Image



Grayscale Image

Color-to-Grayscale – Extreme Case

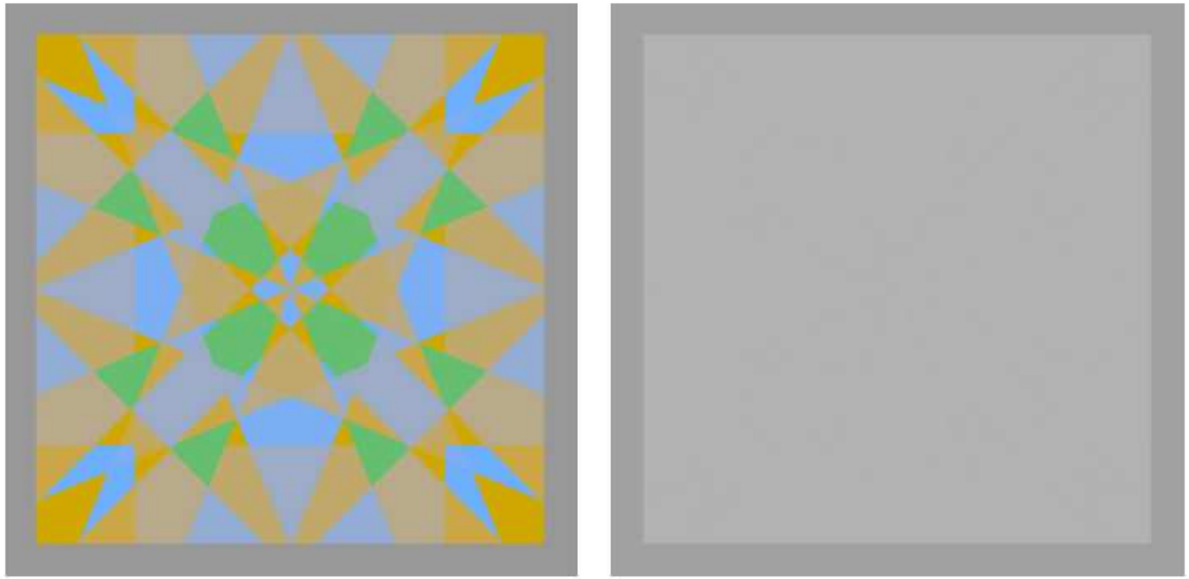
- Color image with constant luminance



Color-to-Grayscale – Extreme Case

- Color image with constant luminance

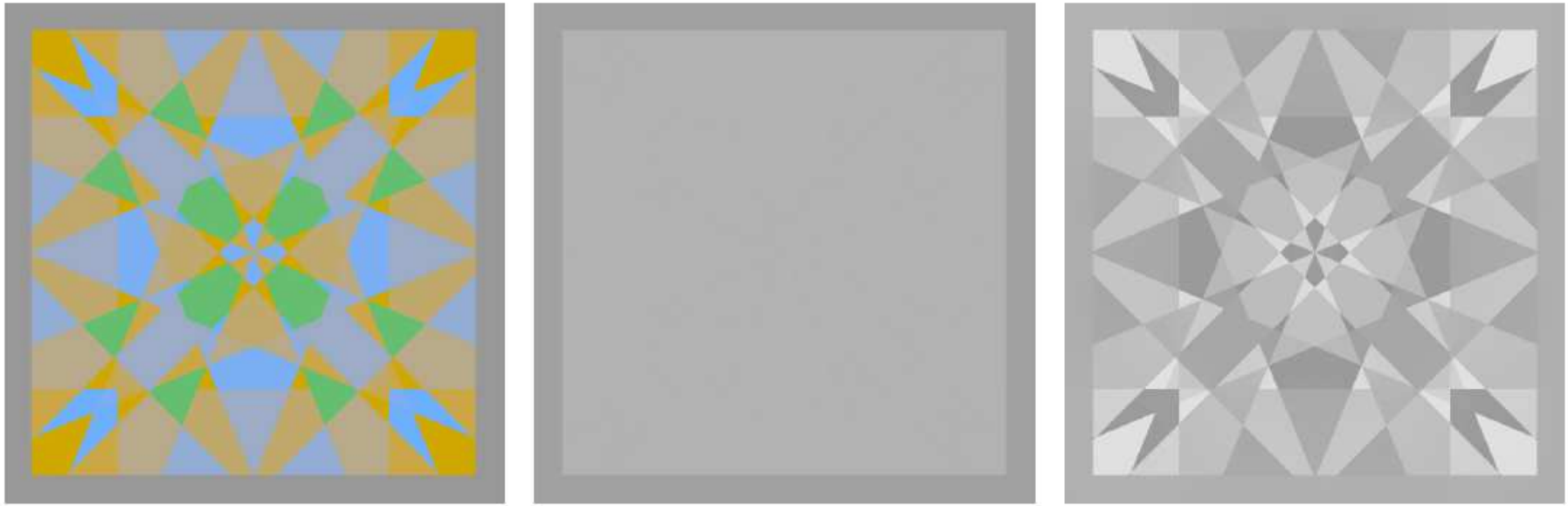
CIE-Y luminance conversion



Color-to-Grayscale – Extreme Case

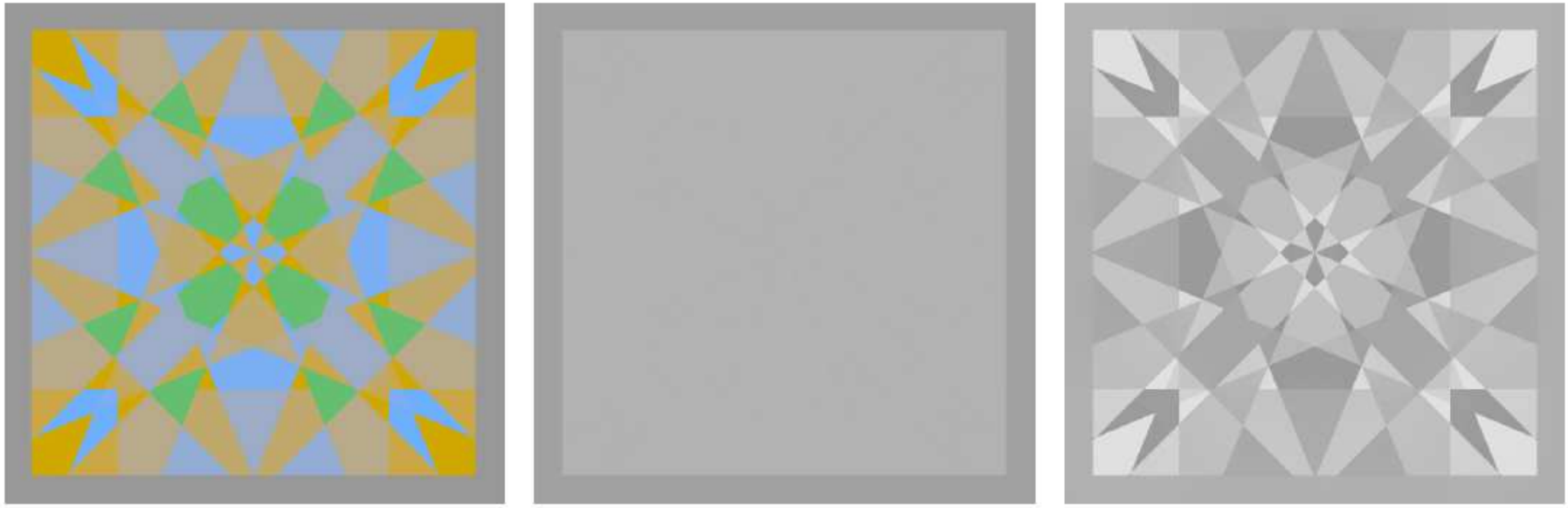
- Color image with constant luminance

[Neumann et al. 07]



Color-to-Grayscale – Extreme Case

- New methods advocated in this way
- But how do the conversions perform in practice?



Experimental Evaluation – Motivation

- Fair evaluation of conversions
- Assessment of strengths and weaknesses
- Deeper understanding of the examined field

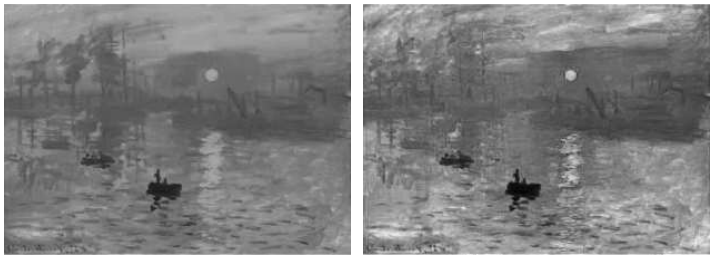
- However, no deep experimental study exists

Related Work – Evaluations

- [Bala & Eschbach 04] – preference experiment
  - 3 input images, 6 observers, hardcopy prints
  - 2 conversions: [Bala & Eschbach 04], CIE Y
  - result: [Bala & Eschbach 04] better than CIE Y
- [Rasche et al. 05] – accuracy experiment
  - 6 input images, 17 observers
  - 2 conversions: [Rasche et al. 05], CIE Y
  - result: Rasche05 better or comparable to CIE Y

- [Connah et al. 07] – preference experiment
  - small, but interesting study, parallel to our research
  - 6 input images, 6 observers
  - 6 conversions: CIE Y, [Alsam & Kolas 06], Decolorize, Rasche05, Bala04, [Socolinsky & Wolff 02]
  - result: the (preference) performance is image dependent

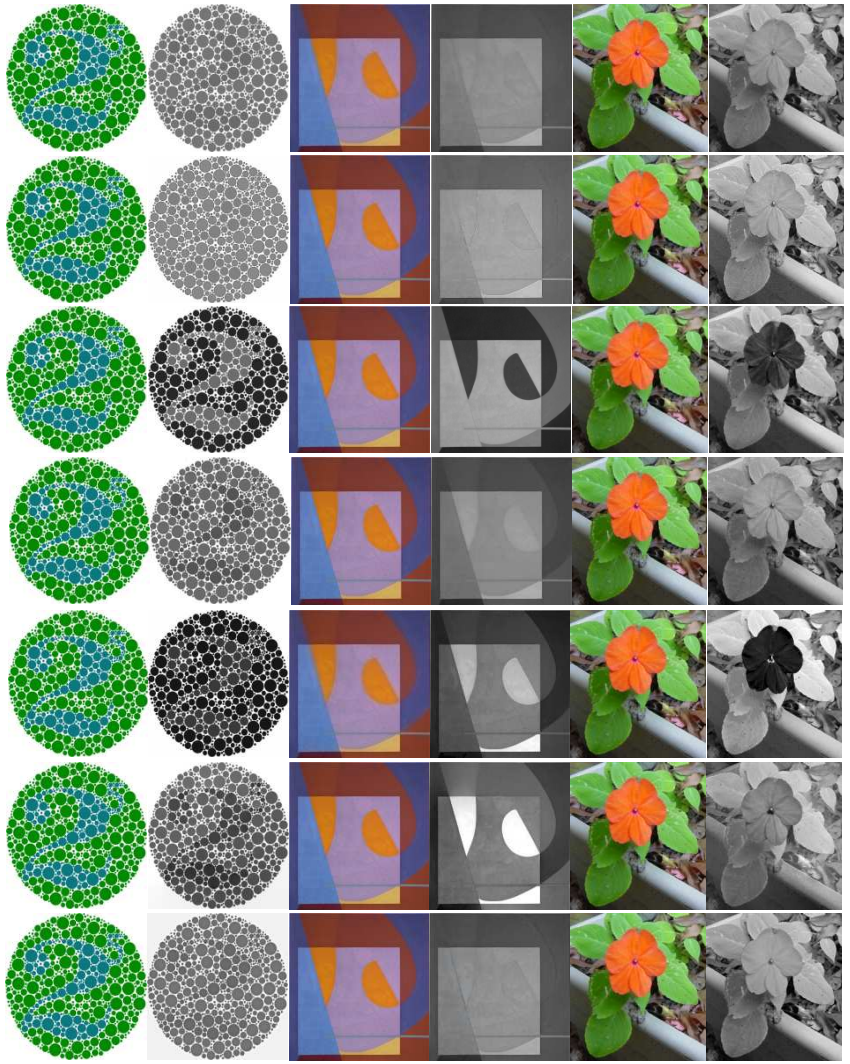
Our Experiments



- Accuracy
- Preference
- 2AFC design
  - **`http://ranker.sourceforge.net`**
- 119 Participants
- 7 state-of-the art methods
  - default parameters to convert 24 input color images

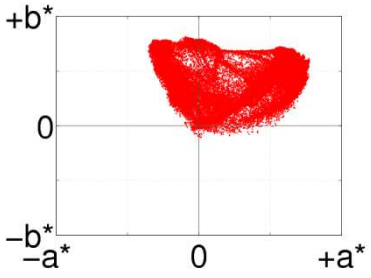
Evaluated Color-to-Grayscale Conversions

- CIE Y
  - Y channel of CIE XYZ model [1931]
- Bala04
  - [Bala & Eschbach 04]
- Decolorize
  - [Grundland & Dodgson 05]
- Color2Gray
  - [Gooch et al. 05]
- Rasche05
  - [Rasche et al. 05]
- Neumann07
  - [Neumann et al. 07]
- Smith08
  - [Smith et al. 08]



Conducted Experiments – Input Stimuli

- 24 color images
- Varying characteristics, motifs, and origins
- Plants, foliage, fruits & vegetables, portraits, photos, paintings, cartoons, color testing images, computational images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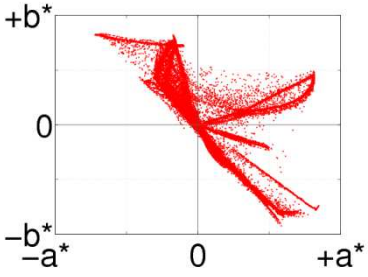
© ImageKingdom.com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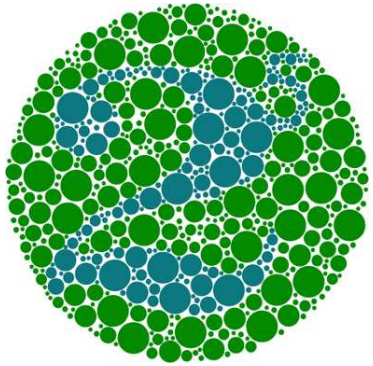

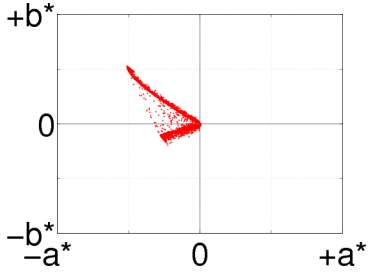
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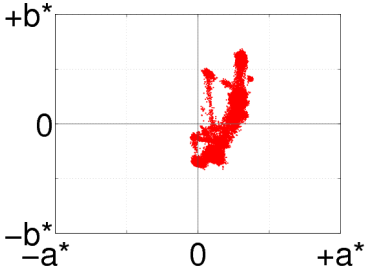
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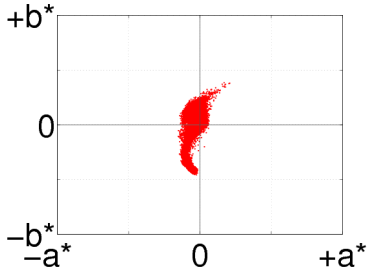
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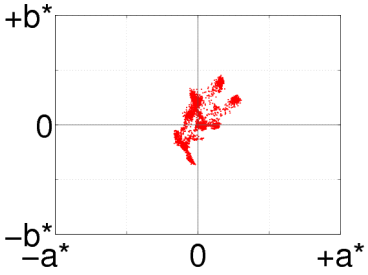
COLORS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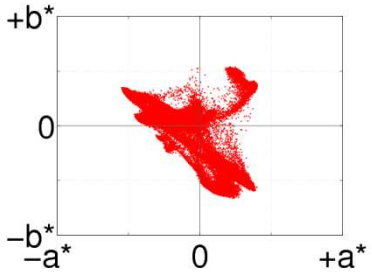
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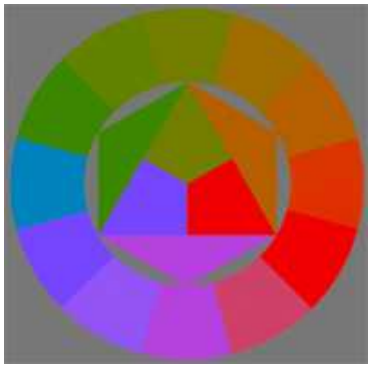

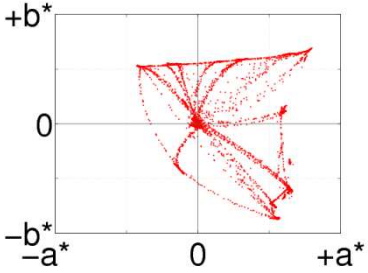
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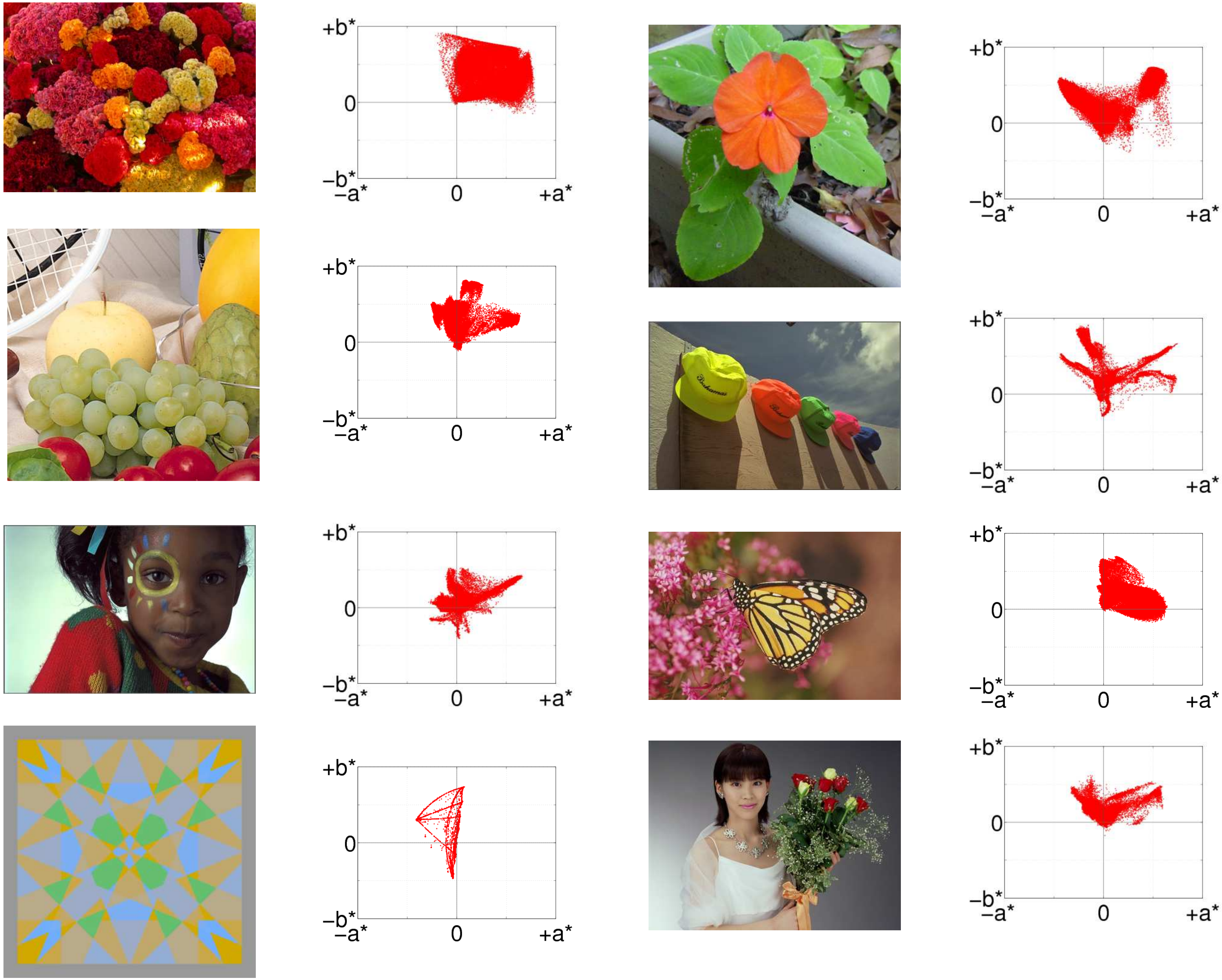

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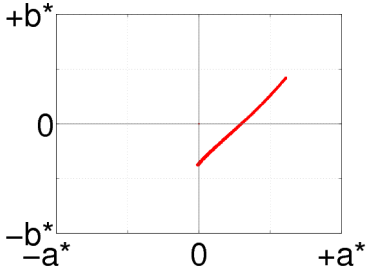
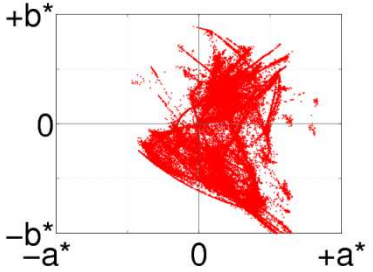
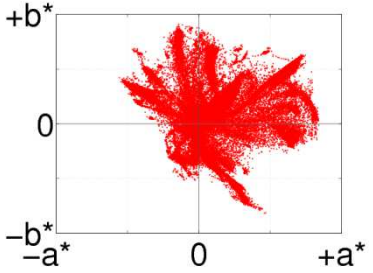
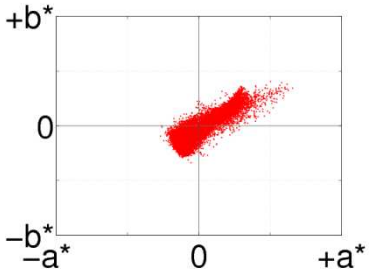


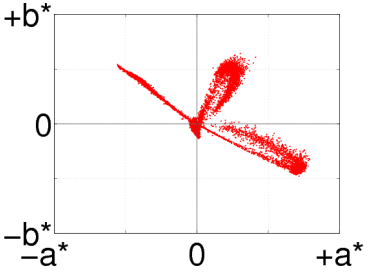


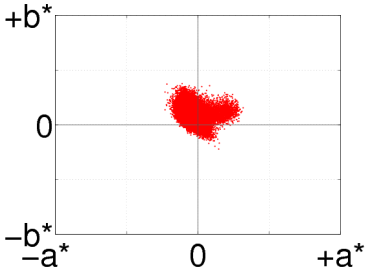


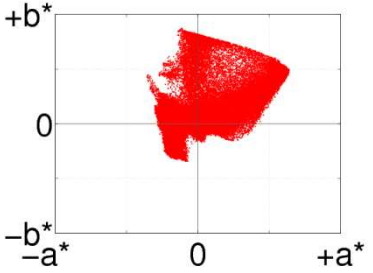


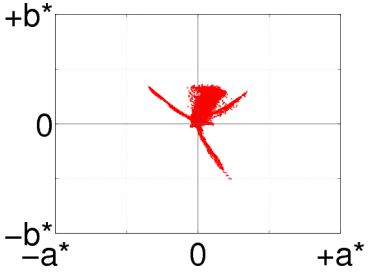
The luminance generated by a physical device is generally not a linear function of the applied signal. A conventional CRT has a power-law response to voltage: luminance produced at the face of the display is approximately proportional to the applied voltage raised to the 2.5 power. The numerical value of the exponent of this power function is colloquially known as *gamma*. This nonlinearity must be compensated in order to achieve correct reproduction of luminance.

As mentioned above (*What is lightness?*), human vision has a nonuniform perceptual response to luminance. If luminance is to be coded into a small number of steps, say 256, then in order for the most effective perceptual









Results

- Over 20 000 human responses collected ➔ Thurstone's Law of Comp. Judgments (case V) ➔ z-scores (standard scores) ➔ statistics

- Multifactorial (n-way) ANOVA
  - Factors: *input images (24)*, *experiments (2)*, *conversions (7)*
  - Statistically significant main effect: *conversion* ➔ meaningful to proceed with the evaluation
  - Statistically significant interaction effects: *conversion x experiment*, *conversion x input image* ➔ meaningful to show results separately for each input image and each experiment

Results – Overall

- Multiple comparison test [Tukey]
  - Overall ranking of conversions
  - Statistical significance of differences

Decolorize	Smith08	CIE Y	Color2Gray	Rasche05	Neumann07	Bala04
0.544	0.487	0.158	0.149	-0.203	-0.317	-0.819

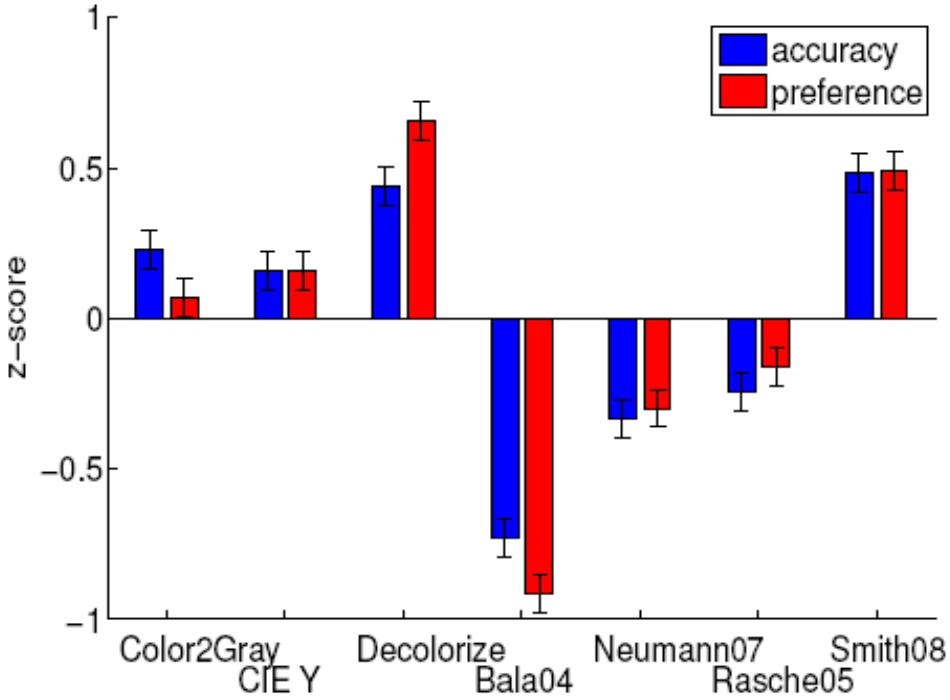
Results – Preference and Accuracy

- Strong correlation between conversion **accuracy** and the grayscale image **preference**

  (r=0.97)

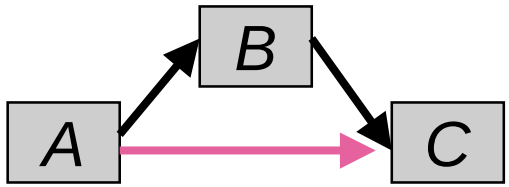
- PCA
  - 1st component: 96% of data variance
  - One dimension prevails

- CIE Y and Smith08 – consistent performance

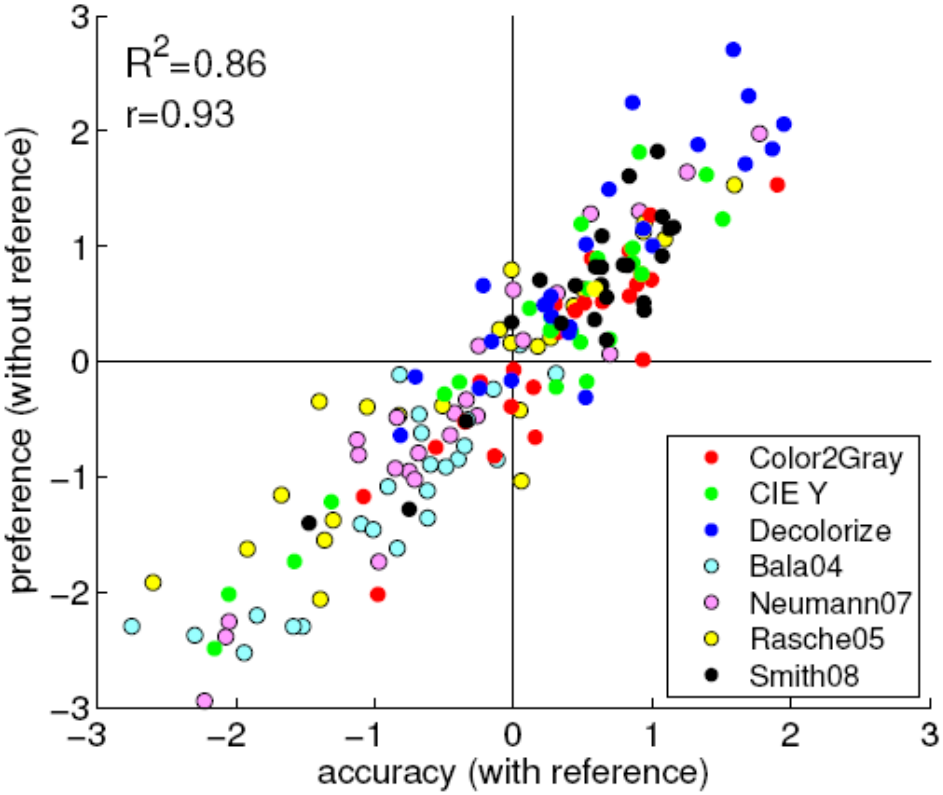


Results – Individual Images

- z-scores independently for each image
- coef. of agreement
- coef. of consistency



- details tabulated in the paper



http://www.cgg.cvut.cz/~cadikm/color_to_gray_evaluation

Results – Individual Images

- No conversion produces universally good results
- Each of inquired conversions ranked the worst for at least one input image
- Apart from Bala04, each conversion ranked the best for some input image

- Decolorize good for images with narrow gamuts
- Smith08 good for colorful images

➔ To improve robustness of current conversions over various inputs

Conclusions

- The first representative evaluation of color-to-grayscale conversions
- 7 conversions, 24 input images, 119 observers
- Accuracy and preference experiments

- Overall best **accuracy**: Smith08
- Overall best **preference**: Decolorize
- **Accuracy** and **preference** highly correlated
- No universally best conversion

Conclusions

- Future Work
  - exploration of space of parameters
  - evaluation with regard to videos (non-still images)

- Acknowledgements
  - Grants MSM 6840770014 and LC-06008
  - Z. Míkovec, I. Malý, O. Poláček (Ulab team)
  - M. Kalouš, J. Křivánek, J. Bittner
  - all the participants

Thank You for Your Attention

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