THE CORRELATION BETWEEN PREFERENCE COLOUR REPRODUCTION IMAGE QUALITY METRICS AND PSYCHOPHYSICAL DATA

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Aims

- To find out the preferred Gamut Mapping Algorithm(s) by evaluating a set of GMAs from a reference medium gamut to two different sized output gamuts in ICC print workflow

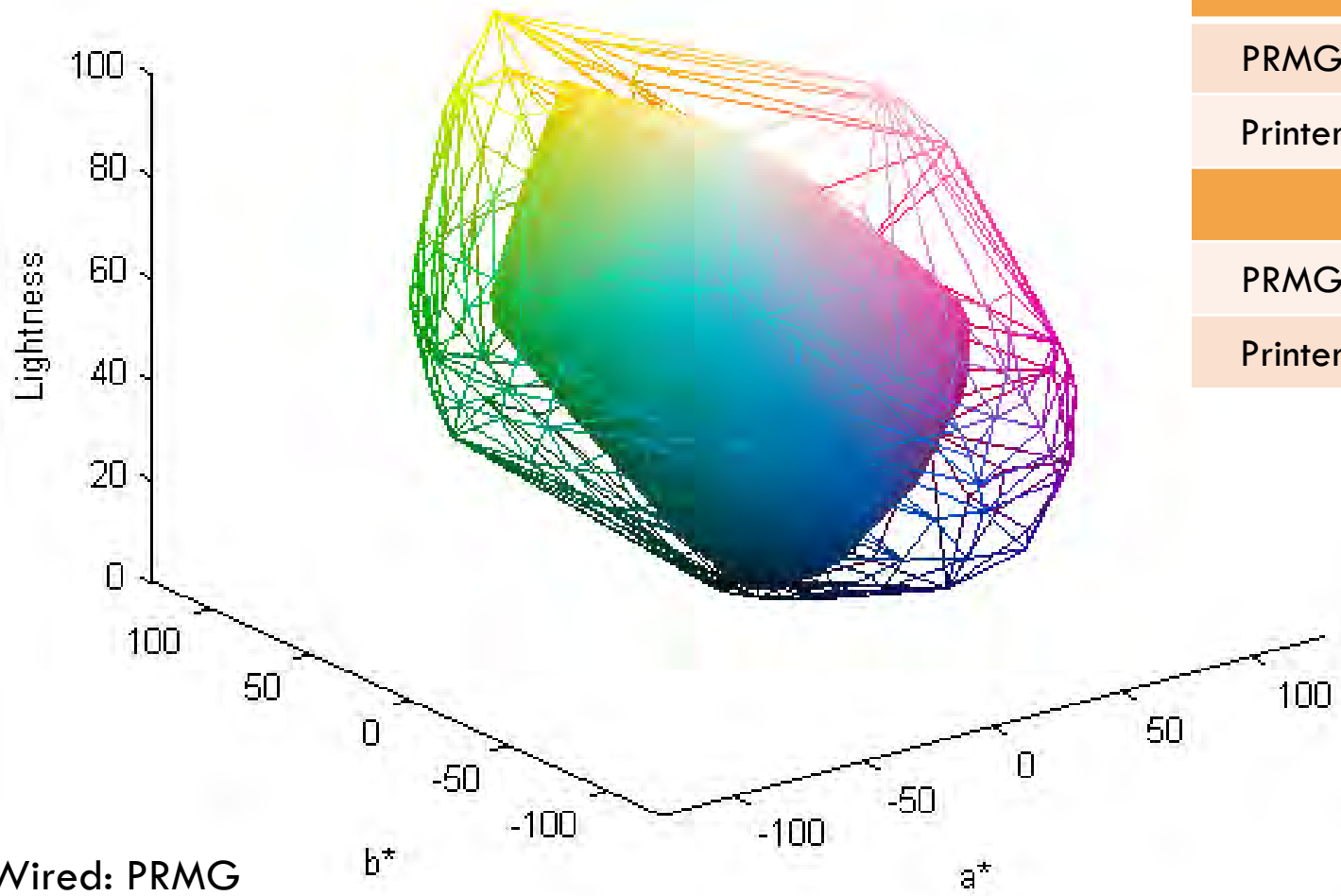
- To investigate correlation between image quality metrics data in preferred colour reproduction and psychophysical data

Specification of the RMG

- Reference medium gamut, RMG
  - Derived from three individually published surface gamuts
    - Pointer's Gamut
    - Printers' gamut proposed by HP
    - PhotoGamutRGB
  - An abstract colour gamut which hypothetically print on a substrate
    - The assumed white point: 89% of a neutral reflectance
    - The assumed black point: 0.30911% of a neutral reflectance (0.34731% of the substrate reflectance)
- Viewing Condition: ISO 3664 P2
- Defined as reference medium gamut for perceptual rendering intent in ICC v4 profile, PRMG

(ISO12640-3, ICC.1, 2004-10)

Comparison of PRMG to an Inkjet Printer



	White Point		
PRMG	95	0	0
Printer	94	-0.6	-2
	Black Point		
PRMG	3	0	0
Printer	5	-1	-5

Wired: PRMG

Solid: Epson Stylus Pro 7800

Previous Study & Background

- Study with ICC v2 and v4 profiles (Perceptual Rendering Intent) indicated:
  - In general, v4 workflows were preferred to v2
  - Preferred prints were obtained via ICC v4 print workflows when the printing system has a middle-small sized gamut
  - No significant preference on a system that has a gamut size similar to PRMG
  - None of the tested rendering and re-rendering algorithms was unanimously preferred by a small group of expert observers

(Bonnier, Green and Sarlat, 2009)

- No study has been reported respect to evaluating GMAs from PRMG to output gamut (CIE TC8-03, 2004)

Factors in Image Quality Analyzing

- Contrast
- Relative Colorfulness
- Colour Balance
- Sharpness
- Tone reproduction
- Artifacts
  - Contouring
  - Streaking
  - Colour misregistration

(Keelan, 2002)

Objective Metrics

- Colour Difference: $CIEDE_{76, 94, 00}$, sCIELAB
- Contrast: Gradient of the white and black point
- Resolution: Resolving power
- Sharpness: MTF, PSF, OTF
- Noise: Granularity
- …

Observer and Scene Variance

- Observer Variance
  - Ages
  - Demography
  - Gender

(Ling & Hulburt, 2007)

- Scene Dependency

Example

(Triantaphillidou, 2001)

Image Quality Metrics, IQMs

- An impression of its (image) merit or excellence, as perceived by an observer neither associated with the act of photography, nor closely involved with the subject matter depicted. ---- Keelan, 2002

- The subjective impression of goodness the image conveys. ----- S. Triantaphillidou, PhD thesis, 2001

IQMs in Preferred Colour Reproduction

- General Form

$$\Omega^{n_c} = \sum_{i=1}^{P} w_{i,p} \cdot \left(\sum_{j=1}^{V} w_{j,v} \cdot \Delta v_{i,j}^{n_c} + additional\ terms \right)$$

where $\sum_{i=1}^{P} w_{i,p} = \sum_{j=1}^{V} w_{j,v} = 1$

  - Where n_c depended on the metric is linear or a RMS quantity is one or two, $w_{i,p}$ is the patch weight of i^{th} of P patches, $w_{j,v}$ is the variable weight that j^{th} of V variables characterizing attributes in colour and tone reproduction, $\Delta v_{i,j}$ is the difference of the values of the j^{th} such variable between that of the preferred position of the i^{th} patch and that of its actual production. Additional terms reflects interations between variables or higher order effects.

(Keelan, 2002)

The Simplified form of IQM in Preferred Colour Reproduction

$$\Omega^2 = \frac{1}{P}\sum_{i=1}^{P}\left(w_{a_i^*}\cdot(\Delta a_i^*)^2 + \left(1 - w_{a_i^*}\right)\cdot(\Delta b_i^*)^2\right)$$

- Where Δa_i^* and Δb_i^* are the difference of original value and the measurement of the reproduction. w_{ai*} is the reflecting tonal weighting function derived from the logarithm of the measurement correspondent luminance of the reproduced colour and the perfect diffuser in CIE tristimulus values (Y_0=100):

$$w_{a_i^*} = -\log_{10}\left(\frac{Y_i}{Y_0}\right)$$

(Keelan, 2002)

Experimental

- Tested GMAs
  - HPMINDE, SGCK, LLIN, LCLIP, SGCKC

(CIE TC8-03, 2004)

- Tested Gamuts
  - Source Gamut: PRMG
  - Destination Gamut:
    - Big Gamut (Fogra standard: Coated paper)
    - Small Gamut (Fogra standard: Uncoated paper)

(Fogra data downloaded form www.color.org 5-Sep-2010)

Tested Images

N2

N3

N4

N5

N6

N7

Softcopy & Hardcopy Preparation

- Hardcopy
  - Applied the 5 GMAs on the 6 SCID images
  - Printed images
    - a calibrated laser printer with a Digital-Front-End (DFE)
    - Coated paper conformed ISO standard
    - Print Image size: 8*10 inches
- Softcopy
  - Soft-proofing previous images on a calibrated monitor

Psychophysical Experiment & Data Analysis

- Psychophysical Experiment Design
  - Aim: Preference Choice of tested GMAs
  - Method: Paired Comparison
    - Phase 1: Hardcopy Appraisal
    - Phase 2: Softcopy Appraisal
  - Observer Pool
    - 17 Expert Observers
- Data Analysis
  - Z-Score
  - 95% Confidence Interval
  - Simplified Image Quality Metrics in Preferred Colour Reproduction
  - Pearson Correlation Factor

Scene Setup

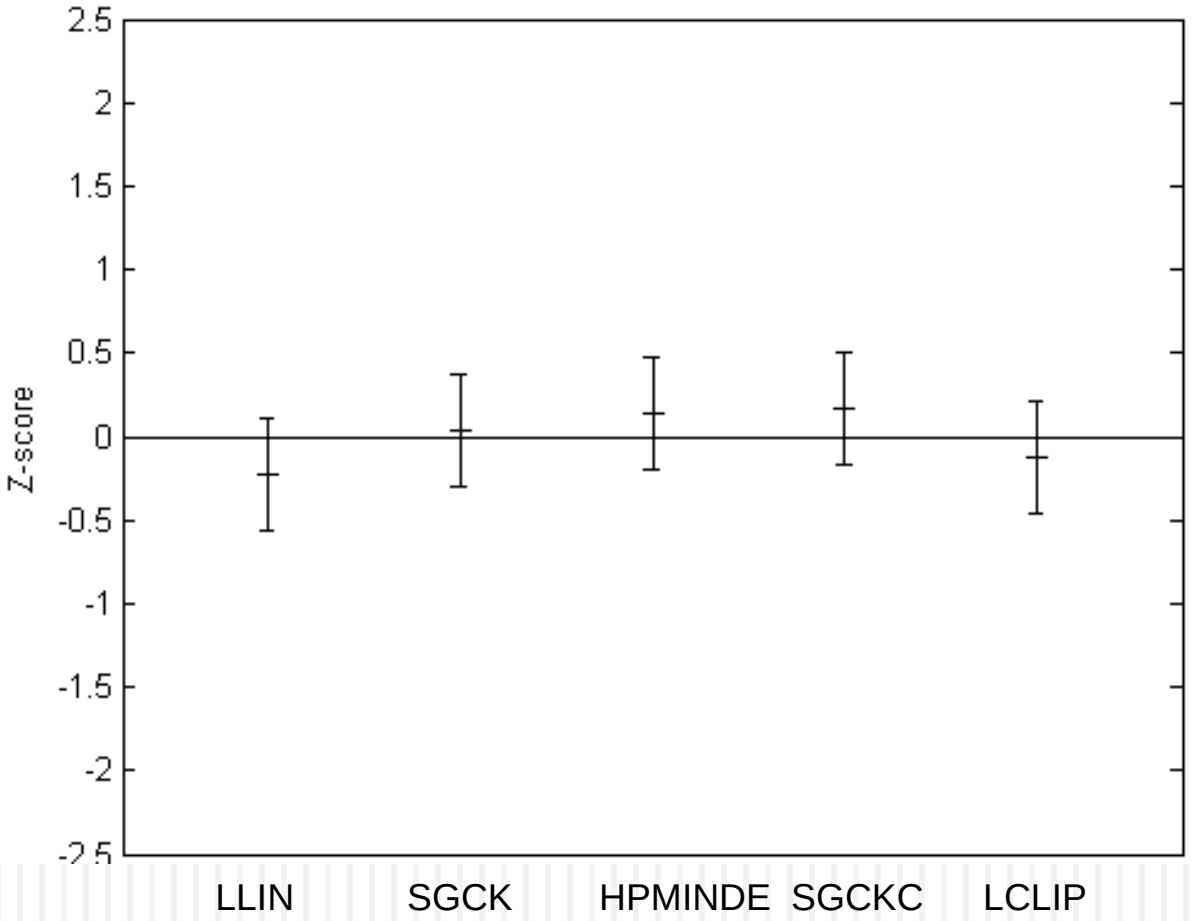
- Viewing Environment
  - A viewing booth: D50 simulating light source
  - A calibrated LCD display
    - Peak White (D50): CIEDE2000=0.7
  - Ambient Lighting: approximate 60 lx
  - Viewing Distance: approximate 25 inches

Stage 1: Hardcopy Appraisal

Stage 2: Softcopy Appraisal

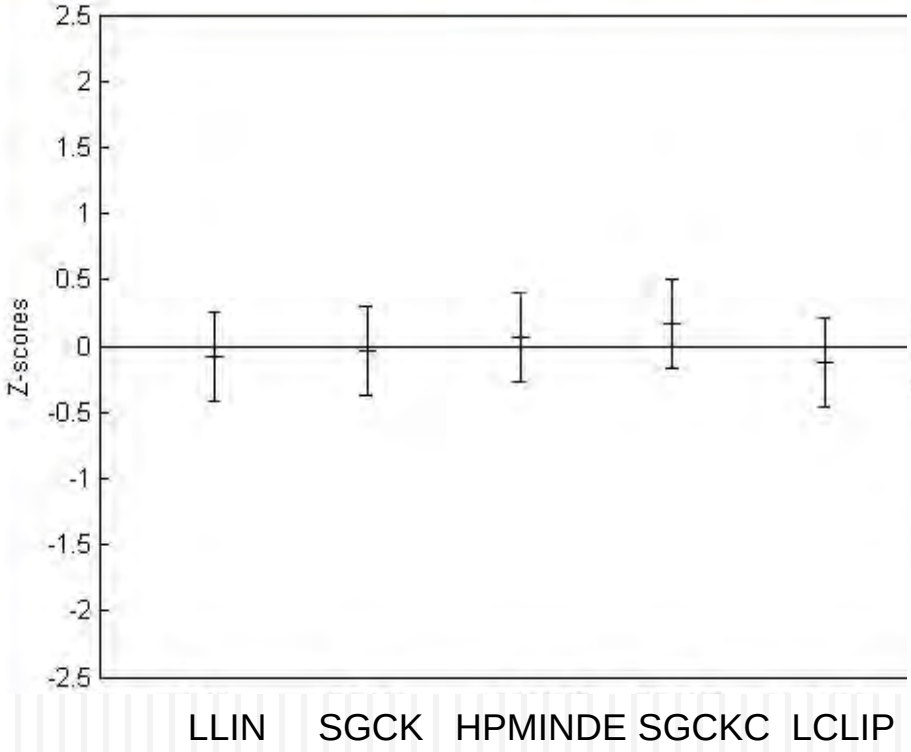
Data Analysis

- General Preference

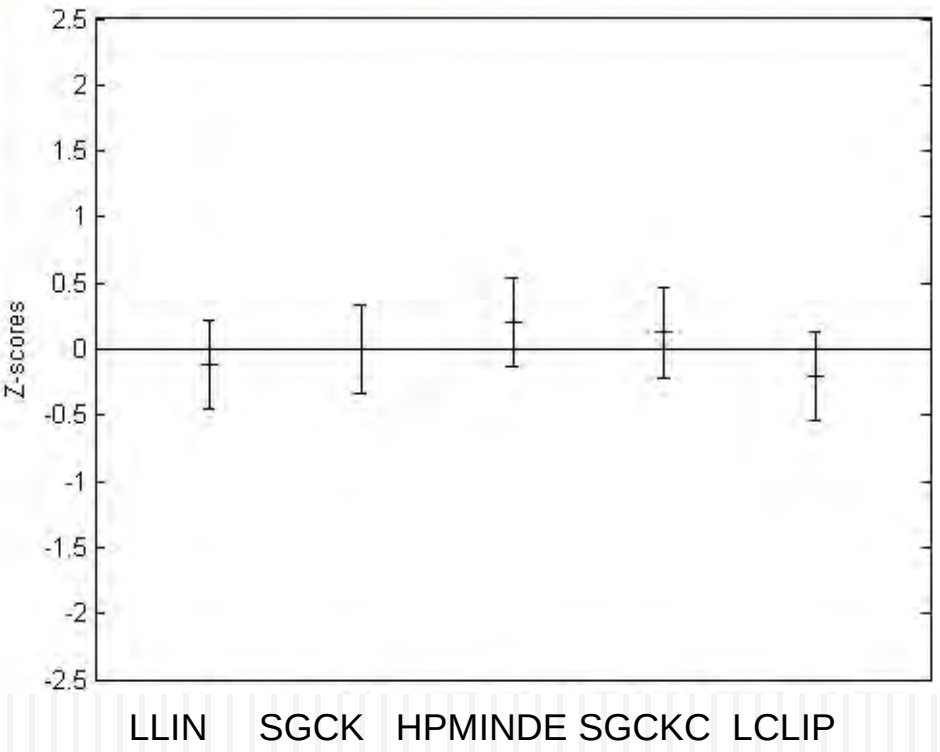


Data Analysis

- Hardcopy Appraisal



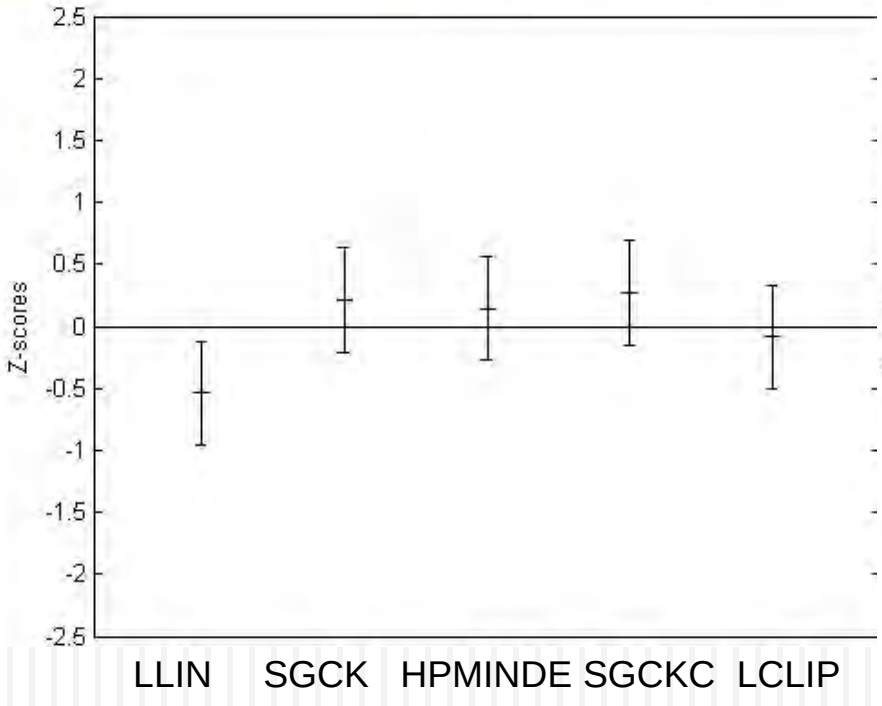
Big Gamut



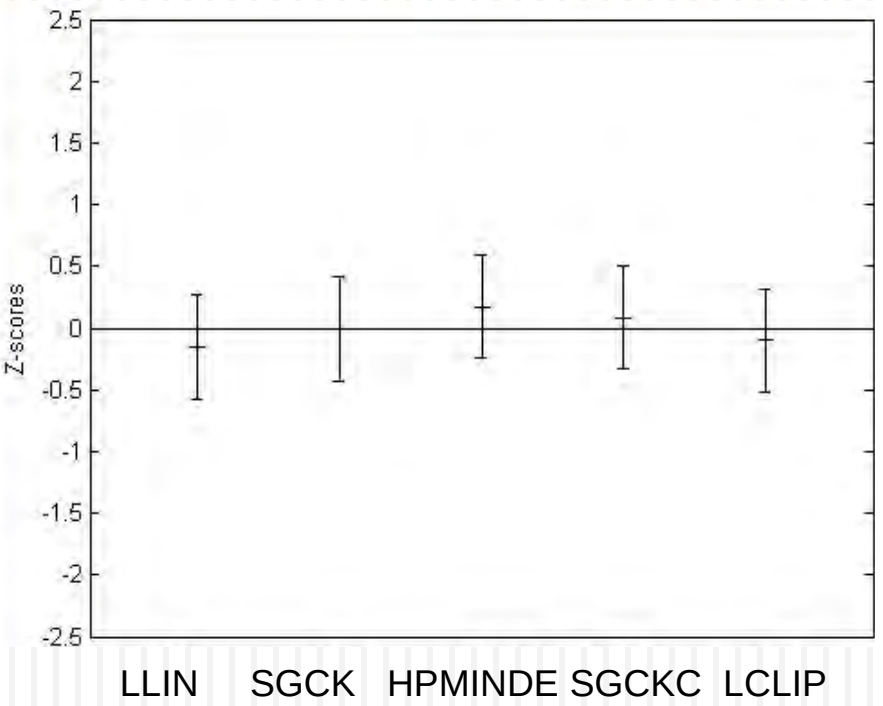
Small Gamut

Data Analysis

- Softcopy Appraisal

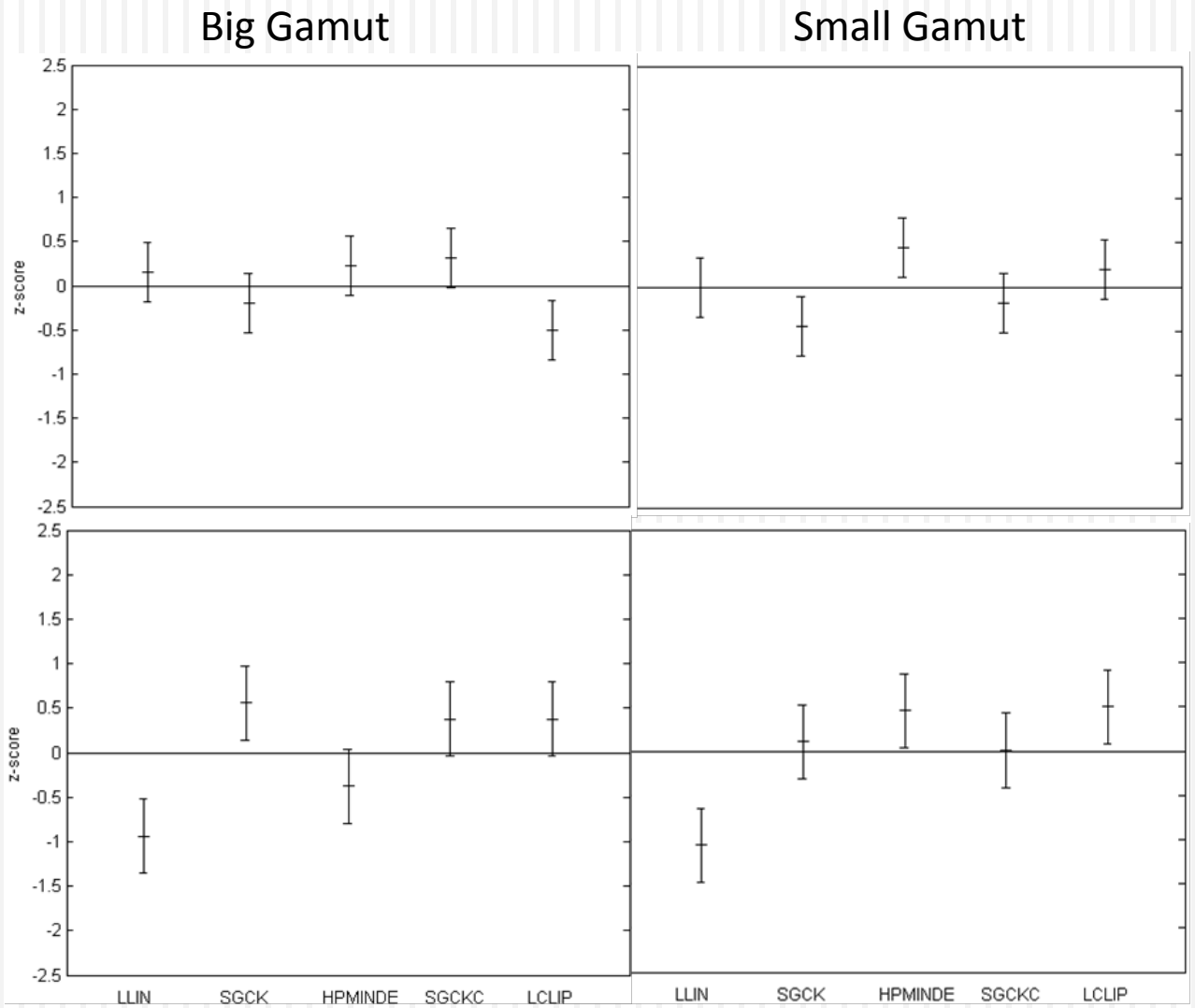


Big Gamut



Small Gamut

Image Dependence



Correlation between Psychophysical Data and the IQM

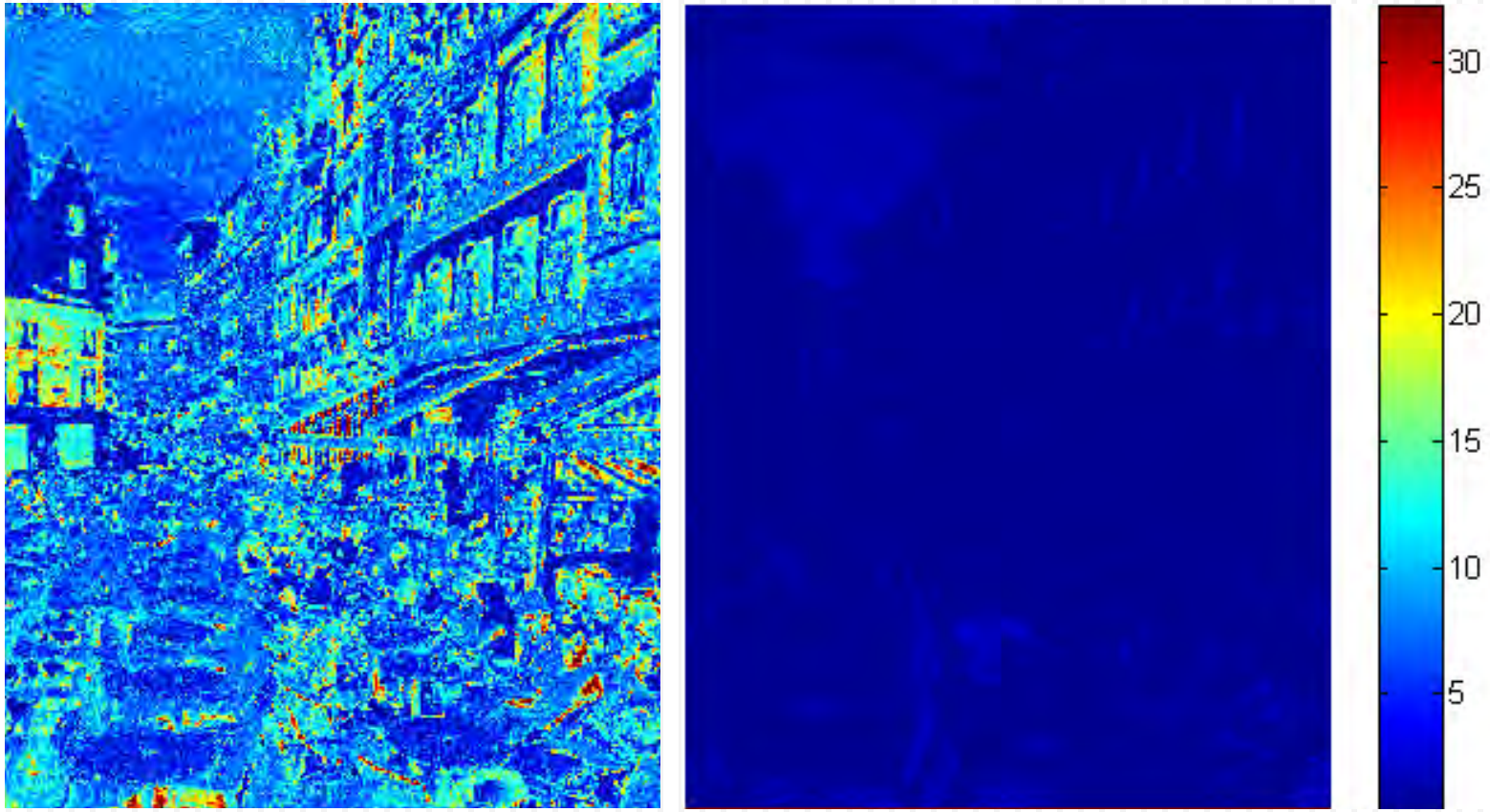
IQM	LLIN	SGCK	HPMINDE	SGCKS	LCLIP	Pearson correlation
Ω_{N2}^2	5.576	0.611	0.028	-	15.8	-0.95
Ω_{N3}^2	38.07	4.263	-	4.266	37.08	-0.77
Ω_{N4}^2	1.708	0.242	0.81	-	0.41	-0.22
Ω_{N5}^2	18.33	0.345	1.397	-	11.74	-0.64
Ω_{N6}^2	-	16.89	7.217	17.09	3.859	-0.92
Ω_{N7}^2	28.99	0.391	3.136	-	73.26	-0.74

Visualization of Image Colour Difference

CIEDE2000

s-CIELAB

SGCKC vs LLIN



Conclusion

- Correlations between the preference colour reproduction IQMs and the psychophysical data exists, it is image dependent though
  - The degree of correlation varied among images
  - Correlation can be positive or negative
- SGCKC was the most preferred GMA when mapped to big gamut. It was superior to SGCK and HPMINDE which had no significant preference over each other
- HPMINDE was the most preferred GMA when mapped to small gamut. It was superior to SGCKC and SGCK which had no significant preference over each other
- LLIN and LCLIP were the least preferred GMAs in both hardcopy and softcopy appraisal

Variants and Uncertainties

- GMAs used in this study
  - Not all of the tested GMAs were fully utilized RMG as source gamut

Future Work

- Evaluation on updated and more complex GMAs
- Extend the IQM in preferred colour reproduction with more object metrics
  - Contrast
  - Spatial filter
  - Granularity
  - ….

Reference

- Bonnier N., Green P.J., and Sarlat A., (2009), *Evaluating the Use of the Perceptual Reference Medium Gamut in ICC Printing Workflows,* Proceedings in 17th Color Imaging Conference
- CIE, (2004), *Guidelines for the Evaluation of Gamut mapping algorithms,* CIE
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- Ling YZ and Hulburt A. (2007), Sex Differences And Favorite Color Preference, *Current Biology*, Volume 17, Issue 16, *21* PP R623-R625
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- Macdonald L. W. and Luo M. R. (eds), (2002), *Colour Image Science: Exploiting Digital Media,* UK: Wiley

Thank You!