Colour accuracy of images for colour research in architecture

A comparison of high dynamic range, hyperspectral and computer-generated images

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context.

> A research project investigating preferences for color combinations in architectural spaces with **psychophysical techniques**

- working in real environments is challenging (uncontrollable variability of daylighting, **need to control experimental conditions**…), images are alternative visual stimuli to actual spaces; however, each step in the production of pictures – from scene creation to display observation – can lead to inaccuracies
- need to **determine limits and opportunities of digital image** as a practical design / scientific investigation tool for designing / studying coloured indoor environments

> Step #1: focus on scene creation, **investigation of 3 types of images** for colour accuracy and sharpness:

- **HDR fisheye pictures**, (+) QTVR panoramas
- **hyperspectral pictures**, (+) spectral information at each pixel
- **spectral simulation**, (+) QTVR panoramas, spectral information, prediction of not yet built environments, control of parameters

question.

> What levels of colorimetric and photometric accuracy are achievable with HDR photography, hyperspectral photography and spectral simulation?

> Is the image quality (sharpness) sufficient for visual psychophysical experiments ?

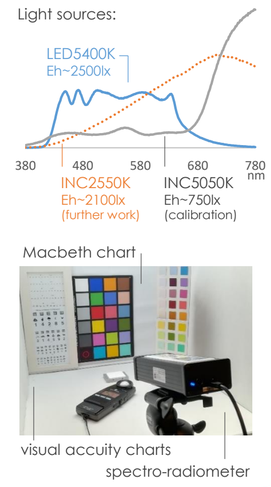
method.

> **Photometric and colorimetric accuracy** are quantified in comparing XYZ values of a Macbeth chart retrieved from images and measured with a spectro-radiometer

> Visual acuity charts are used to evaluate how well the camera or the software creates **sharp images**

> **Calibration**:

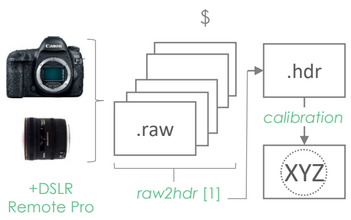
- HDR pictures calibrated with a colour transform matrix determined specifically for each camera-lens association (minXYZ, 18 Macbeth coloured patches, INC5050K) + adjustment by channel
- Specim V10E calibrated by the manufacturer; images taken with the Inno-spec GreenEye camera calibrated using a calibration curve we determined (Macbeth#19, INC5050K) + luminance adjustment
- In Ocean, the light source radiance is adjusted using the 6 Macbeth grey samples



material.

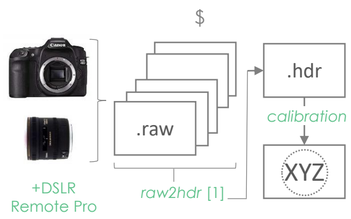
HDR PHOTOGRAPHY

CANON EOS 40D + Sigma 4.5mm F2.8 EX DC



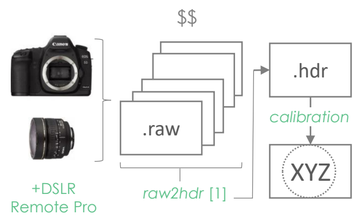
3908*2602px (Ø fisheye ~ 2145px)

CANON EOS 50D + Sigma 4.5mm F2.8 EX DC



4770*3177px (Ø fisheye ~ 2600px)

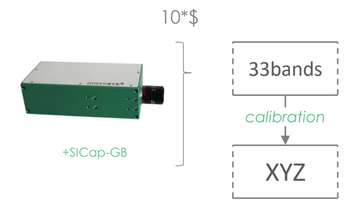
CANON EOS 5D Mark II + Sigma 8mm F3.5 EX DG



5634*3753px (Ø fisheye ~ 3530 px)

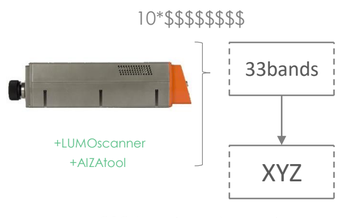
HYPERSPECTRAL PHOTOGRAPHY

Inno-spec GreenEye



1312 px (y definition)
7 nm (spectral resolution)
[355.8;1095.0nm]

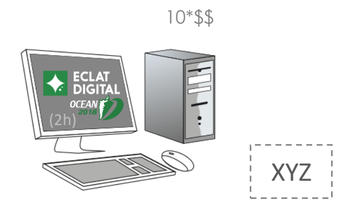
Specim V10E



2184 px (y definition)
2.9 nm (spectral resolution)
[394.6;1007.0nm]

SPECTRAL SIMULATION

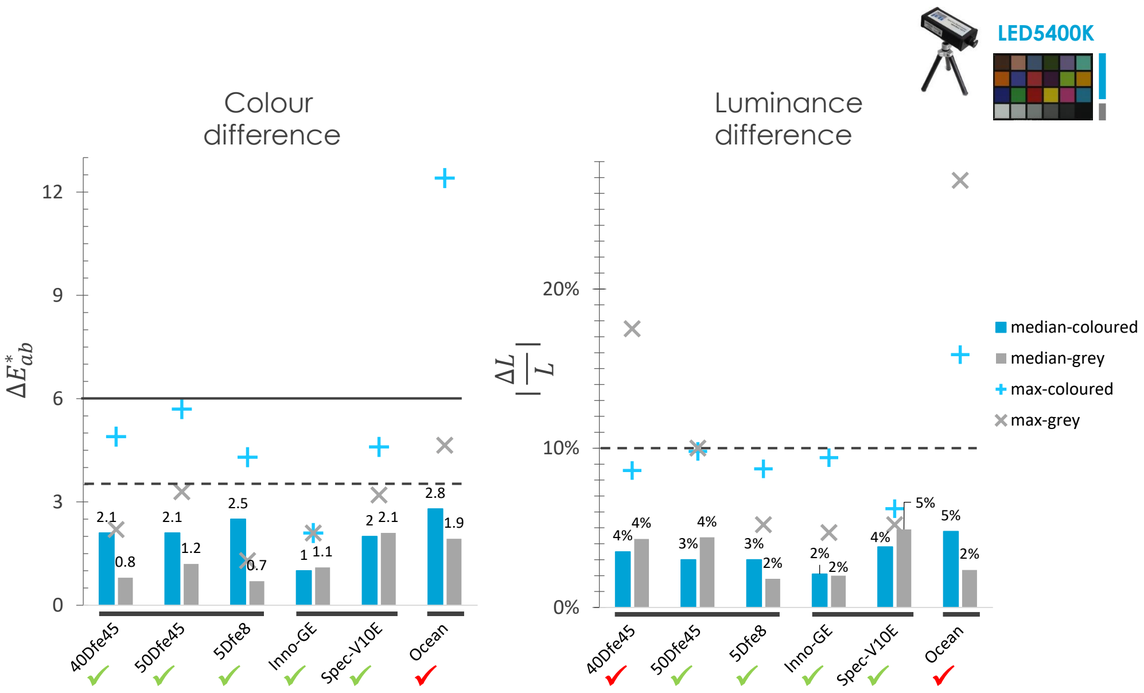
Ocean 2018



results | image quality.

Images were tone-mapped with the iCAM06 algorithm [2] and the following user-controllable parameters : p=0.75, gamma_value=1, D=0.9 (quasi complete adaptation).
QTVR (semi-spherical) panoramas were created using PTGui Stitching software. This type of image was previously identified as a promising tool for studying the appearance of lighting and space [3].

results | accuracy.



ΔE^*_{ab} < 6: not detected in complex images [4].
ΔE^*_{ab} > 3.5: a clear difference in colour is noticed [5].

Previous works validated HDR photography for luminance measurement within 10% accuracy and with peak errors up to 20% or even more [6].

Median differences between two spectro-radiometer measurements (LED5400K, 24mb) are 0.5 (ΔE^*_{ab}) and 1% ($|\Delta L/L|$).

conclusion.

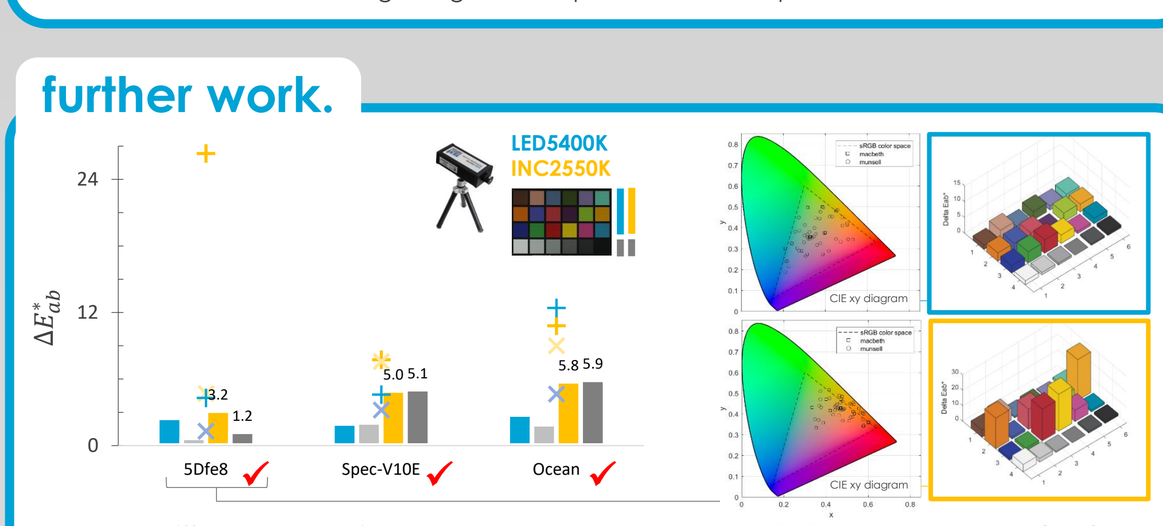
> **5Dfe8** is slightly more accurate for measuring colour and luminance, and produces sharper QTVR panoramas than other DSLR cameras fitted with a fisheye lens

> Similar ranges of differences are observed with HDR and hyperspectral images but consistency between colour and grey samples is higher in hyperspectral images than in HDR pictures; **Spec-V10E** produces images sharp enough for psychophysical experiments

> Differences observed in rendered images are higher than in HDR/hyperspectral pictures

Further work : **other CCTs**, higher light levels, presence of sun spots...

further work.



> Colour differences are higher under INC2550K than under LED5400K: sRGB gamut ? IR ?

Median difference (ΔE^*_{ab}) between two spectro-radiometer measurements (INC2550K, 24mb) is 0.6.

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References:
[1] *Perl scripts*, Ward, 2011
[2] Kuang et al., 2007
[3] Cauwerts, 2013
[4] Meyer, 1988
[5] Mokrzycki and Tatol, 2011
[6] Inanici, 2006

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