

GRAFFITI

Achieving colour-accurate data from images: challenges and solutions

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International Graffiti Symposium

document | archive | disseminate graffiti-scapes

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Adolfo Molada-Tebar

Colorimetry

Spectral data treatment

Image processing

Software development

Cultural Heritage applications, especially rock art paintings or “**prehistoric graffiti**”





Index

Dealing with colour

Relevance and problems

Basic colorimetry

Understanding colour

Working with images

Are they colorimetric?

Providing a solution

Camera characterization
Spectral recovery

Conclusions



Colour

Is it relevant?

Cultural Heritage documentation is a complex task where colour plays a **fundamental role**.

It provides **vital information**: description, cataloguing, changes, and damages.

Powerful **communication tool** in graffiti. To express **ideas** and **feelings**, and to create an **impact** in the viewers.





OBJECTIVE

colour-accurate data

ANALYSIS

overlooked
not rigorously

COMPLEX

understanding colour

CHALLENGE

not trivial



Colour challenges

The objective is to obtain colour-accurate data as **closer to reality** as possible for proper colour documentation.

Colour is often overlooked or even **not rigorously analysed**.

Colour treatment is **complex**.

The acquisition of precise colour data remains a **challenge**, and not trivial labour, in documentation.

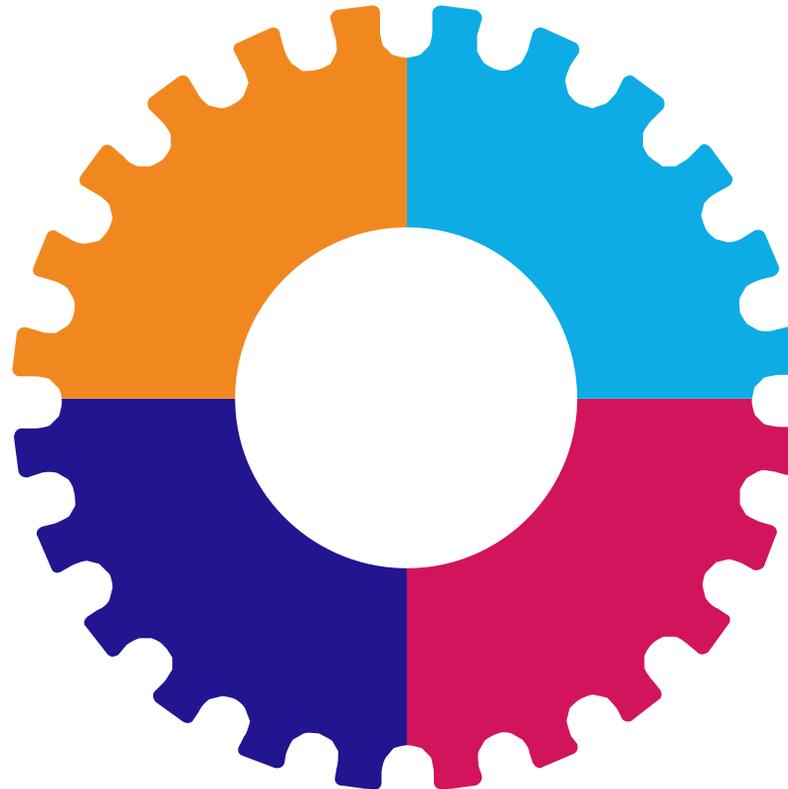
INDIGO solutions

METHODOLOGY

Establishment of an *objective*
and *colour-accurate*
methodology.

OPEN-SOURCE

Design and implementation
of a *Python toolbox*.
Intuitive, easy, user-friendly.



COLORIMETRY

Rigorous colour and spectral
data treatment based on
colorimetric standards.

IMAGE PROCESSING

Creation of a *digital image*
workflow to obtain colour-
accurate data from images.





Understanding colour

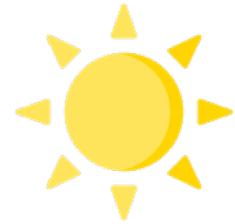
Colour basics

Colour measurement



Colour basics

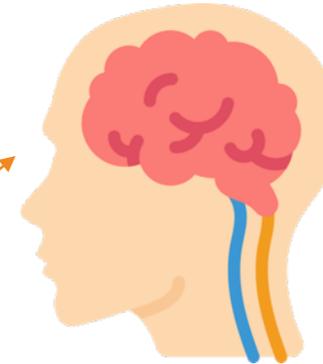
to see colour



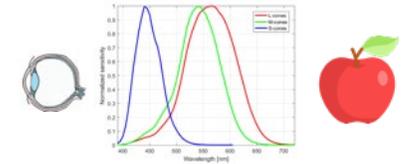
LIGHT SOURCE



OBJECT



OBSERVER

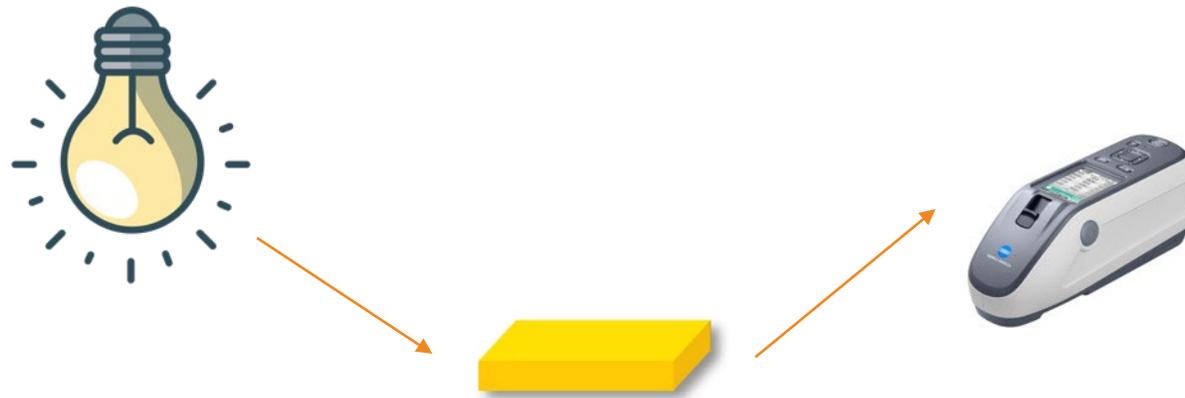


HSV

Is it possible to measure colour?

Colour measurement

to measure colour



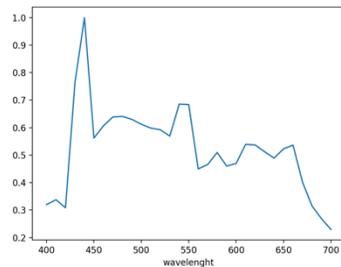
Expressing colours numerically.

Based on colorimetric standards, such as the one developed by the CIE.

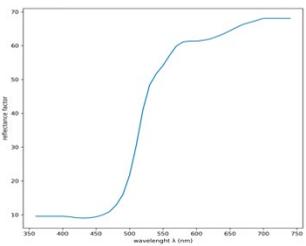
ILLUMINANT

SAMPLE

INSTRUMENT



SPD



REFLECTANCE



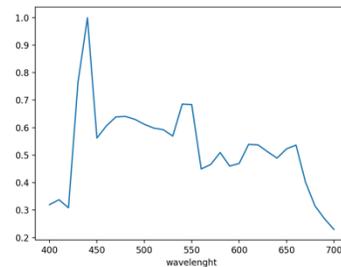
CIE XYZ

Colour measurement

Is it possible to use a digital camera to *measure* colour?



ILLUMINANT



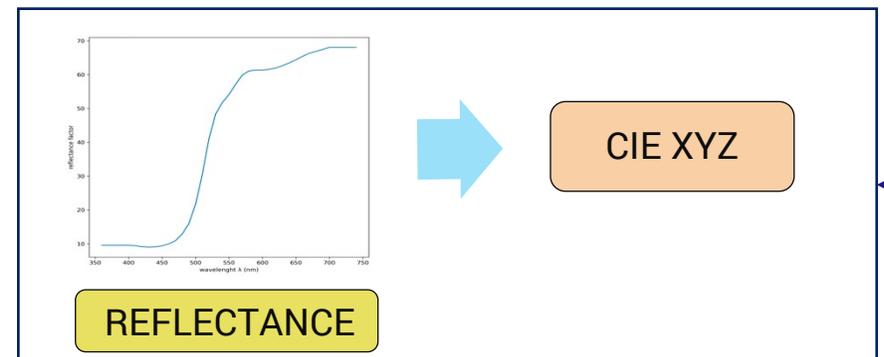
SPD



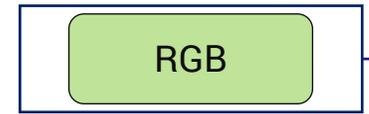
GRAFITTI

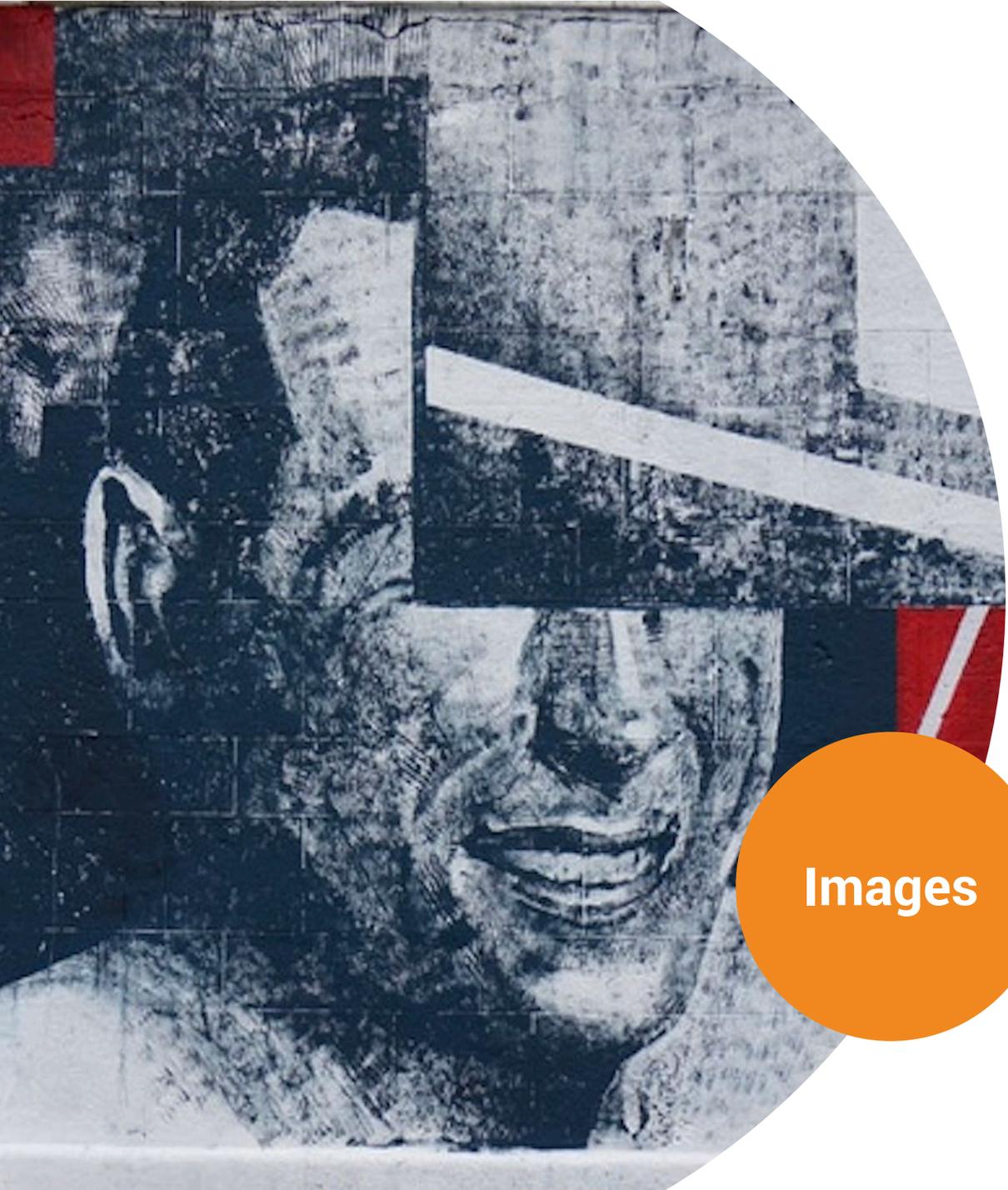


DIGITAL CAMERA



REFLECTANCE





Working with Images

Are they **colorimetric**?

Image processing: general issues and solutions.

Images





Nikon D40



Fujifilm Is Pro

Images are they colorimetric?

Normal exposure



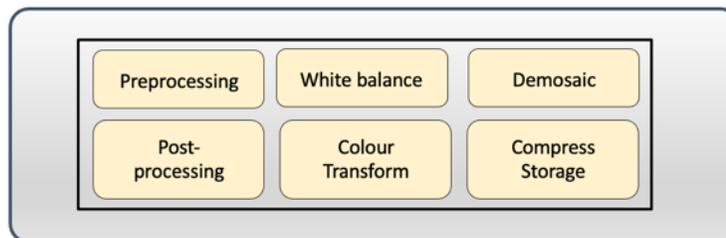
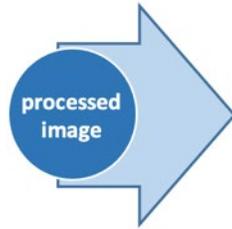
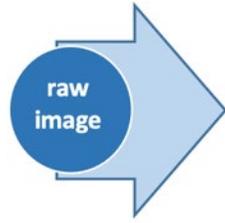
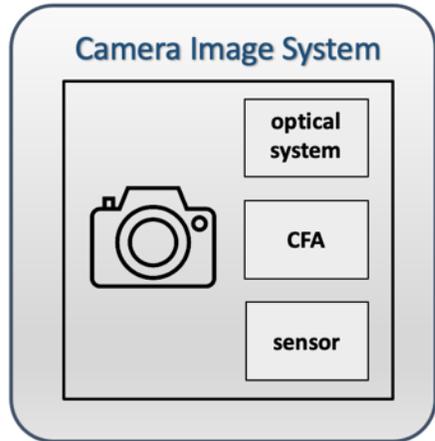
Over exposed

Under exposed

Different **camera built-in sensor** provides different RGB data for the same scene under the same light conditions. RGB values are **device-dependent**.

Shot parameters affect the **intensity values** recorded.

The camera does not satisfy the **Luther-Ives** condition: RGB data are not a linear combination of the tristimulus values defined by the CIE. RGB data are **not colorimetric** (not referred in a physically-based colour space).



Images preprocessing

RAW data must generally be **processed** before it can be displayed.

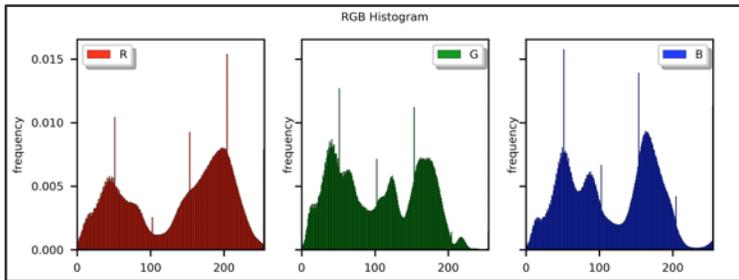
Different camera manufacturers use **different proprietary steps**: hermetic, complex and scene dependent.

Output processed images are **visually pleasing rather than colour-accurate**.

Working directly with **RAW** data is more suitable for **computing** purposes, but not trivial.

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Image processing using Python



Auto bright
Auto scaled rgb values

```
# rawpy tested default parameters
default_kargs = dict(demosaic_algorithm=rawpy.DemosaicAlgorithm.AHD, half_size=False,
four_color_rgb=False, dcb_iterations=0, dcb_enhance=False,
fbdd_noise_reduction=rawpy.FBDDNoiseReductionMode.Off,
noise_thr=0, median_filter_passes=0, use_camera_wb=False, use_auto_wb=False,
user_wb=None,
output_color=rawpy.ColorSpace.sRGB, output_bps=8,
user_flip=None, user_black=None, user_sat=None,
no_auto_bright=0.01, auto_bright_thr=None, adjust_maximum_thr=0.75, bright=1.0,
highlight_mode=rawpy.HighlightMode.Clip,
exp_shift=1, exp_preserve_highlights=0.0, no_auto_scale=False,
gamma=(2.222, 4.5), # default BT.709
chromatic_aberration=(1,1), bad_pixels_path=None)
```

exposure shift in linear scale.
Usable range from 0.25 (2-stop
darken) to 8.0 (3-stop lighter).

HighlightMode

```
class rawpy.HighlightMode(value)
```

Highlight modes.

- Blend= 2
- Clip= 0**
- Ignore= 1

overexposed areas

ColorSpace

```
class rawpy.ColorSpace(value)
```

Color spaces.

- Adobe= 2
- ProPhoto= 4
- Wide= 3
- XYZ= 5
- raw= 0
- sRGB= 1**

DemosaicAlgorithm

```
class rawpy.DemosaicAlgorithm(value)
```

Identifiers for demosaic algorithms.

- AAHD= 12
- AFD= 6
- AHD= 3**
- AMAZE= 10
- DCB= 4
- DHT= 11
- LINEAR= 0
- LMMSE= 9
- MODIFIED_AHD= 5
- PPG= 2
- VCD= 7
- VCD_MODIFIED_AHD= 8
- VNG= 1

FBDDNoiseReductionMode

```
class rawpy.FBDDNoiseReductionMode(value)
```

FBDD noise reduction modes.

- Full= 2
- Light= 1
- Off= 0**



Image Processing challenges

A digital camera cannot be used for rigorous colour determination without any **colour correction** process.

The use of specific Python packages is **complex** for non-programmers.

Proprietary software: users generally do not have full access to intermediate steps during image processing.

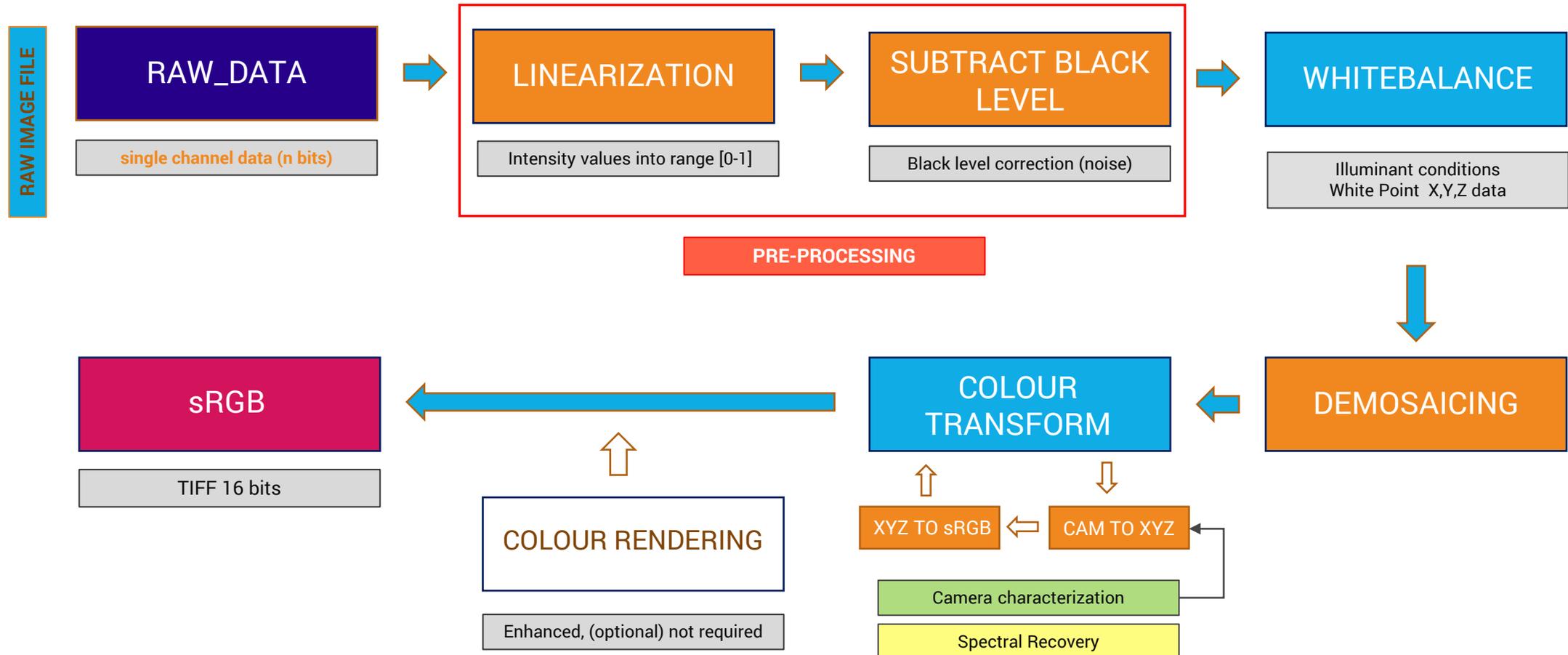
INDIGO solutions

Establishment of a **rigorous** and **colour-accurate workflow** for RAW image processing.

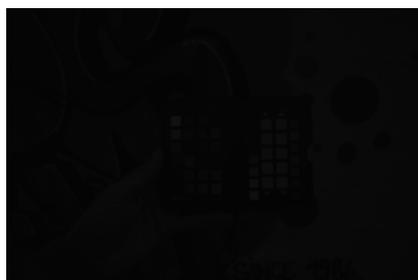
Design and implementation of **INDIGO Python open-source toolbox**: **Easy** to understand and use; giving the users **full control** during the stages of the methodological process.



INDIGO Colour RAW Image Processing

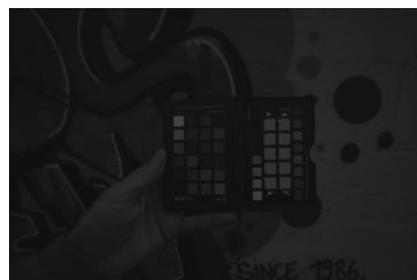


INDIGO Colour RAW Image Processing



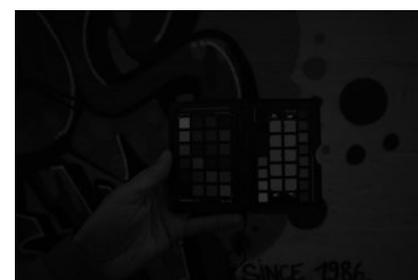
RAW single channel data

using rawpy, without demosaicing,
displayed as grey image
14 bits



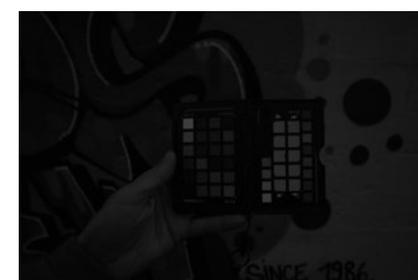
Linearization

Intensity values into range [0,1]



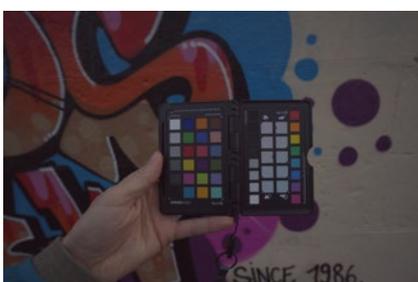
Subtract Black Level

Black level correction (noise)

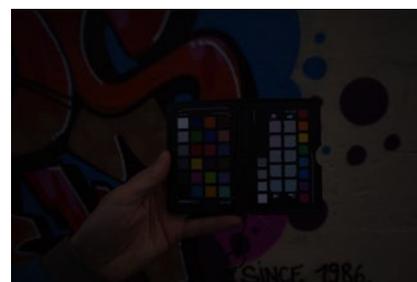


WHITEBALANCE

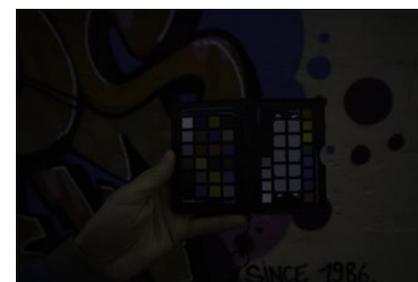
PRE-PROCESSING



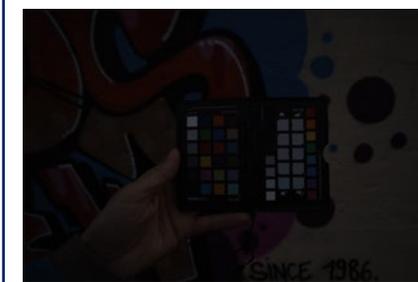
sRGB



sRGB linear



CIE XYZ



DEMOSAICING

COLOUR TRANSFORM

Camera characterization

Spectral Recovery



images

Camera characterization spectral recovery

The aim of camera characterization is to compute the **mathematical model** to transform the RGB data acquired by the camera (device-dependent) into the CIE XYZ tristimulus values (independent colour space).

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Polynomial models are accurate enough.

Spectral recovery: estimation of reflectance data from RGB.

Camera characterization / spectral recovery



ILLUMINANT

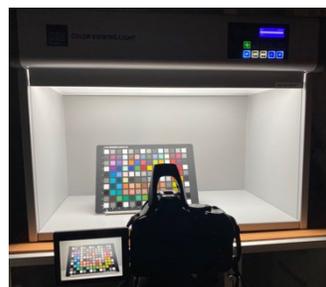


IMAGE



RAW RGB

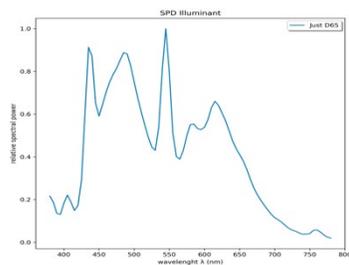
Camera characterization / spectral recovery



ILLUMINANT

IMAGE

RAW RGB



SPD

Camera characterization / spectral recovery

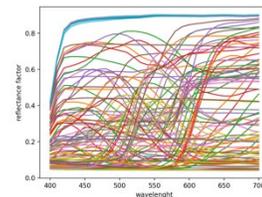
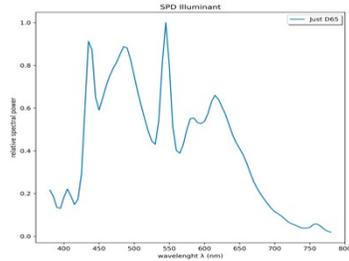


ILLUMINANT

IMAGE

RAW RGB

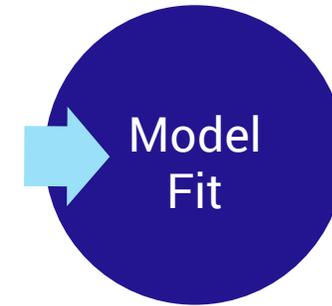
CIE XYZ



SPD

REFLECTANCE

Camera characterization / spectral recovery

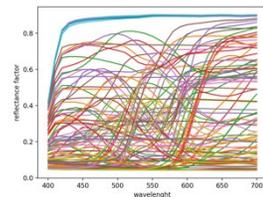
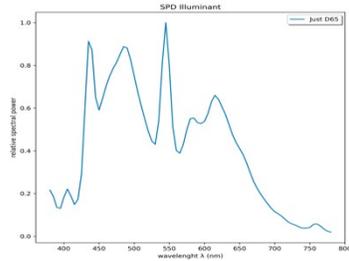
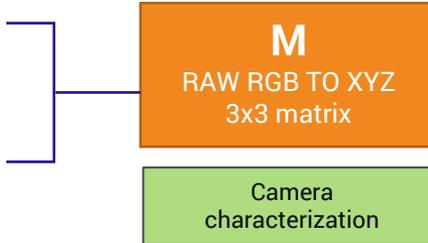


ILLUMINANT

IMAGE

RAW RGB

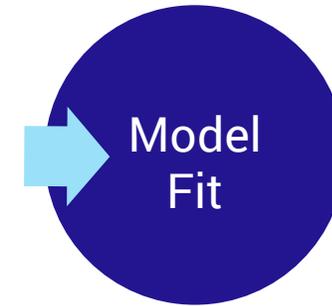
CIE XYZ



REFLECTANCE

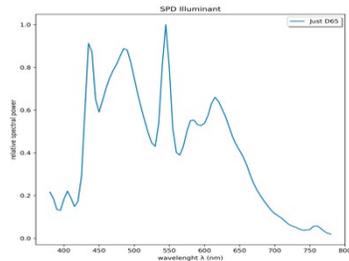
SPD

Camera characterization / spectral recovery



ILLUMINANT

IMAGE

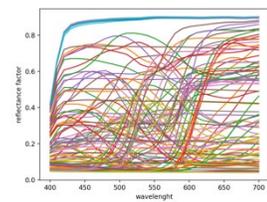


SPD



RAW RGB

CIE XYZ



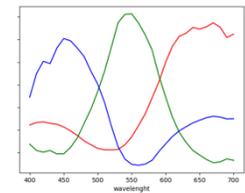
REFLECTANCE

M
RAW RGB TO XYZ
3x3 matrix

Camera
characterization

Q
RAW RGB TO REFLECTANCE
3x31 matrix

Spectral Recovery



Camera characterization



ILLUMINANT

RAW RGB

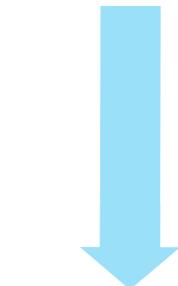
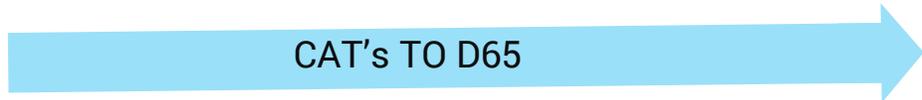
×

M
RAW RGB
TO XYZ
3x3 matrix

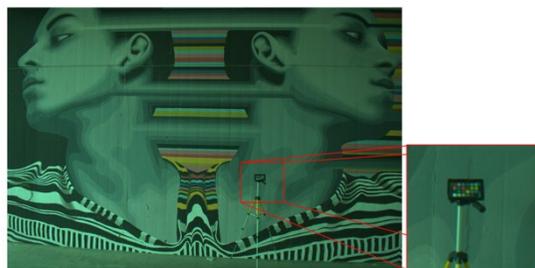


CIE XYZ

Camera
characterization

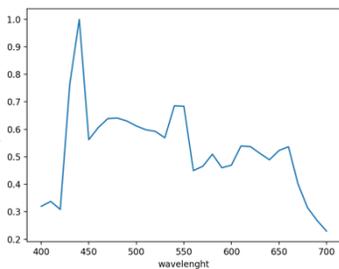


CIE XYZ



sRGB

TIFF 16 bits



SPD

Camera spectral recovery



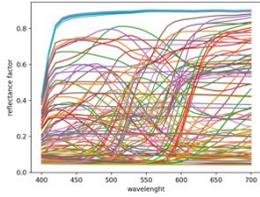
ILLUMINANT

RAW RGB

\times

Q
RAW RGB TO REFLECTANCE
3x31 matrix

Spectral Recovery



REFLECTANCE

CAT's TO D65

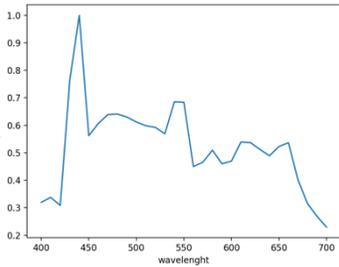
CIE XYZ

CIE XYZ



sRGB

TIFF 16 bits



SPD



Characterization advantages

A conventional digital camera could be used to get **colour-accurate data** simulating a colourimeter/ spectrophotometer.

This methodology can be used in combination with **other techniques** for the proper documentation of colour.

The use of digital cameras is an **objective, cost-effective,** and **non-invasive** methodology; and allows to obtain **colour-accurate** data from images.

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Colour conclusions

METHODOLOGY

Accurate registration of colour.
Colorimetric and spectral data
treatment based on CIE standards.
Cost-effective, non-invasive, objective.

EXTENDED

graffitists – scholars – public.
Cultural Heritage applications.
Fields where colour plays a
fundamental role.



IMAGE PROCESSING

RAW-based colour-accurate workflow.
sRGB complete scenes in a physically-
based colour space.

OPEN-SOURCE

Design and implementation of INDIGO
Python toolbox.
Intuitive, easy, user-friendly; giving full
control during the methodological
stages to users.



Thank You

