

# GRAFFITI

## Achieving colour-accurate data from images: challenges and solutions

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Geert Verhoeven

International Graffiti Symposium

*document | archive | disseminate graffiti-scapes*

*11-13 May 2022 Vienna, Austria*

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## Adolfo Molada-Tebar

Researcher from the **Polytechnic University of Valencia** (UPV)

Technical Surveying Engineer (1999)

Engineer in Geodesy and Cartography (2013)

Master's Degree in Geomatics Engineering  
and Geoinformation (2016)

PhD Geomatics (2020)



*UPV, València, Spain*



## 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.

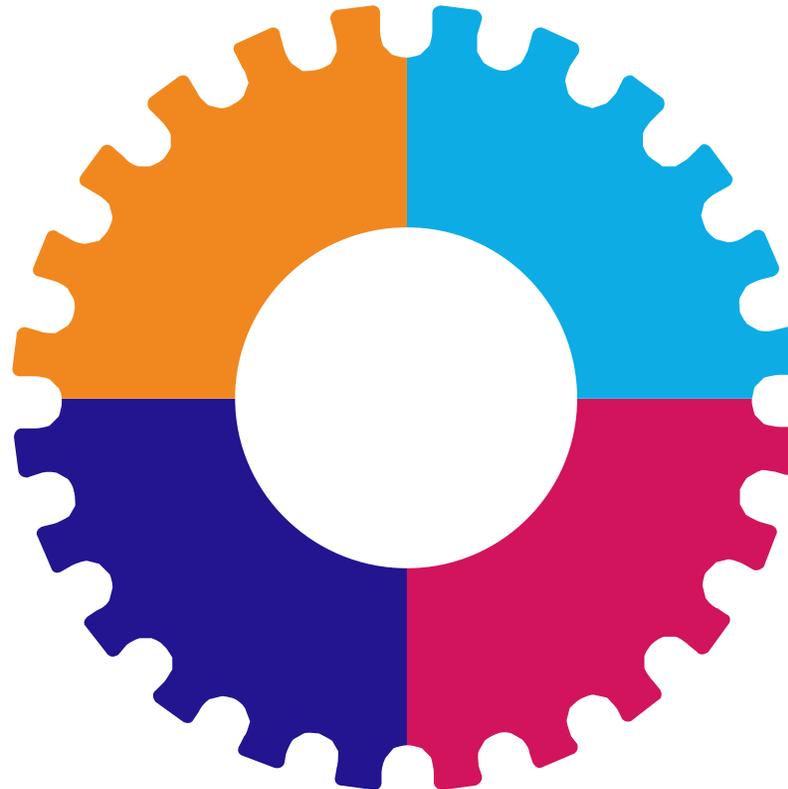
# INDIGO solutions

## 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

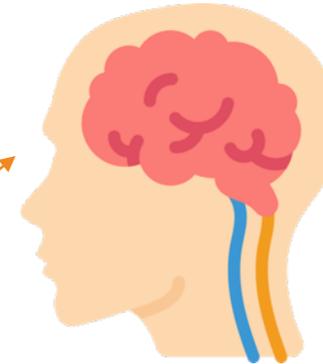
to see colour



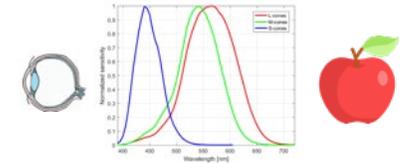
LIGHT SOURCE



OBJECT



OBSERVER

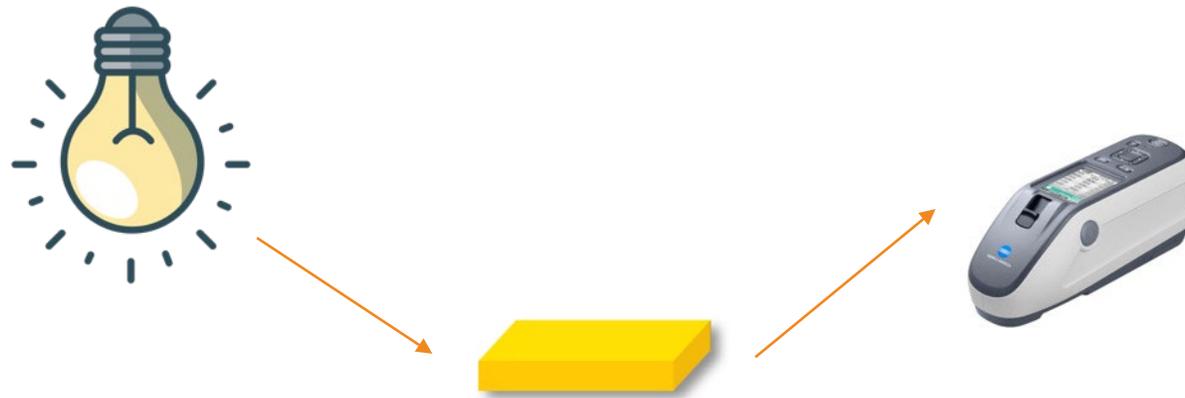


HSV

*Is it possible to measure colour?*

# Colour measurement

to measure colour



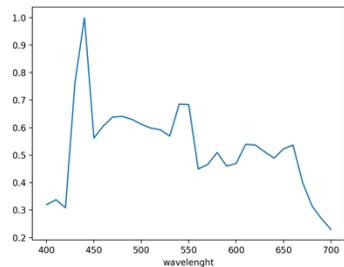
Expressing colours numerically.

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

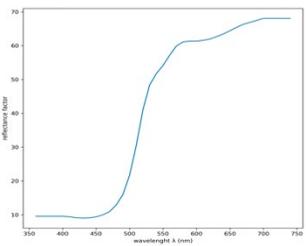
ILLUMINANT

SAMPLE

INSTRUMENT



SPD



REFLECTANCE



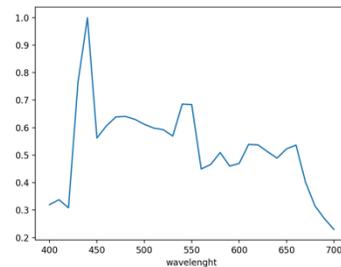
CIE XYZ

# Colour measurement

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



ILLUMINANT



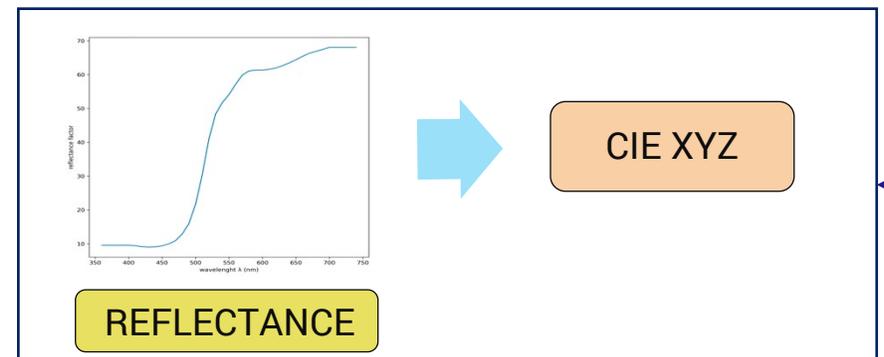
SPD



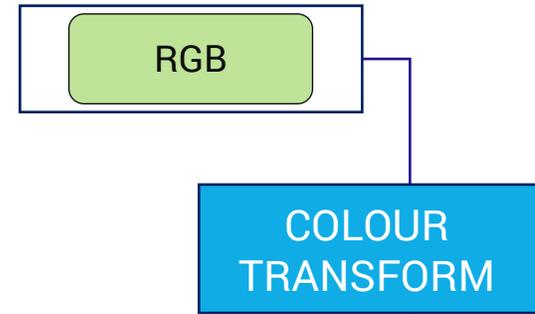
GRAFITTI



DIGITAL CAMERA



REFLECTANCE



COLOUR TRANSFORM

CIE XYZ



# Working with Images

Are they **colorimetric**?

**Image processing:** general issues and solutions.

Images





Nikon D40



Fujifilm Is Pro

# Images are they colorimetric?

Normal exposure



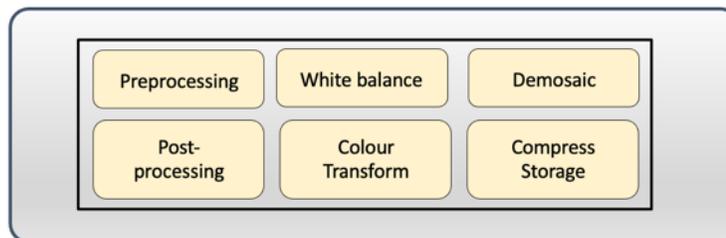
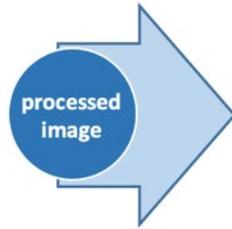
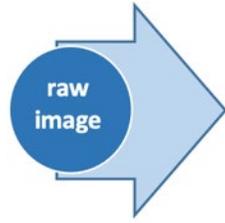
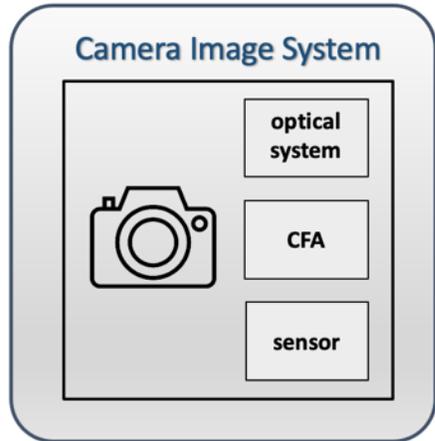
Over exposed

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.

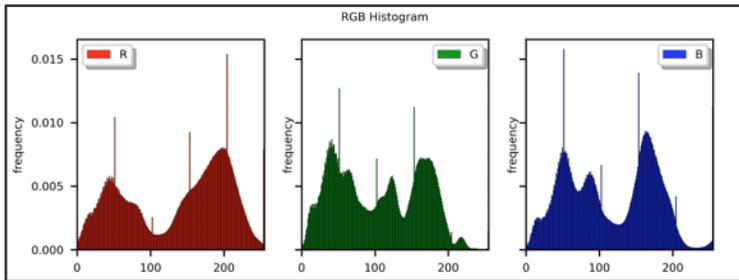
Different camera manufacturers use **different proprietary steps**: hermetic, complex and scene dependent.

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.

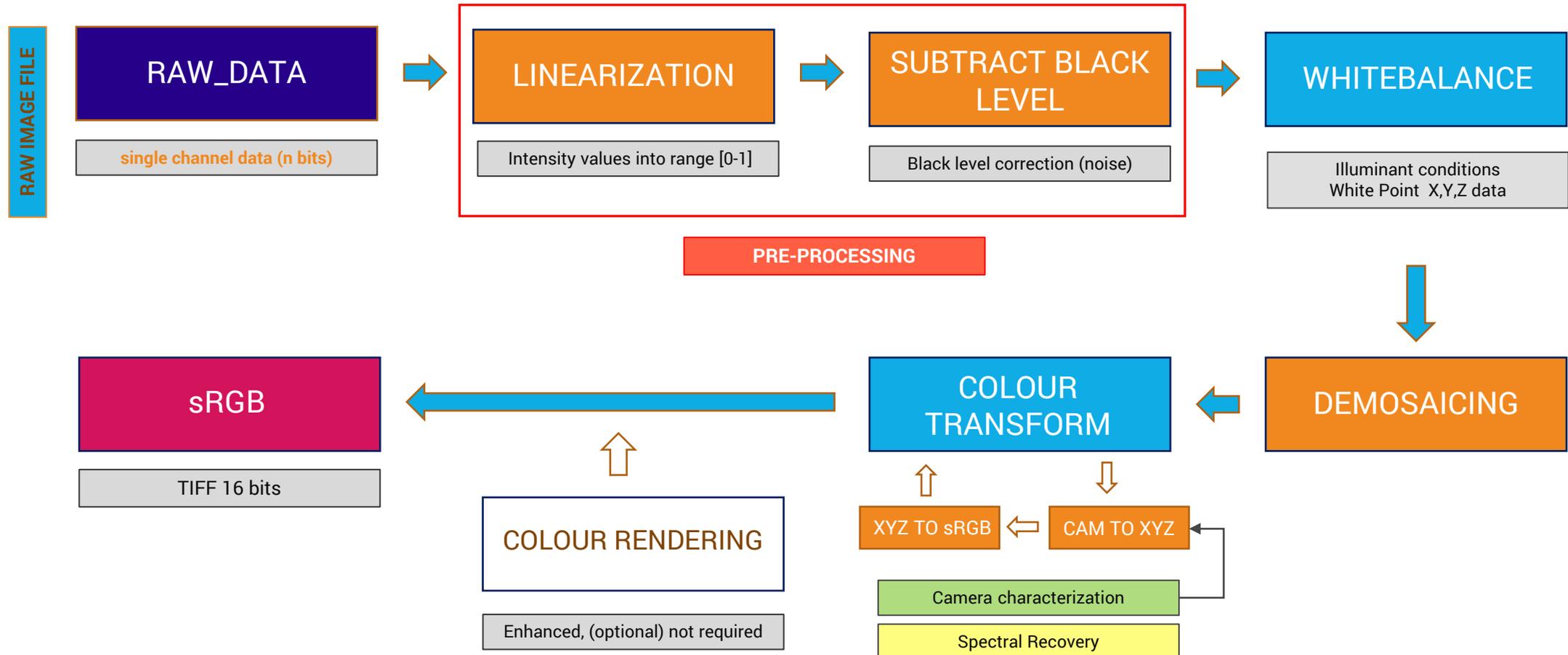
## INDIGO solutions

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

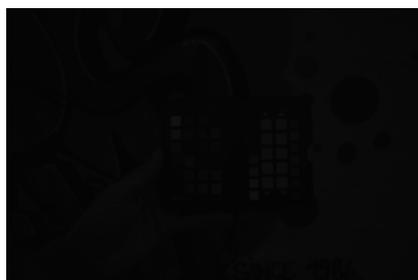
Design and implementation of **INDIGO Python open-source toolbox**: **Easy** to understand and use; giving the users **full control** during the stages of the methodological process.



# INDIGO Colour RAW Image Processing

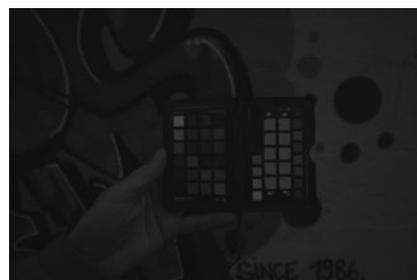


# INDIGO Colour RAW Image Processing



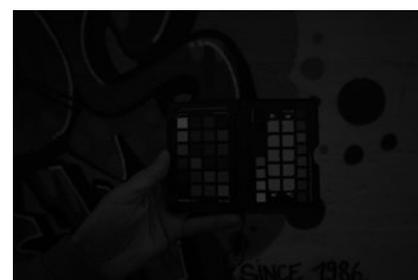
RAW single channel data

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



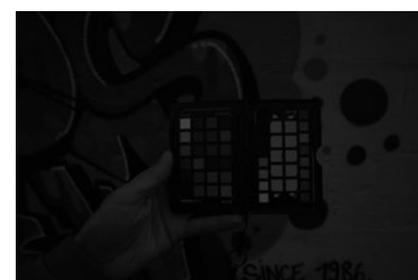
Linearization

Intensity values into range [0,1]



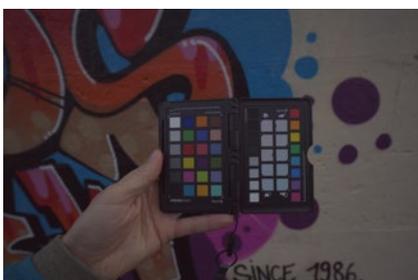
Subtract Black Level

Black level correction (noise)

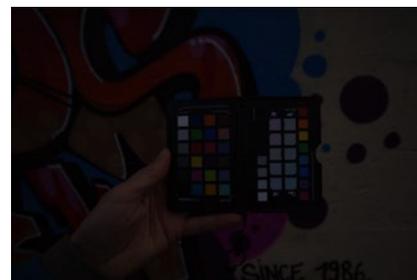


WHITEBALANCE

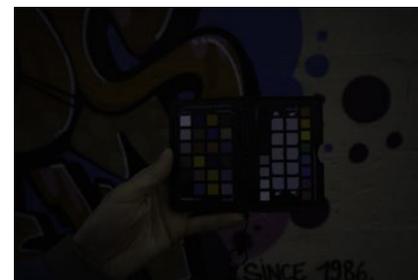
PRE-PROCESSING



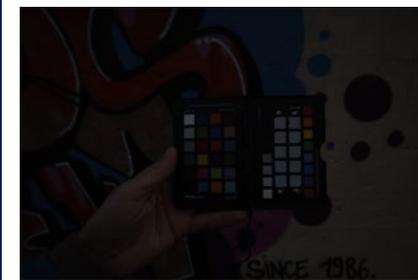
sRGB



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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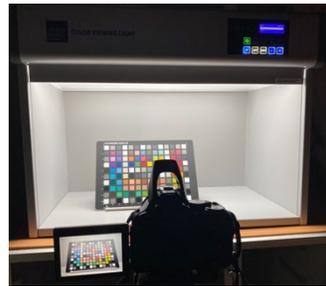
**Polynomial models** are accurate enough.

**Spectral recovery:** estimation of reflectance data from RGB.

# Camera characterization / spectral recovery



ILLUMINANT



IMAGE

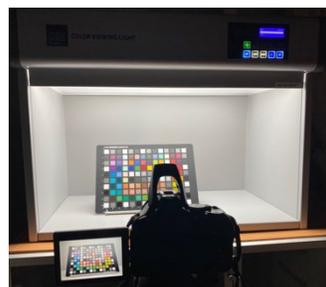


RAW RGB

# Camera characterization / spectral recovery



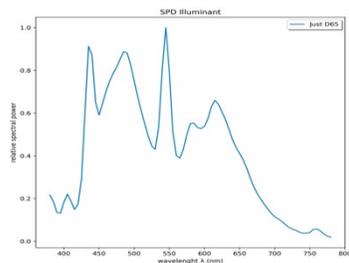
ILLUMINANT



IMAGE



RAW RGB



SPD

# Camera characterization / spectral recovery

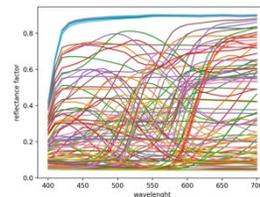
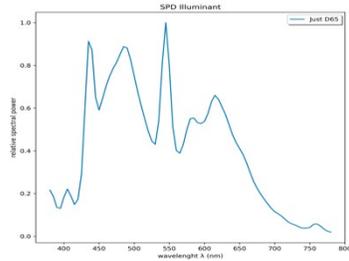


ILLUMINANT

IMAGE

RAW RGB

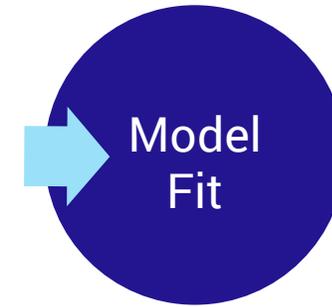
CIE XYZ



SPD

REFLECTANCE

# Camera characterization / spectral recovery

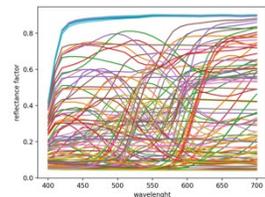
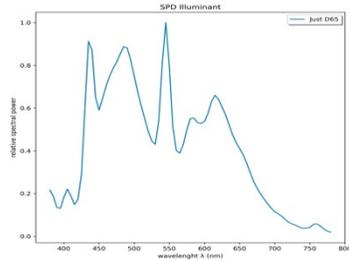
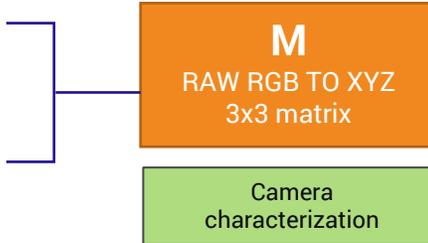


ILLUMINANT

IMAGE

RAW RGB

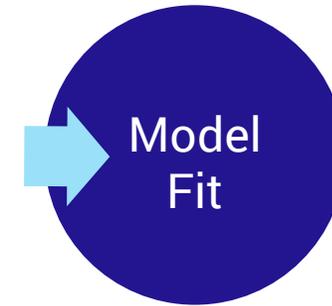
CIE XYZ



SPD

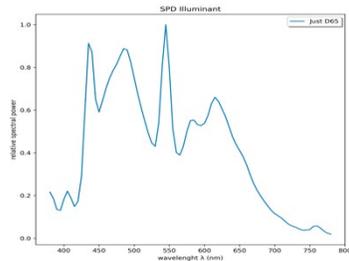
REFLECTANCE

# Camera characterization / spectral recovery



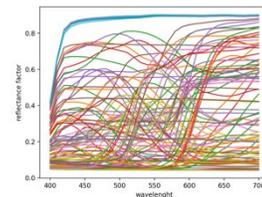
ILLUMINANT

IMAGE



RAW RGB

CIE XYZ



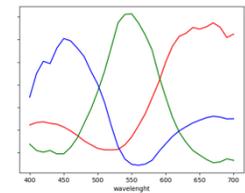
REFLECTANCE

**M**  
RAW RGB TO XYZ  
3x3 matrix

Camera  
characterization

**Q**  
RAW RGB TO REFLECTANCE  
3x31 matrix

Spectral Recovery



SPD

# Camera characterization



ILLUMINANT

RAW RGB

×

M  
RAW RGB  
TO XYZ  
3x3 matrix



CIE XYZ

Camera  
characterization

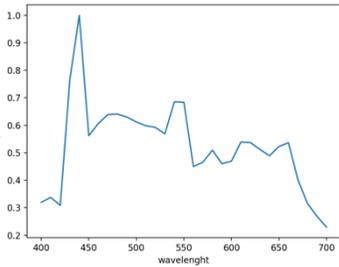


CIE XYZ



sRGB

TIFF 16 bits



SPD

CAT's TO D65



# Camera spectral recovery



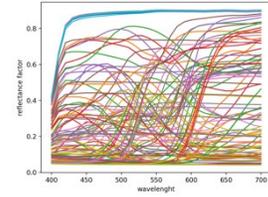
ILLUMINANT

RAW RGB

$\times$

**Q**  
RAW RGB TO REFLECTANCE  
3x31 matrix

Spectral Recovery



REFLECTANCE

CAT's TO D65

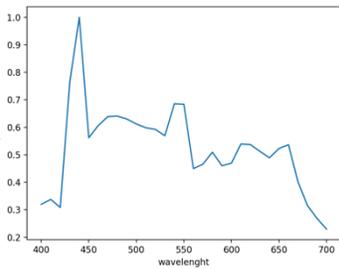
CIE XYZ

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

