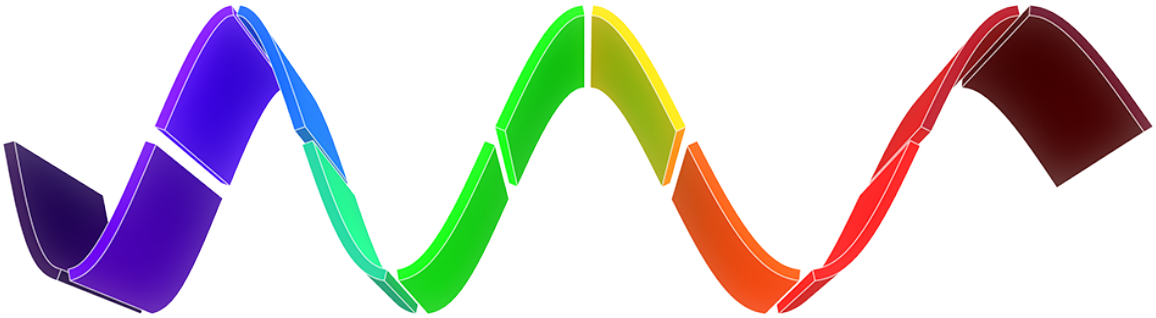


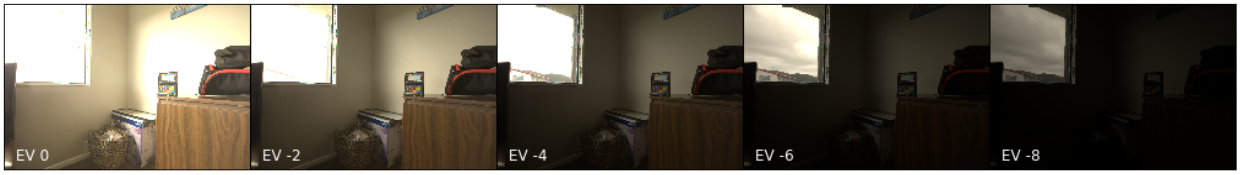
Colour - HDRI Documentation

Release 0.1.4

Colour Developers

Mar 24, 2019

Contents



A Python package implementing various HDRI / Radiance image processing algorithms.

It is open source and freely available under the New BSD License terms.

CHAPTER 1

Features

The following features are available:

- HDRI / Radiance Image Generation
- Debevec (1997) Camera Response Function Computation
- Grossberg (2003) Histogram Based Image Sampling
- Variance Minimization Light Probe Sampling
- Global Tonemapping Operators
- Adobe DNG SDK Colour Processing
- Absolute Luminance Calibration
- Raw Processing Helpers

CHAPTER 2

Installation

Because of their size, the resources dependencies needed to run the various examples and unit tests are not provided within the Pypi package. They are separately available as Git Submodules when cloning the repository.

2.1 Primary Dependencies

Colour - HDRI requires various dependencies in order to run:

- Python 2.7 or Python 3.5
- NumPy
- OpenImageIO

2.2 Optional Features Dependencies

- colour-demosaicing
- Adobe DNG Converter
- dcraw
- ExifTool
- rawpy

2.3 Pypi

Once the dependencies satisfied, **Colour - HDRI** can be installed from the Python Package Index by issuing this command in a shell:

```
pip install colour-hdri
```

The optional features dependencies are installed as follows:

```
pip install 'colour-hdri[optional]'
```

The figures plotting dependencies are installed as follows:

```
pip install 'colour-hdri[plotting]'
```

The tests suite dependencies are installed as follows:

```
pip install 'colour-hdri[tests]'
```

The documentation building dependencies are installed as follows:

```
pip install 'colour-hdri[docs]'
```

CHAPTER 3

Usage

3.1 API

The main reference for Colour - HDRI is the manual:

3.1.1 Colour - HDRI Manual

3.1.1.1 Reference

Colour - HDRI

Camera Calibration

- *Absolute Luminance - Lagarde (2016)*
- *Debevec (1997)*

Absolute Luminance - Lagarde (2016)

`colour_hdri`

`absolute_luminance_calibration_Lagarde2016(...)`	Performs absolute *Luminance* calibration of given *RGB* panoramic image using *Lagarde (2016)* method.

Continued on next page

Table 1 – continued from previous page

upper_hemisphere_illuminance_weights_Lagarde2016(...)	Computes upper hemisphere illuminance weights for use with applications unable to perform the computation directly, i.e.

colour_hdri.absolute_luminance_calibration_Lagarde2016

colour_hdri.**absolute_luminance_calibration_Lagarde2016**(*RGB*, *measured_illuminance*, *colourspace=RGB_Colourspace(sRGB[[, 0.64, 0.33][, 0.3, 0.6][, 0.15, 0.06]][, 0.3127, 0.329], D65[[, 0.4124, 0.3576, 0.1805][, 0.2126, 0.7152, 0.0722][, 0.0193, 0.1192, 0.9505]][[, 3.2406, -1.5372, -0.4986][, -0.9689, 1.8758, 0.0415][, 0.0557, -0.204, 1.057]]*, *<function oetf_sRGB>*, *<function oetf_reverse_sRGB>*, *False*, *False)*)

Performs absolute *Luminance* calibration of given *RGB* panoramic image using *Lagarde (2016)* method.

Parameters

- **RGB** (array_like) – *RGB* panoramic image to calibrate.
- **measured_illuminance** (numeric) – Measured illuminance E_v.
- **colourspace** (*colour.RGB_Colourspace*, optional) – *RGB* colourspace used for internal *Luminance* computation.

Returns Absolute *Luminance* calibrated *RGB* panoramic image.

Return type ndarray

Examples

```
>>> RGB = np.ones((4, 8, 3))
>>> absolute_luminance_calibration_Lagarde2016(  # doctest: +ELLIPSIS
...     RGB, 500)
array([[[ 233.9912506...,  233.9912506...,  233.9912506...],
        [ 233.9912506...,  233.9912506...,  233.9912506...],
        [ 233.9912506...,  233.9912506...,  233.9912506...],
        [ 233.9912506...,  233.9912506...,  233.9912506...],
        [ 233.9912506...,  233.9912506...,  233.9912506...],
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        [ 233.9912506...,  233.9912506...,  233.9912506...],
        [ 233.9912506...,  233.9912506...,  233.9912506...]],
```

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```
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       [[ 233.9912506...,  233.9912506...,  233.9912506...],
        [ 233.9912506...,  233.9912506...,  233.9912506...],
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        [ 233.9912506...,  233.9912506...,  233.9912506...],
        [ 233.9912506...,  233.9912506...,  233.9912506...],
        [ 233.9912506...,  233.9912506...,  233.9912506...],
        [ 233.9912506...,  233.9912506...,  233.9912506...],
        [ 233.9912506...,  233.9912506...,  233.9912506...]]])
```

colour_hdri.upper_hemisphere_illuminance_weights_Lagarde2016

colour_hdri.**upper_hemisphere_illuminance_weights_Lagarde2016**(*height*, *width*)

Computes upper hemisphere illuminance weights for use with applications unable to perform the computation directly, i.e. *Adobe Photoshop*.

Parameters

- **height** (int) – Output array height.
- **width** (int) – Output array width.

Returns Upper hemisphere illuminance weights.

Return type ndarray

References

- [LLJ16]

Examples

```
>>> upper_hemisphere_illuminance_weights_Lagarde2016(  # doctest: +ELLIPSIS
...     16, 1)
array([[ 0...        ],
       [ 4.0143297...],
       [ 7.3345454...],
       [ 9.3865515...],
       [ 9.8155376...],
       [ 8.5473281...],
       [ 5.8012079...],
       [ 2.0520061...],
       [ 0...        ],
       [ 0...        ],
       [ 0...        ],
```

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```
       [ 0...        ],
       [ 0...        ],
       [ 0...        ],
       [ 0...        ],
       [ 0...        ]])
```

Debevec (1997)

colour_hdri

g_solve(Z, B[, l_s, w, n])	Given a set of pixel values observed for several pixels in several images with different exposure times, this function returns the imaging system's response function g as well as the log film irradiance values lE for the observed pixels.
camera_response_functions_Debevec1997(...[, ...])	Returns the camera response functions for given image stack using *Debevec (1997)* method.

colour_hdri.g_solve

colour_hdri.**g_solve**(*Z*, *B*, *l_s=30*, *w=<function weighting_function_Debevec1997>*, *n=256*)

Given a set of pixel values observed for several pixels in several images with different exposure times, this function returns the imaging system's response function g as well as the log film irradiance values lE for the observed pixels.

Parameters

- **Z** (array_like) – Set of pixel values observed for several pixels in several images.
- **B** (array_like) – Log Δt, or log shutter speed for images.
- **l_s** (numeric, optional) – λ smoothing term.
- **w** (callable, optional) – Weighting function w.
- **n** (int, optional) – n constant.

Returns Camera response functions $g(z)$ and log film irradiance values lE.

Return type tuple

References

- [DM97]

colour_hdri.camera_response_functions_Debevec1997

colour_hdri.**camera_response_functions_Debevec1997**(*image_stack*, *s=<function samples_Grossberg2003>*, *samples=1000*, *l_s=30*, *w=<function weighting_function_Debevec1997>*, *n=256*, *normalise=True*)

Returns the camera response functions for given image stack using *Debevec (1997)* method.

Image channels are sampled with s sampling function and the output samples are passed to colour_hdri.g_solve().

Parameters

- **image_stack** (colour_hdri.ImageStack) – Stack of single channel or multi-channel floating point images.
- **s** (callable, optional) – Sampling function s.
- **samples** (int, optional) – Samples count per images.
- **l_s** (numeric, optional) – λ smoothing term.
- **w** (callable, optional) – Weighting function w.
- **n** (int, optional) – n constant.
- **normalise** (bool, optional) – Enables the camera response functions normalisation. Uncertain camera response functions values resulting from w function are set to zero.

Returns Camera response functions $g(z)$.

Return type ndarray

References

- [DM97]

HDRI / Radiance Image Generation

- *Generation*
- *Weighting Functions*

Generation

colour_hdri

image_stack_to_radiance_image(image_stack[, ...])	Generates a HDRI / radiance image from given image stack.

colour_hdri.image_stack_to_radiance_image

colour_hdri.**image_stack_to_radiance_image**(*image_stack*, *weighting_function=<function weighting_function_Debevec1997>*, *weighting_average=False*, *camera_response_functions=None*)

Generates a HDRI / radiance image from given image stack.

Parameters

- **image_stack** (colour_hdri.ImageStack) – Stack of single channel or multi-channel floating point images. The stack is assumed to be representing linear values except if camera_response_functions argument is provided.
- **weighting_function** (callable, optional) – Weighting function w.
- **weighting_average** (bool, optional) – Enables weighting function w computation on channels average instead of on a per channel basis.
- **camera_response_functions** (array_like, optional) – Camera response functions $g(z)$ of the imaging system / camera if the stack is representing non linear values.

Returns Radiance image.

Return type ndarray

Warning: If the image stack contains images with negative or equal to zero values, unpredictable results may occur and NaNs might be generated. It is thus recommended to encode the images in a wider RGB colourspace or clamp negative values.

References

- [BADC11a]

Weighting Functions

colour_hdri

normal_distribution_function(a[, mu, sigma])	Returns given array weighted by a normal distribution function.
hat_function(a)	Returns given array weighted by a hat function.
weighting_function_Debevec1997(a[, ...])	Returns given array weighted by *Debevec (1997)* function.

colour_hdri.normal_distribution_function

colour_hdri.**normal_distribution_function**(*a*, *mu=0.5*, *sigma=0.15*)

Returns given array weighted by a normal distribution function.

Parameters

- **a** (array_like) – Array to apply the weighting function onto.
- **mu** (numeric, optional) – Mean or expectation.

- **sigma** (numeric, optional) – Standard deviation.

Returns Weighted array.

Return type ndarray

Examples

```
>>> normal_distribution_function(np.linspace(0, 1, 10))
array([ 0.00386592,  0.03470859,  0.18002174,  0.53940751,  0.93371212,
        0.93371212,  0.53940751,  0.18002174,  0.03470859,  0.00386592])
```

colour_hdri.hat_function

colour_hdri.**hat_function**(*a*)

Returns given array weighted by a hat function.

Parameters **a** (array_like) – Array to apply the weighting function onto.

Returns Weighted array.

Return type ndarray

Examples

```
>>> hat_function(np.linspace(0, 1, 10))
array([ 0.        ,  0.95099207,  0.99913557,  0.99999812,  1.        ,
        1.        ,  0.99999812,  0.99913557,  0.95099207,  0.        ])
```

colour_hdri.weighting_function_Debevec1997

colour_hdri.**weighting_function_Debevec1997**(*a*, *domain_l=0.01*, *domain_h=0.99*)

Returns given array weighted by *Debevec (1997)* function.

Parameters

- **a** (array_like) – Array to apply the weighting function onto.
- **domain_l** (numeric, optional) – Domain lowest possible value, values less than domain_l will be set to zero.
- **domain_h** (numeric, optional) – Domain highest possible value, values greater than domain_h will be set to zero.

Returns Weighted array.

Return type ndarray

References

- [DM97]

Examples

```
>>> weighting_function_Debevec1997(np.linspace(0, 1, 10))
array([ 0.        ,  0.23273657,  0.48849105,  0.74424552,  1.        ,
        1.        ,  0.74424552,  0.48849105,  0.23273657,  0.        ])
```

Colour Models

- *Adobe DNG SDK*
- *RGB Models*

Adobe DNG SDK

colour_hdri

xy_to_camera_neutral(xy, ...)	Converts given *xy* white balance chromaticity coordinates to *Camera Neutral* coordinates.
camera_neutral_to_xy(camera_neutral, ...[, ...])	Converts given *Camera Neutral* coordinates to *xy* white balance chromaticity coordinates.
XYZ_to_camera_space_matrix(xy, ...)	Returns the *CIE XYZ* to *Camera Space* matrix for given *xy* white balance chromaticity coordinates.
camera_space_to_XYZ_matrix(xy, ...[, ...])	Returns the *Camera Space* to *CIE XYZ* matrix for given *xy* white balance chromaticity coordinates.

colour_hdri.xy_to_camera_neutral

colour_hdri.**xy_to_camera_neutral**(*xy*, *CCT_calibration_illuminant_1*, *CCT_calibration_illuminant_2*, *M_color_matrix_1*, *M_color_matrix_2*, *M_camera_calibration_1*, *M_camera_calibration_2*, *analog_balance*)

Converts given *xy* white balance chromaticity coordinates to *Camera Neutral* coordinates.

Parameters

- **xy** (array_like) – *xy* white balance chromaticity coordinates.
- **CCT_calibration_illuminant_1** (numeric) – Correlated colour temperature of *CalibrationIlluminant1*.
- **CCT_calibration_illuminant_2** (numeric) – Correlated colour temperature of *CalibrationIlluminant2*.
- **M_color_matrix_1** (array_like) – *ColorMatrix1* tag matrix.
- **M_color_matrix_2** (array_like) – *ColorMatrix2* tag matrix.
- **M_camera_calibration_1** (array_like) – *CameraCalibration1* tag matrix.
- **M_camera_calibration_2** (array_like) – *CameraCalibration2* tag matrix.
- **analog_balance** (array_like) – *AnalogBalance* tag vector.

Returns *Camera Neutral* coordinates.

Return type ndarray

References

- [AdobeSystems12d]
- [AdobeSystems12b]
- [AdobeSystems15c]
- [McG12]

Examples

```
>>> M_color_matrix_1 = np.array(
...     [[0.5309, -0.0229, -0.0336],
...      [-0.6241, 1.3265, 0.3337],
...      [-0.0817, 0.1215, 0.6664]])
>>> M_color_matrix_2 = np.array(
...     [[0.4716, 0.0603, -0.0830],
...      [-0.7798, 1.5474, 0.2480],
...      [-0.1496, 0.1937, 0.6651]])
>>> M_camera_calibration_1 = np.identity(3)
>>> M_camera_calibration_2 = np.identity(3)
>>> analog_balance = np.ones(3)
>>> xy_to_camera_neutral(  # doctest: +ELLIPSIS
...     np.array([0.32816244, 0.34698169]),
...     2850,
...     6500,
...     M_color_matrix_1,
...     M_color_matrix_2,
...     M_camera_calibration_1,
...     M_camera_calibration_2,
...     analog_balance)
array([ 0.4130699...,  1...        ,  0.646465...])
```

colour_hdri.camera_neutral_to_xy

colour_hdri.**camera_neutral_to_xy**(*camera_neutral*, *CCT_calibration_illuminant_1*, *CCT_calibration_illuminant_2*, *M_color_matrix_1*, *M_color_matrix_2*, *M_camera_calibration_1*, *M_camera_calibration_2*, *analog_balance*, *epsilon=2.2204460492503131e-16*)

Converts given *Camera Neutral* coordinates to *xy* white balance chromaticity coordinates.

Parameters

- **camera_neutral** (array_like) – *Camera Neutral* coordinates.
- **CCT_calibration_illuminant_1** (numeric) – Correlated colour temperature of *CalibrationIlluminant1*.
- **CCT_calibration_illuminant_2** (numeric) – Correlated colour temperature of *CalibrationIlluminant2*.

- **M_color_matrix_1** (array_like) – *ColorMatrix1* tag matrix.
- **M_color_matrix_2** (array_like) – *ColorMatrix2* tag matrix.
- **M_camera_calibration_1** (array_like) – *CameraCalibration1* tag matrix.
- **M_camera_calibration_2** (array_like) – *CameraCalibration2* tag matrix.
- **analog_balance** (array_like) – *AnalogBalance* tag vector.
- **epsilon** (numeric, optional) – Threshold value for computation convergence.

Returns *xy* white balance chromaticity coordinates.

Return type ndarray

Raises RuntimeError – If the given *Camera Neutral* coordinates did not converge to *xy* white balance chromaticity coordinates.

References

- [AdobeSystems12c]
- [AdobeSystems12b]
- [AdobeSystems15c]
- [McG12]

Examples

```
>>> M_color_matrix_1 = np.array(
...     [[0.5309, -0.0229, -0.0336],
...      [-0.6241, 1.3265, 0.3337],
...      [-0.0817, 0.1215, 0.6664]])
>>> M_color_matrix_2 = np.array(
...     [[0.4716, 0.0603, -0.0830],
...      [-0.7798, 1.5474, 0.2480],
...      [-0.1496, 0.1937, 0.6651]])
>>> M_camera_calibration_1 = np.identity(3)
>>> M_camera_calibration_2 = np.identity(3)
>>> analog_balance = np.ones(3)
>>> camera_neutral_to_xy(  # doctest: +ELLIPSIS
...     np.array([0.413070, 1.000000, 0.646465]),
...     2850,
...     6500,
...     M_color_matrix_1,
...     M_color_matrix_2,
...     M_camera_calibration_1,
...     M_camera_calibration_2,
...     analog_balance)
array([ 0.3281624...,  0.3469816...])
```

colour_hdri.XYZ_to_camera_space_matrix

colour_hdri.**XYZ_to_camera_space_matrix**(*xy*, *CCT_calibration_illuminant_1*, *CCT_calibration_illuminant_2*, *M_color_matrix_1*, *M_color_matrix_2*, *M_camera_calibration_1*, *M_camera_calibration_2*, *analog_balance*)

Returns the *CIE XYZ* to *Camera Space* matrix for given *xy* white balance chromaticity coordinates.

Parameters

- **xy** (array_like) – *xy* white balance chromaticity coordinates.
- **CCT_calibration_illuminant_1** (numeric) – Correlated colour temperature of *CalibrationIlluminant1*.
- **CCT_calibration_illuminant_2** (numeric) – Correlated colour temperature of *CalibrationIlluminant2*.
- **M_color_matrix_1** (array_like) – *ColorMatrix1* tag matrix.
- **M_color_matrix_2** (array_like) – *ColorMatrix2* tag matrix.
- **M_camera_calibration_1** (array_like) – *CameraCalibration1* tag matrix.
- **M_camera_calibration_2** (array_like) – *CameraCalibration2* tag matrix.
- **analog_balance** (array_like) – *AnalogBalance* tag vector.

Returns *CIE XYZ* to *Camera Space* matrix.

Return type ndarray

Notes

- The reference illuminant is D50 as defined per colour_hdri.models.dataset.dng.ADOBE_DNG_XYZ_ILLUMINANT attribute.

References

- [AdobeSystems12b]
- [AdobeSystems15c]
- [McG12]

Examples

```
>>> M_color_matrix_1 = np.array(
...     [[0.5309, -0.0229, -0.0336],
...      [-0.6241, 1.3265, 0.3337],
...      [-0.0817, 0.1215, 0.6664]])
>>> M_color_matrix_2 = np.array(
...     [[0.4716, 0.0603, -0.0830],
...      [-0.7798, 1.5474, 0.2480],
...      [-0.1496, 0.1937, 0.6651]])
>>> M_camera_calibration_1 = np.identity(3)
>>> M_camera_calibration_2 = np.identity(3)
>>> analog_balance = np.ones(3)
```

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```
>>> XYZ_to_camera_space_matrix(  # doctest: +ELLIPSIS
...     np.array([0.34510414, 0.35162252]),
...     2850,
...     6500,
...     M_color_matrix_1,
...     M_color_matrix_2,
...     M_camera_calibration_1,
...     M_camera_calibration_2,
...     analog_balance)
array([[ 0.4854908...,  0.0408106..., -0.0714282...],
       [-0.7433278...,  1.4956549...,  0.2680749...],
       [-0.1336946...,  0.1767874...,  0.6654045...]])
```

colour_hdri.camera_space_to_XYZ_matrix

colour_hdri.**camera_space_to_XYZ_matrix**(*xy*, *CCT_calibration_illuminant_1*, *CCT_calibration_illuminant_2*, *M_color_matrix_1*, *M_color_matrix_2*, *M_camera_calibration_1*, *M_camera_calibration_2*, *analog_balance*, *M_forward_matrix_1*, *M_forward_matrix_2*, *chromatic_adaptation_transform='Bradford'*)

Returns the *Camera Space* to *CIE XYZ* matrix for given *xy* white balance chromaticity coordinates.

Parameters

- **xy** (array_like) – *xy* white balance chromaticity coordinates.
- **CCT_calibration_illuminant_1** (numeric) – Correlated colour temperature of *CalibrationIlluminant1*.
- **CCT_calibration_illuminant_2** (numeric) – Correlated colour temperature of *CalibrationIlluminant2*.
- **M_color_matrix_1** (array_like) – *ColorMatrix1* tag matrix.
- **M_color_matrix_2** (array_like) – *ColorMatrix2* tag matrix.
- **M_camera_calibration_1** (array_like) – *CameraCalibration1* tag matrix.
- **M_camera_calibration_2** (array_like) – *CameraCalibration2* tag matrix.
- **analog_balance** (array_like) – *AnalogBalance* tag vector.
- **M_forward_matrix_1** (array_like) – *ForwardMatrix1* tag matrix.
- **M_forward_matrix_2** (array_like) – *ForwardMatrix2* tag matrix.
- **chromatic_adaptation_transform** (unicode, optional) – **{'CAT02', 'XYZ Scaling', 'Von Kries', 'Bradford', 'Sharp', 'Fairchild', 'CMCCAT97', 'CMCCAT2000', 'CAT02_BRILL_CAT', 'Bianco', 'Bianco PC'}**, Chromatic adaptation transform.

Returns *Camera Space* to *CIE XYZ* matrix.

Return type ndarray

Notes

- The reference illuminant is D50 as defined per colour_hdri.models.dataset.dng.ADOBE_DNG_XYZ_ILLUMINANT attribute.

References

- [AdobeSystems12b]
- [AdobeSystems12a]
- [AdobeSystems15c]
- [McG12]

Examples

```
>>> M_color_matrix_1 = np.array(
...     [[0.5309, -0.0229, -0.0336],
...      [-0.6241, 1.3265, 0.3337],
...      [-0.0817, 0.1215, 0.6664]])
>>> M_color_matrix_2 = np.array(
...     [[0.4716, 0.0603, -0.0830],
...      [-0.7798, 1.5474, 0.2480],
...      [-0.1496, 0.1937, 0.6651]])
>>> M_camera_calibration_1 = np.identity(3)
>>> M_camera_calibration_2 = np.identity(3)
>>> analog_balance = np.ones(3)
>>> M_forward_matrix_1 = np.array(
...     [[0.8924, -0.1041, 0.1760],
...      [0.4351, 0.6621, -0.0972],
...      [0.0505, -0.1562, 0.9308]])
>>> M_forward_matrix_2 = np.array(
...     [[0.8924, -0.1041, 0.1760],
...      [0.4351, 0.6621, -0.0972],
...      [0.0505, -0.1562, 0.9308]])
>>> camera_space_to_XYZ_matrix(  # doctest: +ELLIPSIS
...     np.array([0.32816244, 0.34698169]),
...     2850,
...     6500,
...     M_color_matrix_1,
...     M_color_matrix_2,
...     M_camera_calibration_1,
...     M_camera_calibration_2,
...     analog_balance,
...     M_forward_matrix_1,
...     M_forward_matrix_2)
array([[ 2.1604087..., -0.1041...    ,  0.2722498...],
       [ 1.0533324...,  0.6621...    , -0.1503561...],
       [ 0.1222553..., -0.1562...    ,  1.4398304...]])
```

RGB Models

colour_hdri

camera_space_to_RGB(RGB, ...)	Converts given *RGB* array from *camera space* to given *RGB* colourspace.
camera_space_to_sRGB(RGB, M_XYZ_to_camera_space)	Converts given *RGB* array from *camera space* to *sRGB* colourspace.

colour_hdri.camera_space_to_RGB

colour_hdri.**camera_space_to_RGB**(*RGB*, *M_XYZ_to_camera_space*, *RGB_to_XYZ_matrix*)

Converts given *RGB* array from *camera space* to given *RGB* colourspace.

Parameters

- **RGB** (array_like) – Camera space *RGB* colourspace array.
- **XYZ_to_camera_matrix** (array_like) – Matrix converting from *CIE XYZ* tristimulus values to *camera space*.
- **RGB_to_XYZ_matrix** (array_like) – Matrix converting from *RGB* colourspace to *CIE XYZ* tristimulus values.

Returns *RGB* colourspace array.

Return type ndarray

Examples

```
>>> RGB = np.array([0.80660, 0.81638, 0.65885])
>>> M_XYZ_to_camera_space = np.array([
...     [0.47160000, 0.06030000, -0.08300000],
...     [-0.77980000, 1.54740000, 0.24800000],
...     [-0.14960000, 0.19370000, 0.66510000]])
>>> RGB_to_XYZ_matrix = np.array([
...     [0.41238656, 0.35759149, 0.18045049],
...     [0.21263682, 0.71518298, 0.07218020],
...     [0.01933062, 0.11919716, 0.95037259]])
>>> camera_space_to_RGB(
...     RGB,
...     M_XYZ_to_camera_space,
...     RGB_to_XYZ_matrix)  # doctest: +ELLIPSIS
array([ 0.7564180...,  0.8683192...,  0.6044589...])
```

colour_hdri.camera_space_to_sRGB

colour_hdri.**camera_space_to_sRGB**(*RGB*, *M_XYZ_to_camera_space*)

Converts given *RGB* array from *camera space* to *sRGB* colourspace.

Parameters

- **RGB** (array_like) – Camera space *RGB* colourspace array.
- **M_XYZ_to_camera_space** (array_like) – Matrix converting from *CIE XYZ* tristimulus values to *camera space*.

Returns *sRGB* colourspace array.

Return type ndarray

Examples

```
>>> RGB = np.array([0.80660, 0.81638, 0.65885])
>>> M_XYZ_to_camera_space = np.array([
...     [0.47160000, 0.06030000, -0.08300000],
...     [-0.77980000, 1.54740000, 0.24800000],
...     [-0.14960000, 0.19370000, 0.66510000]])
>>> camera_space_to_sRGB(RGB, M_XYZ_to_camera_space)  # doctest: +ELLIPSIS
array([ 0.7564350...,  0.8683155...,  0.6044706...])
```

Plotting

HDRI / Radiance Image

colour_hdri.plotting

radiance_image_strip_plot

Tonemapping Operators

colour_hdri.plotting

tonemapping_operator_image_plot

Image Processing

Adobe DNG SDK

Raw Files

colour_hdri

convert_raw_files_to_dng_files(raw_files, ...)	Converts given raw files to *dng* files using given output directory.

Continued on next page

Table 9 – continued from previous page

RAW_CONVERTER	Command line raw conversion application, usually Dave Coffin's *dcraw*.
RAW_CONVERSION_ARGUMENTS	Arguments for the command line raw conversion application for non demosaiced linear *tiff* file format output.
RAW_D_CONVERSION_ARGUMENTS	Arguments for the command line raw conversion application for demosaiced linear *tiff* file format output.

colour_hdri.convert_raw_files_to_dng_files

colour_hdri.**convert_raw_files_to_dng_files**(*raw_files*, *output_directory*)

Converts given raw files to *dng* files using given output directory.

Parameters

- **raw_files** (array_like) – Raw files to convert to *dng* files.
- **output_directory** (unicode) – Output directory.

Returns *dng* files.

Return type list

colour_hdri.RAW_CONVERTER

colour_hdri.**RAW_CONVERTER = 'dcraw'**

Command line raw conversion application, usually Dave Coffin's *dcraw*.

RAW_CONVERTER : unicode

colour_hdri.RAW_CONVERSION_ARGUMENTS

colour_hdri.**RAW_CONVERSION_ARGUMENTS = '-t 0 -D -W -4 -T "{0}"'**

Arguments for the command line raw conversion application for non demosaiced linear *tiff* file format output.

RAW_CONVERSION_ARGUMENTS : unicode

colour_hdri.RAW_D_CONVERSION_ARGUMENTS

colour_hdri.**RAW_D_CONVERSION_ARGUMENTS = '-t 0 -H 1 -r 1 1 1 1 -4 -q 3 -o 0 -T "{0}"'**

Arguments for the command line raw conversion application for demosaiced linear *tiff* file format output.

RAW_D_CONVERSION_ARGUMENTS : unicode

DNG Files

colour_hdri

convert_dng_files_to_intermediate_files(...)	Converts given *dng* files to intermediate *tiff* files using given output directory.
DNG_CONVERTER	
DNG_CONVERSION_ARGUMENTS	Arguments for the command line *dng* conversion application.
DNG_EXIF_TAGS_BINDING	Exif tags binding for a *dng* file.
read_dng_files_exif_tags(dng_files[, ...])	Reads given *dng* files exif tags using given binding.

colour_hdri.convert_dng_files_to_intermediate_files

colour_hdri.**convert_dng_files_to_intermediate_files**(*dng_files*, *output_directory*, *demosaicing=False*)

Converts given *dng* files to intermediate *tiff* files using given output directory.

Parameters

- **dng_files** (array_like) – *dng* files to convert to intermediate *tiff* files.
- **output_directory** (str) – Output directory.
- **demosaicing** (bool) – Perform demosaicing on conversion.

Returns Intermediate *tiff* files.

Return type list

colour_hdri.DNG_CONVERTER

colour_hdri.**DNG_CONVERTER = None**

colour_hdri.DNG_CONVERSION_ARGUMENTS

colour_hdri.**DNG_CONVERSION_ARGUMENTS = '-l -d "{0}" "{1}"'**

Arguments for the command line *dng* conversion application.

DNG_CONVERSION_ARGUMENTS : unicode

colour_hdri.DNG_EXIF_TAGS_BINDING

colour_hdri.**DNG_EXIF_TAGS_BINDING = CaseInsensitiveMapping({'EXIF': CaseInsensitiveMapping({'Make': (<functi**

Exif tags binding for a *dng* file.

DNG_EXIF_TAGS_BINDING : CaseInsensitiveMapping

colour_hdri.read_dng_files_exif_tags

colour_hdri.**read_dng_files_exif_tags**(*dng_files*, *exif_tags_binding=CaseInsensitiveMapping({'EXIF': CaseInsensitiveMapping({'Make': (<function parse_exif_string>, None), 'Camera Model Name': (<function parse_exif_string>, None), 'Camera Serial Number': (<function parse_exif_string>, None), 'Lens Model': (<function parse_exif_string>, None), 'DNG Lens Info': (<function parse_exif_string>, None), 'Focal Length': (<function parse_exif_numeric>, None), 'Exposure Time': (<function parse_exif_numeric>, None), 'F Number': (<function parse_exif_numeric>, None), 'ISO': (<function parse_exif_numeric>, None), 'CFA Pattern 2': (<function <lambda>>, None), 'CFA Plane Color': (<function <lambda>>, None), 'Black Level Repeat Dim': (<function <lambda>>, None), 'Black Level': (<function <lambda>>, None), 'White Level': (<function <lambda>>, None), 'Samples Per Pixel': (<function <lambda>>, None), 'Active Area': (<function <lambda>>, None), 'Orientation': (<function <lambda>>, None), 'Camera Calibration Sig': (<function parse_exif_string>, None), 'Profile Calibration Sig': (<function parse_exif_string>, None), 'Calibration Illuminant 1': (<function <lambda>>, 17), 'Calibration Illuminant 2': (<function <lambda>>, 21), 'Color Matrix 1': (<function <lambda>>, '1 0 0 0 1 0 0 0 1'), 'Color Matrix 2': (<function <lambda>>, '1 0 0 0 1 0 0 0 1'), 'Camera Calibration 1': (<function <lambda>>, '1 0 0 0 1 0 0 0 1'), 'Camera Calibration 2': (<function <lambda>>, '1 0 0 0 1 0 0 0 1'), 'Analog Balance': (<function <lambda>>, '1 1 1'), 'Reduction Matrix 1': (<function <lambda>>, '1 0 0 0 1 0 0 0 1'), 'Reduction Matrix 2': (<function <lambda>>, '1 0 0 0 1 0 0 0 1'), 'Forward Matrix 1': (<function <lambda>>, '1 0 0 0 1 0 0 0 1'), 'Forward Matrix 2': (<function <lambda>>, '1 0 0 0 1 0 0 0 1'), 'As Shot Neutral': (<function <lambda>>, '1 1 1'), 'Baseline Exposure': (<function <lambda>>, None), 'Baseline Noise': (<function <lambda>>, None)})})*)

Reads given *dng* files exif tags using given binding.

Parameters

- **dng_files** (array_like) – *dng* files to read the exif tags from.
- **exif_tags_binding** (dict_like) – Exif tags binding.

Returns *dng* files exif tags.

Return type list

Highlights Recovery

- *Clipped Highlights Recovery*

Clipped Highlights Recovery

colour_hdri

highlights_recovery_blend(RGB, multipliers)	Performs highlights recovery using *Coffin (1997)* method from *dcraw*.
highlights_recovery_LCHab(RGB[, threshold, ...])	Performs highlights recovery in *CIE L*C*Hab* colourspace.

colour_hdri.highlights_recovery_blend

colour_hdri.**highlights_recovery_blend**(*RGB*, *multipliers*, *threshold=0.99*)

Performs highlights recovery using *Coffin (1997)* method from *dcraw*.

Parameters

- **RGB** (array_like) – *RGB* colourspace array.
- **multipliers** (array_like) – Normalised camera white level or white balance multipliers.
- **threshold** (numeric, optional) – Threshold for highlights selection.

Returns Highlights recovered *RGB* colourspace array.

Return type ndarray

References

- [Cof15]

colour_hdri.highlights_recovery_LCHab

colour_hdri.**highlights_recovery_LCHab**(*RGB*, *threshold=None*, *RGB_colourspace=RGB_Colourspace(sRGB[[, 0.64, 0.33][, 0.3, 0.6][, 0.15, 0.06]][, 0.3127, 0.329], D65[[, 0.4124, 0.3576, 0.1805][, 0.2126, 0.7152, 0.0722][, 0.0193, 0.1192, 0.9505]][[, 3.2406, -1.5372, -0.4986][, -0.9689, 1.8758, 0.0415][, 0.0557, -0.204, 1.057]]*, *<function oetf_sRGB>*, *<function oetf_reverse_sRGB>*, *False*, *False)*)

Performs highlights recovery in *CIE L*C*Hab* colourspace.

Parameters

- **RGB** (array_like) – *RGB* colourspace array.
- **threshold** (numeric, optional) – Threshold for highlights selection, automatically computed if not given.
- **RGB_colourspace** (RGB_Colourspace, optional) – Working *RGB* colourspace to perform the *CIE L*C*Hab* to and from.

Returns Highlights recovered *RGB* colourspace array.

Return type ndarray

Image Sampling

- *Viriyothai (2009)*
- *Grossberg (2013)*

Viriyothai (2009)

colour_hdri

light_probe_sampling_variance_minimization_Viriyothai2009(...)	Sample given light probe to find lights using *Viriyothai (2009)* variance minimization light probe sampling algorithm.

colour_hdri.light_probe_sampling_variance_minimization_Viriyothai2009

colour_hdri.**light_probe_sampling_variance_minimization_Viriyothai2009**(*light_probe*, *lights_count=16*, *colourspace=RGB_Colourspace(sRGB[[, 0.64, 0.33][, 0.3, 0.6][, 0.15, 0.06]][, 0.3127, 0.329], D65[[, 0.4124, 0.3576, 0.1805][, 0.2126, 0.7152, 0.0722][, 0.0193, 0.1192, 0.9505]][[, 3.2406, -1.5372, -0.4986][, -0.9689, 1.8758, 0.0415][, 0.0557, -0.204, 1.057]], <function oetf_sRGB>, <function oetf_reverse_sRGB>, False, False)*)

Sample given light probe to find lights using *Viriyothai (2009)* variance minimization light probe sampling algorithm.

Parameters

- **light_probe** (array_like) – Array to sample for lights.
- **lights_count** (int) – Amount of lights to generate.
- **colourspace** (*colour.RGB_Colourspace*, optional) – *RGB* colourspace used for internal *Luminance* computation.

Returns list of colour_hdri.sampling.variance_minimization.Light_Specification lights.

Return type list

References

- [VD09]

Grossberg (2013)

colour_hdri

samples_Grossberg2003(image_stack[, samples, n])	Returns the samples for given image stack intensity histograms using *Grossberg (2003)* method.

colour_hdri.samples_Grossberg2003

colour_hdri.**samples_Grossberg2003**(*image_stack*, *samples=1000*, *n=256*)

Returns the samples for given image stack intensity histograms using *Grossberg (2003)* method.

Parameters

- **image_stack** (array_like) – Stack of single channel or multi-channel floating point images.
- **samples** (int, optional) – Samples count.
- **n** (int, optional) – Histograms bins count.

Returns Intensity histograms samples.

Return type ndarray

References

- [BB14]
- [GN03]

Tonemapping Operators

- *Global*
  - *Simple*
  - *Normalisation*
  - *Gamma*
  - *Logarithmic*
  - *Logarithmic Mapping*
  - *Exponential*
  - *Exponentiation Mapping*

- *Schlick (1994)*
- *Tumblin, Hodgins and Guenter (1999)*
- *Reinhard and Devlin (2004)*
- *Habble (2010) - Filmic*

Global

Simple

colour_hdri

tonemapping_operator_simple(RGB)	Performs given *RGB* array tonemapping using the simple method: $\frac{RGB}{RGB + 1}$.

colour_hdri.tonemapping_operator_simple

colour_hdri.**tonemapping_operator_simple**(*RGB*)

Performs given *RGB* array tonemapping using the simple method: $\frac{RGB}{RGB + 1}$.

Parameters **RGB** (array_like) – *RGB* array to perform tonemapping onto.

Returns Tonemapped *RGB* array.

Return type ndarray

References

- [Wikb]

Examples

```
>>> tonemapping_operator_simple(np.array(
...     [[[0.48046875, 0.35156256, 0.23632812],
...       [1.39843753, 0.55468757, 0.39062594]],
...      [[4.40625388, 2.15625895, 1.34375372],
...       [6.59375023, 3.43751395, 2.21875829]]]))  # doctest: +ELLIPSIS
array([[[ 0.3245382...,  0.2601156...,  0.1911532...],
        [ 0.5830618...,  0.3567839...,  0.2808993...]],
<BLANKLINE>
       [[ 0.8150290...,  0.6831692...,  0.5733340...],
        [ 0.8683127...,  0.7746486...,  0.6893211...]]])
```

Normalisation

colour_hdri

tonemapping_operator_normalisation(RGB[, ...])	Performs given *RGB* array tonemapping using the normalisation method.

colour_hdri.tonemapping_operator_normalisation

colour_hdri.**tonemapping_operator_normalisation**(*RGB*, *colourspace=RGB_Colourspace(sRGB[[, 0.64, 0.33][, 0.3, 0.6][, 0.15, 0.06]][, 0.3127, 0.329], D65[[, 0.4124, 0.3576, 0.1805][, 0.2126, 0.7152, 0.0722][, 0.0193, 0.1192, 0.9505]][[, 3.2406, -1.5372, -0.4986][, -0.9689, 1.8758, 0.0415][, 0.0557, -0.204, 1.057]]*, *<function oetf_sRGB>*, *<function oetf_reverse_sRGB>*, *False*, *False)*)

Performs given *RGB* array tonemapping using the normalisation method.

Parameters

- **RGB** (array_like) – *RGB* array to perform tonemapping onto.
- **colourspace** (*colour.RGB_Colourspace*, optional) – *RGB* colourspace used for internal *Luminance* computation.

Returns Tonemapped *RGB* array.

Return type ndarray

References

- [BADC11b]

Examples

```
>>> tonemapping_operator_normalisation(np.array(
...     [[[0.48046875, 0.35156256, 0.23632812],
...       [1.39843753, 0.55468757, 0.39062594]],
...      [[4.40625388, 2.15625895, 1.34375372],
...       [6.59375023, 3.43751395, 2.21875829]]]))  # doctest: +ELLIPSIS
array([[[ 0.1194997...,  0.0874388...,  0.0587783...],
        [ 0.3478122...,  0.1379590...,  0.0971544...]],
<BLANKLINE>
       [[ 1.0959009...,  0.5362936...,  0.3342115...],
        [ 1.6399638...,  0.8549608...,  0.5518382...]]])
```

Gamma

colour_hdri

tonemapping_operator_gamma(RGB[, gamma, EV])	Performs given *RGB* array tonemapping using the gamma and exposure correction method.

colour_hdri.tonemapping_operator_gamma

colour_hdri.**tonemapping_operator_gamma**(*RGB*, *gamma=1*, *EV=0*)

Performs given *RGB* array tonemapping using the gamma and exposure correction method.

Parameters

- **RGB** (array_like) – *RGB* array to perform tonemapping onto.
- **gamma** (numeric, optional) – γ correction value.
- **EV** (numeric, optional) – Exposure adjustment value.

Returns Tonemapped *RGB* array.

Return type ndarray

References

- [BADC11b]

Examples

```
>>> tonemapping_operator_gamma(np.array(
...     [[[0.48046875, 0.35156256, 0.23632812],
...       [1.39843753, 0.55468757, 0.39062594]],
...      [[4.40625388, 2.15625895, 1.34375372],
...       [6.59375023, 3.43751395, 2.21875829]]]),
...      1.0, -3.0)  # doctest: +ELLIPSIS
array([[[ 0.0600585...,  0.0439453...,  0.0295410...],
        [ 0.1748046...,  0.0693359...,  0.0488282...]],
<BLANKLINE>
       [[ 0.5507817...,  0.2695323...,  0.1679692...],
        [ 0.8242187...,  0.4296892...,  0.2773447...]]])
```

Logarithmic

colour_hdri

tonemapping_operator_logarithmic(RGB[, q, ...])	Performs given *RGB* array tonemapping using the logarithmic method.
tonemapping_operator_exponential(RGB[, q, ...])	Performs given *RGB* array tonemapping using the exponential method.
tonemapping_operator_logarithmic_mapping(RGB)	Performs given *RGB* array tonemapping using the logarithmic mapping method.
tonemapping_operator_exponentiation_mapping(RGB[, p, ...])	Performs given *RGB* array tonemapping using the exponentiation mapping method.
tonemapping_operator_Schlick1994(RGB[, p, ...])	Performs given *RGB* array tonemapping using *Schlick (1994)* method.
tonemapping_operator_Tumblin1999(RGB[, ...])	Performs given *RGB* array tonemapping using *Tumblin, Hodgins and Guenter (1999)* method.
tonemapping_operator_Reinhard2004(RGB[, f, ...])	Performs given *RGB* array tonemapping using *Reinhard and Devlin (2004)* method.

Continued on next page

Table 17 – continued from previous page

tonemapping_operator_filmic(RGB[, ...])	Performs given *RGB* array tonemapping using *Hable (2010)* method.

colour_hdri.tonemapping_operator_logarithmic

colour_hdri.**tonemapping_operator_logarithmic**(*RGB*, *q=1*, *k=1*, *colourspace=RGB_Colourspace(sRGB*[[, *0.64*, *0.33*][, *0.3*, *0.6*][, *0.15*, *0.06*]][, *0.3127*, *0.329*], *D65*[[, *0.4124*, *0.3576*, *0.1805*][, *0.2126*, *0.7152*, *0.0722*][, *0.0193*, *0.1192*, *0.9505*]][[, *3.2406*, *-1.5372*, *-0.4986*][, *-0.9689*, *1.8758*, *0.0415*][, *0.0557*, *-0.204*, *1.057*]], *<function oetf_sRGB>*, *<function oetf_reverse_sRGB>*, *False*, *False)*)

Performs given *RGB* array tonemapping using the logarithmic method.

Parameters

- **RGB** (array_like) – *RGB* array to perform tonemapping onto.
- **q** (numeric, optional) – q.
- **k** (numeric, optional) – k.
- **colourspace** (*colour.RGB_Colourspace*, optional) – *RGB* colourspace used for internal *Luminance* computation.

Returns Tonemapped *RGB* array.

Return type ndarray

References

- [BADC11b]

Examples

```
>>> tonemapping_operator_logarithmic(np.array(
...     [[[0.48046875, 0.35156256, 0.23632812],
...       [1.39843753, 0.55468757, 0.39062594]],
...      [[4.40625388, 2.15625895, 1.34375372],
...       [6.59375023, 3.43751395, 2.21875829]]]),
...       1.0, 25)  # doctest: +ELLIPSIS
array([[[ 0.0884587...,  0.0647259...,  0.0435102...],
        [ 0.2278222...,  0.0903652...,  0.0636376...]],
<BLANKLINE>
       [[ 0.4717487...,  0.2308565...,  0.1438669...],
        [ 0.5727396...,  0.2985858...,  0.1927235...]]])
```

colour_hdri.tonemapping_operator_exponential

colour_hdri.**tonemapping_operator_exponential**(*RGB*, *q=1*, *k=1*, *colourspace=RGB_Colourspace(sRGB*[[, *0.64*, *0.33*][, *0.3*, *0.6*][, *0.15*, *0.06*]][, *0.3127*, *0.329*], *D65*[[, *0.4124*, *0.3576*, *0.1805*][, *0.2126*, *0.7152*, *0.0722*][, *0.0193*, *0.1192*, *0.9505*]][[, *3.2406*, *-1.5372*, *-0.4986*][, *-0.9689*, *1.8758*, *0.0415*][, *0.0557*, *-0.204*, *1.057*]], *<function oetf_sRGB>*, *<function oetf_reverse_sRGB>*, *False*, *False)*)

Performs given *RGB* array tonemapping using the exponential method.

Parameters

- **RGB** (array_like) – *RGB* array to perform tonemapping onto.
- **q** (numeric, optional) – q.
- **k** (numeric, optional) – k.
- **colourspace** (*colour.RGB_Colourspace*, optional) – *RGB* colourspace used for internal *Luminance* computation.

Returns Tonemapped *RGB* array.

Return type ndarray

References

- [BADC11b]

Examples

```
>>> tonemapping_operator_exponential(np.array(
...     [[[0.48046875, 0.35156256, 0.23632812],
...       [1.39843753, 0.55468757, 0.39062594]],
...      [[4.40625388, 2.15625895, 1.34375372],
...       [6.59375023, 3.43751395, 2.21875829]]]),
...       1.0, 25)  # doctest: +ELLIPSIS
array([[[ 0.0148082...,  0.0108353...,  0.0072837...],
        [ 0.0428669...,  0.0170031...,  0.0119740...]],
<BLANKLINE>
       [[ 0.1312736...,  0.0642404...,  0.0400338...],
        [ 0.1921684...,  0.1001830...,  0.0646635...]]])
```

colour_hdri.tonemapping_operator_logarithmic_mapping

colour_hdri.**tonemapping_operator_logarithmic_mapping**(*RGB*, *p=1*, *q=1*, *colourspace=RGB_Colourspace(sRGB[[, 0.64, 0.33][, 0.3, 0.6][, 0.15, 0.06]][, 0.3127, 0.329], D65[[, 0.4124, 0.3576, 0.1805][, 0.2126, 0.7152, 0.0722][, 0.0193, 0.1192, 0.9505]][[, 3.2406, -1.5372, -0.4986][, -0.9689, 1.8758, 0.0415][, 0.0557, -0.204, 1.057]]*, *<function oetf_sRGB>*, *<function oetf_reverse_sRGB>*, *False*, *False)*)

Performs given *RGB* array tonemapping using the logarithmic mapping method.

Parameters

- **RGB** (array_like) – *RGB* array to perform tonemapping onto.
- **p** (numeric, optional) – p.
- **q** (numeric, optional) – q.
- **colourspace** (*colour.RGB_Colourspace*, optional) – *RGB* colourspace used for internal *Luminance* computation.

Returns Tonemapped *RGB* array.

Return type ndarray

References

- [Sch94]

Examples

```
>>> tonemapping_operator_logarithmic_mapping(np.array(
...     [[[0.48046875, 0.35156256, 0.23632812],
...       [1.39843753, 0.55468757, 0.39062594]],
...      [[4.40625388, 2.15625895, 1.34375372],
...       [6.59375023, 3.43751395, 2.21875829]]]))  # doctest: +ELLIPSIS
array([[[ 0.2532899...,  0.1853341...,  0.1245857...],
        [ 0.6523387...,  0.2587489...,  0.1822179...]],
<BLANKLINE>
       [[ 1.3507897...,  0.6610269...,  0.4119437...],
        [ 1.6399638...,  0.8549608...,  0.5518382...]]])
```

colour_hdri.tonemapping_operator_exponentiation_mapping

colour_hdri.**tonemapping_operator_exponentiation_mapping**(*RGB*, *p=1*, *q=1*, *colourspace=RGB_Colourspace(sRGB[[, 0.64, 0.33][, 0.3, 0.6][, 0.15, 0.06]][, 0.3127, 0.329], D65[[, 0.4124, 0.3576, 0.1805][, 0.2126, 0.7152, 0.0722][, 0.0193, 0.1192, 0.9505]][[, 3.2406, -1.5372, -0.4986][, -0.9689, 1.8758, 0.0415][, 0.0557, -0.204, 1.057]], <function oetf_sRGB>, <function oetf_reverse_sRGB>, False, False)*)

Performs given *RGB* array tonemapping using the exponentiation mapping method.

Parameters

- **RGB** (array_like) – *RGB* array to perform tonemapping onto.
- **p** (numeric, optional) – p.
- **q** (numeric, optional) – q.
- **colourspace** (*colour.RGB_Colourspace*, optional) – *RGB* colourspace used for internal *Luminance* computation.

Returns Tonemapped *RGB* array.

Return type ndarray

References

- [Sch94]

Examples

```
>>> tonemapping_operator_exponentiation_mapping(np.array(
...     [[[0.48046875, 0.35156256, 0.23632812],
...       [1.39843753, 0.55468757, 0.39062594]],
...      [[4.40625388, 2.15625895, 1.34375372],
...       [6.59375023, 3.43751395, 2.21875829]]]))  # doctest: +ELLIPSIS
array([[[ 0.1194997...,  0.0874388...,  0.0587783...],
        [ 0.3478122...,  0.1379590...,  0.0971544...]],
<BLANKLINE>
       [[ 1.0959009...,  0.5362936...,  0.3342115...],
        [ 1.6399638...,  0.8549608...,  0.5518382...]]])
```

colour_hdri.tonemapping_operator_Schlick1994

colour_hdri.**tonemapping_operator_Schlick1994**(*RGB*, *p=1*, *colourspace=RGB_Colourspace(sRGB[[, 0.64, 0.33][, 0.3, 0.6][, 0.15, 0.06]][, 0.3127, 0.329]*, *D65[[, 0.4124, 0.3576, 0.1805][, 0.2126, 0.7152, 0.0722][, 0.0193, 0.1192, 0.9505]][[, 3.2406, -1.5372, -0.4986][, -0.9689, 1.8758, 0.0415][, 0.0557, -0.204, 1.057]]*, *<function oetf_sRGB>*, *<function oetf_reverse_sRGB>*, *False*, *False)*)

Performs given *RGB* array tonemapping using *Schlick (1994)* method.

Parameters

- **RGB** (array_like) – *RGB* array to perform tonemapping onto.
- **p** (numeric, optional) – p.
- **colourspace** (*colour.RGB_Colourspace*, optional) – *RGB* colourspace used for internal *Luminance* computation.

Returns Tonemapped *RGB* array.

Return type ndarray

References

- [BADC11b]
- [Sch94]

Examples

```
>>> tonemapping_operator_Schlick1994(np.array(
...     [[[0.48046875, 0.35156256, 0.23632812],
...       [1.39843753, 0.55468757, 0.39062594]],
...      [[4.40625388, 2.15625895, 1.34375372],
...       [6.59375023, 3.43751395, 2.21875829]]]))  # doctest: +ELLIPSIS
array([[[ 0.1194997...,  0.0874388...,  0.0587783...],
        [ 0.3478122...,  0.1379590...,  0.0971544...]],
<BLANKLINE>
       [[ 1.0959009...,  0.5362936...,  0.3342115...],
        [ 1.6399638...,  0.8549608...,  0.5518382...]]])
```

colour_hdri.tonemapping_operator_Tumblin1999

colour_hdri.**tonemapping_operator_Tumblin1999**(*RGB*, *L_da=20*, *C_max=100*, *L_max=100*, *colourspace=RGB_Colourspace(sRGB[[, 0.64, 0.33][, 0.3, 0.6][, 0.15, 0.06]][, 0.3127, 0.329], D65[[, 0.4124, 0.3576, 0.1805][, 0.2126, 0.7152, 0.0722][, 0.0193, 0.1192, 0.9505]][[, 3.2406, -1.5372, -0.4986][, -0.9689, 1.8758, 0.0415][, 0.0557, -0.204, 1.057]], <function oetf_sRGB>, <function oetf_reverse_sRGB>, False, False)*)

Performs given *RGB* array tonemapping using *Tumblin, Hodgins and Guenter (1999)* method.

Parameters

- **RGB** (array_like) – *RGB* array to perform tonemapping onto.
- **L_da** (numeric, optional) – L_{da} display adaptation luminance, a mid-range display value.
- **C_max** (numeric, optional) – C_{max} maximum contrast available from the display.
- **L_max** (numeric, optional) – L_{max} maximum display luminance.
- **colourspace** (*colour.RGB_Colourspace*, optional) – *RGB* colourspace used for internal *Luminance* computation.

Returns Tonemapped *RGB* array.

Return type ndarray

References

- [THG99]

Examples

```
>>> tonemapping_operator_Tumblin1999(np.array(
...     [[[0.48046875, 0.35156256, 0.23632812],
...       [1.39843753, 0.55468757, 0.39062594]],
...      [[4.40625388, 2.15625895, 1.34375372],
...       [6.59375023, 3.43751395, 2.21875829]]]))  # doctest: +ELLIPSIS
array([[[ 0.0400492...,  0.0293043...,  0.0196990...],
        [ 0.1019768...,  0.0404489...,  0.0284852...]],
<BLANKLINE>
       [[ 0.2490212...,  0.1218618...,  0.0759427...],
        [ 0.3408366...,  0.1776880...,  0.1146895...]]])
```

colour_hdri.tonemapping_operator_Reinhard2004

colour_hdri.**tonemapping_operator_Reinhard2004**(*RGB*, *f=0*, *m=0.3*, *a=0*, *c=0*, *colourspace=RGB_Colourspace(sRGB[[, 0.64, 0.33][, 0.3, 0.6][, 0.15, 0.06]][, 0.3127, 0.329], D65[[, 0.4124, 0.3576, 0.1805][, 0.2126, 0.7152, 0.0722][, 0.0193, 0.1192, 0.9505]][[, 3.2406, -1.5372, -0.4986][, -0.9689, 1.8758, 0.0415][, 0.0557, -0.204, 1.057]]*, *<function oetf_sRGB>*, *<function oetf_reverse_sRGB>*, *False*, *False)*)

Performs given *RGB* array tonemapping using *Reinhard and Devlin (2004)* method.

Parameters

- **RGB** (array_like) – *RGB* array to perform tonemapping onto.
- **f** (numeric, optional) – f.
- **m** (numeric, optional) – m.
- **a** (numeric, optional) – a.
- **c** (numeric, optional) – c.
- **colourspace** (*colour.RGB_Colourspace*, optional) – *RGB* colourspace used for internal *Luminance* computation.

Returns Tonemapped *RGB* array.

Return type ndarray

References

- [RD05]

Examples

```
>>> tonemapping_operator_Reinhard2004(np.array(
...     [[[0.48046875, 0.35156256, 0.23632812],
...       [1.39843753, 0.55468757, 0.39062594]],
...      [[4.40625388, 2.15625895, 1.34375372],
...       [6.59375023, 3.43751395, 2.21875829]]]),
...     -10)  # doctest: +ELLIPSIS
array([[[ 0.0216792...,  0.0159556...,  0.0107821...],
        [ 0.0605894...,  0.0249445...,  0.0176972...]],
<BLANKLINE>
       [[ 0.1688972...,  0.0904532...,  0.0583584...],
        [ 0.2331935...,  0.1368456...,  0.0928316...]]])
```

colour_hdri.tonemapping_operator_filmic

colour_hdri.**tonemapping_operator_filmic**(*RGB*, *shoulder_strength=0.22*, *linear_strength=0.3*, *linear_angle=0.1*, *toe_strength=0.2*, *toe_numerator=0.01*, *toe_denominator=0.3*, *exposure_bias=2*, *linear_whitepoint=11.2*)

Performs given *RGB* array tonemapping using *Habble (2010)* method.

Parameters

- **RGB** (array_like) – *RGB* array to perform tonemapping onto.
- **shoulder_strength** (numeric, optional) – Shoulder strength.
- **linear_strength** (numeric, optional) – Linear strength.
- **linear_angle** (numeric, optional) – Linear angle.
- **toe_strength** (numeric, optional) – Toe strength.
- **toe_numerator** (numeric, optional) – Toe numerator.
- **toe_denominator** (numeric, optional) – Toe denominator.
- **exposure_bias** (numeric, optional) – Exposure bias.
- **linear_whitepoint** (numeric, optional) – Linear whitepoint.

Returns Tonemapped *RGB* array.

Return type ndarray

References

- [Hab10a]
- [Hab10b]

Examples

```
>>> tonemapping_operator_filmic(np.array(
...     [[[0.48046875, 0.35156256, 0.23632812],
...       [1.39843753, 0.55468757, 0.39062594]],
...      [[4.40625388, 2.15625895, 1.34375372],
...       [6.59375023, 3.43751395, 2.21875829]]]))  # doctest: +ELLIPSIS
array([[[ 0.4507954...,  0.3619673...,  0.2617269...],
        [ 0.7567191...,  0.4933310...,  0.3911730...]],
<BLANKLINE>
       [[ 0.9725554...,  0.8557374...,  0.7465713...],
        [ 1.0158782...,  0.9382937...,  0.8615161...]]])
```

Logarithmic Mapping

colour_hdri

tonemapping_operator_logarithmic_mapping(RGB)	Performs given *RGB* array tonemapping using the logarithmic mapping method.

Exponential

colour_hdri

tonemapping_operator_exponential(RGB[, q, ...])	Performs given *RGB* array tonemapping using the exponential method.

Exponentiation Mapping

colour_hdri

tonemapping_operator_exponentiation_mapping(RGB[, p, ...])	Performs given *RGB* array tonemapping using the exponentiation mapping method.
tonemapping_operator_Schlick1994(RGB[, p, ...])	Performs given *RGB* array tonemapping using *Schlick (1994)* method.
tonemapping_operator_Tumblin1999(RGB[, ...])	Performs given *RGB* array tonemapping using *Tumblin, Hodgins and Guenter (1999)* method.
tonemapping_operator_Reinhard2004(RGB[, f, ...])	Performs given *RGB* array tonemapping using *Reinhard and Devlin (2004)* method.
tonemapping_operator_filmic(RGB[, ...])	Performs given *RGB* array tonemapping using *Hable (2010)* method.

Schlick (1994)

colour_hdri

tonemapping_operator_Schlick1994(RGB[, p, ...])	Performs given *RGB* array tonemapping using *Schlick (1994)* method.

Tumblin, Hodgins and Guenter (1999)

colour_hdri

tonemapping_operator_Tumblin1999(RGB[, ...])	Performs given *RGB* array tonemapping using *Tumblin, Hodgins and Guenter (1999)* method.

Reinhard and Devlin (2004)

colour_hdri

tonemapping_operator_Reinhard2004(RGB[, f, ...])	Performs given *RGB* array tonemapping using *Reinhard and Devlin (2004)* method.

Habble (2010) - Filmic

colour_hdri

tonemapping_operator_filmic(RGB[, ...])	Performs given *RGB* array tonemapping using *Habble (2010)* method.

Utilities

- *Common*
- *EXIF Data Manipulation*
- *Image Exposure Value Computation*
- *Image Data & Metadata Utilities*

Common

colour_hdri

vivification()	Implements supports for vivification of the underlying dict like data-structure, magical!
vivified_to_dict(vivified)	Converts given vivified data-structure to dictionary.
path_exists(path)	Returns if given path exists.
filter_files(directory, extensions)	Filters given directory for files matching given extensions.

colour_hdri.vivification

colour_hdri.**vivification**()

Implements supports for vivification of the underlying dict like data-structure, magical!

Returns

Return type defaultdict

Examples

```
>>> vivified = vivification()
>>> vivified['my']['attribute'] = 1
>>> vivified['my']  # doctest: +ELLIPSIS
defaultdict(<function vivification at 0x...>, {u'attribute': 1})
```

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```
>>> vivified['my']['attribute']
1
```

colour_hdri.vivified_to_dict

colour_hdri.**vivified_to_dict**(*vivified*)

Converts given vivified data-structure to dictionary.

Parameters **vivified** (defaultdict) – Vivified data-structure.

Returns

Return type dict

Examples

```
>>> vivified = vivification()
>>> vivified['my']['attribute'] = 1
>>> vivified_to_dict(vivified)
{u'my': {u'attribute': 1}}
```

colour_hdri.path_exists

colour_hdri.**path_exists**(*path*)

Returns if given path exists.

Parameters **path** (unicode) – Path to check the existence.

Returns

Return type bool

Examples

```
>>> path_exists(__file__)
True
>>> path_exists('')
False
```

colour_hdri.filter_files

colour_hdri.**filter_files**(*directory*, *extensions*)

Filters given directory for files matching given extensions.

Parameters

- **directory** (unicode) – Directory to filter.
- **extensions** (tuple or list) – Extensions to filter on.

Returns Filtered files.

Return type list

EXIF Data Manipulation

colour_hdri

EXIF_EXECUTABLE	Command line exif manipulation application, usually Phil Harvey's *ExifTool*.
ExifTag	Hunt colour appearance model induction factors.
parse_exif_string(exif_tag)	Parses given exif tag assuming it is a string and return its value.
parse_exif_numeric(exif_tag[, dtype])	Parses given exif tag assuming it is a numeric type and return its value.
parse_exif_fraction(exif_tag[, dtype])	Parses given exif tag assuming it is a fraction and return its value.
parse_exif_array(exif_tag[, dtype, shape])	Parses given exif tag assuming it is an array and return its value.
parse_exif_data(data)	Parses given exif data output from *exiftool*.
read_exif_tags(image)	Returns given image exif image tags.
copy_exif_tags(source, target)	Copies given source image file exif tag to given image target.
update_exif_tags(images)	Updates given images siblings images pairs exif tags.
delete_exif_tags(image)	Deletes all given image exif tags.
read_exif_tag(image, tag)	Returns given image exif tag value.
write_exif_tag(image, tag, value)	Sets given image exif tag value.

colour_hdri.EXIF_EXECUTABLE

colour_hdri.**EXIF_EXECUTABLE = 'exiftool'**
Command line exif manipulation application, usually Phil Harvey's *ExifTool*.

EXIF_EXECUTABLE : unicode

colour_hdri.ExifTag

class colour_hdri.**ExifTag**
Hunt colour appearance model induction factors.

Parameters

- **group** (unicode, optional) – Exif tag group name.
- **name** (unicode, optional) – Exif tag name.
- **value** (object, optional) – Exif tag value.
- **identifier** (numeric, optional) – Exif tag identifier.

Returns a new instance of the colour_hdri.ExifTag class.

__init__()
Initialize self. See help(type(self)) for accurate signature.

Methods

`count`	Return number of occurrences of value.
`index`	Return first index of value.

colour_hdri.parse_exif_string

`colour_hdri.`**`parse_exif_string`**(*exif_tag*)

Parses given exif tag assuming it is a string and return its value.

Parameters **exif_tag** (ExifTag) – Exif tag to parse.

Returns Parsed exif tag value.

Return type unicode

colour_hdri.parse_exif_numeric

`colour_hdri.`**`parse_exif_numeric`**(*exif_tag*, *dtype=<class 'numpy.float64'>*)

Parses given exif tag assuming it is a numeric type and return its value.

Parameters

- **exif_tag** (ExifTag) – Exif tag to parse.
- **dtype** (object, optional) – Return value data type.

Returns Parsed exif tag value.

Return type numeric

colour_hdri.parse_exif_fraction

`colour_hdri.`**`parse_exif_fraction`**(*exif_tag*, *dtype=<class 'numpy.float64'>*)

Parses given exif tag assuming it is a fraction and return its value.

Parameters

- **exif_tag** (ExifTag) – Exif tag to parse.
- **dtype** (object, optional) – Return value data type.

Returns Parsed exif tag value.

Return type numeric

colour_hdri.parse_exif_array

`colour_hdri.`**`parse_exif_array`**(*exif_tag*, *dtype=<class 'numpy.float64'>*, *shape=None*)

Parses given exif tag assuming it is an array and return its value.

Parameters

- **exif_tag** (ExifTag) – Exif tag to parse.
- **dtype** (object, optional) – Return value data type.
- **shape** (array_like, optional) – Shape of

Returns Parsed exif tag value.

Return type ndarray

colour_hdri.parse_exif_data

colour_hdri.**parse_exif_data**(*data*)
Parses given exif data output from *exiftool*.

Parameters **data** (unicode) – Exif data.

Returns Parsed exif data.

Return type list

colour_hdri.read_exif_tags

colour_hdri.**read_exif_tags**(*image*)
Returns given image exif image tags.

Parameters **image** (unicode) – Image file.

Returns Exif tags.

Return type defaultdict

colour_hdri.copy_exif_tags

colour_hdri.**copy_exif_tags**(*source*, *target*)
Copies given source image file exif tag to given image target.

Parameters

- **source** (unicode) – Source image file.
- **target** (unicode) – Target image file.

Returns Definition success.

Return type bool

colour_hdri.update_exif_tags

colour_hdri.**update_exif_tags**(*images*)
Updates given images siblings images pairs exif tags.

Parameters **images** (list) – Image files to update.

Returns Definition success.

Return type bool

colour_hdri.delete_exif_tags

colour_hdri.**delete_exif_tags**(*image*)
Deletes all given image exif tags.

Parameters **image** (unicode) – Image file.

Returns Definition success.

Return type bool

colour_hdri.read_exif_tag

colour_hdri.**read_exif_tag**(*image*, *tag*)
Returns given image exif tag value.

Parameters

- **image** (unicode) – Image file.
- **tag** (unicode) – Tag.

Returns Tag value.

Return type unicode

colour_hdri.write_exif_tag

colour_hdri.**write_exif_tag**(*image*, *tag*, *value*)
Sets given image exif tag value.

Parameters

- **image** (unicode) – Image file.
- **tag** (unicode) – Tag.
- **value** (unicode) – Value.

Returns Definition success.

Return type bool

Image Exposure Value Computation

colour_hdri

exposure_value(f_number, exposure_time, iso)	Computes the exposure value from given image *FNumber*, *Exposure Time* and *ISO* values.
adjust_exposure(a, EV)	Adjusts given array exposure using given EV exposure value.
average_luminance(f_number, exposure_time, iso)	Computes the average luminance from given image *FNumber*, *Exposure Time* and *ISO* values.

colour_hdri.exposure_value

colour_hdri.**exposure_value**(*f_number*, *exposure_time*, *iso*)

Computes the exposure value from given image *FNumber*, *Exposure Time* and *ISO* values.

Parameters

- **f_number** (array_like) – Image *FNumber*.
- **exposure_time** (array_like) – Image *Exposure Time*.
- **iso** (array_like) – Image *ISO*.

Returns Image exposure value.

Return type ndarray

Examples

```
>>> exposure_value(8, 1, 100)
6.0
```

colour_hdri.adjust_exposure

colour_hdri.**adjust_exposure**(*a*, *EV*)

Adjusts given array exposure using given EV exposure value.

Parameters

- **a** (array_like) – Array to adjust the exposure.
- **EV** (numeric) – Exposure adjustment value.

Returns Exposure adjusted array.

Return type ndarray

Examples

```
>>> adjust_exposure(np.array([0.25, 0.5, 0.75, 1]), 1)
array([ 0.5,  1. ,  1.5,  2. ])
```

colour_hdri.average_luminance

colour_hdri.**average_luminance**(*f_number*, *exposure_time*, *iso*, *k=12.5*)

Computes the average luminance from given image *FNumber*, *Exposure Time* and *ISO* values.

Parameters

- **f_number** (array_like) – Image *FNumber*.
- **exposure_time** (array_like) – Image *Exposure Time*.
- **iso** (array_like) – Image *ISO*.
- **k** (numeric, optional) – Reflected light calibration constant K.

Returns Image average luminance.

Return type ndarray

References

- [Wika]

Examples

```
>>> average_luminance(8, 1, 100)
0.125
```

Image Data & Metadata Utilities

colour_hdri

Metadata	Defines the base object for storing exif metadata relevant to HDRI / radiance image generation.
Image([path, data, metadata])	Defines the base object for storing an image along its path, pixel data and metadata needed for HDRI / radiance images generation.
ImageStack()	Defines a convenient stack storing a sequence of images for HDRI / radiance images generation.

colour_hdri.Metadata

class colour_hdri.**Metadata**

Defines the base object for storing exif metadata relevant to HDRI / radiance image generation.

Parameters

- **f_number** (array_like) – Image *FNumber*.
- **exposure_time** (array_like) – Image *Exposure Time*.
- **iso** (array_like) – Image *ISO*.
- **black_level** (array_like) – Image *Black Level*.
- **white_level** (array_like) – Image *White Level*.
- **white_balance_multipliers** (array_like) – Image white balance multipliers, usually the *As Shot Neutral* matrix.

__init__()

Initialize self. See help(type(self)) for accurate signature.

colour_hdri.Image

class colour_hdri.**Image**(*path=None*, *data=None*, *metadata=None*)

Defines the base object for storing an image along its path, pixel data and metadata needed for HDRI / radiance images generation.

Parameters

- **path** (unicode, optional) – Image path.
- **data** (array_like, optional) – Image pixel data array.
- **metadata** (Metadata, optional) – Image exif metadata.

path

data

metadata

read_data()

read_metadata()

__init__(*path=None*, *data=None*, *metadata=None*)
Initialize self. See help(type(self)) for accurate signature.

Methods

__init__([path, data, metadata])	Initialize self.
read_data([decoding_cctf])	Reads image pixel data at Image.path attribute.
read_metadata()	Reads image relevant exif metadata at Image.path attribute.

colour_hdri.ImageStack

class colour_hdri.**ImageStack**
Defines a convenient stack storing a sequence of images for HDRI / radiance images generation.

ImageStack()

__init__()

__getitem__()

__setitem__()

__delitem__()

__len__()

__getattr__()

__setattr__()

sort()

insert()

from_files()

__init__()
Initialize self. See help(type(self)) for accurate signature.

Methods

`__init__`()	Initialize self.
`append`(value)	S.append(value) – append value to the end of the sequence
`count`(value)	
`extend`(values)	S.extend(iterable) – extend sequence by appending elements from the iterable
`from_files`(image_files[, decoding_cctf])	Returns a `colour_hdri.ImageStack` instance with given image files.
`index`(value, [start, [stop]])	Raises ValueError if the value is not present.
`insert`(index, value)	Reimplements the `MutableSequence.insert()` method.
`pop`([index])	Raise IndexError if list is empty or index is out of range.
`remove`(value)	S.remove(value) – remove first occurrence of value.
`reverse`()	S.reverse() – reverse *IN PLACE*
`sort`([key])	Sorts the underlying data structure.

Indices and tables

- genindex
- search

3.1.1.2 Bibliography

Indirect References

Some extra references used in the codebase but not directly part of the public api:

- [AdobeSystems15a]
- [AdobeSystems15b]

3.2 Examples

Various usage examples are available from the examples directory.

CHAPTER 4

Contributing

If you would like to contribute to Colour - HDRI, please refer to the following Contributing guide for Colour.

CHAPTER 5

Bibliography

The bibliography is available in the repository in BibTeX format.

CHAPTER 6

About

Colour - HDRI by Colour Developers
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This software is released under terms of New BSD License: http://opensource.org/licenses/BSD-3-Clause
http://github.com/colour-science/colour-hdri

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Index

Symbols

A

C

D

E

F

G

H

I

L

M

N

P

R

S

T

U

V

W

X