LuxPy Documentation

Release 1.3.7

Kevin A.G. Smet

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CONTENTS:

- Author: K. A.G. Smet (ksmet1977 at gmail.com)
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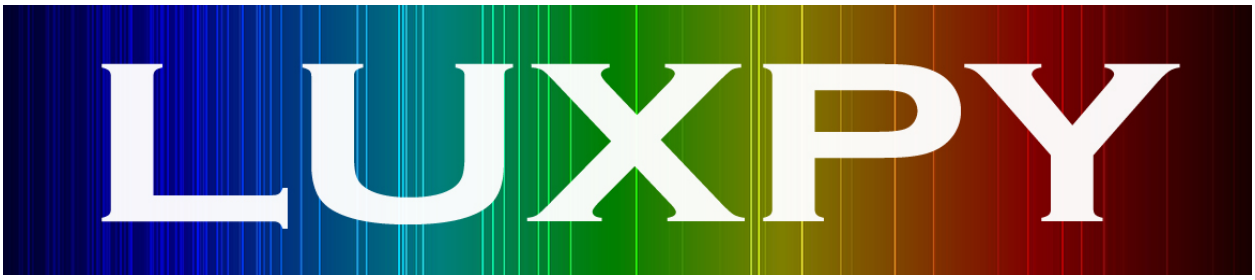
- License: GPLv3



CHAPTER

ONE

LICENSE: GPLV3

CHAPTER

TWO

INSTALLATION

2.1 Install luxpy

1. **Install miniconda**
    - download the installer from: https://conda.io/miniconda.html or https://repo.continuum.io/miniconda/)
    - e.g. https://repo.continuum.io/miniconda/Miniconda3-latest-Windows-x86_64.exe
    - Make sure 'conda.exe' can be found on the windows system path, if necessary do a manual add.
2. Create a virtual environment with full anaconda distribution by typing the following at the commandline:

    ```
    >> conda create --name py36 python=3.6 anaconda
    ```

3. Activate the virtual environment:

    ```
    >> activate py36
    ```

4. **Install pip to virtual environment (just to ensure any packages to be** installed with pip to this virt. env. will be installed here and not globally):

    ```
    >> conda install -n py36 pip
    ```

5. Install luxpy package from pypi:

    ```
    >> pip install luxpy
    ```

    Note If any errors show up, try and do a manual install of the dependencies: scipy, numpy, pandas, matplotlib and setuptools, either using e.g. `>> conda install scipy` or `>> pip install scipy`, and try and reinstall luxpy using pip.

2.2 Use of LuxPy package in Spyder IDE

6. Install spyder in py36 environment:

    ```
    >> conda install -n py36 spyder
    ```

7. Run spyder

    ```
    >> spyder
    ```

8. To import the luxpy package, on Spyder's commandline for the IPython kernel (or in script) type:

    ```
    import luxpy as lx
    ```

2.3 Use of LuxPy package in Jupyter notebook

6. Install jupyter in py36 environment:

   ```
   >> conda install -n py36 jupyter
   ```

7. Start jupyter notebook:

   ```
   >> jupyter notebook
   ```

8. **Open an existing or new notebook:** e.g. open "luxpy_basic_usage.ipynb" for an overview of how to use the LuxPy package.

9. To import LuxPy package type:

   ```
   import luxpy as lx
   ```

CHAPTER

THREE

IMPORTED (REQUIRED) PACKAGES

3.1 Core

- import os
- import warnings
- from collections import OrderedDict as odict
- from mpl_toolkits.mplot3d import Axes3D
- import colorsys
- import itertools

3.2 3e party

- import numpy as np
- import pandas as pd
- import matplotlib.pyplot as plt
- import scipy as sp
- from scipy import interpolate
- from scipy.optimize import minimize
- from scipy.spatial import cKDTree
- import cv2

CHAPTER

FOUR

LUXPY PACKAGE STRUCTURE

4.1 Utils sub-package

4.1.1 helpers/

py

- __init__.py
- helpers.py

namespace luxpy

Module with helper functions

np2d() Make a tuple, list or array at least a 2D numpy array.

np2dT() Make a tuple, list or array at least a 2D numpy array and tranpose.

np3d() Make a tuple, list or array at least a 3D numpy array.

np3dT() Make a tuple, list or array at least a 3D numpy array and tranpose (swap) first two axes.

normalize_3x3_matrix() Normalize 3x3 matrix M to xyz0 – > [1,1,1]

put_args_in_db()

Takes the args with not-None input values of a function and overwrites the values of the corresponding keys in dict db.

See put_args_in_db? for more info.

vec_to_dict() Convert dict to vec and vice versa.

getdata(): Get data from csv-file or convert between pandas dataframe and numpy 2d-array.

dictkv() Easy input of of keys and values into dict (both should be iterable lists).

OD() Provides a nice way to create OrderedDict “literals”.

meshblock()

Create a meshed block.

(Similar to meshgrid, but axis = 0 is retained)

To enable fast blockwise calculation.

aplit() Split ndarray data on (default = last) axis.

ajoin() Join tuple of ndarray data on (default = last) axis.

broadcast_shape()

Broadcasts shapes of data to a target_shape.
Useful for block/vector calculations when numpy fails to broadcast correctly.

todim() Expand x to dimensions that are broadcast-compatable with shape of another array.

---

luxpy.utils.helpers.**np2d**(*data*)
Make a tuple, list or numpy array at least a 2D numpy array.

Args:

data

tuple, list, ndarray

Returns:

returns

ndarray with .ndim >= 2

luxpy.utils.helpers.**np3d**(*data*)
Make a tuple, list or numpy array at least a 3d numpy array.

Args:

data

tuple, list, ndarray

Returns:

returns

ndarray with .ndim >= 3

luxpy.utils.helpers.**np2dT**(*data*)
Make a tuple, list or numpy array at least a 2D numpy array and transpose.

Args:

data

tuple, list, ndarray

Returns:

returns

ndarray with .ndim >= 2 and with transposed axes.

luxpy.utils.helpers.**np3dT**(*data*)
Make a tuple, list or numpy array at least a 3d numpy array and transposed first 2 axes.

Args:

data

tuple, list, ndarray

Returns:

returns

ndarray with .ndim >= 3 and with first two axes transposed (axis=3 is kept the same).

luxpy.utils.helpers.**put_args_in_db**(*db*, *args*)

Takes the args with not-None input values of a function and overwrites the values of the corresponding keys in dict db. | (args are collected with the built-in function locals(), | See example usage below)

Args:

db

dict

Returns:

returns

dict with the values of specific keys overwritten by the
not-None values of corresponding args of a function fcn.

Example usage:

```
_db = {'c' : 'c1', 'd' : 10, 'e' : {'e1':'hello', 'e2':1000}}

def test_put_args_in_db(a, b, db = None, c = None,d = None,e = None):

    args = locals().copy() # get dict with keyword input arguments to
                # function 'test_put_args_in_db'

        db = put_args_in_db(db,args) # overwrite non-None args in db copy.

    if db is not None: # unpack db for further use
            c,d,e = [db[x] for x in sorted(db.keys())]

        print(' a : {}'.format(a))
        print(' b : {}'.format(b))
        print(' db: {}'.format(db))
        print(' c : {}'.format(c))
        print(' d : {}'.format(d))
        print(' e : {}'.format(e))
        print('_db: {}'.format(_db))
```

luxpy.utils.helpers.**vec_to_dict**(*vec=None*, *dic={}*, *vsize=None*, *keys=None*)

Convert dict to vec and vice versa.

Args:

vec

list or vector array, optional

dic

dict, optional

vsize

list or vector array with size of values of dict, optional

keys

list or vector array with keys in dict (must be provided).

Returns:

returns

x, vsize
x is an array, if vec is None
x is a dict, if vec is not None

luxpy.utils.helpers.**getdata**(*data*, *kind='np'*, *columns=None*, *header=None*, *sep=','*, *datatype='S'*, *verbosity=True*)

Get data from csv-file or convert between pandas dataframe and numpy 2d-array.

Args:

data

- str with path to file containing data
- ndarray with data
- pandas.dataframe with data

kind

str ['np','df'], optional
Determines type(:returns:), np: ndarray, df: pandas.dataframe

columns

None or list[str] of column names for dataframe, optional

header

None, optional
- None: no header in file
- 'infer': infer headers from file

sep

',' or ' ' or other char, optional
Column separator in data file

datatype'

'S',optional
Specifies a type of data.
Is used when creating column headers (:column: is None).
-'S': light source spectrum
-'R': reflectance spectrum
or other.

verbosity

True, False, optional
Print warning when inferring headers from file.

Returns:

returns

data as ndarray or pandas.dataframe

luxpy.utils.helpers.**dictkv**(*keys=None*, *values=None*, *ordered=True*)

Easy input of of keys and values into dict.

Args:

keys

iterable list[str,...] of keys

values

iterable list[...,...,] of values

ordered

True, False, optional
True: creates an ordered dict using 'collections.OrderedDict()'

Returns:

returns

(ordered) dict

luxpy.utils.helpers.**meshblock**(*x*, *y*)

Create a meshed block from x and y.

(Similar to meshgrid, but axis = 0 is retained).
To enable fast blockwise calculation.

Args:

x

ndarray with ndim == 2

y

ndarray with ndim == 2

Returns:

X,Y

2 ndarrays with ndim == 3
X.shape = (x.shape[0],y.shape[0],x.shape[1])
Y.shape = (x.shape[0],y.shape[0],y.shape[1])

luxpy.utils.helpers.**asplit**(*data*)

Split data on last axis

Args:

data

ndarray

Returns:

returns

ndarray, ndarray, ...
(number of returns is equal data.shape[-1])

luxpy.utils.helpers.**ajoin**(*data*)

Join data on last axis.

Args:

data

tuple (ndarray, ndarray, . . .)

Returns:

returns

ndarray (shape[-1] is equal to tuple length)

luxpy.utils.helpers.**broadcast_shape**(*data*, *target_shape=None*, *expand_2d_to_3d=None*, *axis0_repeats=None*, *axis1_repeats=None*)

Broadcasts shapes of data to a target_shape.

Useful for block/vector calc. when numpy fails to broadcast correctly.

Args:

data

ndarray

target_shape

None or tuple with requested shape, optional
- None: returns unchanged :data:

expand_2d_to_3d

None (do nothing) or . . . , optional
If ndim == 2, expand from 2 to 3 dimensions

axis0_repeats

None or number of times to repeat axis=0, optional
- None: keep axis=0 same size

axis1_repeats

None or number of times to repeat axis=1, optional
- None: keep axis=1 same size

Returns:

returns

reshaped ndarray

luxpy.utils.helpers.**todim**(*x*, *tshape*, *add_axis=1*, *equal_shape=False*)

Expand x to dims that are broadcast-compatable with shape of another array.

Args:

x

ndarray

tshape

tuple with target shape

add_axis

1, optional

Determines where in x.shape an axis should be added

equal_shape

False or True, optional
True: expand :x: to identical dimensions (speficied by :tshape:)

Returns:

returns

ndarray broadcast-compatable with tshape.

`luxpy.utils.helpers.`**`write_to_excel`**(*filename*, *df*, *sheet_name='Sheet1'*, *startrow=None*, *truncate_sheet=False*, ***to_excel_kwargs*)

Writes a DataFrame to an existing Excel file into a specified sheet. | If [filename] doesn't exist, then this function will create it.

Args:

filename

File path or existing ExcelWriter
(Example: '/path/to/file.xlsx')

df

dataframe to save to workbook

sheet_name

Name of sheet which will contain DataFrame.
(default: 'Sheet1')

startrow

upper left cell row to dump data frame.
Per default (startrow=None) calculate the last row
in the existing DF and write to the next row...

truncate_sheet

truncate (remove and recreate) [sheet_name]
before writing DataFrame to Excel file

to_excel_kwargs

arguments which will be passed to *DataFrame.to_excel()*
[can be dictionary]

Returns: None

Notes: Copied from https://stackoverflow.com/questions/20219254/how-to-write-to-an-existing-excel-file-without-overwriting-

4.1.2 math/

py

- basics.py
- optimizers.py

namespace luxpy.math

Module with useful math functions

normalize_3x3_matrix() Normalize 3x3 matrix M to xyz0 – > [1,1,1]

line_intersect()

Line intersections of series of two line segments a and b.
https://stackoverflow.com/questions/3252194/numpy-and-line-intersections

positive_arctan() Calculates the positive angle (0°-360° or 0 - 2*pi rad.) from x and y.

dot23() Dot product of a 2-d ndarray with a (N x K x L) 3-d ndarray using einsum().

check_symmetric() Checks if A is symmetric.

check_posdef() Checks positive definiteness of a matrix via Cholesky.

symmM_to_posdefM()

Converts a symmetric matrix to a positive definite one.
Two methods are supported:
* 'make': A Python/Numpy port of Muhammad Asim Mubeen's matlab function Spd_Mat.m (https://nl.mathworks.com/matlabcentral/fileexchange/45873-positive-definite-matrix)
* 'nearest': A Python/Numpy port of John D'Errico's 'nearestSPD' MATLAB code. (https://stackoverflow.com/questions/43238173/python-convert-matrix-to-positive-semi-definite)

bvgpdf() Evaluate bivariate Gaussian probability density function (BVGPDF) at (x,y) with center mu and inverse covariance matric, sigmainv.

mahalanobis2() Evaluate the squared mahalanobis distance with center mu and shape and orientation determined by sigmainv.

rms() Calculates root-mean-square along axis.

geomean() Calculates geometric mean along axis.

polyarea()

Calculates area of polygon.
(First coordinate should also be last)

erf() erf-function, direct import from scipy.special

cart2pol() Converts Cartesian to polar coordinates.

pol2cart() Converts polar to Cartesian coordinates.

magnitude_v() Calculates magnitude of vector.

angle_v1v2() Calculates angle between two vectors.

histogram()

Histogram function that can take as bins either the center
(cfr. matlab hist) or bin-edges.

minimizebnd() scipy.minimize() that allows contrained parameters on unconstrained methods(port of Matlab's fminsearchbnd). Starting, lower and upper bounds values can also be provided as a dict.

DEMO Module for Differential Evolutionary Multi-objective Optimization (DEMO).

---

luxpy.utils.math.**normalize_3x3_matrix**(*M*, *xyz0=array([[1.0000e+00, 1.0000e+00, 1.0000e+00]])*)

Normalize 3x3 matrix M to xyz0 – > [1,1,1] If M.shape == (1,9): M is reshaped to (3,3)

Args:

M

ndarray((3,3) or ndarray((1,9))

xyz0

2darray, optional

Returns:

returns

normalized matrix such that M*xyz0 = [1,1,1]

luxpy.utils.math.**symmM_to_posdefM**(*A=None*, *atol=1e-09*, *rtol=1e-09*, *method='make'*, *forcesymm=True*)

Convert a symmetric matrix to a positive definite one.

Args:

A

ndarray

atol

float, optional
The absolute tolerance parameter (see Notes of numpy.allclose())

rtol

float, optional
The relative tolerance parameter (see Notes of numpy.allclose())

method

'make' or 'nearest', optional (see notes for more info)

forcesymm

True or False, optional
If A is not symmetric, force symmetry using:
A = numpy.triu(A) + numpy.triu(A).T - numpy.diag(numpy.diag(A))

Returns:

returns

ndarray with positive-definite matrix.

Notes on supported methods: 1. 'make': A Python/Numpy port of Muhammad Asim Mubeen's matlab function Spd_Mat.m 2. *'nearest': A Python/Numpy port of John D'Errico's 'nearestSPD* MATLAB code. <https://stackoverflow.com/questions/43238173/python-convert-matrix-to-positive-semi-definite>'_

luxpy.utils.math.**check_symmetric**(*A*, *atol=1e-09*, *rtol=1e-09*)

Check if A is symmetric.

Args:

A

ndarray

atol

float, optional
The absolute tolerance parameter (see Notes of numpy.allclose())

rtol

float, optional
The relative tolerance parameter (see Notes of numpy.allclose())

Returns:

returns

Bool
True: the array is symmetric within the given tolerance

luxpy.utils.math.**check_posdef**(*A*, *atol=1e-09*, *rtol=1e-09*)
Checks positive definiteness of a matrix via Cholesky.

Args:

A

ndarray

atol

float, optional
The absolute tolerance parameter (see Notes of numpy.allclose())

rtol

float, optional
The relative tolerance parameter (see Notes of numpy.allclose())

Returns:

returns

Bool
True: the array is positive-definite within the given tolerance

luxpy.utils.math.**positive_arctan**(*x*, *y*, *htype='deg'*)
Calculate positive angle (0°-360° or 0 - 2*pi rad.) from x and y.

Args:

x

ndarray of x-coordinates

y

ndarray of y-coordinates

htype

'deg' or 'rad', optional
- 'deg': hue angle between 0° and 360°
- 'rad': hue angle between 0 and 2pi radians

Returns:

returns

ndarray of positive angles.

luxpy.utils.math.**line_intersect**(*a1*, *a2*, *b1*, *b2*)
Line intersections of series of two line segments a and b.

Args:

a1

ndarray (.shape = (N,2)) specifying end-point 1 of line a

a2

ndarray (.shape = (N,2)) specifying end-point 2 of line a

b1

ndarray (.shape = (N,2)) specifying end-point 1 of line b

b2

ndarray (.shape = (N,2)) specifying end-point 2 of line b

Note: N is the number of line segments a and b.

Returns:

returns

ndarray with line-intersections (.shape = (N,2))

References:

1. https://stackoverflow.com/questions/3252194/numpy-and-line-intersections

luxpy.utils.math.**erfinv**(*y*)
Inverse function for erf.

luxpy.utils.math.**histogram**(*a*, *bins=10*, *bin_center=False*, *range=None*, *normed=False*, *weights=None*, *density=None*)
Histogram function that can take as bins either the center (cfr. matlab hist) or bin-edges.

Args:

bin_center

False, optional
False: if :bins: int, str or sequence of scalars:
default to numpy.histogram (uses bin edges).
True: if :bins: is a sequence of scalars:
bins (containing centers) are transformed to edges
and nump.histogram is run.
Mimicks matlab hist (uses bin centers).

Note: For other armuments and output, see ?numpy.histogram

Returns:

returns

ndarray with histogram

luxpy.utils.math.**pol2cart**(*theta*, *r=None*, *htype='deg'*)
Convert Cartesion to polar coordinates.

Args:

theta

float or ndarray with theta-coordinates

r

None or float or ndarray with r-coordinates, optional
If None, r-coordinates are assumed to be in :theta:.

htype

'deg' or 'rad, optional
Intput type of :theta:.

Returns:

returns

(float or ndarray of x, float or ndarray of y) coordinates

luxpy.utils.math.**cart2pol**(*x*, *y=None*, *htype='deg'*)
Convert Cartesion to polar coordinates.

Args:

x

float or ndarray with x-coordinates

y

None or float or ndarray with x-coordinates, optional
If None, y-coordinates are assumed to be in :x:.

htype

'deg' or 'rad, optional
Output type of theta.

Returns:

returns

(float or ndarray of theta, float or ndarray of r) values

luxpy.utils.math.**bvgpdf**(*x*, *y=None*, *mu=None*, *sigmainv=None*)
Evaluate bivariate Gaussian probability density function (BVGPDF) at (x,y) with center mu and inverse covariance matric, sigmainv.

Args:

x

scalar or list or ndarray (.ndim = 1 or 2) with
x(y)-coordinates at which to evaluate bivariate Gaussian PD.

y

None or scalar or list or ndarray (.ndim = 1) with
y-coordinates at which to evaluate bivariate Gaussian PD, optional.
If :y: is None, :x: should be a 2d array.

mu

None or ndarray (.ndim = 2) with center coordinates of

bivariate Gaussian PD, optional.
None defaults to ndarray([0,0]).

sigmainv

None or ndarray with 'inverse covariance matrix', optional
Determines the shape and orientation of the PD.
None default to numpy.eye(2).

Returns:

returns

ndarray with magnitude of BVGPDF(x,y)

luxpy.utils.math.**mahalanobis2**(*x*, *y=None*, *mu=None*, *sigmainv=None*)
Evaluate the squared mahalanobis distance with center mu and shape and orientation determined by sigmainv.

Args:

x

scalar or list or ndarray (.ndim = 1 or 2) with x(y)-coordinates at which to evaluate the mahalanobis distance squared.

y

None or scalar or list or ndarray (.ndim = 1) with y-coordinates at which to evaluate the mahalanobis distance squared, optional.
If :y: is None, :x: should be a 2d array.

mu

None or ndarray (.ndim = 2) with center coordinates of the mahalanobis ellipse, optional.
None defaults to ndarray([0,0]).

sigmainv

None or ndarray with 'inverse covariance matrix', optional
Determines the shape and orientation of the PD.
None default to np.eye(2).

Returns:

returns

ndarray with magnitude of mahalanobis2(x,y)

luxpy.utils.math.**dot23**(*A*, *B*, *keepdims=False*)
Dot product of a 2-d ndarray with a (N x K x L) 3-d ndarray using einsum().

Args:

A

ndarray (.shape = (M,N))

B

ndarray (.shape = (N,K,L))

Returns:

returns

ndarray (.shape = (M,K,L))

luxpy.utils.math.**rms**(*data*, *axis=0*, *keepdims=False*)
Calculate root-mean-square along axis.

Args:

data

list of values or ndarray

axis

0, optional
Axis along which to calculate rms.

keepdims

False or True, optional
Keep original dimensions of array.

Returns:

returns

ndarray with rms values.

luxpy.utils.math.**geomean**(*data*, *axis=0*, *keepdims=False*)
Calculate geometric mean along axis.

Args:

data

list of values or ndarray

axis

0, optional
Axis along which to calculate geomean.

keepdims

False or True, optional
Keep original dimensions of array.

Returns:

returns

ndarray with geomean values.

luxpy.utils.math.**polyarea**(*x*, *y*)
Calculates area of polygon.

First coordinate should also be last.

Args:

x

ndarray of x-coordinates of polygon vertices.

y

ndarray of x-coordinates of polygon vertices.

Returns:

returns

float (area or polygon)

luxpy.utils.math.**magnitude_v**(*v*)

Calculates magnitude of vector.

Args:

v

ndarray with vector

Returns:

magnitude

ndarray

luxpy.utils.math.**angle_v1v2**(*v1*, *v2*, *htype='deg'*)

Calculates angle between two vectors.

Args:

v1

ndarray with vector 1

v2

ndarray with vector 2

htype

'deg' or 'rad', optional

Requested angle type.

Returns:

ang

ndarray

luxpy.utils.math.**minimizebnd**(*fun*, *x0*, *args=()*, *method='nelder-mead'*, *use_bnd=True*, *bounds=(None, None)*, *options=None*, *x0_vsize=None*, *x0_keys=None*, ***kwargs*)

Minimization function that allows for bounds on any type of method in SciPy's minimize function by transforming the parameters values | (see Matlab's fminsearchbnd). | Starting values, and lower and upper bounds can also be provided as a dict.

Args:

x0

parameter starting values

If x0_keys is None then :x0: is vector else, :x0: is dict and

x0_size should be provided with length/size of values for each of the keys in :x0: to convert it to a vector.

use_bnd

True, optional

False: omits bounds and defaults to regular minimize function.

bounds

(lower, upper), optional
Tuple of lists or dicts (x0_keys is None) of lower and upper bounds for each of the parameters values.

kwargs

allows input for other type of arguments (e.g. in OutputFcn)

Note: For other input arguments, see ?scipy.minimize()

Returns:

res

dict with minimize() output.
Additionally, function value, fval, of solution is also in :res:, as well as a vector or dict (if x0 was dict) with final solutions (res['x'])

4.2 Spectrum sub-package

4.2.1 basics/

py

- __init__.py
- cmf.py
- spectral.py
- spectral_databases.py

namespace luxpy

spectrum: sub-package supporting basic spectral calculations

spectrum/cmf.py

luxpy._CMF

Dict with keys 'types' and x | x are dicts with keys 'bar', 'K', 'M'

* luxpy._CMF['types'] = ['1931_2','1964_10','2006_2','2006_10', '1931_2_judd1951','1931_2_juddvos1978', '1951_20_scotopic']
* luxpy._CMF[x]['bar'] = numpy array with CMFs for type x between 360 nm and 830 nm (has shape: (4,471))
* luxpy._CMF[x]['K'] = Constant converting Watt to lumen for CMF type x.
* luxpy._CMF[x]['M'] = XYZ to LMS conversion matrix for CMF type x. Matrix is numpy arrays with shape: (3,3)

Notes:

1. **All functions have been expanded (when necessary) using zeros to a** full 360-830 range. This way those wavelengths do not contribute in the calculation, AND are not extrapolated using the closest known value, as per CIE recommendation.
2. **There are no XYZ to LMS conversion matrices defined for the** 1964 10°, 1931 2° Judd corrected (1951) and 1931 2° Judd-Vos corrected (1978) cmf sets. The Hunt-Pointer-Estevez conversion matrix of the 1931 2° is therefore used as an approximation!
3. **The K lm to Watt conversion factors for the Judd and Judd-Vos cmf** sets have been set to 683.002 lm/W (same as for standard 1931 2°).
4. **The 1951 scoptopic V' function has been replicated in the 3** xbar, ybar, zbar columns to obtain a data format similar to the photopic color matching functions. This way V' can be called in exactly the same way as other V functions can be called from the X,Y,Z cmf sets. The K value has been set to 1700.06 lm/W and the conversion matrix to np.eye().

spectrum/spectral.py

_WL3 Default wavelength specification in vector-3 format: numpy.array([start, end, spacing])

_BB Dict with constants for blackbody radiator calculation constant are (c1, c2, n, na, c, h, k).

_S012_DAYLIGHTPHASE numpy.ndarray with CIE S0,S1, S2 curves for daylight phase calculation.

_INTERP_TYPES Dict with interpolation types associated with various types of spectral data according to CIE recommendation:

_S_INTERP_TYPE Interpolation type for light source spectral data

_R_INTERP_TYPE Interpolation type for reflective/transmissive spectral data

_CRI_REF_TYPE Dict with blackbody to daylight transition (mixing) ranges for various types of reference illuminants used in color rendering index calculations.

getwlr() Get/construct a wavelength range from a (start, stop, spacing) 3-vector.

getwld() Get wavelength spacing of numpy.ndarray with wavelengths.

spd_normalize() Spectrum normalization (supports: area, max, lambda, radiometric, photometric and quantal energy units).

cie_interp() Interpolate / extrapolate spectral data following standard [CIE15:2004, "Colorimetry," CIE, Vienna, Austria, 2004.]

spd()

All-in-one function that can:

1. Read spectral data from data file or take input directly as pandas.dataframe or numpy.array.
2. Convert spd-like data from numpy.array to pandas.dataframe and back.
3. Interpolate spectral data.
4. Normalize spectral data.

xyzbar() Get color matching functions.

vlbar() Get Vlambda function.

spd_to_xyz() Calculates xyz tristimulus values from spectral data.

spd_to_ler() Calculates Luminous efficacy of radiation (LER) from spectral data.

spd_to_power() Calculate power of spectral data in radiometric, photometric or quantal energy units.

blackbody() Calculate blackbody radiator spectrum.

daylightlocus() Calculates daylight chromaticity from cct.

daylightphase() Calculate daylight phase spectrum

cri_ref()

Calculates a reference illuminant spectrum based on cct for color rendering index calculations.

(CIE15:2004CIE15:2004, "Colorimetry," CIE, Vienna, Austria, 2004., cie224:2017, CIE 2017 Colour Fidelity Index for accurate scientific use. (2017), ISBN 978-3-902842-61-9., IES-TM-30-15: Method for Evaluating Light Source Color Rendition. New York, NY: The Illuminating Engineering Society of North America.

spectrum/spectral_databases.py

_S_PATH Path to light source spectra data.

_R_PATH Path to with spectral reflectance data

_IESTM30 Database with spectral reflectances related to and light source spectra contained excel calculator of IES TM30-15 publication.

_IESTM30_S Database with only light source spectra contained in the IES TM30-15 excel calculator.

_CIE_ILLUMINANTS

Database with CIE illuminants:
* 'E', 'D65', 'A', 'C',
* 'F1', 'F2', 'F3', 'F4', 'F5', 'F6', 'F7', 'F8', 'F9', 'F10', 'F11', 'F12'

_CRI_RFL

Database with spectral reflectance functions for various color rendition calculators:
* CIE 13.3-1995 (8, 14 munsell samples)
* CIE 224:2015 (99 set)
* CRI2012 (HL17 & HL1000 spectrally uniform and 210 real samples)
* IES TM30 (99, 4880 sepctrally uniform samples)
* MCRI (10 familiar object set)
* CQS (v7.5 and v9.0 sets)

_MUNSELL Database (dict) with 1269 Munsell spectral reflectance functions and Value (V), Chroma (C), hue (h) and (ab) specifications.

References

1. CIE15-2004 (2004). Colorimetry (Vienna, Austria: CIE)

2. CIE, and CIE (2006). Fundamental Chromaticity Diagram with Physiological Axes - Part I.(Vienna: CIE).

3. cie224:2017, CIE 2017 Colour Fidelity Index for accurate scientific use. (2017), ISBN 978-3-902842-61-9.

4. IES-TM-30-15: Method for Evaluating Light Source Color Rendition. New York, NY: The Illuminating Engineering Society of North America.

`luxpy.spectrum.`**`getwlr`**(*wl3=None*)

Get/construct a wavelength range from a 3-vector (start, stop, spacing).

Args:

wl3

list[start, stop, spacing], optional
(defaults to luxpy._WL3)

Returns:

returns

ndarray (.shape = (n,)) with n wavelengths ranging from start to stop, with wavelength interval equal to spacing.

`luxpy.spectrum.`**`getwld`**(*wl*)

Get wavelength spacing.

Args:

wl

ndarray with wavelengths

Returns:

returns

- float: for equal wavelength spacings
- ndarray (.shape = (n,)): for unequal wavelength spacings

`luxpy.spectrum.`**`spd_normalize`**(*data*, *norm_type=None*, *norm_f=1*, *wl=True*, *cieobs='1931_2'*)

Normalize a spectral power distribution (SPD).

Args:

data

ndarray

norm_type

None, optional
- 'lambda': make lambda in norm_f equal to 1
- 'area': area-normalization times norm_f
- 'max': max-normalization times norm_f
- 'ru': to :norm_f: radiometric units

- 'pu': to :norm_f: photometric units
- 'qu': to :norm_f: quantal energy units

norm_f

1, optional
Normalization factor that determines the size of normalization for 'max' and 'area' or which wavelength is normalized to 1 for 'lambda' option.

wl

True or False, optional
If True, the first column of data contains wavelengths.

cieobs

_CIEOBS or str, optional
Type of cmf set to use for normalization using photometric units (norm_type == 'pu')

Returns:

returns

ndarray with normalized data.

`luxpy.spectrum.`**`cie_interp`**(*data*, *wl_new*, *kind=None*, *negative_values_allowed=False*)

Interpolate / extrapolate spectral data following standard CIE15-2004.

The kind of interpolation depends on the spectrum type defined in :kind:.
Extrapolation is always done by replicate the closest known values.

Args:

data

ndarray with spectral data
(.shape = (number of spectra + 1, number of original wavelengths))

wl_new

ndarray with new wavelengths

kind

None, optional
- If :kind: is None, return original data.
- If :kind: is a spectrum type (see _INTERP_TYPES), the correct interpolation type if automatically chosen.
- Or :kind: can be any interpolation type supported by scipy.interpolate.interp1d

negative_values_allowed

False, optional
If False: negative values are clipped to zero.

Returns:

returns

ndarray of interpolated spectral data. (.shape = (number of spectra + 1, number of wavelength in wl_new))

luxpy.spectrum.**spd**(*data=None*, *interpolation=None*, *kind='np'*, *wl=None*, *columns=None*, *sep=','*, *header=None*, *datatype='S'*, *norm_type=None*, *norm_f=None*)

All-in-one function that can:

1. Read spectral data from data file or take input directly as pandas.dataframe or ndarray.
2. Convert spd-like data from ndarray to pandas.dataframe and back.
3. Interpolate spectral data.
4. Normalize spectral data.

Args:

data

- str with path to file containing spectral data
- ndarray with spectral data
- pandas.dataframe with spectral data
(.shape = (number of spectra + 1, number of original wavelengths))

interpolation

None, optional
- None: don't interpolate
- str with interpolation type or spectrum type

kind

str ['np','df'], optional
Determines type(:returns:), np: ndarray, df: pandas.dataframe

wl

None, optional
New wavelength range for interpolation.
Defaults to wavelengths specified by luxpy._WL3.

columns

- None or list[str] of column names for dataframe, optional

header

None or 'infer', optional
- None: no header in file
- 'infer': infer headers from file

sep

',' or ' ' or other char, optional
Column separator in case :data: specifies a data file.

datatype'

'S' (light source) or 'R' (reflectance) or other, optional
Specifies a type of spectral data.
Is used when creating column headers when :column: is None.

norm_type

None, optional
- 'lambda': make lambda in norm_f equal to 1
- 'area': area-normalization times norm_f
- 'max': max-normalization times norm_f
- 'ru': to :norm_f: radiometric units
- 'pu': to :norm_f: photometric units
- 'qu': to :norm_f: quantal energy units

norm_f

1, optional
Normalization factor that determines the size of normalization for 'max' and 'area' or which wavelength is normalized to 1 for 'lambda' option.

Returns:

returns

ndarray or pandas.dataframe
with interpolated and/or normalized spectral data.

`luxpy.spectrum.`**`xyzbar`**(*cieobs='1931_2'*, *scr='dict'*, *wl_new=None*, *norm_type=None*, *norm_f=None*, *kind='np'*)

Get color matching functions.

Args:

cieobs

luxpy._CIEOBS, optional
Sets the type of color matching functions to load.

scr

'dict' or 'file', optional
Determines whether to load cmfs from file (./data/cmfs/) or from dict defined in .cmf.py

wl

None, optional
New wavelength range for interpolation.
Defaults to wavelengths specified by luxpy._WL3.

norm_type

None, optional
- 'lambda': make lambda in norm_f equal to 1
- 'area': area-normalization times norm_f
- 'max': max-normalization times norm_f
- 'ru': to :norm_f: radiometric units
- 'pu': to :norm_f: photometric units
- 'qu': to :norm_f: quantal energy units

norm_f

1, optional
Normalization factor that determines the size of normalization for 'max' and 'area' or which wavelength is normalized to 1 for 'lambda' option.

kind

str ['np','df'], optional
Determines type(:returns:), np: ndarray, df: pandas.dataframe

Returns:

returns

ndarray or pandas.dataframe with CMFs

References: 1. CIE15:2004. Colorimetry. CIE, Vienna.

luxpy.spectrum.**vlbar**(*cieobs='1931_2'*, *scr='dict'*, *wl_new=None*, *norm_type=None*, *norm_f=None*, *kind='np'*, *out=1*)

Get Vlambda functions.

Args:

cieobs

str, optional
Sets the type of Vlambda function to obtain.

scr

'dict' or array, optional
- 'dict': get from ybar from _CMF
- 'array': ndarray in :cieobs:
Determines whether to load cmfs from file (./data/cmfs/) or from dict defined in .cmf.py
Vlambda is obtained by collecting Ybar.

wl

None, optional
New wavelength range for interpolation.
Defaults to wavelengths specified by luxpy._WL3.

norm_type

None, optional
- 'lambda': make lambda in norm_f equal to 1
- 'area': area-normalization times norm_f
- 'max': max-normalization times norm_f
- 'ru': to :norm_f: radiometric units
- 'pu': to :norm_f: photometric units
- 'qu': to :norm_f: quantal energy units

norm_f

1, optional
Normalization factor that determines the size of normalization for 'max' and 'area' or which wavelength is normalized to 1 for 'lambda' option.

kind

str ['np','df'], optional
Determines type(:returns:), np: ndarray, df: pandas.dataframe

out

1 or 2, optional
1: returns Vlambda

2: returns (Vlambda, Km)

Returns:

returns

dataframe or ndarray with Vlambda of type :cieobs:

References: 1. CIE15:2004. Colorimetry. CIE, Vienna

`luxpy.spectrum.`**`spd_to_xyz`**(*data*, *relative=True*, *rfl=None*, *cieobs='1931_2'*, *K=None*, *out=None*, *cie_std_dev_obs=None*)

Calculates xyz tristimulus values from spectral data.

Args:

data

ndarray or pandas.dataframe with spectral data
(.shape = (number of spectra + 1, number of wavelengths))
Note that :data: is never interpolated, only CMFs and RFLs.
This way interpolation errors due to peaky spectra are avoided. Conform CIE15-2004.

relative

True or False, optional
Calculate relative XYZ (Yw = 100) or absolute XYZ (Y = Luminance)

rfl

ndarray with spectral reflectance functions.
Will be interpolated if wavelengths do not match those of :data:

cieobs

luxpy._CIEOBS or str, optional
Determines the color matching functions to be used in the calculation of XYZ.

K

None, optional
e.g. K = 683 lm/W for '1931_2' (relative == False)
or K = 100/sum(spd*dl) (relative == True)

out

None or 1 or 2, optional
Determines number and shape of output. (see :returns:)

cie_std_dev_obs

None or str, optional
- None: don't use CIE Standard Deviate Observer function.
- 'f1': use F1 function.

Returns:

returns

If rfl is None:
If out is None: ndarray of xyz values
(.shape = (data.shape[0],3))
If out == 1: ndarray of xyz values

(.shape = (data.shape[0],3))
If out == 2: (ndarray of xyz, ndarray of xyzw) values
Note that xyz == xyzw, with (.shape = (data.shape[0],3))
If rfl is not None:
If out is None: ndarray of xyz values
(.shape = (rfl.shape[0],data.shape[0],3))
If out == 1: ndarray of xyz values
(.shape = (rfl.shape[0]+1,data.shape[0],3))
The xyzw values of the light source spd are the first set
of values of the first dimension. The following values
along this dimension are the sample (rfl) xyz values.
If out == 2: (ndarray of xyz, ndarray of xyzw) values
with xyz.shape = (rfl.shape[0],data.shape[0],3)
and with xyzw.shape = (data.shape[0],3)

References: 1. CIE15:2004. Colorimetry. CIE, Vienna.

`luxpy.spectrum.`**`spd_to_ler`**(*data*, *cieobs='1931_2'*, *K=None*)

Calculates Luminous efficacy of radiation (LER) from spectral data.

Args:

data

ndarray or pandas.dataframe with spectral data
(.shape = (number of spectra + 1, number of wavelengths))
Note that :data: is never interpolated, only CMFs and RFLs.
This way interpolation errors due to peaky spectra are avoided.
Conform CIE15-2004.

cieobs

luxpy._CIEOBS, optional
Determines the color matching function set used in the
calculation of LER. For cieobs = '1931_2' the ybar CMF curve equals
the CIE 1924 Vlambda curve.

K

None, optional
e.g. K = 683 lm/W for '1931_2'

Returns:

ler

ndarray of LER values.

References: 1. CIE15:2004. Colorimetry. CIE, Vienna.

`luxpy.spectrum.`**`spd_to_power`**(*data*, *ptype='ru'*, *cieobs='1931_2'*)

Calculate power of spectral data in radiometric, photometric or quantal energy units.

Args:

data

ndarray with spectral data

ptype

'ru' or str, optional
str: - 'ru': in radiometric units

- 'pu': in photometric units
- 'qu': in quantal energy units

cieobs

_CIEOBS or str, optional
Type of cmf set to use for photometric units.

Returns:

returns:

ndarray with normalized spectral data (SI units)

luxpy.spectrum.**blackbody**(*cct*, *wl3=None*, *norm_type=None*, *norm_f=None*)

Calculate blackbody radiator spectrum for correlated color temperature (cct).

Args:

cct

int or float
(for list of cct values, use cri_ref() with ref_type = 'BB')

wl3

None, optional
New wavelength range for interpolation.
Defaults to wavelengths specified by luxpy._WL3.

norm_type

None, optional
- 'lambda': make lambda in norm_f equal to 1
- 'area': area-normalization times norm_f
- 'max': max-normalization times norm_f
- 'ru': to :norm_f: radiometric units
- 'pu': to :norm_f: photometric units
- 'qu': to :norm_f: quantal energy units

norm_f

1, optional
Normalization factor that determines the size of normalization for 'max' and 'area' or which wavelength is normalized to 1 for 'lambda' option.

Returns:

returns

ndarray with blackbody radiator spectrum (:returns:[0] contains wavelengths)

References: 1. CIE15:2004. Colorimetry.

luxpy.spectrum.**daylightlocus**(*cct*, *force_daylight_below4000K=False*)

Calculates daylight chromaticity from correlated color temperature (cct).

Args:

cct

int or float or list of int/floats or ndarray

force_daylight_below4000K

False or True, optional
Daylight locus approximation is not defined below 4000 K,
but by setting this to True, the calculation can be forced to
calculate it anyway.

Returns:

returns

(ndarray of x-coordinates, ndarray of y-coordinates)

References: 1. CIE15:2004. Colorimetry.

luxpy.spectrum.**daylightphase**(*cct*, *wl3=None*, *norm_type=None*, *norm_f=None*, *force_daylight_below4000K=False*, *verbosity=None*)

Calculate daylight phase spectrum for correlated color temperature (cct).

Args:

cct

int or float

(for list of cct values, use cri_ref() with ref_type = 'DL')

wl3

None, optional

New wavelength range for interpolation.

Defaults to wavelengths specified by luxpy._WL3.

norm_type

None, optional

- 'lambda': make lambda in norm_f equal to 1
- 'area': area-normalization times norm_f
- 'max': max-normalization times norm_f
- 'ru': to :norm_f: radiometric units
- 'pu': to :norm_f: photometric units
- 'qu': to :norm_f: quantal energy units

norm_f

1, optional

Normalization factor that determines the size of normalization for 'max' and 'area' or which wavelength is normalized to 1 for 'lambda' option.

force_daylight_below4000K

False or True, optional

Daylight locus approximation is not defined below 4000 K,

but by setting this to True, the calculation can be forced to

calculate it anyway.

verbosity

None, optional

If None: do not print warning when CCT < 4000 K.

Returns:

returns

ndarray with daylight phase spectrum (:returns:[0] contains wavelengths)

References: 1. CIE15:2004. Colorimetry.

luxpy.spectrum.**cri_ref**(*ccts*, *wl3=None*, *ref_type='ciera'*, *mix_range=None*, *cieobs='1931_2'*, *norm_type=None*, *norm_f=None*, *force_daylight_below4000K=False*)

Calculates a reference illuminant spectrum based on cct for color rendering index calculations .

Args:

ccts

list of int/floats or ndarray with ccts.

wl3

None, optional
New wavelength range for interpolation.
Defaults to wavelengths specified by luxpy._WL3.

ref_type

str or list[str], optional
Specifies the type of reference spectrum to be calculated.
Defaults to luxpy._CRI_REF_TYPE.
If :ref_type: is list of strings, then for each cct in :ccts: a different reference illuminant can be specified.
If :ref_type: == 'spd', then :ccts: is assumed to be an ndarray of reference illuminant spectra.

mix_range

None or ndarray, optional
Determines the cct range between which the reference illuminant is
a weigthed mean of a Planckian and Daylight Phase spectrum.
Weighthing is done as described in IES TM30:
SPDreference = (Te-T)/(Te-Tb)*Planckian+(T-Tb)/(Te-Tb)*daylight
with Tb and Te are resp. the starting and end CCTs of the
mixing range and whereby the Planckian and Daylight SPDs
have been normalized for equal luminous flux.
If None: use the default specified for :ref_type:.
Can be a ndarray with shape[0] > 1, in which different mixing
ranges will be used for cct in :ccts:.

cieobs

luxpy._CIEOBS, optional
Required for the normalization of the Planckian and Daylight SPDs when calculating a 'mixed' reference illuminant.

norm_type

None, optional
- 'lambda': make lambda in norm_f equal to 1
- 'area': area-normalization times norm_f
- 'max': max-normalization times norm_f
- 'ru': to :norm_f: radiometric units
- 'pu': to :norm_f: photometric units
- 'qu': to :norm_f: quantal energy units

norm_f

1, optional
Normalization factor that determines the size of normalization for 'max' and 'area' or which wavelength is normalized to 1 for 'lambda' option.

force_daylight_below4000K

False or True, optional

Daylight locus approximation is not defined below 4000 K,
but by setting this to True, the calculation can be forced to calculate it anyway.

Returns:

returns

ndarray with reference illuminant spectra. (:returns:[0] contains wavelengths)

Note: Future versions will have the ability to take a dict as input for ref_type. This way other reference illuminants can be specified than the ones in _CRI_REF_TYPES.

4.3 Color sub-package

4.3.1 utils/

py

- __init__.py
- plotters.py

namespace luxpy

Module with functions related to plotting of color data

plot_color_data() Plot color data (local helper function)

plotDL() Plot daylight locus.

plotBB() Plot blackbody locus.

plotSL()

Plot spectrum locus.
(plotBB() and plotDL() are also called, but can be turned off).

plotcerulean()

Plot cerulean (yellow (577 nm) - blue (472 nm)) line
(Kuehni, CRA, 2014: Table II: spectral lights)
Kuehni, R. G. (2014). Unique hues and their stimuli—state of the art. Color Research & Application, 39(3), 279–287.

plotUH()

Plot unique hue lines from color space center point xyz0.
(Kuehni, CRA, 2014: uY,uB,uG: Table II: spectral lights;
uR: Table IV: Xiao data)
Kuehni, R. G. (2014). Unique hues and their stimuli—state of the art. Color Research & Application, 39(3), 279–287.

plotcircle() Plot one or more concentric circles.

`luxpy.color.utils.`**`plotSL`**(*cieobs='1931_2'*, *cspace='Yuv'*, *DL=True*, *BBL=True*, *D65=False*, *EEW=False*, *cctlabels=False*, *axh=None*, *show=True*, *cspace_pars={}*, *formatstr='k-'*, ***kwargs*)

Plot spectrum locus for cieobs in cspace.

Args:

DL

True or False, optional
True plots Daylight Locus as well.

BBL

True or False, optional
True plots BlackBody Locus as well.

D65

False or True, optional
True plots D65 chromaticity as well.

EEW

False or True, optional
True plots Equi-Energy-White chromaticity as well.

cctlabels

False or True, optional
Add cct text labels at various points along the blackbody locus.

axh

None or axes handle, optional
Determines axes to plot data in.
None: make new figure.

show

True or False, optional
Invoke matplotlib.pyplot.show() right after plotting

cieobs

luxpy._CIEOBS or str, optional
Determines CMF set to calculate spectrum locus or other.

cspace

luxpy._CSPACE or str, optional
Determines color space / chromaticity diagram to plot data in.
Note that data is expected to be in specified :cspace:

formatstr

'k-' or str, optional
Format str for plotting (see ?matplotlib.pyplot.plot)

cspace_pars

{} or dict, optional
Dict with parameters required by color space specified in :cspace:
(for use with luxpy.colortf())

kwargs

additional keyword arguments for use with matplotlib.pyplot.

Returns:

returns

None (:show: == True)

or

handle to current axes (:show: == False)

luxpy.color.utils.**plotDL**(*ccts=None*, *cieobs='1931_2'*, *cspace='Yuv'*, *axh=None*, *show=True*, *force_daylight_below4000K=False*, *cspace_pars={}*, *formatstr='k-'*, ***kwargs*)

Plot daylight locus.

Args:

ccts

None or list[float], optional

None defaults to [4000 K to 1e19 K] in 100 steps on a log10 scale.

force_daylight_below4000K

False or True, optional

CIE daylight phases are not defined below 4000 K.

If True plot anyway.

axh

None or axes handle, optional

Determines axes to plot data in.

None: make new figure.

show

True or False, optional

Invoke matplotlib.pyplot.show() right after plotting

cieobs

luxpy._CIEOBS or str, optional

Determines CMF set to calculate spectrum locus or other.

cspace

luxpy._CSPACE or str, optional

Determines color space / chromaticity diagram to plot data in.

Note that data is expected to be in specified :cspace:

formatstr

'k-' or str, optional

Format str for plotting (see ?matplotlib.pyplot.plot)

cspace_pars

{} or dict, optional

Dict with parameters required by color space specified in :cspace: (for use with luxpy.colortf())

kwargs

additional keyword arguments for use with matplotlib.pyplot.

Returns:

returns

None (:show: == True)

or

handle to current axes (:show: == False)

luxpy.color.utils.**plotBB**(*ccts=None*, *cieobs='1931_2'*, *cspace='Yuv'*, *axh=None*, *cctlabels=True*, *show=True*, *cspace_pars={}*, *formatstr='k-'*, ***kwargs*)

Plot blackbody locus.

Args:

ccts

None or list[float], optional
None defaults to [1000 to 1e19 K].
Range:
[1000,1500,2000,2500,3000,3500,4000,5000,6000,8000,10000]
+ [15000 K to 1e19 K] in 100 steps on a log10 scale

cctlabels

True or False, optional
Add cct text labels at various points along the blackbody locus.

axh

None or axes handle, optional
Determines axes to plot data in.
None: make new figure.

show

True or False, optional
Invoke matplotlib.pyplot.show() right after plotting

cieobs

luxpy._CIEOBS or str, optional
Determines CMF set to calculate spectrum locus or other.

cspace

luxpy._CSPACE or str, optional
Determines color space / chromaticity diagram to plot data in.
Note that data is expected to be in specified :cspace:

formatstr

'k-' or str, optional
Format str for plotting (see ?matplotlib.pyplot.plot)

cspace_pars

{} or dict, optional
Dict with parameters required by color space specified in :cspace: (for use with luxpy.colortf())

kwargs

additional keyword arguments for use with matplotlib.pyplot.

Returns:

returns

None (:show: == True)
or
handle to current axes (:show: == False)

luxpy.color.utils.**plot_color_data**(*x*, *y*, *z=None*, *axh=None*, *show=True*, *cieobs='1931_2'*, *cspace='Yuv'*, *formatstr='k-'*, ***kwargs*)

Plot color data from x,y [,z].

Args:

x

float or ndarray with x-coordinate data

y

float or ndarray with y-coordinate data

z

None or float or ndarray with Z-coordinate data, optional
If None: make 2d plot.

axh

None or axes handle, optional
Determines axes to plot data in.
None: make new figure.

show

True or False, optional
Invoke matplotlib.pyplot.show() right after plotting

cieobs

luxpy._CIEOBS or str, optional
Determines CMF set to calculate spectrum locus or other.

cspace

luxpy._CSPACE or str, optional
Determines color space / chromaticity diagram to plot data in.
Note that data is expected to be in specified :cspace:

formatstr

'k-' or str, optional
Format str for plotting (see ?matplotlib.pyplot.plot)

kwargs

additional keyword arguments for use with matplotlib.pyplot.

Returns:

returns

None (:show: == True)
or
handle to current axes (:show: == False)

luxpy.color.utils.**plotceruleanline**(*cieobs='1931_2'*, *cspace='Yuv'*, *axh=None*, *formatstr='ko-'*, *cspace_pars={}*)

Plot cerulean (yellow (577 nm) - blue (472 nm)) line

Kuehni, CRA, 2014:
Table II: spectral lights.

Args:

axh

None or axes handle, optional
Determines axes to plot data in.
None: make new figure.

cieobs

luxpy._CIEOBS or str, optional
Determines CMF set to calculate spectrum locus or other.

cspace

luxpy._CSPACE or str, optional
Determines color space / chromaticity diagram to plot data in.
Note that data is expected to be in specified :cspace:

formatstr

'k-' or str, optional
Format str for plotting (see ?matplotlib.pyplot.plot)

cspace_pars

{} or dict, optional
Dict with parameters required by color space specified in :cspace:
(for use with luxpy.colortf())

kwargs

additional keyword arguments for use with matplotlib.pyplot.

Returns:

returns

handle to cerulean line

References: 1. Kuehni, R. G. (2014). Unique hues and their stimuli—state of the art. Color Research & Application, 39(3), 279–287. (see Table II, IV)

`luxpy.color.utils.`**`plotUH`**(*xyz0=None, uhues=[0, 1, 2, 3], cieobs='1931_2', cspace='Yuv', axh=None, formatstr=['yo-.', 'bo-.', 'ro-.', 'go-.'], excludefromlegend='', cspace_pars={}*)

Plot unique hue lines from color space center point xyz0.

Kuehni, CRA, 2014:
uY,uB,uG: Table II: spectral lights;
uR: Table IV: Xiao data.

Args:

xyz0

None, optional
Center of color space (unique hue lines are expected to cross here)
None defaults to equi-energy-white.

uhues

[0,1,2,3], optional
Unique hue lines to plot [0:'yellow',1:'blue',2:'red',3:'green']

axh

None or axes handle, optional
Determines axes to plot data in.
None: make new figure.

cieobs

luxpy._CIEOBS or str, optional
Determines CMF set to calculate spectrum locus or other.

cspace

luxpy._CSPACE or str, optional
Determines color space / chromaticity diagram to plot data in.
Note that data is expected to be in specified :cspace:

formatstr

['yo-','bo-','ro-','go-'] or list[str], optional
Format str for plotting the different unique lines
(see also ?matplotlib.pyplot.plot)

excludefromlegend

'' or str, optional
To exclude certain hues from axes legend.

cspace_pars

{} or dict, optional
Dict with parameters required by color space specified in :cspace:
(for use with luxpy.colortf())

Returns:

returns

list[handles] to unique hue lines

References: 1. Kuehni, R. G. (2014). Unique hues and their stimuli—state of the art. Color Research & Application, 39(3), 279–287. (see Table II, IV)

luxpy.color.utils.**plotcircle**(*center=array([0.0000e+00, 0.0000e+00])*, *radii=array([0, 10, 20, 30, 40, 50])*, *angles=array([0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340])*, *color='k'*, *linestyle='–'*, *out=None*)

Plot one or more concentric circles.

Args:

center

np.array([0.,0.]) or ndarray with center coordinates, optional

radii

np.arange(0,60,10) or ndarray with radii of circle(s), optional

angles

np.arange(0,350,10) or ndarray with angles (°), optional

color

'k', optional

Color for plotting.

linestyle

'–', optional
Linestyle of circles.

out

None, optional
If None: plot circles, return (x,y) otherwise.

4.3.2 ctf/

py

- __init__.py
- colortransformations.py
- colortf.py

namespace luxpy

Module with functions related to basic colorimetry

Note

Note that colorimetric data is always located in the last axis of the data arrays. (See also xyz specification in __doc__ string of luxpy.spd_to_xyz())

colortransforms.py

- **_CSPACE_AXES: dict with list[str,str,str] containing axis labels** of defined cspaces

Chromaticity / colorspace functions

* xyz_to_Yxy(), Yxy_to_xyz(): (X,Y,Z) <-> (Y,x,y);
* xyz_to_Yuv(), Yuv_to_Yxy(): (X,Y,Z) <-> CIE 1976 (Y,u',v');
* xyz_to_xyz(), lms_to_xyz(): (X,Y,Z) <-> (X,Y,Z); for use with colortf()
* xyz_to_lms(), lms_to_xyz(): (X,Y,Z) <-> (L,M,S) cone fundamental responses
* xyz_to_lab(), lab_to_xyz(): (X,Y,Z) <-> CIE 1976 (L*,a*,b*)
* xyz_to_luv(), luv_to_xyz(): (X,Y,Z) <-> CIE 1976 (L*,u*,v*)
* xyz_to_Vrb_mb(),Vrb_mb_to_xyz(): (X,Y,Z) <-> (V,r,b); [Macleod & Boyton, 1979]
* xyz_to_ipt(), ipt_to_xyz(): (X,Y,Z) <-> (I,P,T); [Ebner et al, 1998]
* xyz_to_Ydlep(), Ydlep_to_xyz(): (X,Y,Z) <-> (Y,dl, ep);
  Y, dominant wavelength (dl) and excitation purity (ep)
* xyz_to_srgb(), srgb_to_xyz(): (X,Y,Z) <-> sRGB; (IEC:61966 sRGB)

References

1. CIE15-2004 (2004). Colorimetry (Vienna, Austria: CIE)
2. Ebner F, and Fairchild MD (1998). Development and testing of a color space (IPT) with improved hue uniformity. In IS&T 6th Color Imaging Conference, (Scottsdale, Arizona, USA), pp. 8–13.
3. MacLeod DI, and Boynton RM (1979). Chromaticity diagram showing cone excitation by stimuli of equal luminance. J. Opt. Soc. Am. 69, 1183–1186.

luxpy.color.ctf.colortransforms.**xyz_to_Yxy**(*xyz*, ***kwargs*)

Convert XYZ tristimulus values CIE Yxy chromaticity values.

Args:

xyz

ndarray with tristimulus values

Returns:

Yxy

ndarray with Yxy chromaticity values (Y value refers to luminance or luminance factor)

luxpy.color.ctf.colortransforms.**Yxy_to_xyz**(*Yxy*, ***kwargs*)

Convert CIE Yxy chromaticity values to XYZ tristimulus values.

Args:

Yxy

ndarray with Yxy chromaticity values (Y value refers to luminance or luminance factor)

Returns:

xyz

ndarray with tristimulus values

luxpy.color.ctf.colortransforms.**xyz_to_Yuv**(*xyz*, ***kwargs*)

Convert XYZ tristimulus values CIE 1976 Yu'v' chromaticity values.

Args:

xyz

ndarray with tristimulus values

Returns:

Yuv

ndarray with CIE 1976 Yu'v' chromaticity values (Y value refers to luminance or luminance factor)

luxpy.color.ctf.colortransforms.**Yuv_to_xyz**(*Yuv*, ***kwargs*)

Convert CIE 1976 Yu'v' chromaticity values to XYZ tristimulus values.

Args:

Yuv

ndarray with CIE 1976 Yu'v' chromaticity values (Y value refers to luminance or luminance factor)

Returns:

xyz

ndarray with tristimulus values

luxpy.color.ctf.colortransforms.**xyz_to_wuv**(*xyz*, *xyzw=array([1.0000e+02, 1.0000e+02, 1.0000e+02])*, ***kwargs*)

Convert XYZ tristimulus values CIE 1964 U*V*W* color space.

Args:

xyz

ndarray with tristimulus values

xyzw

ndarray with tristimulus values of white point, optional (Defaults to luxpy._COLORTF_DEFAULT_WHITE_POINT)

Returns:

wuv

ndarray with W*U*V* values

luxpy.color.ctf.colortransforms.**wuv_to_xyz**(*wuv*, *xyzw=array([1.0000e+02, 1.0000e+02, 1.0000e+02])*, ***kwargs*)

Convert CIE 1964 U*V*W* color space coordinates to XYZ tristimulus values.

Args:

wuv

ndarray with W*U*V* values

xyzw

ndarray with tristimulus values of white point, optional (Defaults to luxpy._COLORTF_DEFAULT_WHITE_POINT)

Returns:

xyz

ndarray with tristimulus values

luxpy.color.ctf.colortransforms.**xyz_to_xyz**(*xyz*, ***kwargs*)

Convert XYZ tristimulus values to XYZ tristimulus values.

Args:

xyz

ndarray with tristimulus values

Returns:

xyz

ndarray with tristimulus values

luxpy.color.ctf.colortransforms.**xyz_to_lms**(*xyz*, *cieobs='1931_2'*, *M=None*, ***kwargs*)

Convert XYZ tristimulus values to LMS cone fundamental responses.

Args:

xyz

ndarray with tristimulus values

cieobs

_CIEOBS or str, optional

M

None, optional

Conversion matrix for xyz to lms.

If None: use the one defined by :cieobs:

Returns:

lms

ndarray with LMS cone fundamental responses

luxpy.color.ctf.colortransforms.**lms_to_xyz**(*lms*, *cieobs='1931_2'*, *M=None*, ***kwargs*)

Convert LMS cone fundamental responses to XYZ tristimulus values.

Args:

lms

ndarray with LMS cone fundamental responses

cieobs

_CIEOBS or str, optional

M

None, optional
Conversion matrix for xyz to lms.
If None: use the one defined by :cieobs:

Returns:

xyz

ndarray with tristimulus values

luxpy.color.ctf.colortransforms.**xyz_to_lab**(*xyz*, *xyzw=None*, *cieobs='1931_2'*, ***kwargs*)

Convert XYZ tristimulus values to CIE 1976 L*a*b* (CIELAB) coordinates.

Args:

xyz

ndarray with tristimulus values

xyzw

None or ndarray with tristimulus values of white point, optional
None defaults to xyz of CIE D65 using the :cieobs: observer.

cieobs

luxpy._CIEOBS, optional
CMF set to use when calculating xyzw.

Returns:

lab

ndarray with CIE 1976 L*a*b* (CIELAB) color coordinates

luxpy.color.ctf.colortransforms.**lab_to_xyz**(*lab*, *xyzw=None*, *cieobs='1931_2'*, ***kwargs*)

Convert CIE 1976 L*a*b* (CIELAB) color coordinates to XYZ tristimulus values.

Args:

lab

ndarray with CIE 1976 L*a*b* (CIELAB) color coordinates

xyzw

None or ndarray with tristimulus values of white point, optional
None defaults to xyz of CIE D65 using the :cieobs: observer.

cieobs

luxpy._CIEOBS, optional
CMF set to use when calculating xyzw.

Returns:

xyz

ndarray with tristimulus values

luxpy.color.ctf.colortransforms.**xyz_to_luv**(*xyz*, *xyzw=None*, *cieobs='1931_2'*, ***kwargs*)

Convert XYZ tristimulus values to CIE 1976 L*u*v* (CIELUV) coordinates.

Args:

xyz

ndarray with tristimulus values

xyzw

None or ndarray with tristimulus values of white point, optional
None defaults to xyz of CIE D65 using the :cieobs: observer.

cieobs

luxpy._CIEOBS, optional
CMF set to use when calculating xyzw.

Returns:

luv

ndarray with CIE 1976 L*u*v* (CIELUV) color coordinates

luxpy.color.ctf.colortransforms.**luv_to_xyz**(*luv*, *xyzw=None*, *cieobs='1931_2'*, ***kwargs*)

Convert CIE 1976 L*u*v* (CIELUVB) coordinates to XYZ tristimulus values.

Args:

luv

ndarray with CIE 1976 L*u*v* (CIELUV) color coordinates

xyzw

None or ndarray with tristimulus values of white point, optional
None defaults to xyz of CIE D65 using the :cieobs: observer.

cieobs

luxpy._CIEOBS, optional
CMF set to use when calculating xyzw.

Returns:

xyz

ndarray with tristimulus values

luxpy.color.ctf.colortransforms.**xyz_to_Vrb_mb**(*xyz*, *cieobs='1931_2'*, *scaling=[1, 1]*, *M=None*, ***kwargs*)

Convert XYZ tristimulus values to V,r,b (Macleod-Boynton) color coordinates.

Macleod Boynton: V = R+G, r = R/V, b = B/V
Note that R,G,B ~ L,M,S

Args:

xyz

ndarray with tristimulus values

cieobs

luxpy._CIEOBS, optional
CMF set to use when getting the default M, which is the xyz to lms conversion matrix.

scaling

list of scaling factors for r and b dimensions.

M

None, optional
Conversion matrix for going from XYZ to RGB (LMS)
If None, :cieobs: determines the M (function does inversion)

Returns:

Vrb

ndarray with V,r,b (Macleod-Boynton) color coordinates

Reference:

1. MacLeod DI, and Boynton RM (1979). Chromaticity diagram showing cone excitation by stimuli of equal luminance. J. Opt. Soc. Am. 69, 1183–1186.

luxpy.color.ctf.colortransforms.**Vrb_mb_to_xyz**(*Vrb, cieobs='1931_2', scaling=[1, 1], M=None, Minverted=False, **kwargs*)

Convert V,r,b (Macleod-Boynton) color coordinates to XYZ tristimulus values.

Macleod Boynton: V = R+G, r = R/V, b = B/V
Note that R,G,B ~ L,M,S

Args:

Vrb

ndarray with V,r,b (Macleod-Boynton) color coordinates

cieobs

luxpy._CIEOBS, optional
CMF set to use when getting the default M, which is the xyz to lms conversion matrix.

scaling

list of scaling factors for r and b dimensions.

M

None, optional
Conversion matrix for going from XYZ to RGB (LMS)
If None, :cieobs: determines the M (function does inversion)

Minverted

False, optional
Bool that determines whether M should be inverted.

Returns:

xyz

ndarray with tristimulus values

Reference:

1. MacLeod DI, and Boynton RM (1979). Chromaticity diagram showing cone excitation by stimuli of equal luminance. J. Opt. Soc. Am. 69, 1183–1186.

luxpy.color.ctf.colortransforms.**xyz_to_ipt**(*xyz*, *cieobs='1931_2'*, *xyzw=None*, *M=None*, ***kwargs*)

Convert XYZ tristimulus values to IPT color coordinates.

I: Lightness axis, P, red-green axis, T: yellow-blue axis.

Args:

xyz

ndarray with tristimulus values

xyzw

None or ndarray with tristimulus values of white point, optional
None defaults to xyz of CIE D65 using the :cieobs: observer.

cieobs

luxpy._CIEOBS, optional
CMF set to use when calculating xyzw for rescaling M (only when not None).

M

None, optional
None defaults to xyz to lms conversion matrix determined by :cieobs:

Returns:

ipt

ndarray with IPT color coordinates

Note:

xyz is assumed to be under D65 viewing conditions! If necessary perform chromatic adaptation !

Reference:

1. Ebner F, and Fairchild MD (1998). Development and testing of a color space (IPT) with improved hue uniformity. In IS&T 6th Color Imaging Conference, (Scottsdale, Arizona, USA), pp. 8–13.

luxpy.color.ctf.colortransforms.**ipt_to_xyz**(*ipt*, *cieobs='1931_2'*, *xyzw=None*, *M=None*, ***kwargs*)

Convert XYZ tristimulus values to IPT color coordinates.

I: Lightness axis, P, red-green axis, T: yellow-blue axis.

Args:

ipt

ndarray with IPT color coordinates

xyzw

None or ndarray with tristimulus values of white point, optional
None defaults to xyz of CIE D65 using the :cieobs: observer.

cieobs

luxpy._CIEOBS, optional
CMF set to use when calculating xyzw for rescaling Mxyz2lms (only when not None).

M

None, optional
None defaults to xyz to lms conversion matrix determined by:cieobs:

Returns:

xyz

ndarray with tristimulus values

Note:

xyz is assumed to be under D65 viewing conditions! If necessary perform chromatic adaptation !

Reference:

1. Ebner F, and Fairchild MD (1998). Development and testing of a color space (IPT) with improved hue uniformity. In IS&T 6th Color Imaging Conference, (Scottsdale, Arizona, USA), pp. 8–13.

luxpy.color.ctf.colortransforms.**xyz_to_Ydlep**(*xyz*, *cieobs='1931_2'*, *xyzw=array([1.0000e+02, 1.0000e+02, 1.0000e+02])*, ***kwargs*)

Convert XYZ tristimulus values to Y, dominant (complementary) wavelength and excitation purity.

Args:

xyz

ndarray with tristimulus values

xyzw

None or ndarray with tristimulus values of white point, optional
None defaults to xyz of CIE D65 using the :cieobs: observer.

cieobs

luxpy._CIEOBS, optional
CMF set to use when calculating spectrum locus coordinates.

Returns:

Ydlep

ndarray with Y, dominant (complementary) wavelength and excitation purity

luxpy.color.ctf.colortransforms.**Ydlep_to_xyz**(*Ydlep*, *cieobs='1931_2'*, *xyzw=array([1.0000e+02, 1.0000e+02, 1.0000e+02])*, ***kwargs*)

Convert Y, dominant (complementary) wavelength and excitation purity to XYZ tristimulus values.

Args:

Ydlep

ndarray with Y, dominant (complementary) wavelength and excitation purity

xyzw

None or narray with tristimulus values of white point, optional
None defaults to xyz of CIE D65 using the :cieobs: observer.

cieobs

luxpy._CIEOBS, optional
CMF set to use when calculating spectrum locus coordinates.

Returns:

xyz

ndarray with tristimulus values

luxpy.color.ctf.colortransforms.**xyz_to_srgb**(*xyz*, ***kwargs*)

Calculates IEC:61966 sRGB values from xyz.

Args:

xyz

ndarray with relative tristimulus values.

Returns:

rgb

ndarray with R,G,B values.

luxpy.color.ctf.colortransforms.**srgb_to_xyz**(*rgb*, ***kwargs*)

Calculates xyz from IEC:61966 sRGB values.

Args:

rgb

ndarray with srgb values.

Returns:

xyz

ndarray with relative tristimulus values.

Extension of basic colorimetry module

Global internal variables:

_COLORTF_DEFAULT_WHITE_POINT ndarray with XYZ values of default white point (equi-energy white) for color transformation if none is supplied.

Functions:

colortf() Calculates conversion between any two color spaces ('cspace') for which functions xyz_to_cspace() and cspace_to_xyz() are defined.

---

luxpy.color.ctf.colortf.**colortf**(*data*, *tf='Yuv'*, *fwtf={}*, *bwtf={}*, ***kwargs*)

Wrapper function to perform various color transformations.

Args:

data

ndarray

tf

_CSPACE or str specifying transform type, optional

E.g. tf = 'spd>xyz' or 'spd>Yuv' or 'Yuv>cct'

or 'Yuv' or 'Yxy' or ...

If tf is for example 'Yuv', it is assumed to be a transformation of type: 'xyz>Yuv'

fwtf

dict with parameters (keys) and values required by some color transformations for the forward transform:

i.e. 'xyz>...'

bwtf

dict with parameters (keys) and values required by some color transformations for the backward transform:

i.e. '...>xyz'

Returns:

returns

ndarray with data transformed to new color space

Note: For the forward transform ('xyz>...'), one can input the keyword arguments specifying the transform parameters directly without having to use the dict :fwtf: (should be empty!) [i.e. kwargs overwrites empty fwtf dict]

4.3.3 cct/

py

- __init__.py
- cct.py

namespace luxpy

cct: Module with functions related to correlated color temperature calculations

_CCT_LUT_PATH Folder with Look-Up-Tables (LUT) for correlated color temperature calculation followings Ohno's method.

_CCT_LUT Dict with LUTs.

_CCT_LUT_CALC Boolean determining whether to force LUT calculation, even if the LUT can be fuond in ./data/cctluts/.

calculate_lut() Function that calculates the LUT for the ccts stored in ./data/cctluts/cct_lut_cctlist.dat or given as input argument. Calculation is performed for CMF set specified in cieobs. Adds a new (temprorary) field to the _CCT_LUT dict.

calculate_luts() Function that recalculates (and overwrites) LUTs in ./data/cctluts/ for the ccts stored in ./data/cctluts/cct_lut_cctlist.dat or given as input argument. Calculation is performed for all CMF sets listed in _CMF['types'].

xyz_to_cct()

Calculates CCT, Duv from XYZ

wrapper for xyz_to_cct_ohno() & xyz_to_cct_search()

xyz_to_duv() Calculates Duv, (CCT) from XYZ wrapper for xyz_to_cct_ohno() & xyz_to_cct_search()

cct_to_xyz() Calculates xyz from CCT, Duv [100 K < CCT < 10**20]

xyz_to_cct_mcamy()

Calculates CCT from XYZ using Mcamy model:

McCamy, Calvin S. (April 1992). Correlated color temperature as an explicit function of chromaticity coordinates. Color Research & Application. 17 (2): 142–144.

xyz_to_cct_HA()

Calculate CCT from XYZ using Hernández-Andrés et al. model.

Hernández-Andrés, Javier; Lee, RL; Romero, J (September 20, 1999). Calculating Correlated Color Temperatures Across the Entire Gamut of Daylight and Skylight Chromaticities. Applied Optics. 38 (27), 5703–5709. PMID 18324081.

xyz_to_cct_ohno()

Calculates CCT, Duv from XYZ using a LUT following:

Ohno Y. (2014) Practical use and calculation of CCT and Duv. Leukos. 2014 Jan 2;10(1):47-55.

xyz_to_cct_search() Calculates CCT, Duv from XYZ using brute-force search algorithm (between 1e2 K - 1e20 K on a log scale)

cct_to_mired() Converts from CCT to Mired scale (or back).

luxpy.color.cct.**calculate_luts**(*ccts=None*)

Function that recalculates (and overwrites) LUTs in ./data/cctluts/ for the ccts stored in ./data/cctluts/cct_lut_cctlist.dat or given as input argument. Calculation is performed for all CMF sets listed in _CMF['types'].

Args:

ccts

ndarray or str, optional

List of ccts for which to (re-)calculate the LUTs.

If str, ccts contains path/filename.dat to list.

Returns:

None

Note: Function writes LUTs to ./data/cctluts/ folder!

luxpy.color.cct.**xyz_to_cct**(*xyzw*, *cieobs='1931_2'*, *out='cct'*, *mode='lut'*, *wl=None*, *accuracy=0.1*, *force_out_of_lut=True*, *upper_cct_max=1e+20*, *approx_cct_temp=True*)

Convert XYZ tristimulus values to correlated color temperature (CCT) and Duv (distance above (>0) or below (<0) the Planckian locus) using either the brute-force search method or Ohno's method.

Wrapper function for use with luxpy.colortf().

Args:

xyzw

ndarray of tristimulus values

cieobs

luxpy._CIEOBS, optional

CMF set used to calculated xyzw.

mode

'lut' or 'search', optional

Determines what method to use.

out

'cct' (or 1), optional

Determines what to return.

Other options: 'duv' (or -1), 'cct,duv'(or 2), "[cct,duv]" (or -2)

wl

None, optional

Wavelengths used when calculating Planckian radiators.

accuracy

float, optional

Stop brute-force search when cct :accuracy: is reached.

upper_cct_max

10.0**20, optional

Limit brute-force search to this cct.

approx_cct_temp

True, optional
If True: use xyz_to_cct_HA() to get a first estimate of cct to speed up search.

force_out_of_lut

True, optional
If True and cct is out of range of the LUT, then switch to brute-force search method, else return numpy.nan values.

Returns:

returns

ndarray with:
cct: out == 'cct' (or 1)
Optional:
duv: out == 'duv' (or -1),
cct, duv: out == 'cct,duv' (or 2),
[cct,duv]: out == "[cct,duv]" (or -2)

luxpy.color.cct.**xyz_to_duv**(*xyzw*, *cieobs='1931_2'*, *out='duv'*, *mode='lut'*, *wl=None*, *accuracy=0.1*, *force_out_of_lut=True*, *upper_cct_max=1e+20*, *approx_cct_temp=True*)

Convert XYZ tristimulus values to Duv (distance above (>0) or below (<0) the Planckian locus) and correlated color temperature (CCT) values using either the brute-force search method or Ohno's method.

Wrapper function for use with luxpy.colortf().

Args:

xyzw

ndarray of tristimulus values

cieobs

luxpy._CIEOBS, optional
CMF set used to calculated xyzw.

mode

'lut' or 'search', optional
Determines what method to use.

out

'duv' (or 1), optional
Determines what to return.
Other options: 'duv' (or -1), 'cct,duv'(or 2), "[cct,duv]" (or -2)

wl

None, optional
Wavelengths used when calculating Planckian radiators.

accuracy

float, optional

Stop brute-force search when cct :accuracy: is reached.

upper_cct_max

10.0**20, optional
Limit brute-force search to this cct.

approx_cct_temp

True, optional
If True: use xyz_to_cct_HA() to get a first estimate of cct to speed up search.

force_out_of_lut

True, optional
If True and cct is out of range of the LUT, then switch to brute-force search method, else return numpy.nan values.

Returns:

returns

ndarray with:
duv: out == 'duv' (or -1)
Optional:
duv: out == 'duv' (or -1),
cct, duv: out == 'cct,duv' (or 2),
[cct,duv]: out == "[cct,duv]" (or -2)

`luxpy.color.cct.`**`cct_to_xyz`**(*ccts*, *duv=None*, *cieobs='1931_2'*, *wl=None*, *mode='lut'*, *out=None*, *accuracy=0.1*, *force_out_of_lut=True*, *upper_cct_max=200.0*, *approx_cct_temp=True*)

Convert correlated color temperature (CCT) and Duv (distance above (>0) or below (<0) the Planckian locus) to XYZ tristimulus values.

Finds xyzw_estimated by minimization of:

F = numpy.sqrt(((100.0*(cct_min - cct)/(cct))**2.0)
+ (((duv_min - duv)/(duv))**2.0))

with cct,duv the input values and cct_min, duv_min calculated using luxpy.xyz_to_cct(xyzw_estimated,...).

Args:

ccts

ndarray of cct values

duv

None or ndarray of duv values, optional
Note that duv can be supplied together with cct values in :ccts: as ndarray with shape (N,2)

cieobs

luxpy._CIEOBS, optional
CMF set used to calculated xyzw.

mode

'lut' or 'search', optional
Determines what method to use.

out

None (or 1), optional
If not None or 1: output a ndarray that contains estimated xyz and minimization results:
(cct_min, duv_min, F_min (objective fcn value))

wl

None, optional
Wavelengths used when calculating Planckian radiators.

accuracy

float, optional
Stop brute-force search when cct :accuracy: is reached.

upper_cct_max

10.0**20, optional
Limit brute-force search to this cct.

approx_cct_temp

True, optional
If True: use xyz_to_cct_HA() to get a first estimate of cct to speed up search.

force_out_of_lut

True, optional
If True and cct is out of range of the LUT, then switch to brute-force search method, else return numpy.nan values.

Returns:

returns

ndarray with estimated XYZ tristimulus values

Note: If duv is not supplied (:ccts:.shape is (N,1) and :duv: is None), source is assumed to be on the Planckian locus.

luxpy.color.cct.**cct_to_mired**(*data*)

Convert cct to Mired scale (or back).

Args:

data

ndarray with cct or Mired values.

Returns:

returns

ndarray ((10**6) / data)

luxpy.color.cct.**xyz_to_cct_ohno**(*xyzw*, *cieobs='1931_2'*, *out='cct'*, *wl=None*, *accuracy=0.1*, *force_out_of_lut=True*, *upper_cct_max=1e+20*, *approx_cct_temp=True*)

Convert XYZ tristimulus values to correlated color temperature (CCT) and Duv (distance above (>0) or below (<0) the Planckian locus) using Ohno's method.

Args:

xyzw

ndarray of tristimulus values

cieobs

luxpy._CIEOBS, optional
CMF set used to calculated xyzw.

out

'cct' (or 1), optional
Determines what to return.
Other options: 'duv' (or -1), 'cct,duv'(or 2), "[cct,duv]" (or -2)

wl

None, optional
Wavelengths used when calculating Planckian radiators.

accuracy

float, optional
Stop brute-force search when cct :accuracy: is reached.

upper_cct_max

10.0**20, optional
Limit brute-force search to this cct.

approx_cct_temp

True, optional
If True: use xyz_to_cct_HA() to get a first estimate of cct to speed up search.

force_out_of_lut

True, optional
If True and cct is out of range of the LUT, then switch to brute-force search method, else return numpy.nan values.

Returns:

returns

ndarray with:
cct: out == 'cct' (or 1)
duv: out == 'duv' (or -1)
cct, duv: out == 'cct,duv' (or 2)
[cct,duv]: out == "[cct,duv]" (or -2)

Note: LUTs are stored in ./data/cctluts/

Reference: 1. Ohno Y. Practical use and calculation of CCT and Duv. Leukos. 2014 Jan 2;10(1):47-55.

`luxpy.color.cct.`**`xyz_to_cct_search`**(*xyzw*, *cieobs='1931_2'*, *out='cct'*, *wl=None*, *accuracy=0.1*, *upper_cct_max=1e+20*, *approx_cct_temp=True*)

Convert XYZ tristimulus values to correlated color temperature (CCT) and Duv(distance above (> 0) or below (< 0) the Planckian locus) by a brute-force search.

The algorithm uses an approximate cct_temp (HA approx., see xyz_to_cct_HA) as starting point or uses the middle of the allowed cct-range (1e2 K - 1e20 K, higher causes overflow) on a log-scale, then constructs a 4-step section of the blackbody (Planckian) locus on which to find the minimum distance to the 1960 uv chromaticity of the test source.

Args:

xyzw

ndarray of tristimulus values

cieobs

luxpy._CIEOBS, optional
CMF set used to calculated xyzw.

out

'cct' (or 1), optional
Determines what to return.
Other options: 'duv' (or -1), 'cct,duv'(or 2), "[cct,duv]" (or -2)

wl

None, optional
Wavelengths used when calculating Planckian radiators.

accuracy

float, optional
Stop brute-force search when cct :accuracy: is reached.

upper_cct_max

10.0**20, optional
Limit brute-force search to this cct.

approx_cct_temp

True, optional
If True: use xyz_to_cct_HA() to get a first estimate of cct to speed up search.

Returns:

returns

ndarray with:
cct: out == 'cct' (or 1)
duv: out == 'duv' (or -1)
cct, duv: out == 'cct,duv' (or 2)
[cct,duv]: out == "[cct,duv]" (or -2)

Notes: This program is more accurate, but slower than xyz_to_cct_ohno! Note that cct must be between 1e3 K - 1e20 K (very large cct take a long time!!!)

luxpy.color.cct.**xyz_to_cct_HA**(*xyzw*)

Convert XYZ tristimulus values to correlated color temperature (CCT).

Args:

xyzw

ndarray of tristimulus values

Returns:

cct

ndarray of correlated color temperatures estimates

References: 1. Hernández-Andrés, Javier; Lee, RL; Romero, J (September 20, 1999). Calculating Correlated Color Temperatures Across the Entire Gamut of Daylight and Skylight Chromaticities. Applied Optics. 38 (27), 5703–5709. P

Notes: According to paper small error from 3000 - 800 000 K, but a test with Planckians showed errors up to 20% around 500 000 K; e>0.05 for T>200 000, e>0.1 for T>300 000, ...

luxpy.color.cct.**xyz_to_cct_mcamy**(*xyzw*)

Convert XYZ tristimulus values to correlated color temperature (CCT) using the mccamy approximation.

Only valid for approx. 3000 < T < 9000, if < 6500, error < 2 K.

Args:

xyzw

ndarray of tristimulus values

Returns:

cct

ndarray of correlated color temperatures estimates

References: 1. McCamy, Calvin S. (April 1992). "Correlated color temperature as an explicit function of chromaticity coordinates". Color Research & Application. 17 (2): 142–144.

4.3.4 cat/

py

- __init__.py
- chromaticadaptation.py

namespace luxpy.cat

cat: Module supporting chromatic adaptation transforms (corresponding colors)

_WHITE_POINT default adopted white point

_LA default luminance of the adaptation field

_MCATS default chromatic adaptation sensor spaces

- 'hpe': Hunt-Pointer-Estevez: R. W. G. Hunt, The Reproduction of Colour: Sixth Edition, 6th ed. Chichester, UK: John Wiley & Sons Ltd, 2004.
- 'cat02': from ciecam02: CIE159-2004, "A Colour Apperance Model for Color Management System: CIECAM02," CIE, Vienna, 2004.
- 'cat02-bs': cat02 adjusted to solve yellow-blue problem (last line = [0 0 1]): Brill MH, Süsstrunk S. Repairing gamut problems in CIECAM02: A progress report. Color Res Appl 2008;33(5), 424–426.
- 'cat02-jiang': cat02 modified to solve yb-probem + purple problem: Jun Jiang, Zhifeng Wang,M. Ronnier Luo,Manuel Melgosa,Michael H. Brill,Changjun Li, Optimum solution of the CIECAM02 yellow–blue and purple problems, Color Res Appl 2015: 40(5), 491-503.
- 'kries'
- 'judd-1945': from CIE16-2004, Eq.4, a23 modified from 0.1 to 0.1020 for increased accuracy
- 'bfd': bradford transform : G. D. Finlayson and S. Susstrunk, "Spectral sharpening and the Bradford transform," 2000, vol. Proceeding, pp. 236–242.

- 'sharp': sharp transform: S. Süsstrunk, J. Holm, and G. D. Finlayson, "Chromatic adaptation performance of different RGB sensors," IS&T/SPIE Electronic Imaging 2001: Color Imaging, vol. 4300. San Jose, CA, January, pp. 172–183, 2001.
- 'cmc': C. Li, M. R. Luo, B. Rigg, and R. W. G. Hunt, "CMC 2000 chromatic adaptation transform: CMCCAT2000," Color Res. Appl., vol. 27, no. 1, pp. 49–58, 2002.
- 'ipt': F. Ebner and M. D. Fairchild, "Development and testing of a color space (IPT) with improved hue uniformity," in IS&T 6th Color Imaging Conference, 1998, pp. 8–13.
- 'lms':
- 'bianco': S. Bianco and R. Schettini, "Two new von Kries based chromatic adaptation transforms found by numerical optimization," Color Res. Appl., vol. 35, no. 3, pp. 184–192, 2010.
- 'bianco-pc': S. Bianco and R. Schettini, "Two new von Kries based chromatic adaptation transforms found by numerical optimization," Color Res. Appl., vol. 35, no. 3, pp. 184–192, 2010.
- 'cat16': C. Li, Z. Li, Z. Wang, Y. Xu, M. R. Luo, G. Cui, M. Melgosa, M. H. Brill, and M. Pointer, "Comprehensive color solutions: CAM16, CAT16, and CAM16-UCS," Color Res. Appl., p. n/a–n/a.

check_dimensions() Check if dimensions of data and xyzw match.

get_transfer_function()

Calculate the chromatic adaptation diagonal matrix transfer function Dt.
Default = 'vonkries' (others: 'rlab', see Fairchild 1990)

smet2017_D()

Calculate the degree of adaptation based on chromaticity.
Smet, K.A.G.*, Zhai, Q., Luo, M.R., Hanselaer, P., (2017), Study of chromatic adaptation using memory color matches, Part II: colored illuminants. Opt. Express, 25(7), pp. 8350-8365

get_degree_of_adaptation()

Calculates the degree of adaptation.
D passes either right through or D is calculated following some D-function (Dtype) published in literature (cat02, cat16, cmccat, smet2017) or set manually.

parse_x1x2_parameters() local helper function that parses input parameters and makes them the target_shape for easy calculation

apply() Calculate corresponding colors by applying a von Kries chromatic adaptation transform (CAT), i.e. independent rescaling of 'sensor sensitivity' to data to adapt from current adaptation conditions (1) to the new conditions (2).

`luxpy.color.cat.`**`check_dimensions`**(*data*, *xyzw*, *caller='cat.apply()'*)
Check if dimensions of data and xyzw match.

Does nothing when they do, but raises error if dimensions don't match.

Args:

data

ndarray with color data.

xyzw

ndarray with white point tristimulus values.

caller

str with caller function for error handling, optional

Returns:

returns

ndarray with input color data,
Raises error if dimensions don't match.

`luxpy.color.cat.`**`get_transfer_function`**(*cattype='vonkries'*, *catmode='1>0>2'*, *lmsw1=None*, *lmsw2=None*, *lmsw0=array([[100*, *100*, *100]])*, *D10=1.0*, *D20=1.0*, *La1=100.0*, *La2=100.0*, *La0=100.0*)

Calculate the chromatic adaptation diagonal matrix transfer function Dt.

Args:

cattype

'vonkries' (others: 'rlab', see Farchild 1990), optional

catmode

'1>0>2, optional
-'1>0>2': Two-step CAT
from illuminant 1 to baseline illuminant 0 to illuminant 2.
-'1>0': One-step CAT
from illuminant 1 to baseline illuminant 0.
-'0>2': One-step CAT
from baseline illuminant 0 to illuminant 2.

lmsw1

None, depending on :catmode: optional

lmsw2

None, depending on :catmode: optional

lmsw0

_WHITE_POINT, optional

D10

1.0, optional
Degree of adaptation for ill. 1 to ill. 0

D20

1.0, optional
Degree of adaptation for ill. 2 to ill. 0

La1

luxpy._LA, optional
Adapting luminance under ill. 1

La2

luxpy._LA, optional
Adapting luminance under ill. 2

La0

luxpy._LA, optional
Adapting luminance under baseline ill. 0

Returns:

Dt

ndarray (diagonal matrix)

luxpy.color.cat.**get_degree_of_adaptation**(*Dtype=None*, ***kwargs*)

Calculates the degree of adaptation according to some function published in literature.

Args:

Dtype

None, optional
If None: kwargs should contain 'D' with value.
If 'manual: kwargs should contain 'D' with value.
If 'cat02' or 'cat16': kwargs should contain keys 'F' and 'La'.
Calculate D according to CAT02 or CAT16 model:
D = F*(1-(1/3.6)*numpy.exp((-La-42)/92))
If 'cmc': kwargs should contain 'La', 'La0'(or 'La2') and 'order'
for 'order' = '1>0': 'La' is set La1 and 'La0' to La0.
for 'order' = '0>2': 'La' is set La0 and 'La0' to La1.
for 'order' = '1>2': 'La' is set La1 and 'La2' to La0.
D is calculated as follows:
D = 0.08*numpy.log10(La1+La0)+0.76-0.45*(La1-La0)/(La1+La0)
If 'smet2017': kwargs should contain 'xyzw' and 'Dmax' (see Smet2017_D for more details).
If "? user defined", then D is calculated by:
D = ndarray(eval(:Dtype:))

Returns:

D

ndarray with degree of adaptation values.

Notes:

1. D passes either right through or D is calculated following some D-function (Dtype) published in literature.
2. D is limited to values between zero and one
3. If kwargs do not contain the required parameters, an exception is raised.

luxpy.color.cat.**smet2017_D**(*xyzw*, *Dmax=None*, *cieobs='1964_10'*)

Calculate the degree of adaptation based on chromaticity following Smet et al. (2017)

Args:

xyzw

ndarray with white point data

Dmax

None or float, optional
Defaults to 0.6539 (max D obtained under experimental conditions, but probably too low due to dark surround leading to incomplete chromatic adaptation even for neutral

illuminants resulting in background luminance (fov~50Â°) of 760 cd/mÂ^2))

cieobs

'1964_10', optional
CMF set used in deriving model in cited paper.

Returns:

D

ndarray with degrees of adaptation

References: 1. Smet, K.A.G.*, Zhai, Q., Luo, M.R., Hanselaer, P., (2017), Study of chromatic adaptation using memory color matches, Part II: colored illuminants, Opt. Express, 25(7), pp. 8350-8365.

`luxpy.color.cat.`**`parse_x1x2_parameters`**(*x, target_shape, catmode, expand_2d_to_3d=None, default=[1.0, 1.0]*)

Parse input parameters x and make them the target_shape for easy calculation.

Input in main function can now be a single value valid for all xyzw or an array with a different value for each xyzw.

Args:

x

list[float, float] or ndarray

target_shape

tuple with shape information

catmode

'1>0>2, optional
-'1>0>2': Two-step CAT
from illuminant 1 to baseline illuminant 0 to illuminant 2.
-'1>0': One-step CAT
from illuminant 1 to baseline illuminant 0.
-'0>2': One-step CAT
from baseline illuminant 0 to illuminant 2.

expand_2d_to_3d

None, optional
[will be removed in future, serves no purpose]
Expand :x: from 2 to 3 dimensions.

default

[1.0,1.0], optional
Default values for :x:

Returns:

returns

(ndarray, ndarray) for x10 and x20

`luxpy.color.cat.`**`apply`**(*data, catmode='1>0>2', cattype='vonkries', xyzw1=None, xyzw2=None, xyzw0=None, D=None, mcat=['cat02'], normxyz0=None, outtype='xyz', La=None, F=None, Dtype=None*)

Calculate corresponding colors by applying a von Kries chromatic adaptation transform (CAT), i.e. independent rescaling of 'sensor sensitivity' to data to adapt from current adaptation conditions (1) to the new conditions (2).

Args:

data

ndarray of tristimulus values (can be NxMx3)

catmode

'1>0>2, optional
-'1>0>2': Two-step CAT
from illuminant 1 to baseline illuminant 0 to illuminant 2.
-'1>0': One-step CAT
from illuminant 1 to baseline illuminant 0.
-'0>2': One-step CAT
from baseline illuminant 0 to illuminant 2.

cattype

'vonkries' (others: 'rlab', see Farchild 1990), optional

xyzw1

None, depending on :catmode: optional (can be Mx3)

xyzw2

None, depending on :catmode: optional (can be Mx3)

xyzw0

None, depending on :catmode: optional (can be Mx3)

D

None, optional
Degrees of adaptation. Defaults to [1.0, 1.0].

La

None, optional
Adapting luminances.
If None: xyz values are absolute or relative.
If not None: xyz are relative.

F

None, optional
Surround parameter(s) for CAT02/CAT16 calculations (:Dtype: == 'cat02' or 'cat16')
Defaults to [1.0, 1.0].

Dtype

None, optional
Type of degree of adaptation function from literature
See luxpy.cat.get_degree_of_adaptation()

mcat

['cat02'], optional
List[str] or List[ndarray] of sensor space matrices for each condition pair. If len(:mcat:) == 1, the same matrix is used.

normxyz0

None, optional
Set of xyz tristimulus values to normalize the sensor space matrix to.

outtype

'xyz' or 'lms', optional
- 'xyz': return corresponding tristimulus values
- 'lms': return corresponding sensor space excitation values
(e.g. for further calculations)

Returns:

returns

ndarray with corresponding colors

4.3.5 cam/

py

- __init__.py
- colorappearancemodels.py
- cam_02_X.py
- cam15u
- sww2016.py

namespace luxpy.cam

cam: sub-package with color appearance models

_UNIQUE_HUE_DATA database of unique hues with corresponding Hue quadratures and eccentricity factors for ciecam02, cam16, ciecam97s, cam15u)

_SURROUND_PARAMETERS database of surround param. c, Nc, F and FLL for ciecam02, cam16, ciecam97s and cam15u.

_NAKA_RUSHTON_PARAMETERS

database with parameters (n, sig, scaling and noise) for the Naka-Rushton function:
scaling * ((data**n) / ((data**n) + (sig**n))) + noise

_CAM_02_X_UCS_PARAMETERS

database with parameters specifying the conversion from ciecam02/cam16 to:
cam[x]ucs (uniform color space),
cam[x]lcd (large color diff.),
cam[x]scd (small color diff).

_CAM15U_PARAMETERS database with CAM15u model parameters.

_CAM_SWW16_PARAMETERS cam_sww16 model parameters.

_CAM_DEFAULT_WHITE_POINT Default internal reference white point (xyz)

_CAM_DEFAULT_TYPE Default CAM type str specifier.

_CAM_DEFAULT_MCAT Default MCAT specifier.

_CAM_02_X_DEFAULT_CONDITIONS Default CAM model parameters for model in cam._CAM_DEFAULT_TYPE

_CAM_AXES dict with list[str,str,str] containing axis labels of defined cspaces.

naka_rushton() applies a Naka-Rushton function to the input

hue_angle() calculates a positive hue angle

hue_quadrature() calculates the Hue quadrature from the hue.

cam_structure_ciecam02_cam16()

basic structure of ciecam02 and cam16 models.

Has 'forward' (xyz –> color attributes) and 'inverse' (color attributes –> xyz) modes.

ciecam02()

calculates ciecam02 output

(wrapper for cam_structure_ciecam02_cam16 with specifics of ciecam02):

N. Moroney, M. D. Fairchild, R. W. G. Hunt, C. Li, M. R. Luo, and T. Newman, "The CIECAM02 color appearance model," IS&T/SID Tenth Color Imaging Conference. p. 23, 2002.

cam16()

calculates cam16 output

(wrapper for cam_structure_ciecam02_cam16 with specifics of cam16):

C. Li, Z. Li, Z. Wang, Y. Xu, M. R. Luo, G. Cui, M. Melgosa, M. H. Brill, and M. Pointer, "Comprehensive color solutions: CAM16, CAT16, and CAM16-UCS," Color Res. Appl., p. n/a–n/a.

camucs_structure() basic structure to go to ucs, lcd and scd color spaces (forward + inverse available)

cam02ucs()

calculates ucs (or lcd, scd) output based on ciecam02 (forward + inverse available)

M. R. Luo, G. Cui, and C. Li, "Uniform colour spaces based on CIECAM02 colour appearance model," Color Res. Appl., vol. 31, no. 4, pp. 320–330, 2006.

cam16ucs()

calculates ucs (or lcd, scd) output based on cam16 (forward + inverse available)

C. Li, Z. Li, Z. Wang, Y. Xu, M. R. Luo, G. Cui, M. Melgosa, M. H. Brill, and M. Pointer, "Comprehensive color solutions: CAM16, CAT16, and CAM16-UCS," Color Res. Appl., p. n/a–n/a.

cam15u()

calculates the output for the CAM15u model for self-luminous unrelated stimuli.

M. Withouck, K. A. G. Smet, W. R. Ryckaert, and P. Hanselaer, "Experimental driven modelling of the color appearance of unrelated self-luminous stimuli: CAM15u," Opt. Express, vol. 23, no. 9, pp. 12045–12064, 2015.

M. Withouck, K. A. G. Smet, and P. Hanselaer, (2015), "Brightness prediction of different sized unrelated self-luminous stimuli," Opt. Express, vol. 23, no. 10, pp. 13455–13466.

cam_sww16() A simple principled color appearance model based on a mapping of the Munsell color system.

wrappers

'xyz_to_jabM_ciecam02', 'jabM_ciecam02_to_xyz',
'xyz_to_jabC_ciecam02', 'jabC_ciecam02_to_xyz',
'xyz_to_jabM_cam16', 'jabM_cam16_to_xyz',
'xyz_to_jabC_cam16', 'jabC_cam16_to_xyz',
'xyz_to_jab_cam02ucs', 'jab_cam02ucs_to_xyz',
'xyz_to_jab_cam02lcd', 'jab_cam02lcd_to_xyz',
'xyz_to_jab_cam02scd', 'jab_cam02scd_to_xyz',
'xyz_to_jab_cam16ucs', 'jab_cam16ucs_to_xyz',
'xyz_to_jab_cam16lcd', 'jab_cam16lcd_to_xyz',
'xyz_to_jab_cam16scd', 'jab_cam16scd_to_xyz',
'xyz_to_qabW_cam15u', 'qabW_cam15u_to_xyz',
'xyz_to_lAb_cam_sww16', 'lab_cam_sww16_to_xyz'

luxpy.color.cam.**hue_angle**(*a*, *b*, *htype='deg'*)

Calculate positive hue angle (0°-360° or 0 - 2*pi rad.) from opponent signals a and b.

Args:

a

ndarray of a-coordinates

b

ndarray of b-coordinates

htype

'deg' or 'rad', optional
- 'deg': hue angle between 0° and 360°
- 'rad': hue angle between 0 and 2pi radians

Returns:

returns

ndarray of positive hue angles.

luxpy.color.cam.**hue_quadrature**(*h*, *unique_hue_data=None*)

Get hue quadrature H from h.

Args:

h

float or list[float] or ndarray with hue data in degrees (!).

unique_hue data

None or str or dict, optional
- None: H = h.
- str: CAM specifier that gets parameters from .cam._UNIQUE_HUE_DATA
  (For supported models, see .cam._UNIQUE_HUE_DATA['models'])
- dict: user specified unique hue data
  (see luxpy.cam._UNIQUE_HUE_DATA for expected structure)

Returns:

H

float or list[float] or ndarray of Hue quadrature value(s).

luxpy.color.cam.**naka_rushton**(*data*, *sig=2.0*, *n=0.73*, *scaling=1.0*, *noise=0.0*, *cam=None*, *direction='forward'*)

Apply a Naka-Rushton response compression (n) and an adaptive shift (sig).

NK(x) = scaling * ((x**n) / ((x**n) + (sig**n))) + noise

Args:

data

float or ndarray

sig

2.0, optional
Semi-saturation constant. Value for which NK(:data:) is 1/2

n

0.73, optional
Compression power.

scaling

1.0, optional
Maximum value of NK-function.

noise

0.0, optional
Cone excitation noise.

cam

None or str, optional
Use NK parameters values specific to the color appearance model.
See .cam._NAKA_RUSHTON_PARAMETERS['models'] for supported types.

direction

'forward' or 'inverse', optional
Perform either NK(x) or NK(x)**(-1).

Returns:

returns

float or ndarray with NK-(de)compressed input :x:

luxpy.color.cam.**ciecam02**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *mcat='cat02'*, *Yw=array([[1.0000e+02]])*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *direction='forward'*, *outin='J, aM, bM'*, *yellowbluepurplecorrect=False*)

Convert between XYZ tristsimulus values and ciecam02 color appearance correlates.

Wrapper for luxpy.cam.cam_structure_ciecam02_cam16() designed specifically for camtype = 'ciecam02.

Args:

data

ndarray with input tristimulus values or input color appearance correlates
Can be of shape: (N [, xM], x 3), whereby N refers to samples, M to light sources.

xyzw

_CAM_02_X_DEFAULT_WHITE_POINT or ndarray with tristimulus values of white point(s), optional

Can be multiple by specifying a Mx3 ndarray, instead of 1x3.

Yw

luxpy.np2d(100), optional
Luminance factor of white point.
Is normally 100 for perfect white diffuser, is < 100 for e.g. paper as white point.

mcat

'cat02' or str or ndarray, optional
Specifies CAT sensor space.
- None defaults to the one native to the camtype
  (others e.g. 'cat02-bs', 'cat02-jiang',
  all trying to correct gamut problems of original cat02 matrix)
- str: see see luxpy.cat._MCATS.keys() for options
  (details on type, ?luxpy.cat)
- ndarray: matrix with sensor primaries

condition

luxpy.cam._CAM_02_X_DEFAULT_CONDITIONS, optional
Dict with condition parameters, D, La, surround ([c,Nc,F]), Yb
Can be user defined, but dict must have same structure.

direction

'forward' or 'inverse', optional
-'forward': xyz -> ciecam02
-'inverse': ciecam02 -> xyz
(input data must be:
(J or Q, aM, bM) or
(J or Q, aC,bC) or
(J or Q, aS, bS) !!)

outin

'J,aM,bM' or str, optional
Str specifying the type of
input (:direction: == 'inverse') and
output (:direction: == 'forward')

yellowbluepurplecorrect

True or False, optional
Correct for yellow-blue and purple problems in ciecam02 (Is not used in cam16 because cat16 solves issues)

Returns:

returns

ndarray with color appearance correlates (:direction: == 'forward')
or
XYZ tristimulus values (:direction: == 'inverse')

References: 1. N. Moroney, M. D. Fairchild, R. W. G. Hunt, C. Li, M. R. Luo, and T. Newman, (2002), "The CIECAM02 color appearance model," IS&T/SID Tenth Color Imaging Conference. p. 23, 2002.

luxpy.color.cam.**cam16**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *mcat='cat16'*, *Yw=array([[1.0000e+02]])*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *direction='forward'*, *outin='J, aM, bM'*)

Convert between XYZ tristsimulus values and cam16 color appearance correlates.

Wrapper for luxpy.cam.cam_structure_ciecam02_cam16() designed specifically for camtype = 'cam16'.

Args:

data

ndarray with input tristimulus values or input color appearance correlates
Can be of shape: (N [, xM], x 3), whereby N refers to samples, M to light sources.

xyzw

_CAM_02_X_DEFAULT_WHITE_POINT or ndarray with tristimulus values of white point(s), optional
Can be multiple by specifying a Mx3 ndarray, instead of 1x3.

Yw

luxpy.np2d(100), optional
Luminance factor of white point.
Is normally 100 for perfect white diffuser, is < 100 for e.g. paper as white point.

mcat

'cat16' or str or ndarray, optional
Specifies CAT sensor space.
- None defaults back to 'cat02!'.
  (others e.g. 'cat02-bs', 'cat02-jiang',
  all trying to correct gamut problems of original cat02 matrix)
- str: see see luxpy.cat._MCATS.keys() for options
  (details on type, ?luxpy.cat)
- ndarray: matrix with sensor primaries

condition

luxpy.cam._CAM_02_X_DEFAULT_CONDITIONS, optional
Dict with condition parameters, D, La, surround ([c,Nc,F]), Yb
Can be user defined, but dict must have same structure.

direction

'forward' or 'inverse', optional
- 'forward': xyz -> cam16
- 'inverse': cam16 -> xyz
  (input data must be:
  (J or Q, aM, bM) or
  (J or Q, aC,bC) or
  (J or Q, aS, bS) !!)

outin

'J,aM,bM' or str, optional
Str specifying the type of
input (:direction: == 'inverse') and
output (:direction: == 'forward')

Returns:

returns

ndarray with color appearance correlates (:direction: == 'forward')
or
XYZ tristimulus values (:direction: == 'inverse')

References:

..[1] C. Li, Z. Li, Z. Wang, Y. Xu, M. R. Luo, G. Cui, M. Melgosa, M. H. Brill, and M. Pointer, "Comprehensive color solutions: CAM16, CAT16, and CAM16-UCS," Color Res. Appl., p. n/a–n/a.

luxpy.color.cam.**cam02ucs**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=array([[1.0000e+02]])*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *direction='forward'*, *ucstype='ucs'*, *yellowbluepurplecorrect=False*, *mcat='cat02'*)

Convert between XYZ tristsimulus values and cam02ucs type color appearance correlates.

Wrapper for luxpy.cam.camucs_structure() specifically designed for 'ciecam02' + 'ucs'

Args:

data

ndarray with input tristimulus values or input color appearance correlates
Can be of shape: (N [, xM], x 3), whereby N refers to samples, M to light sources.

xyzw

_CAM_02_X_DEFAULT_WHITE_POINT or ndarray with tristimulus values of white point(s), optional
Can be multiple by specifying a Mx3 ndarray, instead of 1x3.

Yw

luxpy.np2d(100), optional
Luminance factor of white point.
Is normally 100 for perfect white diffuser, is < 100 for e.g. paper as white point.

mcat

'cat02' or str or ndarray, optional
Specifies CAT sensor space.
- None defaults to the one native to the camtype
(others e.g. 'cat02-bs', 'cat02-jiang',
all trying to correct gamut problems of original cat02 matrix)
- str: see see luxpy.cat._MCATS.keys() for options
(details on type, ?luxpy.cat)
- ndarray: matrix with sensor primaries

condition

luxpy.cam._CAM_02_X_DEFAULT_CONDITIONS, optional
Dict with condition parameters, D, La, surround ([c,Nc,F]), Yb
Can be user defined, but dict must have same structure.

direction

'forward' or 'inverse', optional
-'forward': xyz -> cam02ucs
-'inverse': cam02ucs -> xyz
(input data must be:
(J or Q, aM, bM) or
(J or Q, aC,bC) or
(J or Q, aS, bS) !!)

outin

'J,aM,bM' or str, optional
Str specifying the type of
input (:direction: == 'inverse') and
output (:direction: == 'forward')

yellowbluepurplecorrect

True or False, optional
Correct for yellow-blue and purple problems in ciecam02 (Is not used in cam16 because cat16 solves issues)

ucstype

'ucs' or 'lcd' or 'scd', optional
Str specifier for which type of color attribute compression
parameters to use:
-'ucs': uniform color space,
-'lcd', large color differences,
-'scd': small color differences

Returns:

returns

ndarray with color appearance correlates (:direction: == 'forward')
or
XYZ tristimulus values (:direction: == 'inverse')

References: 1. M.R. Luo, G. Cui, and C. Li, 'Uniform colour spaces based on CIECAM02 colour appearance model,' Color Res. Appl., vol. 31, no. 4, pp. 320–330, 2006.

luxpy.color.cam.**cam16ucs**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=array([[1.0000e+02]])*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *direction='forward'*, *ucstype='ucs'*, *mcat='cat16'*)

Convert between XYZ tristsimulus values and cam16ucs type color appearance correlates.

Wrapper for luxpy.cam.camucs_structure() specifically designed for 'cam16' + 'ucs'

Args:

data

ndarray with input tristimulus values or input color appearance correlates
Can be of shape: (N [, xM], x 3), whereby N refers to samples, M to light sources.

xyzw

_CAM_02_X_DEFAULT_WHITE_POINT or ndarray with tristimulus values of white point(s), optional
Can be multiple by specifying a Mx3 ndarray, instead of 1x3.

Yw

luxpy.np2d(100), optional
Luminance factor of white point.
Is normally 100 for perfect white diffuser, is < 100 for e.g. paper as white point. .

mcat

'cat16' or str or ndarray, optional
Specifies CAT sensor space.
- None defaults to 'cat02'!
  (others e.g. 'cat02-bs', 'cat02-jiang',
  all trying to correct gamut problems of original cat02 matrix)
- str: see see luxpy.cat._MCATS.keys() for options
  (details on type, ?luxpy.cat)
- ndarray: matrix with sensor primaries

condition

luxpy.cam._CAM_02_X_DEFAULT_CONDITIONS, optional
Dict with condition parameters, D, La, surround ([c,Nc,F]), Yb
Can be user defined, but dict must have same structure.

direction

'forward' or 'inverse', optional
-'forward': xyz -> cam16ucs
-'inverse': cam16ucs -> xyz
(input data must be:
(J or Q, aM, bM) or
(J or Q, aC,bC) or
(J or Q, aS, bS) !!)

outin

'J,aM,bM' or str, optional
Str specifying the type of
input (:direction: == 'inverse') and
output (:direction: == 'forward')

yellowbluepurplecorrect

True or False, optional
Correct for yellow-blue and purple problems in ciecam02 (Is not used in cam16 because cat16 solves issues)

ucstype

'ucs' or 'lcd' or 'scd', optional

Str specifier for which type of color attribute compression
parameters to use:
-'ucs': uniform color space,
-'lcd', large color differences,
-'scd': small color differences

Returns:

returns

ndarray with color appearance correlates (:direction: == 'forward')
or
XYZ tristimulus values (:direction: == 'inverse')

References: 1. M. R. Luo, G. Cui, and C. Li, (2006), "Uniform colour spaces based on CIECAM02 colour appearance model," Color Res. Appl., vol. 31, no. 4, pp. 320–330. 2. C. Li, Z. Li, Z. Wang, Y. Xu, M. R. Luo, G. Cui, M. Melgosa, M. H. Brill, and M. Pointer, (2017), "Comprehensive color solutions: CAM16, CAT16, and CAM16-UCS," Color Res. Appl., p. n/a–n/a.

`luxpy.color.cam.`**`cam15u`**(*data*, *fov=10.0*, *inputtype='xyz'*, *direction='forward'*, *outin='Q, aW, bW'*, *parameters=None*)

Convert between CIE 2006 10° XYZ tristimulus values (or spectral data) and CAM15u color appearance correlates.

Args:

data

ndarray of CIE 2006 10° XYZ tristimulus values or spectral data or color appearance attributes

fov

10.0, optional
Field-of-view of stimulus (for size effect on brightness)

inputtpe

'xyz' or 'spd', optional
Specifies the type of input:
tristimulus values or spectral data for the forward mode.

direction

'forward' or 'inverse', optional
-'forward': xyz -> cam15u
-'inverse': cam15u -> xyz

outin

'Q,aW,bW' or str, optional
'Q,aW,bW' (brightness and opponent signals for amount-of-neutral)
other options: 'Q,aM,bM' (colorfulness) and 'Q,aS,bS' (saturation)
Str specifying the type of
input (:direction: == 'inverse') and
output (:direction: == 'forward')

parameters

None or dict, optional
Set of model parameters.
- None: defaults to luxpy.cam._CAM15U_PARAMETERS
(see references below)

Returns:

returns

ndarray with color appearance correlates (:direction: == 'forward')

or

XYZ tristimulus values (:direction: == 'inverse')

References: 1. M. Withouck, K. A. G. Smet, W. R. Ryckaert, and P. Hanselaer, "Experimental driven modelling of the color appearance of unrelated self-luminous stimuli: CAM15u," Opt. Express, vol. 23, no. 9, pp. 12045–12064, 2015. 2. M. Withouck, K. A. G. Smet, and P. Hanselaer, (2015), "Brightness prediction of different sized unrelated self-luminous stimuli," Opt. Express, vol. 23, no. 10, pp. 13455–13466.

`luxpy.color.cam.`**`cam_sww16`**(*data*, *dataw=None*, *Yb=20.0*, *Lw=400.0*, *Ccwb=None*, *relative=True*, *parameters=None*, *inputtype='xyz'*, *direction='forward'*, *cieobs='2006_10'*)

A simple principled color appearance model based on a mapping of the Munsell color system.

This function implements the JOSA A (parameters = 'JOSA') published model.

Args:

data

ndarray with input tristimulus values
or spectral data
or input color appearance correlates
Can be of shape: (N [, xM], x 3), whereby:
N refers to samples and M refers to light sources.
Note that for spectral input shape is (N x (M+1) x wl)

dataw

None or ndarray, optional
Input tristimulus values or spectral data of white point.
None defaults to the use of CIE illuminant C.

Yb

20.0, optional
Luminance factor of background (perfect white diffuser, Yw = 100)

Lw

400.0, optional
Luminance (cd/m^2) of white point.

Ccwb

None, optional
Degree of cognitive adaptation (white point balancing)
If None: use [..,..] from parameters dict.

relative

True or False, optional
True: xyz tristimulus values are relative (Yw = 100)

parameters

None or str or dict, optional

Dict with model parameters.
- None: defaults to luxpy.cam._CAM_SWW_2016_PARAMETERS['JOSA']
- str: 'best-fit-JOSA' or 'best-fit-all-Munsell'
- dict: user defined model parameters
(dict should have same structure)

inputtpe

'xyz' or 'spd', optional
Specifies the type of input:
tristimulus values or spectral data for the forward mode.

direction

'forward' or 'inverse', optional
-'forward': xyz -> cam_sww_2016
-'inverse': cam_sww_2016 -> xyz

cieobs

'2006_10', optional
CMF set to use to perform calculations where spectral data is involved (inputtype == 'spd'; dataw = None)
Other options: see luxpy._CMF['types']

Returns:

returns

ndarray with color appearance correlates (:direction: == 'forward')
or
XYZ tristimulus values (:direction: == 'inverse')

Notes:

This function implements the JOSA A (parameters = 'JOSA') published model.
With:
1. A correction for the parameter
in Eq.4 of Fig. 11: 0.952 –> -0.952

2. The delta_ac and delta_bc white-balance shifts in Eq. 5e & 5f
should be: -0.028 & 0.821

(cfr. Ccwb = 0.66 in:
ab_test_out = ab_test_int - Ccwb*ab_gray_adaptation_field_int))

References: 1. Smet, K. A. G., Webster, M. A., & Whitehead, L. A. (2016). A simple principled approach for modeling and understanding uniform color metrics. Journal of the Optical Society of America A, 33(3), A319–A331.

luxpy.color.cam.**xyz_to_jabM_ciecam02**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *yellowbluepurplecorrect=None*, *mcat='cat02'*, ***kwargs*)

Wrapper function for ciecam02 forward mode with J,aM,bM output.

For help on parameter details: ?luxpy.cam.ciecam02

luxpy.color.cam.**jabM_ciecam02_to_xyz**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *yellowbluepurplecorrect=None*, *mcat='cat02'*, ***kwargs*)

Wrapper function for ciecam02 inverse mode with J,aM,bM input.

For help on parameter details: ?luxpy.cam.ciecam02

luxpy.color.cam.**xyz_to_jabC_ciecam02**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *yellowbluepurplecorrect=None*, *mcat='cat02'*, ***kwargs*)

Wrapper function for ciecam02 forward mode with J,aC,bC output.

For help on parameter details: ?luxpy.cam.ciecam02

luxpy.color.cam.**jabC_ciecam02_to_xyz**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *yellowbluepurplecorrect=None*, *mcat='cat02'*, ***kwargs*)

Wrapper function for ciecam02 inverse mode with J,aC,bC input.

For help on parameter details: ?luxpy.cam.ciecam02

luxpy.color.cam.**xyz_to_jabM_cam16**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16 forward mode with J,aM,bM output.

For help on parameter details: ?luxpy.cam.cam16

luxpy.color.cam.**jabM_cam16_to_xyz**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16 inverse mode with J,aM,bM input.

For help on parameter details: ?luxpy.cam.cam16

luxpy.color.cam.**xyz_to_jabC_cam16**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16 forward mode with J,aC,bC output.

For help on parameter details: ?luxpy.cam.cam16

luxpy.color.cam.**jabC_cam16_to_xyz**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16 inverse mode with J,aC,bC input.

For help on parameter details: ?luxpy.cam.cam16

luxpy.color.cam.**xyz_to_jab_cam02ucs**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *yellowbluepurplecorrect=None*, *mcat='cat02'*, ***kwargs*)

Wrapper function for cam02ucs forward mode with J,aM,bM output.

For help on parameter details: ?luxpy.cam.cam02ucs

luxpy.color.cam.**jab_cam02ucs_to_xyz**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *yellowbluepurplecorrect=None*, *mcat='cat02'*, ***kwargs*)

Wrapper function for cam02ucs inverse mode with J,aM,bM input.

For help on parameter details: ?luxpy.cam.cam02ucs

luxpy.color.cam.**xyz_to_jab_cam02lcd**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *yellowbluepurplecorrect=None*, *mcat='cat02'*, ***kwargs*)

Wrapper function for cam02ucs forward mode with J,aMp,bMp output and ucstype = lcd.

For help on parameter details: ?luxpy.cam.cam02ucs

luxpy.color.cam.**jab_cam02lcd_to_xyz**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *yellowbluepurplecorrect=None*, *mcat='cat02'*, ***kwargs*)

Wrapper function for cam02ucs inverse mode with J,aMp,bMp input and ucstype = lcd.

For help on parameter details: ?luxpy.cam.cam02ucs

luxpy.color.cam.**xyz_to_jab_cam02scd**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *yellowbluepurplecorrect=None*, *mcat='cat02'*, ***kwargs*)

Wrapper function for cam02ucs forward mode with J,aMp,bMp output and ucstype = scd.

For help on parameter details: ?luxpy.cam.cam02ucs

luxpy.color.cam.**jab_cam02scd_to_xyz**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *yellowbluepurplecorrect=None*, *mcat='cat02'*, ***kwargs*)

Wrapper function for cam02ucs inverse mode with J,aMp,bMp input and ucstype = scd.

For help on parameter details: ?luxpy.cam.cam02ucs

luxpy.color.cam.**xyz_to_jab_cam16ucs**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16ucs forward mode with J,aM,bM output and ucstype = 'ucs'.

For help on parameter details: ?luxpy.cam.cam16ucs

luxpy.color.cam.**jab_cam16ucs_to_xyz**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16ucs inverse mode with J,aM,bM input and ucstype = 'ucs'.

For help on parameter details: ?luxpy.cam.cam16ucs

luxpy.color.cam.**xyz_to_jab_cam16lcd**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16ucs forward mode with J,aM,bM output and ucstype = 'lcd'.

For help on parameter details: ?luxpy.cam.cam16ucs

luxpy.color.cam.**jab_cam16lcd_to_xyz**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16ucs inverse mode with J,aM,bM input and ucstype = 'lcd'.

For help on parameter details: ?luxpy.cam.cam16ucs

luxpy.color.cam.**xyz_to_jab_cam16scd**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16ucs forward mode with J,aM,bM output and ucstype = 'scd'.

For help on parameter details: ?luxpy.cam.cam16ucs

luxpy.color.cam.**jab_cam16scd_to_xyz**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=100.0*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16ucs inverse mode with J,aM,bM input and ucstype = 'scd'.

For help on parameter details: ?luxpy.cam.cam16ucs

luxpy.color.cam.**xyz_to_qabW_cam15u**(*xyz*, *fov=10.0*, *parameters=None*, ***kwargs*)

Wrapper function for cam15u forward mode with 'Q,aW,bW' output.

For help on parameter details: ?luxpy.cam.cam15u

luxpy.color.cam.**qabW_cam15u_to_xyz**(*qab*, *fov=10.0*, *parameters=None*, ***kwargs*)

Wrapper function for cam15u inverse mode with 'Q,aW,bW' input.

For help on parameter details: ?luxpy.cam.cam15u

luxpy.color.cam.**xyz_to_lab_cam_sww16**(*xyz*, *xyzw=None*, *Yb=20.0*, *Lw=400.0*, *Ccwb=None*, *relative=True*, *parameters=None*, *inputtype='xyz'*, *cieobs='2006_10'*, ***kwargs*)

Wrapper function for cam_sww16 forward mode with 'xyz' input.

For help on parameter details: ?luxpy.cam.cam_sww16

luxpy.color.cam.**lab_cam_sww16_to_xyz**(*lab*, *xyzw=None*, *Yb=20.0*, *Lw=400.0*, *Ccwb=None*, *relative=True*, *parameters=None*, *inputtype='xyz'*, *cieobs='2006_10'*, ***kwargs*)

Wrapper function for cam_sww16 inverse mode with 'xyz' input.

For help on parameter details: ?luxpy.cam.cam_sww16

4.3.6 deltaE/

py

- __init__.py
- colordifferences.py

namespace luxpy.deltaE

Module for color difference calculations

process_DEi() Process color difference input DEi for output (helper fnc).

DE_camucs() Calculate color appearance difference DE using camucs type model.

DE_2000() Calculate DE2000 color difference.

DE_cspace() Calculate color difference DE in specific color space.

luxpy.color.deltaE.**DE_camucs**(*xyzt*, *xyzr*, *DEtype='jab'*, *avg=None*, *avg_axis=0*, *out='DEi'*, *xyzwt=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *xyzwr=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Ywt=array([[1.0000e+02]])*, *conditionst={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *Ywr=array([[1.0000e+02]])*, *conditionsr={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *camtype='ciecam02'*, *ucstype='ucs'*, *mcat=None*, *outin='J, aM, bM'*, *yellowbluepurplecorrect=False*, ***kwargs*)

Calculate color appearance difference DE using camucs type model.

Args:

xyzt

ndarray with tristimulus values of test data.

xyzr

ndarray with tristimulus values of reference data.

DEtype

'jab' or str, optional

Options:
- 'jab' : calculates full color difference over all 3 dimensions.
- 'ab' : calculates chromaticity difference.
- 'j' : calculates lightness or brightness difference (depending on :outin:).
- 'j,ab': calculates both 'j' and 'ab' options and returns them as a tuple.

avg

None, optional
None: don't calculate average DE,
otherwise use function handle in :avg:.

avg_axis

axis to calculate average over, optional

out

'DEi' or str, optional
Requested output.

camtype

luxpy.cam._CAM_02_X_DEFAULT_TYPE, optional
Str specifier for CAM type to use, options: 'ciecam02' or 'cam16'.

ucstype

'ucs' or 'lcd' or 'scd', optional
Str specifier for which type of color attribute compression parameters to use:
-'ucs': uniform color space,
-'lcd', large color differences,
-'scd': small color differences

Note: For the other input arguments, see ?luxpy.cam.camucs_structure.

Returns:

returns

ndarray with DEi [, DEa] or other as specified by :out:

`luxpy.color.deltaE.DE2000`(*xyzt*, *xyzr*, *dtype='xyz'*, *DEtype='jab'*, *avg=None*, *avg_axis=0*, *out='DEi'*, *xyzwt=None*, *xyzwr=None*, *KLCH=None*)

Calculate DE2000 color difference.

Args:

xyzt

ndarray with tristimulus values of test data.

xyzr

ndarray with tristimulus values of reference data.

dtype

'xyz' or 'lab', optional
Specifies data type in :xyzt: and :xyzr:.

xyzwt

None or ndarray, optional
White point tristimulus values of test data

None defaults to the one set in lx.xyz_to_lab()

xyzwr

None or ndarray, optional
Whitepoint tristimulus values of reference data
None defaults to the one set in lx.xyz_to_lab()

DEtype

'jab' or str, optional
Options:
- 'jab' : calculates full color difference over all 3 dimensions.
- 'ab' : calculates chromaticity difference.
- 'j' : calculates lightness or brightness difference
(depending on :outin:).
- 'j,ab': calculates both 'j' and 'ab' options and returns them as a tuple.

KLCH

None, optional
Weigths for L, C, H
None: default to [1,1,1]

avg

None, optional
None: don't calculate average DE,
otherwise use function handle in :avg:.

avg_axis

axis to calculate average over, optional

out

'DEi' or str, optional
Requested output.

Note: For the other input arguments, see specific color space used.

Returns:

returns

ndarray with DEi [, DEa] or other as specified by :out:

References: 1. Sharma, G., Wu, W., & Dalal, E. N. (2005). The CIEDE2000 color-difference formula: Implementation notes, supplementary test data, and mathematical observations. Color Research & Application, 30(1), 21–30.

`luxpy.color.deltaE.DE_cspace`(*xyzt*, *xyzr*, *dtype='xyz'*, *tf='Yuv'*, *DEtype='jab'*, *avg=None*, *avg_axis=0*, *out='DEi'*, *xyzwt=None*, *xyzwr=None*, *fwtft={}*, *fwtfr={}*, *KLCH=None*, *camtype='ciecam02'*, *ucstype='ucs'*)

Calculate color difference DE in specific color space.

Args:

xyzt

ndarray with tristimulus values of test data.

xyzr

ndarray with tristimulus values of reference data.

dtype

'xyz' or 'jab', optional
Specifies data type in :xyzt: and :xyzr:.

xyzwt

None or ndarray, optional
White point tristimulus values of test data
None defaults to the one set in :fwtft: or else to the default of cspace.

xyzwr

None or ndarray, optional
Whitepoint tristimulus values of reference data
None defaults to the one set in non-empty :fwtfr: or else to default of cspace.

tf

_CSPACE, optional
Color space to use for color difference calculation.

fwtft

{}, optional
Dict with parameters for forward transform from xyz to cspace for test data.

fwtfr

{}, optional
Dict with parameters for forward transform from xyz to cspace for reference data.

KLCH

None, optional
Weigths for L, C, H
None: default to [1,1,1]
KLCH is not used when tf == 'camucs'.

DEtype

'jab' or str, optional
Options:
- 'jab' : calculates full color difference over all 3 dimensions.
- 'ab' : calculates chromaticity difference.
- 'j' : calculates lightness or brightness difference
(depending on :outin:).
- 'j,ab': calculates both 'j' and 'ab' options and returns them as a tuple.

avg

None, optional
None: don't calculate average DE,
otherwise use function handle in :avg:.

avg_axis

axis to calculate average over, optional

out

'DEi' or str, optional

Requested output.

camtype

luxpy.cam._CAM_02_X_DEFAULT_TYPE, optional
Str specifier for CAM type to use, options: 'ciecam02' or 'cam16'.
Only when DEtype == 'camucs'.

ucstype

'ucs' or 'lcd' or 'scd', optional
Str specifier for which type of color attribute compression
parameters to use:
-'ucs': uniform color space,
-'lcd', large color differences,
-'scd': small color differences
Only when DEtype == 'camucs'.

Note: For the other input arguments, see specific color space used.

Returns:

returns

ndarray with DEi [, DEa] or other as specified by :out:

4.3.7 cri/

py

- __init__.py
- colorrendition.py
- **/utils/**
  - __init__.py
  - init_cri_defaults_database.py
  - DE_scalers.py
  - helpers.py
  - graphics.py
- **/indices/**
  - __init__.py
  - indices.py
  - ciewrappers.py
  - ieswrappers.py
  - cri2012.py
  - mcri.py
  - cqs.py
- **/iestm30/**
  - __init__.py
  - ies_tm30_metrics.py

        - ies_tm30_graphics.py
    - **/VFPX/**
        - __inint__.py
        - vectorshiftmodel.py
        - pixelshiftmodel.py
        - VF_PX_models.py

namespace luxpy.cri

cri: sub-package suppporting color rendition calculations (colorrendition.py)

utils/init_cri_defaults_database.py

_CRI_TYPE_DEFAULT Default cri_type.

_CRI_DEFAULTS

default parameters for color fidelity and gamut area metrics (major dict has 9 keys (04-Jul-2017): sampleset [str/dict], ref_type [str], cieobs [str], avg [fcn handle], scale [dict], cspace [dict], catf [dict], rg_pars [dict], cri_specific_pars [dict])

- **Supported cri-types:**
    - 'ciera','ciera-8','ciera-14','cierf',
    - 'iesrf','iesrf-tm30-15','iesrf-tm30-18',
    - 'cri2012','cri2012-hl17','cri2012-hl1000','cri2012-real210',
    - 'mcri',
    - 'cqs-v7.5','cqs-v9.0'

process_cri_type_input() load a cri_type dict but overwrites any keys that have a non-None input in calling function.

utils/DE_scalers.py

linear_scale()

Linear color rendering index scale from CIE13.3-1974/1995:
Rfi,a = 100 - c1*DEi,a. (c1 = 4.6)

log_scale()

Log-based color rendering index scale from Davis & Ohno (2009):
Rfi,a = 10 * ln(exp((100 - c1*DEi,a)/10) + 1)

psy_scale()

Psychometric based color rendering index scale from Smet et al. (2013):
Rfi,a = 100 * (2 / (exp(c1*abs(DEi,a)**(c2) + 1))) ** c3

utils/helpers.py

gamut_slicer() Slices the gamut in nhbins slices and provides normalization of test gamut to reference gamut.

jab_to_rg() Calculates gamut area index, Rg.

jab_to_rhi()

Calculate hue bin measures:
Rfhi (local (hue bin) color fidelity)
Rcshi (local chroma shift)
Rhshi (local hue shift)

spd_to_jab_t_r() Calculates jab color values for a sample set illuminated with test source and its reference illuminant.

spd_to_rg() Calculates the color gamut index of spectral data for a sample set illuminated with test source (data) with respect to some reference illuminant.

spd_to_DEi() Calculates color difference (~fidelity) of spectral data between sample set illuminated with test source (data) and some reference illuminant.

optimize_scale_factor() Optimize scale_factor of cri-model in cri_type such that average Rf for a set of light sources is the same as that of a target-cri (default: 'ciera')

spd_to_cri() Calculates the color rendering fidelity index (CIE Ra, CIE Rf, IES Rf, CRI2012 Rf) of spectral data. Can also output Rg, Rfhi, Rcshi, Rhshi, cct, duv, ...

utils/graphics.py

plot_hue_bins() Makes basis plot for Color Vector Graphic (CVG).

plot_ColorVectorGraphic() Plots Color Vector Graphic (see IES TM30).

indices/indices.py

wrapper_functions_for_fidelity_type_metrics

spd_to_ciera(): CIE 13.3 1995 version
spd_to_ciera_133_1995(): CIE 13.3 1995 version
spd_to_cierf(): latest version
spd_to_cierf_224_2017(): CIE224-2017 version

spd_to_iesrf(): latest version
spd_to_iesrf_tm30(): latest version
spd_to_iesrf_tm30_15(): TM30-15 version
spd_to_iesrf_tm30_18(): TM30-18 version

spd_to_cri2012()
spd_to_cri2012_hl17()
spd_to_cri2012_hl1000()
spd_to_cri2012_real210()

wrapper_functions_for_gamut_area_metrics

spd_to_iesrg(): latest version
spd_to_iesrg_tm30(): latest version
spd_to_iesrg_tm30_15(): TM30-15 version
spd_to_iesrg_tm30_18(): TM30-18 version

indices/mcri.py

spd_to_mcri()

Calculates the memory color rendition index, Rm:
K. A. G. Smet, W. R. Ryckaert, M. R. Pointer, G. Deconinck, and P. Hanselaer, (2012)
"A memory colour quality metric for white light sources,"
Energy Build., vol. 49, no. C, pp. 216–225.

indices/cqs.py

spd_to_cqs()

versions 7.5 and 9.0 are supported.
W. Davis and Y. Ohno,
"Color quality scale," (2010),
Opt. Eng., vol. 49, no. 3, pp. 33602–33616.

iestm30/iestm30_metrics.py

spd_to_ies_tm30_metrics() Calculates IES TM30 metrics from spectral data.

iestm30/iestm30_graphics.py

plot_cri_graphics() Plot graphical information on color rendition properties.

VFPX

:Module_for_VectorField_and_Pixelation_CRI models.

- see ?luxpy.cri.VFPX

`luxpy.color.cri.`**`linear_scale`**(*data, scale_factor=[4.6], scale_max=100.0*)

Linear color rendering index scale from CIE13.3-1974/1995:

Rfi,a = 100 - c1*DEi,a. (c1 = 4.6)

Args:

data

float or list[floats] or ndarray

scale_factor

[4.6] or list[float] or ndarray, optional
Rescales color differences before subtracting them from :scale_max:

scale_max

100.0, optional
Maximum value of linear scale

Returns:

returns

float or list[floats] or ndarray

References: 1. CIE13.3-1995, "Method of Measuring and Specifying Colour Rendering Properties of Light Sources," CIE, Vienna, Austria, 1995.,ISBN 978 3 900734 57 2

`luxpy.color.cri.`**`log_scale`**(*data, scale_factor=[6.73], scale_max=100.0*)

Log-based color rendering index scale from Davis & Ohno (2009):

Rfi,a = 10 * ln(exp((100 - c1*DEi,a)/10) + 1).

Args:

data

float or list[floats] or ndarray

scale_factor

[6.73] or list[float] or ndarray, optional
Rescales color differences before subtracting them from :scale_max:
Note that the default value is the one from cie-224-2017.

scale_max

100.0, optional
Maximum value of linear scale

Returns:

returns

float or list[floats] or ndarray

References: 1. W. Davis and Y. Ohno, "Color quality scale," (2010), Opt. Eng., vol. 49, no. 3, pp. 33602–33616. 2. CIE224:2017. CIE 2017 Colour Fidelity Index for accurate scientific use. Vienna, Austria: CIE. (2017).

`luxpy.color.cri.`**`psy_scale`**(*data, scale_factor=[0.01818181818181818, 1.5, 2.0], scale_max=100.0*)

Psychometric based color rendering index scale from CRI2012:

Rfi,a = 100 * (2 / (exp(c1*abs(DEi,a)**(c2) + 1))) ** c3.

Args:

data

float or list[floats] or ndarray

scale_factor

[1/55, 3/2, 2.0] or list[float] or ndarray, optional
Rescales color differences before subtracting them from :scale_max:

Note that the default value is the one from (Smet et al. 2013, LRT).

scale_max

100.0, optional
Maximum value of linear scale

Returns:

returns

float or list[floats] or ndarray

References: 1. Smet, K., Schanda, J., Whitehead, L., & Luo, R. (2013). CRI2012: A proposal for updating the CIE colour rendering index. Lighting Research and Technology, 45, 689–709.

`luxpy.color.cri.`**`gamut_slicer`**(*jab_test*, *jab_ref*, *out='jabt*, *jabr'*, *nhbins=None*, *start_hue=0.0*, *normalize_gamut=True*, *normalized_chroma_ref=100*, *close_gamut=False*)

Slices the gamut in hue bins.

Args:

jab_test

ndarray with Cartesian color coordinates (e.g. Jab) of the samples under the test SPD

jab_ref

ndarray with Cartesian color coordinates (e.g. Jab) of the samples under the reference SPD

out

'jabt,jabr' or str, optional
Specifies which variables to output as ndarray

nhbins

None or int, optional
- None: defaults to using the sample hues themselves as 'bins'.
  In other words, the number of bins will be equal to the number of samples.
- float: number of bins to slice the sample gamut in.

start_hue

0.0 or float, optional
Hue angle to start bin slicing

normalize_gamut

True or False, optional
True normalizes the gamut of test to that of ref. (perfect agreement results in circle).

normalized_chroma_ref

100.0 or float, optional
Controls the size (chroma/radius) of the normalization circle/gamut.

close_gamut

False or True, optional
True appends the first jab coordinates to the end of the output (for plotting closed gamuts)

Returns:

returns

ndarray with average jabt,jabr of each hue bin.
(.shape = (number of hue bins, 3))

(or outputs whatever is specified in :out:)

luxpy.color.cri.**jab_to_rg**(*jabt*, *jabr*, *max_scale=100*, *ordered_and_sliced=False*, *nhbins=None*, *start_hue=0.0*, *normalize_gamut=True*, *normalized_chroma_ref=100*, *out='Rg,jabt,jabr'*)

Calculates gamut area index, Rg.

Args:

jabt

ndarray with Cartesian color coordinates (e.g. Jab) of the samples under the test SPD

jabr

ndarray with Cartesian color coordinates (e.g. Jab) of the samples under the reference SPD

max_scale

100.0, optional
Value of Rg when Rf = max_scale (i.e. DEavg = 0)

ordered_and_sliced

False or True, optional
- False: Hue ordering will be done with lux.cri.gamut_slicer().
- True: user is responsible for hue-ordering and closing gamut (i.e. first element in :jab: equals the last).

nhbins

None or int, optional
- None: defaults to using the sample hues themselves as 'bins'.
  In other words, the number of bins will be equal to the number of samples.
- float: number of bins to slice the sample gamut in.

start_hue

0.0 or float, optional
Hue angle to start bin slicing

normalize_gamut

True or False, optional
True normalizes the gamut of test to that of ref. (perfect agreement results in circle).

normalized_chroma_ref

100.0 or float, optional
Controls the size (chroma/radius) of the normalization circle/gamut

out

'Rg,jabt,jabr' or str, optional
Specifies which variables to output as ndarray

Returns:

Rg

float or ndarray with gamut area indices Rg.

luxpy.color.cri.**jab_to_rhi**(*jabt*, *jabr*, *DEi*, *cri_type='ies-tm30'*, *start_hue=None*, *nhbins=None*, *scale_factor=None*, *scale_fcn=None*, *use_bin_avg_DEi=True*)

Calculate hue bin measures: Rfhi, Rcshi and Rhshi.

Rfhi: local (hue bin) color fidelity
Rcshi: local chroma shift
Rhshi: local hue shift

(See IES TM30)

Args:

jabt

ndarray with jab coordinates under test SPD

jabr

ndarray with jab coordinates under reference SPD

DEi

ndarray with DEi (from gamut_slicer()).

use_bin_avg_DEi

True, optional
Note that following IES-TM30 DEi from gamut_slicer() is obtained by averaging the DEi per hue bin (True), and NOT by averaging the jabt and jabr per hue bin and then calculating the DEi (False).

nhbins

int, number of hue bins to slice gamut (None use the one specified in :cri_type: dict).

start_hue

float (°), hue at which to start slicing

scale_fcn

function handle to type of cri scale,
e.g.
* linear()_scale –> (100 - scale_factor*DEi),
* log_scale –> (cfr. Ohno's CQS),
* psy_scale (Smet et al.'s cri2012,See: LRT 2013)

scale_factor

factors used in scaling function

Returns:

returns

ndarrays of Rfhi, Rcshi and Rhshi

References: 1. IES TM30, Method for Evaluating Light Source Color Rendition. New York, NY: The Illuminating Engineering Society of North America.

luxpy.color.cri.**jab_to_DEi**(*jabt*, *jabr*, *out='DEi'*, *avg=None*)

Calculates color differences (~fidelity), DEi, of Jab input.

Args:

jabt

ndarray with Cartesian color coordinates (e.g. Jab) of the samples under the test SPD

jabr

ndarray with Cartesian color coordinates (e.g. Jab) of the samples under the reference SPD

avg

None, optional

If None: don't calculate average, else: avg must be function handle

out

'DEi' or str, optional

Specifies requested output (e.g. 'DEi,DEa')

Returns:

returns

float or ndarray with DEi for :out: 'DEi'

Other output is also possible by changing the :out: str value.

luxpy.color.cri.**spd_to_DEi**(*SPD*, *cri_type='ies-tm30'*, *out='DEi'*, *wl=None*, *sampleset=None*, *ref_type=None*, *cieobs=None*, *avg=None*, *cspace=None*, *catf=None*, *cri_specific_pars=None*)

Calculates color differences (~fidelity), DEi, of spectral data.

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

out

'DEi' or str, optional

Specifies requested output (e.g. 'DEi,DEa,cct,duv')

wl

None, optional

Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.

None: default to no interpolation

cri_type

_CRI_TYPE_DEFAULT or str or dict, optional

-'str: specifies dict with default cri model parameters

(for supported types, see luxpy.cri._CRI_DEFAULTS['cri_types'])

- dict: user defined model parameters

(see e.g. luxpy.cri._CRI_DEFAULTS['cierf']

for required structure)

Note that any non-None input arguments to the function will override default values in cri_type dict.

sampleset

None or ndarray or str, optional

Specifies set of spectral reflectance samples for cri calculations.

- None defaults to standard set for metric in cri_type.

- ndarray: user defined set of spectral reflectance functions
(.shape = (N+1, number of wavelengths);
first axis are wavelengths)

ref_type

None or str or ndarray, optional
Specifies type of reference illuminant type.
- None: defaults to metric_specific reference illuminant in
accordance with cri_type.
- str: 'BB' : Blackbody radiatiors,
'DL': daylightphase,
'ciera': used in CIE CRI-13.3-1995,
'cierf': used in CIE 224-2017,
'iesrf': used in TM30-15, ...
- ndarray: user defined reference SPD

cieobs

None or dict, optional
Specifies which CMF sets to use for the calculation of the sample
XYZs and the CCT (for reference illuminant calculation).
None defaults to the one specified in :cri_type: dict.
- key: 'xyz': str specifying CMF set for calculating xyz
of samples and white
- key: 'cct': str specifying CMF set for calculating cct

cspace

None or dict, optional
Specifies which color space to use.
None defaults to the one specified in :cri_type: dict.
- key: 'type': str specifying color space used to calculate
color differences in.
- key: 'xyzw': None or ndarray with white point of color space
If None: use xyzw of test / reference (after chromatic
adaptation, if specified)
- other keys specify other possible parameters needed for color
space calculation,
see lx.cri._CRI_DEFAULTS['iesrf']['cspace'] for details.

catf

None or dict, optional
Perform explicit CAT before converting to color space coordinates.
- None: don't apply a cat (other than perhaps the one built
into the colorspace)
- dict: with CAT parameters:
- key: 'D': ndarray with degree of adaptation
- key: 'mcat': ndarray with sensor matrix specification
- key: 'xyzw': None or ndarray with white point
None: use xyzw of reference otherwise transform both

test and ref to xyzw

cri_specific_pars

None or dict, optional
Specifies other parameters specific to type of cri
(e.g. maxC for CQS calculations)
- None: default to the one specified in :cri_type: dict.
- dict: user specified parameters.
For its use, see for example:
luxpy.cri._CRI_DEFAULTS['mcri']['cri_specific_pars']

Returns:

returns

float or ndarray with DEi for :out: 'DEi'

Other output is also possible by changing the :out: str value.

luxpy.color.cri.**spd_to_rg**(*SPD*, *cri_type='ies-tm30'*, *out='Rg'*, *wl=None*, *sampleset=None*, *ref_type=None*, *cieobs=None*, *avg=None*, *cspace=None*, *catf=None*, *cri_specific_pars=None*, *rg_pars=None*)

Calculates the color gamut index, Rg, of spectral data.

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

out

'Rg' or str, optional
Specifies requested output (e.g. 'Rg,cct,duv')

wl

None, optional
Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.
None: default to no interpolation

cri_type

_CRI_TYPE_DEFAULT or str or dict, optional
-'str: specifies dict with default cri model parameters
(for supported types, see luxpy.cri._CRI_DEFAULTS['cri_types'])
- dict: user defined model parameters
(see e.g. luxpy.cri._CRI_DEFAULTS['cierf']
for required structure)
Note that any non-None input arguments to the function will override default values in cri_type dict.

sampleset

None or ndarray or str, optional
Specifies set of spectral reflectance samples for cri calculations.
- None defaults to standard set for metric in cri_type.
- ndarray: user defined set of spectral reflectance functions
(.shape = (N+1, number of wavelengths);
first axis are wavelengths)

ref_type

None or str or ndarray, optional
Specifies type of reference illuminant type.
- None: defaults to metric_specific reference illuminant in accordance with cri_type.
- str: 'BB' : Blackbody radiatiors,
'DL': daylightphase,
'ciera': used in CIE CRI-13.3-1995,
'cierf': used in CIE 224-2017,
'iesrf': used in TM30-15, ...
- ndarray: user defined reference SPD

cieobs

None or dict, optional
Specifies which CMF sets to use for the calculation of the sample XYZs and the CCT (for reference illuminant calculation).
None defaults to the one specified in :cri_type: dict.
- key: 'xyz': str specifying CMF set for calculating xyz of samples and white
- key: 'cct': str specifying CMF set for calculating cct

cspace

None or dict, optional
Specifies which color space to use.
None defaults to the one specified in :cri_type: dict.
- key: 'type': str specifying color space used to calculate color differences in.
- key: 'xyzw': None or ndarray with white point of color space
If None: use xyzw of test / reference (after chromatic adaptation, if specified)
- other keys specify other possible parameters needed for color space calculation,
see lx.cri._CRI_DEFAULTS['iesrf']['cspace'] for details.

catf

None or dict, optional
Perform explicit CAT before converting to color space coordinates.
- None: don't apply a cat (other than perhaps the one built into the colorspace)
- dict: with CAT parameters:
- key: 'D': ndarray with degree of adaptation
- key: 'mcat': ndarray with sensor matrix specification
- key: 'xyzw': None or ndarray with white point
None: use xyzw of reference otherwise transform both test and ref to xyzw

cri_specific_pars

None or dict, optional

Specifies other parameters specific to type of cri
(e.g. maxC for CQS calculations)
- None: default to the one specified in :cri_type: dict.
- dict: user specified parameters.
For its use, see for example:
luxpy.cri._CRI_DEFAULTS['mcri']['cri_specific_pars']

rg_pars

None or dict, optional
Dict containing specifying parameters for slicing the gamut.
Dict structure:
{'nhbins' : None, 'start_hue' : 0, 'normalize_gamut' : True}
- key: 'nhbins': int, number of hue bins to slice gamut
(None use the one specified in :cri_type: dict).
- key: 'start_hue': float (°), hue at which to start slicing
- key: 'normalize_gamut': True or False:
normalize gamut or not before calculating a gamut
area index Rg.
- key: 'normalized_chroma_ref': 100.0 or float, optional
Controls the size (chroma/radius)
of the normalization circle/gamut.

avg

None or fcn handle, optional
Averaging function (handle) for color differences, DEi
(e.g. numpy.mean, .math.rms, .math.geomean)
None use the one specified in :cri_type: dict.

scale

None or dict, optional
Specifies scaling of color differences to obtain CRI.
- None use the one specified in :cri_type: dict.
- dict: user specified dict with scaling parameters.
- key: 'fcn': function handle to type of cri scale,
e.g.
* linear()_scale –> (100 - scale_factor*DEi),
* log_scale –> (cfr. Ohno's CQS),
* psy_scale (Smet et al.'s cri2012,See: LRT 2013)
- key: 'cfactor': factors used in scaling function,
If None:
Scaling factor value(s) will be optimized to
minimize the rms between the Rf's of the
requested metric and the target metric specified
in:

- key: 'opt_cri_type': str
* str: one of the preset _CRI_DEFAULTS
* dict: user speciied

(dict must contain all keys as normal)
Note that if key not in :scale: dict,
then 'opt_cri_type' is added with default
setting = 'ciera'.
- key: 'opt_spd_set': ndarray with set of light
source spds used to optimize cfactor.
Note that if key not in :scale: dict,
then default = 'F1-F12'.

Returns:

returns

float or ndarray with Rg for :out: 'Rg'
Other output is also possible by changing the :out: str value.

References: 1. IES TM30, Method for Evaluating Light Source Color Rendition. New York, NY: The Illuminating Engineering Society of North America.

2. A. David, P. T. Fini, K. W. Houser, Y. Ohno, M. P. Royer, K. A. G. Smet, M. Wei, and L. Whitehead, "Development of the IES method for evaluating the color rendition of light sources," Opt. Express, vol. 23, no. 12, pp. 15888–15906, 2015.

`luxpy.color.cri.`**`spd_to_cri`**(*SPD*, *cri_type='ies-tm30'*, *out='Rf'*, *wl=None*, *sampleset=None*, *ref_type=None*, *cieobs=None*, *avg=None*, *scale=None*, *opt_scale_factor=False*, *cspace=None*, *catf=None*, *cri_specific_pars=None*, *rg_pars=None*)

Calculates the color rendering fidelity index, Rf, of spectral data.

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

out

'Rf' or str, optional
Specifies requested output (e.g. 'Rf,cct,duv')

wl

None, optional
Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.
None: default to no interpolation

cri_type

_CRI_TYPE_DEFAULT or str or dict, optional
-'str: specifies dict with default cri model parameters
(for supported types, see luxpy.cri._CRI_DEFAULTS['cri_types'])
- dict: user defined model parameters
(see e.g. luxpy.cri._CRI_DEFAULTS['cierf']
for required structure)
Note that any non-None input arguments to the function will override default values in cri_type dict.

sampleset

None or ndarray or str, optional
Specifies set of spectral reflectance samples for cri calculations.
- None defaults to standard set for metric in cri_type.
- ndarray: user defined set of spectral reflectance functions
(.shape = (N+1, number of wavelengths);

first axis are wavelengths)

ref_type

None or str or ndarray, optional
Specifies type of reference illuminant type.
- None: defaults to metric_specific reference illuminant in accordance with cri_type.
- str: 'BB' : Blackbody radiatiors,
'DL': daylightphase,
'ciera': used in CIE CRI-13.3-1995,
'cierf': used in CIE 224-2017,
'iesrf': used in TM30-15, ...
- ndarray: user defined reference SPD

cieobs

None or dict, optional
Specifies which CMF sets to use for the calculation of the sample XYZs and the CCT (for reference illuminant calculation).
None defaults to the one specified in :cri_type: dict.
- key: 'xyz': str specifying CMF set for calculating xyz of samples and white
- key: 'cct': str specifying CMF set for calculating cct

cspace

None or dict, optional
Specifies which color space to use.
None defaults to the one specified in :cri_type: dict.
- key: 'type': str specifying color space used to calculate color differences in.
- key: 'xyzw': None or ndarray with white point of color space
If None: use xyzw of test / reference (after chromatic adaptation, if specified)
- other keys specify other possible parameters needed for color space calculation,
see lx.cri._CRI_DEFAULTS['iesrf']['cspace'] for details.

catf

None or dict, optional
Perform explicit CAT before converting to color space coordinates.
- None: don't apply a cat (other than perhaps the one built into the colorspace)
- dict: with CAT parameters:
- key: 'D': ndarray with degree of adaptation
- key: 'mcat': ndarray with sensor matrix specification
- key: 'xyzw': None or ndarray with white point
None: use xyzw of reference otherwise transform both test and ref to xyzw

cri_specific_pars

None or dict, optional
Specifies other parameters specific to type of cri

(e.g. maxC for CQS calculations)
- None: default to the one specified in :cri_type: dict.
- dict: user specified parameters.
For its use, see for example:
luxpy.cri._CRI_DEFAULTS['mcri']['cri_specific_pars']

rg_pars

None or dict, optional
Dict containing specifying parameters for slicing the gamut.
Dict structure:
{'nhbins' : None, 'start_hue' : 0, 'normalize_gamut' : True}
- key: 'nhbins': int, number of hue bins to slice gamut
(None use the one specified in :cri_type: dict).
- key: 'start_hue': float (°), hue at which to start slicing
- key: 'normalize_gamut': True or False:
normalize gamut or not before calculating a gamut
area index Rg.
- key: 'normalized_chroma_ref': 100.0 or float, optional
Controls the size (chroma/radius)
of the normalization circle/gamut.

avg

None or fcn handle, optional
Averaging function (handle) for color differences, DEi
(e.g. numpy.mean, .math.rms, .math.geomean)
None use the one specified in :cri_type: dict.

scale

None or dict, optional
Specifies scaling of color differences to obtain CRI.
- None use the one specified in :cri_type: dict.
- dict: user specified dict with scaling parameters.
- key: 'fcn': function handle to type of cri scale,
e.g.
* linear()_scale –> (100 - scale_factor*DEi),
* log_scale –> (cfr. Ohno's CQS),
* psy_scale (Smet et al.'s cri2012,See: LRT 2013)
- key: 'cfactor': factors used in scaling function,
If None:
Scaling factor value(s) will be optimized to
minimize the rms between the Rf's of the
requested metric and the target metric specified
in:

- key: 'opt_cri_type': str
* str: one of the preset _CRI_DEFAULTS
* dict: user speciied
(dict must contain all keys as normal)
Note that if key not in :scale: dict,

then 'opt_cri_type' is added with default
setting = 'ciera'.
- key: 'opt_spd_set': ndarray with set of light
source spds used to optimize cfactor.
Note that if key not in :scale: dict,
then default = 'F1-F12'.

opt_scale

True or False, optional
True: optimize scaling-factor, else do nothing and use value of scaling-factor in :scale: dict.

Returns:

returns

float or ndarray with Rf for :out: 'Rf'
Other output is also possible by changing the :out: str value.

References: 1. IES TM30, Method for Evaluating Light Source Color Rendition. New York, NY: The Illuminating Engineering Society of North America.

2. A. David, P. T. Fini, K. W. Houser, Y. Ohno, M. P. Royer, K. A. G. Smet, M. Wei, and L. Whitehead, "Development of the IES method for evaluating the color rendition of light sources," Opt. Express, vol. 23, no. 12, pp. 15888–15906, 2015.

3. CIE224:2017. CIE 2017 Colour Fidelity Index for accurate scientific use. Vienna, Austria: CIE. (2017).

4. Smet, K., Schanda, J., Whitehead, L., & Luo, R. (2013). CRI2012: A proposal for updating the CIE colour rendering index. Lighting Research and Technology, 45, 689–709.

5. CIE13.3-1995. Method of Measuring and Specifying Colour Rendering Properties of Light Sources (Vol. CIE13.3-19). Vienna, Austria: CIE. (1995).

`luxpy.color.cri.`**`spd_to_ciera`**(*SPD*, *out='Rf'*, *wl=None*)

Wrapper function the 'ciera' color rendition (fidelity) metric (CIE 13.3-1995).

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl

None, optional
Wavelengths (or [start, end, spacing]) to interpolate :SPD: to.
None: default to no interpolation

out

'Rf' or str, optional
Specifies requested output (e.g. 'Rf,Rfi,cct,duv')

Returns:

returns

float or ndarray with CIE13.3 Ra for :out: 'Rf'
Other output is also possible by changing the :out: str value.

References: 1. CIE13.3-1995. Method of Measuring and Specifying Colour Rendering Properties of Light Sources (Vol. CIE13.3-19). Vienna, Austria: CIE. (1995).

`luxpy.color.cri.`**`spd_to_cierf`**(*SPD*, *out='Rf'*, *wl=None*)

Wrapper function the 'cierf' color rendition (fidelity) metric (CIE224-2017).

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl

None, optional
Wavelengths (or [start, end, spacing]) to interpolate :SPD: to.
None: default to no interpolation

out

'Rf' or str, optional
Specifies requested output (e.g. 'Rf,Rfi,cct,duv')

Returns:

returns

float or ndarray with CIE224-2017 Rf for :out: 'Rf'
Other output is also possible by changing the :out: str value.

References: 1. CIE224:2017. CIE 2017 Colour Fidelity Index for accurate scientific use. Vienna, Austria: CIE. (2017).

luxpy.color.cri.**spd_to_ciera_133_1995**(*SPD*, *out='Rf'*, *wl=None*)

Wrapper function the 'ciera' color rendition (fidelity) metric (CIE 13.3-1995).

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl

None, optional
Wavelengths (or [start, end, spacing]) to interpolate :SPD: to.
None: default to no interpolation

out

'Rf' or str, optional
Specifies requested output (e.g. 'Rf,Rfi,cct,duv')

Returns:

returns

float or ndarray with CIE13.3 Ra for :out: 'Rf'
Other output is also possible by changing the :out: str value.

References: 1. CIE13.3-1995. Method of Measuring and Specifying Colour Rendering Properties of Light Sources (Vol. CIE13.3-19). Vienna, Austria: CIE. (1995).

luxpy.color.cri.**spd_to_cierf_224_2017**(*SPD*, *out='Rf'*, *wl=None*)

Wrapper function the 'cierf' color rendition (fidelity) metric (CIE224-2017).

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl

None, optional
Wavelengths (or [start, end, spacing]) to interpolate :SPD: to.
None: default to no interpolation

out

'Rf' or str, optional
Specifies requested output (e.g. 'Rf,Rfi,cct,duv')

Returns:

returns

float or ndarray with CIE224-2017 Rf for :out: 'Rf'

Other output is also possible by changing the :out: str value.

References: 1. CIE224:2017. CIE 2017 Colour Fidelity Index for accurate scientific use. Vienna, Austria: CIE. (2017).

luxpy.color.cri.**spd_to_iesrf**(*SPD*, *out='Rf'*, *wl=None*, *cri_type='iesrf-tm30-18'*)

Wrapper function for the 'iesrf' color fidelity index (IES TM30-18).

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl

None, optional

Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.

None: default to no interpolation

out

'Rf' or str, optional

Specifies requested output (e.g. 'Rf,Rfi,cct,duv')

Returns:

returns

float or ndarray with IES TM30_15 Rf for :out: 'Rf'

Other output is also possible by changing the :out: str value.

References: 1. IES TM30 (99, 4880 spectrally uniform samples)

2. A. David, P. T. Fini, K. W. Houser, Y. Ohno, M. P. Royer, K. A. G. Smet, M. Wei, and L. Whitehead, "Development of the IES method for evaluating the color rendition of light sources," Opt. Express, vol. 23, no. 12, pp. 15888–15906, 2015.

3. K. A. G. Smet, A. David, and L. Whitehead, "Why color space uniformity and sample set spectral uniformity are essential for color rendering measures," LEUKOS, vol. 12, no. 1–2, pp. 39–50, 2016

luxpy.color.cri.**spd_to_iesrg**(*SPD*, *out='Rg'*, *wl=None*, *cri_type='iesrf-tm30-18'*)

Wrapper function for the 'spd_to_rg' color gamut area index (IES TM30-18).

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl

None, optional

Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.

None: default to no interpolation

out

'Rg' or str, optional

Specifies requested output (e.g. 'Rg,Rf,Rfi,cct,duv')

Returns:

returns

float or ndarray with IES TM30_15 Rg for :out: 'Rg'

Other output is also possible by changing the :out: str value.

References: 1. IES TM30 (99, 4880 spectrally uniform samples)

2. A. David, P. T. Fini, K. W. Houser, Y. Ohno, M. P. Royer, K. A. G. Smet, M. Wei, and L. Whitehead, "Development of the IES method for evaluating the color rendition of light sources," Opt. Express, vol.

23, no. 12, pp. 15888–15906, 2015.

3. K. A. G. Smet, A. David, and L. Whitehead, "Why color space uniformity and sample set spectral uniformity are essential for color rendering measures," LEUKOS, vol. 12, no. 1–2, pp. 39–50, 2016

luxpy.color.cri.**spd_to_iesrf_tm30**(*SPD*, *out='Rf'*, *wl=None*, *cri_type='iesrf-tm30-18'*)

Wrapper function for the 'iesrf' color fidelity index (IES TM30-18).

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl

None, optional

Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.

None: default to no interpolation

out

'Rf' or str, optional

Specifies requested output (e.g. 'Rf,Rfi,cct,duv')

Returns:

returns

float or ndarray with IES TM30_15 Rf for :out: 'Rf'

Other output is also possible by changing the :out: str value.

References: 1. IES TM30 (99, 4880 spectrally uniform samples)

2. A. David, P. T. Fini, K. W. Houser, Y. Ohno, M. P. Royer, K. A. G. Smet, M. Wei, and L. Whitehead, "Development of the IES method for evaluating the color rendition of light sources," Opt. Express, vol. 23, no. 12, pp. 15888–15906, 2015.

3. K. A. G. Smet, A. David, and L. Whitehead, "Why color space uniformity and sample set spectral uniformity are essential for color rendering measures," LEUKOS, vol. 12, no. 1–2, pp. 39–50, 2016

luxpy.color.cri.**spd_to_iesrg_tm30**(*SPD*, *out='Rg'*, *wl=None*, *cri_type='iesrf-tm30-18'*)

Wrapper function for the 'spd_to_rg' color gamut area index (IES TM30-18).

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl

None, optional

Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.

None: default to no interpolation

out

'Rg' or str, optional

Specifies requested output (e.g. 'Rg,Rf,Rfi,cct,duv')

Returns:

returns

float or ndarray with IES TM30_15 Rg for :out: 'Rg'

Other output is also possible by changing the :out: str value.

References: 1. IES TM30 (99, 4880 spectrally uniform samples)

2. A. David, P. T. Fini, K. W. Houser, Y. Ohno, M. P. Royer, K. A. G. Smet, M. Wei, and L. Whitehead, "Development of the IES method for evaluating the color rendition of light sources," Opt. Express, vol. 23, no. 12, pp. 15888–15906, 2015.

3. K. A. G. Smet, A. David, and L. Whitehead, "Why color space uniformity and sample set spectral uniformity are essential for color rendering measures," LEUKOS, vol. 12, no. 1–2, pp. 39–50, 2016

luxpy.color.cri.**spd_to_iesrf_tm30_15**(*SPD*, *out='Rf'*, *wl=None*, *cri_type='iesrf-tm30-15'*)

Wrapper function for the 'iesrf' color fidelity index (IES TM30-15).

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl

None, optional

Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.

None: default to no interpolation

out

'Rf' or str, optional

Specifies requested output (e.g. 'Rf,Rfi,cct,duv')

Returns:

returns

float or ndarray with IES TM30_15 Rf for :out: 'Rf'

Other output is also possible by changing the :out: str value.

References: 1. IES TM30 (99, 4880 spectrally uniform samples)

2. A. David, P. T. Fini, K. W. Houser, Y. Ohno, M. P. Royer, K. A. G. Smet, M. Wei, and L. Whitehead, "Development of the IES method for evaluating the color rendition of light sources," Opt. Express, vol. 23, no. 12, pp. 15888–15906, 2015.

3. K. A. G. Smet, A. David, and L. Whitehead, "Why color space uniformity and sample set spectral uniformity are essential for color rendering measures," LEUKOS, vol. 12, no. 1–2, pp. 39–50, 2016

luxpy.color.cri.**spd_to_iesrg_tm30_15**(*SPD*, *out='Rg'*, *wl=None*, *cri_type='iesrf-tm30-15'*)

Wrapper function for the 'spd_to_rg' color gamut area index (IES TM30-15).

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl

None, optional

Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.

None: default to no interpolation

out

'Rg' or str, optional

Specifies requested output (e.g. 'RgRf,Rfi,cct,duv')

Returns:

returns

float or ndarray with IES TM30_15 Rg for :out: 'Rg'

Other output is also possible by changing the :out: str value.

References: 1. IES TM30 (99, 4880 spectrally uniform samples)

2. A. David, P. T. Fini, K. W. Houser, Y. Ohno, M. P. Royer, K. A. G. Smet, M. Wei, and L. Whitehead, "Development of the IES method for evaluating the color rendition of light sources," Opt. Express, vol. 23, no. 12, pp. 15888–15906, 2015.

3. K. A. G. Smet, A. David, and L. Whitehead, "Why color space uniformity and sample set spectral uniformity are essential for color rendering measures," LEUKOS, vol. 12, no. 1–2, pp. 39–50, 2016

luxpy.color.cri.**spd_to_iesrf_tm30_18**(*SPD*, *out='Rf'*, *wl=None*, *cri_type='iesrf-tm30-18'*)

Wrapper function for the 'iesrf' color fidelity index (IES TM30-18).

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl

None, optional

Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.

None: default to no interpolation

out

'Rf' or str, optional

Specifies requested output (e.g. 'Rf,Rfi,cct,duv')

Returns:

returns

float or ndarray with IES TM30_15 Rf for :out: 'Rf'

Other output is also possible by changing the :out: str value.

References: 1. IES TM30 (99, 4880 spectrally uniform samples)

2. A. David, P. T. Fini, K. W. Houser, Y. Ohno, M. P. Royer, K. A. G. Smet, M. Wei, and L. Whitehead, "Development of the IES method for evaluating the color rendition of light sources," Opt. Express, vol. 23, no. 12, pp. 15888–15906, 2015.

3. K. A. G. Smet, A. David, and L. Whitehead, "Why color space uniformity and sample set spectral uniformity are essential for color rendering measures," LEUKOS, vol. 12, no. 1–2, pp. 39–50, 2016

luxpy.color.cri.**spd_to_iesrg_tm30_18**(*SPD*, *out='Rg'*, *wl=None*, *cri_type='iesrf-tm30-18'*)

Wrapper function for the 'spd_to_rg' color gamut area index (IES TM30-18).

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl

None, optional

Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.

None: default to no interpolation

out

'Rg' or str, optional

Specifies requested output (e.g. 'Rg,Rf,Rfi,cct,duv')

Returns:

returns

float or ndarray with IES TM30_15 Rg for :out: 'Rg'

Other output is also possible by changing the :out: str value.

References: 1. IES TM30 (99, 4880 spectrally uniform samples)

2. A. David, P. T. Fini, K. W. Houser, Y. Ohno, M. P. Royer, K. A. G. Smet, M. Wei, and L. Whitehead, "Development of the IES method for evaluating the color rendition of light sources," Opt. Express, vol. 23, no. 12, pp. 15888–15906, 2015.

3. K. A. G. Smet, A. David, and L. Whitehead, "Why color space uniformity and sample set spectral uniformity are essential for color rendering measures," LEUKOS, vol. 12, no. 1–2, pp. 39–50, 2016

luxpy.color.cri.**spd_to_cri2012**(*SPD*, *out='Rf'*, *wl=None*)

Wrapper function for the 'cri2012' color rendition (fidelity) metric with the spectally uniform HL17 mathematical sampleset.

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl

None, optional

Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.

None: default to no interpolation

out

'Rf' or str, optional

Specifies requested output (e.g. 'Rf,Rfi,cct,duv')

Returns:

returns

float or ndarray with CRI2012 Rf for :out: 'Rf'

Other output is also possible by changing the :out: str value.

References:

..[1] Smet, K., Schanda, J., Whitehead, L., & Luo, R. (2013). CRI2012: A proposal for updating the CIE colour rendering index. Lighting Research and Technology, 45, 689–709. Retrieved from http://lrt.sagepub.com/content/45/6/689

luxpy.color.cri.**spd_to_cri2012_hl17**(*SPD*, *out='Rf'*, *wl=None*)

Wrapper function for the 'cri2012' color rendition (fidelity) metric with the spectally uniform HL17 mathematical sampleset.

Args:

SPD ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl None, optional Wavelengths (or [start, end, spacing]) to interpolate the SPDs to. None: default to no interpolation

out 'Rf' or str, optional Specifies requested output (e.g. 'Rf,Rfi,cct,duv')

Returns:

returns float or ndarray with CRI2012 Rf for :out: 'Rf' Other output is also possible by changing the :out: str value.

Reference: 1. Smet, K., Schanda, J., Whitehead, L., & Luo, R. (2013). CRI2012: A proposal for updating the CIE colour rendering index. Lighting Research and Technology, 45, 689–709.

luxpy.color.cri.**spd_to_cri2012_hl1000**(*SPD*, *out='Rf'*, *wl=None*)

Wrapper function for the 'cri2012' color rendition (fidelity) metric with the spectally uniform Hybrid HL1000 sampleset.

Args:

SPD ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl None, optional Wavelengths (or [start, end, spacing]) to interpolate the SPDs to. None: default to no interpolation

out 'Rf' or str, optional Specifies requested output (e.g. 'Rf,Rfi,cct,duv')

Returns:

returns float or ndarray with CRI2012 Rf for :out: 'Rf' Other output is also possible by changing the :out: str value.

Reference: 1. Smet, K., Schanda, J., Whitehead, L., & Luo, R. (2013). CRI2012: A proposal for updating the CIE colour rendering index. Lighting Research and Technology, 45, 689–709.

luxpy.color.cri.**spd_to_cri2012_real210**(*SPD*, *out='Rf'*, *wl=None*)

Wrapper function the 'cri2012' color rendition (fidelity) metric with the Real-210 sampleset (normally for special color rendering indices).

Args:

SPD ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

wl None, optional Wavelengths (or [start, end, spacing]) to interpolate the SPDs to. None: default to no interpolation

out 'Rf' or str, optional Specifies requested output (e.g. 'Rf,Rfi,cct,duv')

Returns:

returns float or ndarray with CRI2012 Rf for :out: 'Rf' Other output is also possible by changing the :out: str value.

Reference: 1. Smet, K., Schanda, J., Whitehead, L., & Luo, R. (2013). CRI2012: A proposal for updating the CIE colour rendering index. Lighting Research and Technology, 45, 689–709.

`luxpy.color.cri.`**`spd_to_mcri`**(*SPD*, *D=0.9*, *E=None*, *Yb=20.0*, *out='Rm'*, *wl=None*)

Calculates the MCRI or Memory Color Rendition Index, Rm

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

D

0.9, optional

Degree of adaptation.

E

None, optional

Illuminance in lux

(used to calculate La = (Yb/100)*(E/pi) to then calculate D

following the 'cat02' model).

If None: the degree is determined by :D:

If (:E: is not None) & (:Yb: is None): :E: is assumed to contain the adapting field luminance La (cd/m^2).

Yb

20.0, optional

Luminance factor of background. (used when calculating La from E)

If None, E contains La (cd/m^2).

out

'Rm' or str, optional

Specifies requested output (e.g. 'Rm,Rmi,cct,duv')

wl

None, optional

Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.

None: default to no interpolation

Returns:

returns

float or ndarray with MCRI Rm for :out: 'Rm'

Other output is also possible by changing the :out: str value.

References: 1. K.A.G. Smet, W.R. Ryckaert, M.R. Pointer, G. Deconinck, P. Hanselaer,(2012) "A memory colour quality metric for white light sources," Energy Build., vol. 49, no. C, pp. 216–225.

`luxpy.color.cri.`**`spd_to_cqs`**(*SPD*, *version='v9.0'*, *out='Qa'*, *wl=None*)

Calculates CQS Qa (Qai) or Qf (Qfi) or Qp (Qpi) for versions v9.0 or v7.5.

Args:

SPD

ndarray with spectral data (can be multiple SPDs, first axis are the wavelengths)

version

'v9.0' or 'v7.5', optional

out

'Qa' or str, optional

Specifies requested output (e.g. 'Qa,Qai,Qf,cct,duv')

wl

None, optional

Wavelengths (or [start, end, spacing]) to interpolate the SPDs to.

None: default to no interpolation

Returns:

returns

float or ndarray with CQS Qa for :out: 'Qa'

Other output is also possible by changing the :out: str value.

References: 1. W. Davis and Y. Ohno, "Color quality scale," (2010), Opt. Eng., vol. 49, no. 3, pp. 33602–33616.

`luxpy.color.cri.`**`plot_hue_bins`**(*hbins=16*, *start_hue=0.0*, *scalef=100*, *plot_axis_labels=False*, *bin_labels='#'*, *plot_edge_lines=True*, *plot_center_lines=False*, *plot_bin_colors=True*, *axtype='polar'*, *ax=None*, *force_CVG_layout=False*)

Makes basis plot for Color Vector Graphic (CVG).

Args:

hbins

16 or ndarray with sorted hue bin centers (°), optional

start_hue

0.0, optional

scalef

100, optional

Scale factor for graphic.

plot_axis_labels

False, optional

Turns axis ticks on/off (True/False).

bin_labels

None or list[str] or '#', optional

Plots labels at the bin center hues.

- None: don't plot.
- list[str]: list with str for each bin.
  (len(:bin_labels:) = :nhbins:)
- '#': plots number.

plot_edge_lines

True or False, optional

Plot grey bin edge lines with '–'.

plot_center_lines

False or True, optional

Plot colored lines at 'center' of hue bin.

plot_bin_colors

True, optional
Colorize hue bins.

axtype

'polar' or 'cart', optional
Make polar or Cartesian plot.

ax

None or 'new' or 'same', optional
- None or 'new' creates new plot
- 'same': continue plot on same axes.
- axes handle: plot on specified axes.

force_CVG_layout

False or True, optional
True: Force plot of basis of CVG on first encounter.

Returns:

returns

gcf(), gca(), list with rgb colors for hue bins (for use in other plotting fcns)

luxpy.color.cri.**plot_ColorVectorGraphic**(*jabt*, *jabr*, *hbins=16*, *start_hue=0.0*, *scalef=100*, *plot_axis_labels=False*, *bin_labels=None*, *plot_edge_lines=True*, *plot_center_lines=False*, *plot_bin_colors=True*, *axtype='polar'*, *ax=None*, *force_CVG_layout=False*)

Plot Color Vector Graphic (CVG).

Args:

jabt

ndarray with jab data under test SPD

jabr

ndarray with jab data under reference SPD

hbins

16 or ndarray with sorted hue bin centers (°), optional

start_hue

0.0, optional

scalef

100, optional
Scale factor for graphic.

plot_axis_labels

False, optional
Turns axis ticks on/off (True/False).

bin_labels

None or list[str] or '#', optional
Plots labels at the bin center hues.
- None: don't plot.
- list[str]: list with str for each bin.
  (len(:bin_labels:) = :nhbins:)
- '#': plots number.

plot_edge_lines

True or False, optional

Plot grey bin edge lines with '–'.

plot_center_lines

False or True, optional

Plot colored lines at 'center' of hue bin.

plot_bin_colors

True, optional

Colorize hue-bins.

axtype

'polar' or 'cart', optional

Make polar or Cartesian plot.

ax

None or 'new' or 'same', optional

- None or 'new' creates new plot
- 'same': continue plot on same axes.
- axes handle: plot on specified axes.

force_CVG_layout

False or True, optional

True: Force plot of basis of CVG.

Returns:

returns

gcf(), gca(), list with rgb colors for hue bins (for use in other plotting fcns)

spd_to_ies_tm30_metrics(SPD, cri_type=None, hbins=16, start_hue=0.0, scalef=100, vf_model_t
4.3082e+00, 3.7764e-01, 6.2055e+00, 1.4564e+00, 8.8940e-01]), 'labels': array(['5B', '5BG',
dtype=object), 'sig': 0.3}, scale_vf_chroma_to_sample_chroma=False)

Calculates IES TM30 metrics from spectral data.

Args:

data

numpy.ndarray with spectral data

cri_type

None, optional

If None: defaults to cri_type = 'iesrf'.

Not none values of :hbins:, :start_hue: and :scalef: overwrite input in cri_type['rg_pars']

hbins

None or numpy.ndarray with sorted hue bin centers (°), optional

start_hue

None, optional

scalef

None, optional

Scale factor for reference circle.

vf_pcolorshift

_VF_PCOLORSHIFT or user defined dict, optional

The polynomial models of degree 5 and 6 can be fully specified or summarized by the model parameters themselved OR by calculating the dCoverC and dH at resp. 5 and 6 hues. :VF_pcolorshift: specifies these hues and chroma level.

scale_vf_chroma_to_sample_chroma

False, optional
Scale chroma of reference and test vf fields such that average of binned reference chroma equals that of the binned sample chroma before calculating hue bin metrics.

Returns:

data

dict with color rendering data:
- 'SPD' : ndarray test SPDs
- 'bjabt': ndarray with binned jab data under test SPDs
- 'bjabr': ndarray with binned jab data under reference SPDs
- 'cct' : ndarray with CCT of test SPD
- 'duv' : ndarray with distance to blackbody locus of test SPD
- 'Rf' : ndarray with general color fidelity indices
- 'Rg' : ndarray with gamut area indices
- 'Rfi' : ndarray with specific color fidelity indices
- 'Rfhi' : ndarray with local (hue binned) fidelity indices
- 'Rcshi': ndarray with local chroma shifts indices
- 'Rhshi': ndarray with local hue shifts indices
- 'Rt' : ndarray with general metameric uncertainty index Rt
- 'Rti' : ndarray with specific metameric uncertainty indices Rti
- 'Rfhi_vf' : ndarray with local (hue binned) fidelity indices obtained from VF model predictions at color space pixel coordinates
- 'Rcshi_vf': ndarray with local chroma shifts indices (same as above)
- 'Rhshi_vf': ndarray with local hue shifts indices (same as above)

plot_cri_graphics(data, cri_type=None, hbins=16, start_hue=0.0, scalef=100, plot_axis_labe
4.3082e+00, 3.7764e-01, 6.2055e+00, 1.4564e+00, 8.8940e-01]), 'labels': array(['5B', '5BG',
dtype=object), 'sig': 0.3}, vf_color='k', vf_bin_labels=array(['5B', '5BG', '5G', '5GY', '5

Plot graphical information on color rendition properties.

Args:

data

ndarray with spectral data or dict with pre-computed metrics.

cri_type

None, optional
If None: defaults to cri_type = 'iesrf'.
:hbins:, :start_hue: and :scalef: are ignored if cri_type not None and values are replaced by those in cri_type['rg_pars']

hbins

16 or ndarray with sorted hue bin centers (°), optional

start_hue

0.0, optional

scalef

100, optional

Scale factor for graphic.

plot_axis_labels

False, optional

Turns axis ticks on/off (True/False).

bin_labels

None or list[str] or '#', optional

Plots labels at the bin center hues.

- None: don't plot.
- list[str]: list with str for each bin.
  (len(:bin_labels:) = :nhbins:)
- '#': plots number.

plot_edge_lines

True or False, optional

Plot grey bin edge lines with '–'.

plot_center_lines

False or True, optional

Plot colored lines at 'center' of hue bin.

plot_bin_colors

True, optional

Colorize hue bins.

axtype

'polar' or 'cart', optional

Make polar or Cartesian plot.

ax

None or 'new' or 'same', optional

- None or 'new' creates new plot
- 'same': continue plot on same axes.
- axes handle: plot on specified axes.

force_CVG_layout

False or True, optional

True: Force plot of basis of CVG.

vf_model_type

_VF_MODEL_TYPE or 'M6' or 'M5', optional

Type of polynomial vector field model to use for the calculation of base color shift and metameric uncertainty.

vf_pcolorshift

_VF_PCOLORSHIFT or user defined dict, optional

The polynomial models of degree 5 and 6 can be fully specified or summarized by the model parameters themselved OR by calculating the dCoverC and dH at resp. 5 and 6 hues. :VF_pcolorshift: specifies these hues and chroma level.

vf_color

'k', optional

For plotting the vector fields.

vf_plot_bin_colors

True, optional

Colorize hue bins of VF graph.

scale_vf_chroma_to_sample_chroma

False, optional

Scale chroma of reference and test vf fields such that average of binned reference chroma equals that of the binned sample chroma before calculating hue bin metrics.

vf_bin_labels

see :bin_labels:

Set VF model hue-bin labels.

plot_CF

False, optional

Plot circle fields.

plot_VF

True, optional

Plot vector fields.

plot_SF

True, optional

Plot sample shifts.

Returns:

returns

(data,
[plt.gcf(),ax_spd, ax_CVG, ax_locC, ax_locH, ax_VF],
cmap)

:data: dict with color rendering data
with keys:
- 'SPD' : ndarray test SPDs
- 'bjabt': ndarray with binned jab data under test SPDs
- 'bjabr': ndarray with binned jab data under reference SPDs
- 'cct' : ndarray with CCT of test SPD
- 'duv' : ndarray with distance to blackbody locus of test SPD
- 'Rf' : ndarray with general color fidelity indices
- 'Rg' : ndarray with gamut area indices
- 'Rfi' : ndarray with specific color fidelity indices
- 'Rfhi' : ndarray with local (hue binned) fidelity indices
- 'Rcshi': ndarray with local chroma shifts indices
- 'Rhshi': ndarray with local hue shifts indices
- 'Rt' : ndarray with general metameric uncertainty index Rt
- 'Rti' : ndarray with specific metameric uncertainty indices Rti
- 'Rfhi_vf' : ndarray with local (hue binned) fidelity indices
  obtained from VF model predictions at color space
  pixel coordinates
- 'Rcshi_vf': ndarray with local chroma shifts indices
  (same as above)
- 'Rhshi_vf': ndarray with local hue shifts indices
  (same as above)

:[...]: list with handles to current figure and 5 axes.

:cmap: list with rgb colors for hue bins (for use in other plotting fcns)

4.3.8 cri/VFPX/

py

- __init__.py
- VF_PX_models.py
- vectorshiftmodel.py
- pixelshiftmodel.py

namespace luxpy.cri.VFPX

`luxpy.color.cri.VFPX.`**`get_poly_model`**(*jabt*, *jabr*, *modeltype='M6'*)

Setup base color shift model (delta_a, delta_b), determine model parameters and accuracy.

Calculates a base color shift (delta) from the ref. chromaticity ar, br.

Args:

jabt

ndarray with jab color coordinates under the test SPD.

jabr

ndarray with jab color coordinates under the reference SPD.

modeltype

_VF_MODEL_TYPE or 'M6' or 'M5', optional
Specifies degree 5 or degree 6 polynomial model in ab-coordinates. (see notes below)

Returns:

returns

(poly_model,
pmodel,
dab_model,
dab_res,
dCHoverC_res,
dab_std,
dCHoverC_std)

:poly_model: function handle to model
:pmodel: ndarray with model parameters
:dab_model: ndarray with ab model predictions from ar, br.
:dab_res: ndarray with residuals between 'da,db' of samples and
'da,db' predicted by the model.
:dCHoverC_res: ndarray with residuals between 'dCoverC,dH'
of samples and 'dCoverC,dH' predicted by the model.
Note: dCoverC = (Ct - Cr)/Cr and dH = ht - hr
(predicted from model, see notes below)

:dab_std: ndarray with std of :dab_res:
:dCHoverC_std: ndarray with std of :dCHoverC_res:

Notes:

1. **Model types:**

   poly5_model = lambda a,b,p: p[0]*a + p[1]*b + p[2]*(a**2) + p[3]*a*b + p[4]*(b**2)
   poly6_model = lambda a,b,p: p[0] + p[1]*a + p[2]*b + p[3]*(a**2) + p[4]*a*b + p[5]*(b**2)

2. **Calculation of dCoverC and dH:**

   dCoverC = (np.cos(hr)*da + np.sin(hr)*db)/Cr
   dHoverC = (np.cos(hr)*db - np.sin(hr)*da)/Cr

luxpy.color.cri.VFPX.**apply_poly_model_at_x**(*poly_model*, *pmodel*, *axr*, *bxr*)

Applies base color shift model at cartesian coordinates axr, bxr.

Args:

poly_model

function handle to model

pmodel

ndarray with model parameters.

axr

ndarray with a-coordinates under the reference conditions

bxr

ndarray with b-coordinates under the reference conditions

Returns:

returns

(axt,bxt,Cxt,hxt,
axr,bxr,Cxr,hxr)

ndarrays with ab-coordinates, chroma and hue predicted by the model (xt), under the reference (xr).

luxpy.color.cri.VFPX.**generate_vector_field**(*poly_model*, *pmodel*, *axr=array([-40, -35, -30, -25, -20, -15, -10, -5, 0, 5, 10, 15, 20, 25, 30, 35, 40])*, *bxr=array([-40, -35, -30, -25, -20, -15, -10, -5, 0, 5, 10, 15, 20, 25, 30, 35, 40])*, *make_grid=True*, *limit_grid_radius=0*, *color='k'*)

Generates a field of vectors using the base color shift model.

Has the option to plot vector field.

Args:

poly_model

function handle to model

pmodel

ndarray with model parameters.

axr

np.arange(-_VF_MAXR,_VF_MAXR+_VF_DELTAR,_VF_DELTAR), optional
Ndarray specifying the a-coordinates at which to apply the model.

bxr

np.arange(-_VF_MAXR,_VF_MAXR+_VF_DELTAR,_VF_DELTAR), optional

Ndarray specifying the b-coordinates at which to apply the model.

make_grid

True, optional

True: generate a 2d-grid from :axr:, :bxr:.

limit_grid_radius

0, optional

A value of zeros keeps grid as specified by axr,bxr.

A value > 0 only keeps (a,b) coordinates within :limit_grid_radius:

color

'k', optional

For plotting the vector field.

If :color: == 0, no plot will be generated.

Returns:

returns

If :color: == 0: ndarray of axt,bxt,axr,bxr

Else: handle to axes used for plotting.

VF_colorshift_model(S, cri_type='iesrf', model_type='M6', cspace={'Yw': 100.0, 'conditions
3.4558e+00, 4.0841e+00, 4.7124e+00, 5.3407e+00, 5.9690e+00]), 'sig': 0.3}, vfcolor='k', ve

Applies full vector field model calculations to spectral data.

Args:

S

nump.ndarray with spectral data.

cri_type

_VF_CRI_DEFAULT or str or dict, optional

Specifies type of color fidelity model to use.

Controls choice of ref. ill., sample set, averaging, scaling, etc.

See luxpy.cri.spd_to_cri for more info.

modeltype

_VF_MODEL_TYPE or 'M6' or 'M5', optional

Specifies degree 5 or degree 6 polynomial model in ab-coordinates.

cspace

_VF_CSPACE or dict, optional

Specifies color space. See _VF_CSPACE_EXAMPLE for example structure.

sampleset

None or str or ndarray, optional

Sampleset to be used when calculating vector field model.

pool

False, optional

If :S: contains multiple spectra, True pools all jab data before modeling the vector field, while False models a different field for each spectrum.

pcolorshift

default dict (see below) or user defined dict, optional

Dict containing the specification input for apply_poly_model_at_hue_x().

Default dict = {'href': np.arange(np.pi/10,2*np.pi,2*np.pi/10),
'Cref' : _VF_MAXR,
'sig' : _VF_SIG,
'labels' : '#'}
The polynomial models of degree 5 and 6 can be fully specified or summarized by the model parameters themselved OR by calculating the dCoverC and dH at resp. 5 and 6 hues.

vfcolor

'k', optional
For plotting the vector fields.

verbosity

0, optional
Report warnings or not.

Returns:

returns

list[dict] (each list element refers to a different test SPD)
with the following keys:
- 'Source': dict with ndarrays of the S, cct and duv of source spd.
- 'metrics': dict with ndarrays for:
  * Rf (color fidelity: base + metameric shift)
  * Rt (metameric uncertainty index)
  * Rfi (specific color fidelity indices)
  * Rti (specific metameric uncertainty indices)
  * cri_type (str with cri_type)
- 'Jab': dict with with ndarrays for Jabt, Jabr, DEi
- 'dC/C_dH_x_sig' :
  np.vstack((dCoverC_x,dCoverC_x_sig,dH_x,dH_x_sig)).T
  See get_poly_model() for more info.
- 'fielddata': dict with dicts containing data on the calculated
  vector-field and circle-fields:
  * 'vectorfield' : {'axt': vfaxt, 'bxt' : vfbxt,
    'axr' : vfaxr, 'bxr' : vfbxr},
  * 'circlefield' : {'axt': cfaxt, 'bxt' : cfbxt,
    'axr' : cfaxr, 'bxr' : cfbxr}},
- 'modeldata' : dict with model info:
  {'pmodel': pmodel,
  'pcolorshift' : pcolorshift,
  'dab_model' : dab_model,
  'dab_res' : dab_res,
  'dab_std' : dab_std,
  'modeltype' : modeltype,
  'fmodel' : poly_model,
  'Jabtm' : Jabtm,
  'Jabrm' : Jabrm,
  'DEim' : DEim},
- 'vshifts' :dict with various vector shifts:
  * 'Jabshiftvector_r_to_t' : ndarray with difference vectors

between jabt and jabr.
* 'vshift_ab_s' : vshift_ab_s: ab-shift vectors of samples
* 'vshift_ab_s_vf' : vshift_ab_s_vf: ab-shift vectors of VF model predictions of samples.
* 'vshift_ab_vf' : vshift_ab_vf: ab-shift vectors of VF model predictions of vector field grid.

luxpy.color.cri.VFPX.**initialize_VF_hue_angles**(*hx=None*, *Cxr=40*, *cri_type='iesrf'*, *modeltype='M6'*, *determine_hue_angles=True*)

Initialize the hue angles that will be used to 'summarize' the VF model fitting parameters.

Args:

hx

None or ndarray, optional
None defaults to Munsell H5 hues.

Cxr

_VF_MAXR, optional

cri_type

_VF_CRI_DEFAULT or str or dict, optional,
Cri_type parameters for cri and VF model.

modeltype

_VF_MODEL_TYPE or 'M5' or 'M6', optional
Determines the type of polynomial model.

determine_hue_angles

_DETERMINE_HUE_ANGLES or True or False, optional
True: determines the 10 primary / secondary Munsell hues ('5..').
Note that for 'M6', an additional

Returns:

pcolorshift

{'href': href,
'Cref' : _VF_MAXR,
'sig' : _VF_SIG,
'labels' : list[str]}

luxpy.color.cri.VFPX.**generate_grid**(*jab_ranges=None*, *out='grid'*, *ax=array([-40, -35, -30, -25, -20, -15, -10, -5, 0, 5, 10, 15, 20, 25, 30, 35, 40])*, *bx=array([-40, -35, -30, -25, -20, -15, -10, -5, 0, 5, 10, 15, 20, 25, 30, 35, 40])*, *jx=None*, *limit_grid_radius=0*)

Generate a grid of color coordinates.

Args:

out

'grid' or 'vectors', optional
- 'grid': outputs a single 2d numpy.nd-vector with the grid coordinates
- 'vector': outputs each dimension seperately.

jab_ranges

None or ndarray, optional
Specifies the pixelization of color space. (ndarray.shape = (3,3), with first axis: J,a,b, and second axis: min, max, delta)

ax

default ndarray or user defined ndarray, optional
default = np.arange(-_VF_MAXR,_VF_MAXR+_VF_DELTAR,_VF_DELTAR)

bx

default ndarray or user defined ndarray, optional
default = np.arange(-_VF_MAXR,_VF_MAXR+_VF_DELTAR,_VF_DELTAR)

jx

None, optional
Note that not-None :jab_ranges: override :ax:, :bx: and :jx input.

limit_grid_radius

0, optional
A value of zeros keeps grid as specified by axr,bxr.
A value > 0 only keeps (a,b) coordinates within :limit_grid_radius:

Returns:

returns

single ndarray with ax,bx [,jx]
or
seperate ndarrays for each dimension specified.

luxpy.color.cri.VFPX.**calculate_shiftvectors**(*jabt*, *jabr*, *average=True*, *vtype='ab'*)

Calculate color shift vectors.

Args:

jabt

ndarray with jab coordinates under the test SPD

jabr

ndarray with jab coordinates under the reference SPD

average

True, optional
If True, take mean of difference vectors along axis = 0.

vtype

'ab' or 'jab', optional
Reduce output ndarray to only a,b coordinates of shift vector(s).

Returns:

returns

ndarray of (mean) shift vector(s).

luxpy.color.cri.VFPX.**plot_shift_data**(*data*, *fieldtype='vectorfield'*, *scalef=40*, *color='k'*, *axtype='polar'*, *ax=None*, *hbins=10*, *start_hue=0.0*, *bin_labels='#'*, *plot_center_lines=True*, *plot_axis_labels=False*, *plot_edge_lines=False*, *plot_bin_colors=True*, *force_CVG_layout=True*)

Plots vector or circle fields generated by VFcolorshiftmodel() or PXcolorshiftmodel().

Args:

data

dict generated by VFcolorshiftmodel() or PXcolorshiftmodel()
Must contain 'fielddata'- key, which is a dict with possible keys:
- key: 'vectorfield': ndarray with vector field data
- key: 'circlefield': ndarray with circle field data

color

'k', optional
Color for plotting the vector-fields.

axtype

'polar' or 'cart', optional
Make polar or Cartesian plot.

ax

None or 'new' or 'same', optional
- None or 'new' creates new plot
- 'same': continue plot on same axes.
- axes handle: plot on specified axes.

hbins

16 or ndarray with sorted hue bin centers (°), optional

start_hue

_VF_MAXR, optional
Scale factor for graphic.

plot_axis_labels

False, optional
Turns axis ticks on/off (True/False).

bin_labels

None or list[str] or '#', optional
Plots labels at the bin center hues.
- None: don't plot.
- list[str]: list with str for each bin.
  (len(:bin_labels:) = :nhbins:)
- '#': plots number.

plot_edge_lines

True or False, optional
Plot grey bin edge lines with '–'.

plot_center_lines

False or True, optional
Plot colored lines at 'center' of hue bin.

plot_bin_colors

True, optional
Colorize hue-bins.

force_CVG_layout

False or True, optional
True: Force plot of basis of CVG.

Returns:

returns

figCVG, hax, cmap

:figCVG: handle to CVG figure
:hax: handle to CVG axes
:cmap: list with rgb colors for hue bins
(for use in other plotting fcns)

luxpy.color.cri.VFPX.**plotcircle**(*center=array([0.0000e+00, 0.0000e+00])*, *radii=array([0, 10, 20, 30, 40, 50])*, *angles=array([0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340])*, *color='k'*, *linestyle='–'*, *out=None*)

Plot one or more concentric circles.

Args:

center

np.array([0.,0.]) or ndarray with center coordinates, optional

radii

np.arange(0,60,10) or ndarray with radii of circle(s), optional

angles

np.arange(0,350,10) or ndarray with angles (°), optional

color

'k', optional

Color for plotting.

linestyle

'–', optional

Linestyle of circles.

out

None, optional

If None: plot circles, return (x,y) otherwise.

luxpy.color.cri.VFPX.**get_pixel_coordinates**(*jab*, *jab_ranges=None*, *jab_deltas=None*, *limit_grid_radius=0*)

Get pixel coordinates corresponding to array of jab color coordinates.

Args:

jab

ndarray of color coordinates

jab_ranges

None or ndarray, optional

Specifies the pixelization of color space.

(ndarray.shape = (3,3), with first axis: J,a,b, and second axis: min, max, delta)

jab_deltas

float or ndarray, optional

Specifies the sampling range.

A float uses jab_deltas as the maximum Euclidean distance to select samples around each pixel center. A ndarray of 3 deltas, uses a city block sampling around each pixel center.

limit_grid_radius

0, optional

A value of zeros keeps grid as specified by axr,bxr.

A value > 0 only keeps (a,b) coordinates within :limit_grid_radius:

Returns:

returns

gridp, idxp, jabp, samplenrs, samplesIDs

- :gridp: ndarray with coordinates of all pixel centers.
- :idxp: list[int] with pixel index for each non-empty pixel

- :jabp: ndarray with center color coordinates of non-empty pixels
- :samplenrs: list[list[int]] with sample numbers belong to each
  non-empty pixel
- :sampleIDs: summarizing list,
  with column order: 'idxp, jabp, samplenrs'

luxpy.color.cri.VFPX.**PX_colorshift_model**(*Jabt*, *Jabr*, *jab_ranges=None*, *jab_deltas=None*, *limit_grid_radius=0*)

Pixelates the color space and calculates the color shifts in each pixel.

Args:

Jabt

ndarray with color coordinates under the (single) test SPD.

Jabr

ndarray with color coordinates under the (single) reference SPD.

jab_ranges

None or ndarray, optional

Specifies the pixelization of color space.

(ndarray.shape = (3,3), with first axis: J,a,b, and second axis: min, max, delta)

jab_deltas

float or ndarray, optional

Specifies the sampling range.

A float uses jab_deltas as the maximum Euclidean distance to select samples around each pixel center. A ndarray of 3 deltas, uses a city block sampling around each pixel center.

limit_grid_radius

0, optional

A value of zeros keeps grid as specified by axr,bxr.

A value > 0 only keeps (a,b) coordinates within :limit_grid_radius:

Returns:

returns

dict with the following keys:

- 'Jab': dict with with ndarrays for:
  Jabt, Jabr, DEi, DEi_ab (only ab-coordinates), DEa (mean)
  and DEa_ab
- 'vshifts': dict with:
  * 'vectorshift': ndarray with vector shifts between average
    Jabt and Jabr for each pixel
  * 'vectorshift_ab': ndarray with vector shifts averaged
    over J for each pixel
  * 'vectorshift_ab_J0': ndarray with vector shifts averaged
    over J for each pixel of J=0 plane.
  * 'vectorshift_len': length of 'vectorshift'
  * 'vectorshift_ab_len': length of 'vectorshift_ab'
  * 'vectorshift_ab_J0_len': length of 'vectorshift_ab_J0'
  * 'vectorshift_len_DEnormed': length of 'vectorshift'
    normalized to 'DEa'
  * 'vectorshift_ab_len_DEnormed': length of 'vectorshift_ab'
    normalized to 'DEa_ab'

* 'vectorshift_ab_J0_len_DEnormed': length of 'vectorshift_ab_J0'
normalized to 'DEa_ab'
- 'pixeldata': dict with pixel info:
* 'grid' ndarray with coordinates of all pixel centers.
* 'idx': list[int] with pixel index for each non-empty pixel
* 'Jab': ndarray with center coordinates of non-empty pixels
* 'samplenrs': list[list[int]] with sample numbers belong to each non-empty pixel
* 'IDs: summarizing list, with column order: 'idxp, jabp, samplenrs'
- 'fielddata' : dict with dicts containing data on the calculated vector-field and circle-fields
* 'vectorfield': dict with ndarrays for the ab-coordinates under the ref. (axr, bxr) and test (axt, bxt) illuminants, centered at the pixel centers corresponding to the ab-coordinates of the reference illuminant.

calculate_VF_PX_models(S, cri_type='iesrf', sampleset=None, pool=False, pcolorshift={'Cref 3.4558e+00, 4.0841e+00, 4.7124e+00, 5.3407e+00, 5.9690e+00]), 'labels': '#', 'sig': 0.3}, v

Calculate Vector Field and Pixel color shift models.

Args:

cri_type

_VF_CRI_DEFAULT or str or dict, optional
Specifies type of color fidelity model to use.
Controls choice of ref. ill., sample set, averaging, scaling, etc.
See luxpy.cri.spd_to_cri for more info.

sampleset

None or str or ndarray, optional
Sampleset to be used when calculating vector field model.

pool

False, optional
If :S: contains multiple spectra, True pools all jab data before modeling the vector field, while False models a different field for each spectrum.

pcolorshift

default dict (see below) or user defined dict, optional
Dict containing the specification input for apply_poly_model_at_hue_x().
Default dict = {'href': np.arange(np.pi/10,2*np.pi,2*np.pi/10),
'Cref' : _VF_MAXR,
'sig' : _VF_SIG,
'labels' : '#'}
The polynomial models of degree 5 and 6 can be fully specified or summarized by the model parameters themselved OR by calculating the dCoverC and dH at resp. 5 and 6 hues.

vfcolor

'k', optional
For plotting the vector fields.

verbosity

0, optional
Report warnings or not.

Returns:

returns

:dataVF:, :dataPX:
Dicts, for more info, see output description of resp.: luxpy.cri.VF_colorshift_model() and luxpy.cri.PX_colorshift_model()

luxpy.color.cri.VFPX.**subsample_RFL_set**(*rfl*, *rflpath=''*, *samplefcn='rand'*, *S=array([[3.8000e+02*, *3.8100e+02*, *3.8200e+02*, *3.8300e+02*, *3.8400e+02*, *3.8500e+02*, *3.8600e+02*, *3.8700e+02*, *3.8800e+02*, *3.8900e+02*, *3.9000e+02*, *3.9100e+02*, *3.9200e+02*, *3.9300e+02*, *3.9400e+02*, *3.9500e+02*, *3.9600e+02*, *3.9700e+02*, *3.9800e+02*, *3.9900e+02*, *4.0000e+02*, *4.0100e+02*, *4.0200e+02*, *4.0300e+02*, *4.0400e+02*, *4.0500e+02*, *4.0600e+02*, *4.0700e+02*, *4.0800e+02*, *4.0900e+02*, *4.1000e+02*, *4.1100e+02*, *4.1200e+02*, *4.1300e+02*, *4.1400e+02*, *4.1500e+02*, *4.1600e+02*, *4.1700e+02*, *4.1800e+02*, *4.1900e+02*, *4.2000e+02*, *4.2100e+02*, *4.2200e+02*, *4.2300e+02*, *4.2400e+02*, *4.2500e+02*, *4.2600e+02*, *4.2700e+02*, *4.2800e+02*, *4.2900e+02*, *4.3000e+02*, *4.3100e+02*, *4.3200e+02*, *4.3300e+02*, *4.3400e+02*, *4.3500e+02*, *4.3600e+02*, *4.3700e+02*, *4.3800e+02*, *4.3900e+02*, *4.4000e+02*, *4.4100e+02*, *4.4200e+02*, *4.4300e+02*, *4.4400e+02*, *4.4500e+02*, *4.4600e+02*, *4.4700e+02*, *4.4800e+02*, *4.4900e+02*, *4.5000e+02*, *4.5100e+02*, *4.5200e+02*, *4.5300e+02*, *4.5400e+02*, *4.5500e+02*, *4.5600e+02*, *4.5700e+02*, *4.5800e+02*, *4.5900e+02*, *4.6000e+02*, *4.6100e+02*, *4.6200e+02*, *4.6300e+02*, *4.6400e+02*, *4.6500e+02*, *4.6600e+02*, *4.6700e+02*, *4.6800e+02*, *4.6900e+02*, *4.7000e+02*, *4.7100e+02*, *4.7200e+02*, *4.7300e+02*, *4.7400e+02*, *4.7500e+02*, *4.7600e+02*, *4.7700e+02*, *4.7800e+02*, *4.7900e+02*, *4.8000e+02*, *4.8100e+02*, *4.8200e+02*, *4.8300e+02*, *4.8400e+02*, *4.8500e+02*, *4.8600e+02*, *4.8700e+02*, *4.8800e+02*, *4.8900e+02*, *4.9000e+02*, *4.9100e+02*, *4.9200e+02*, *4.9300e+02*, *4.9400e+02*, *4.9500e+02*, *4.9600e+02*, *4.9700e+02*, *4.9800e+02*, *4.9900e+02*, *5.0000e+02*, *5.0100e+02*, *5.0200e+02*, *5.0300e+02*, *5.0400e+02*, *5.0500e+02*, *5.0600e+02*, *5.0700e+02*, *5.0800e+02*, *5.0900e+02*, *5.1000e+02*, *5.1100e+02*, *5.1200e+02*, *5.1300e+02*, *5.1400e+02*, *5.1500e+02*, *5.1600e+02*, *5.1700e+02*, *5.1800e+02*, *5.1900e+02*, *5.2000e+02*, *5.2100e+02*, *5.2200e+02*, *5.2300e+02*, *5.2400e+02*, *5.2500e+02*, *5.2600e+02*, *5.2700e+02*, *5.2800e+02*, *5.2900e+02*, *5.3000e+02*, *5.3100e+02*, *5.3200e+02*, *5.3300e+02*, *5.3400e+02*, *5.3500e+02*, *5.3600e+02*, *5.3700e+02*, *5.3800e+02*, *5.3900e+02*, *5.4000e+02*, *5.4100e+02*, *5.4200e+02*, *5.4300e+02*, *5.4400e+02*, *5.4500e+02*, *5.4600e+02*, *5.4700e+02*, *5.4800e+02*, *5.4900e+02*, *5.5000e+02*, *5.5100e+02*, *5.5200e+02*, *5.5300e+02*, *5.5400e+02*, *5.5500e+02*,

Sub-samples a spectral reflectance set by pixelization of color space.

Args:

rfl

ndarray or str

Array with of str referring to a set of spectral reflectance functions to be subsampled.

If str to file: file must contain data as columns, with first column the wavelengths.

rflpath

'' or str, optional

Path to folder with rfl-set specified in a str :rfl: filename.

samplefcn

'rand' or 'mean', optional

-'rand': selects a random sample from the samples within each pixel

-'mean': returns the mean spectral reflectance in each pixel.

S

_CIE_ILLUMINANTS['E'], optional

Illuminant used to calculate the color coordinates of the spectral reflectance samples.

jab_ranges

None or ndarray, optional

Specifies the pixelization of color space. (ndarray.shape = (3,3), with first axis: J,a,b, and second axis: min, max, delta)

jab_deltas

float or ndarray, optional

Specifies the sampling range.

A float uses jab_deltas as the maximum Euclidean distance to select samples around each pixel center. A ndarray of 3 deltas, uses a city block sampling around each pixel center.

cspace

_VF_CSPACE or dict, optional

Specifies color space. See _VF_CSPACE_EXAMPLE for example structure.

cieobs

_VF_CIEOBS or str, optional

Specifies CMF set used to calculate color coordinates.

ax

default ndarray or user defined ndarray, optional

default = np.arange(-_VF_MAXR,_VF_MAXR+_VF_DELTAR,_VF_DELTAR)

bx

default ndarray or user defined ndarray, optional

default = np.arange(-_VF_MAXR,_VF_MAXR+_VF_DELTAR,_VF_DELTAR)

jx

None, optional

Note that not-None :jab_ranges: override :ax:, :bx: and :jx input.

limit_grid_radius

0, optional

A value of zeros keeps grid as specified by axr,bxr.

A value > 0 only keeps (a,b) coordinates within :limit_grid_radius:

Returns:

returns

rflsampled, jabp

ndarrays with resp. the subsampled set of spectral reflectance functions and the pixel coordinate centers.

luxpy.color.cri.VFPX.**plot_VF_PX_models**(*dataVF=None, dataPX=None, plot_VF=True, plot_PX=True, axtype='polar', ax='new', plot_circle_field=True, plot_sample_shifts=False, plot_samples_shifts_at_pixel_center=False, jabp_sampled=None, plot_VF_colors=['g'], plot_PX_colors=['r'], hbin_cmap=None, bin_labels=None, plot_bin_colors=True, force_CVG_layout=False*)

Plot the VF and PX model color shift vectors.

Args:

dataVF

None or list[dict] with VF_colorshift_model() output, optional

None plots nothing related to VF model.

Each list element refers to a different test SPD.

dataPX

None or list[dict] with PX_colorshift_model() output, optional

None plots nothing related to PX model.

Each list element refers to a different test SPD.

plot_VF

True, optional

Plot VF model (if :dataVF: is not None).

plot_PX

True, optional

Plot PX model (if :dataPX: is not None).

axtype

'polar' or 'cart', optional

Make polar or Cartesian plot.

ax

None or 'new' or 'same', optional

- None or 'new' creates new plot
- 'same': continue plot on same axes.
- axes handle: plot on specified axes.

plot_circle_field

True or False, optional

Plot lines showing how a series of circles of color coordinates is distorted by the test SPD.

The width (wider means more) and color (red means more) of the lines specify the intensity of the hue part of the color shift.

plot_sample_shifts

False or True, optional

Plots the shifts of the individual samples of the rfl-set used to calculated the VF model.

plot_samples_shifts_at_pixel_center

False, optional

Offers the possibility of shifting the vector shifts of subsampled sets from the reference illuminant positions to the pixel centers.

Note that the pixel centers must be supplied in :jabp_sampled:.

jabp_sampled

None, ndarray, optional

Corresponding pixel center for each sample in a subsampled set.

plot_VF_colors

['g'] or list[str], optional

Specifies the plot color the color shift vectors of the VF model.

If len(:plot_VF_colors:) == 1: same color for each list element of :dataVF:.

plot_VF_colors

['g'] or list[str], optional

Specifies the plot color the color shift vectors of the VF model.

If len(:plot_VF_colors:) == 1: same color for each list element of :dataVF:.

hbin_cmap

None or colormap, optional

Color map with RGB entries for each of the hue bins specified by the hues in _VF_PCOLORSHIFT.

If None: cmap will be obtained on first run by luxpy.cri.plot_shift_data() and returned for use in other functions

plot_bin_colors

True, optional

Colorize hue-bins.

bin_labels

None or list[str] or '#', optional

Plots labels at the bin center hues.

- None: don't plot.
- list[str]: list with str for each bin.
  (len(:bin_labels:) = :nhbins:)
- '#': plots number.
- '_VF_PCOLORSHIFT': uses the labels in _VF_PCOLORSHIFT['labels']
- 'pcolorshift': uses the labels in dataVF['modeldata']['pcolorshift']['labels']

force_CVG_layout

False or True, optional

True: Force plot of basis of CVG.

Returns:

returns

ax (handle to current axes), cmap (hbin_cmap)

4.4 Classes

py

- __init__.py
- SPD.py

- CDATA.py

namespace luxpy

luxpy.classes.**SPD**
alias of *luxpy.classes.SPD*

luxpy.classes.**CDATA**
alias of *luxpy.classes.CDATA*

4.5 Toolboxes

4.5.1 photbiochem/

py

- __init__.py
- cie_tn003_2015.py
- ASNZS_1680_2_5_1997_COI.py
- circadian_CS_CLa_lrc.py

namespace luxpy.photbiochem

Module for calculating CIE (TN003:2015) photobiological quantities

(Eesc, Eemc, Eelc, Eez, Eer and Esc, Emc, Elc, Ez, Er)

Photoreceptor	Photopigment (label, α)	Spectral efficiency s$\alpha(\lambda)$	Quantity (α-opic irradiance)	Q-symbol (Ee,α)	Unit symbol
s-cone	photopsin (sc)	cyanolabe	cyanopic	Ee,sc	W.m2
m-cone	photopsin (mc)	chlorolabe	chloropic	Ee,mc	W.m2
l-cone	photopsin (lc)	erythrolabe	erythropic	Ee,lc	W.m2
ipRGC	melanopsin (z)	melanopic	melanopic	Ee,z	W.m2
rod	rhodopsin (r)	rhodopic	rhodopic	Ee,r	W.m2

CIE recommends that the α-opic irradiance is determined by convolving the spectral irradiance, Ee,$\lambda(\lambda)$ (Wm2), for each wavelength, with the action spectrum, s$\alpha(\lambda)$, where s$\alpha(\lambda)$ is normalized to one at its peak:

$$\text{Ee},\alpha = \int \text{Ee},\lambda(\lambda)\, s\alpha(\lambda)\, d\lambda$$

where the corresponding units are Wm2 in each case.

The equivalent luminance is calculated as:

$$\text{E},\alpha = \text{Km} \int \text{Ee},\lambda(\lambda)\, s\alpha(\lambda)\, d\lambda \int V(\lambda)\, d\lambda \,/\, \int s\alpha(\lambda)\, d\lambda$$

To avoid ambiguity, the weighting function used must be stated, so, for example, cyanopic refers to the cyanopic irradiance weighted using

the s-cone or ssc(λ) spectral efficiency function.

_PHOTORECEPTORS ['l-cone', 'm-cone','s-cone', 'rod', 'iprgc']

_Ee_SYMBOLS ['Ee,lc','Ee,mc', 'Ee,sc','Ee,r', 'Ee,z']

_E_SYMBOLS ['E,lc','E,mc', 'E,sc','E,r', 'E,z']

_Q_SYMBOLS ['Q,lc','Q,mc', 'Q,sc','Q,r', 'Q,z']

_Ee_UNITS ['Wm2'] * 5

_E_UNITS ['lux'] * 5

_Q_UNITS ['photons/m2/s'] * 5

_QUANTITIES

list with actinic types of irradiance, illuminance
['erythropic',
'chloropic',
'cyanopic',
'rhodopic',
'melanopic']

_ACTIONSPECTRA ndarray with alpha-actinic action spectra. (stored in file: './data/cie_tn003_2015_SI_action_spectra.dat')

spd_to_aopicE() Calculate alpha-opic irradiance (Ee,α) and equivalent luminance (Eα) values for the l-cone, m-cone, s-cone, rod and iprgc (α) photoreceptor cells following CIE technical note TN 003:2015.

References: 1. CIE-TN003:2015 (2015). Report on the first international workshop on circadian and neurophysiological photometry, 2013 (Vienna, Austria). (http://files.cie.co.at/785_CIE_TN_003-2015.pdf)

Module for calculation of cyanosis index (AS/NZS 1680.2.5:1997)

_COI_OBS Default CMF set for calculations

_COI_CSPACE Default color space (CIELAB)

_COI_RFL_BLOOD ndarray with reflectance spectra of 100% and 50% oxygenated blood

spd_to_COI_ASNZS1680 Calculate the Cyanosis Observartion Index (COI) [ASNZS 1680.2.5-1995]

Reference: AS/NZS1680.2.5 (1997). INTERIOR LIGHTING PART 2.5: HOSPITAL AND MEDICAL TASKS.

`luxpy.toolboxes.photbiochem.`**`spd_to_aopicE`**(*sid*, *Ee=None*, *E=None*, *Q=None*, *cieobs='1931_2'*, *sid_units='W/m2'*, *out='Eeas, Eas'*)

Calculate alpha-opic irradiance (Ee,α) and equivalent luminance (Eα) values for the l-cone, m-cone, s-cone, rod and iprgc (α) photoreceptor cells following CIE technical note TN 003:2015.

Args:

sid

numpy.ndarray with retinal spectral irradiance in :sid_units:
(if 'uW/cm2', sid will be converted to SI units 'W/m2')

Ee

None, optional

If not None: normalize :sid: to an irradiance of :Ee:

E

None, optional
If not None: normalize :sid: to an illuminance of :E:

Q

None, optional
If not None: nNormalize :sid: to a quantal energy of :Q:

cieobs

_CIEOBS or str, optional
Type of cmf set to use for photometric units.

sid_units

'W/m2', optional
Other option 'uW/m2', input units of :sid:

out

'Eeas, Eas' or str, optional
Determines values to return.

Returns:

returns

(Eeas, Eas) with Eeas and Eas resp. numpy.ndarrays with the α-opic irradiance and equivalent illuminance values of all spectra in :sid: in SI-units.

(other choice can be set using :out:)

luxpy.toolboxes.photbiochem.**spd_to_COI_ASNZS1680**(*S=None*, *tf='lab'*, *cieobs='1931_2'*, *out='COI, cct'*, *extrapolate_rfl=False*)

Calculate the Cyanosis Observation Index (COI) [ASNZS 1680.2.5-1995].

Args:

S

ndarray with light source spectrum (first column are wavelengths).

tf

_COI_CSPACE, optional
Color space in which to calculate the COI.
Default is CIELAB.

cieobs

_COI_CIEOBS, optional
CMF set to use.
Default is '1931_2'.

out

'COI,cct' or str, optional
Determines output.

extrapolate_rfl

False, optional
If False:
limit the wavelength range of the source to that of the standard reflectance spectra for the 50% and 100% oxygenated blood.

Returns:

COI

ndarray with cyanosis indices for input sources.

cct

ndarray with correlated color temperatures.

Note: Clause 7.2 of the ASNZS 1680.2.5-1995. standard mentions the properties demanded of the light source used in region where visual conditions suitable to the detection of cyanosis should be provided:

1. The correlated color temperature (CCT) of the source should be from 3300 to 5300 K.
2. The cyanosis observation index should not exceed 3.3

`luxpy.toolboxes.photbiochem.`**`spd_to_CS_CLa_lrc`**(*El=None*, *E=None*, *sum_sources=False*, *interpolate_sources=True*)

Calculate Circadian Stimulus (CS) and Circadian Light [LRC: Rea et al 2012].

Args:

El

ndarray, optional

Defaults to D65

light source spectral irradiance distribution

E

None, float or ndarray, optional

Illuminance of light sources.

If None: El is used as is, otherwise El is renormalized to have an illuminance equal to E.

sum_sources

False, optional

- False: calculate CS and CLa for all sources in El array.
- True: sum sources in El to a single source and perform calc.

interpolate_sources

True, optional

- True: El is interpolated to wavelength range of efficiency functions (as in LRC calculator).
- False: interpolate efficiency functions to source range. Source interpolation is not recommended due to possible errors for peaky spectra. (see CIE15-2004, "Colorimetry").

Returns:

CS

ndarray with Circadian stimulus values

CLa

ndarray with Circadian Light values

Notes: 1. The original 2012 (E.q. 1) had set the peak wavelength of the melanopsin at 480 nm. Rea et al. later published a corrigendum with updated model parameters for k, a_{b-y} and a_rod. The comparison table between showing values calculated for a number of sources with the old and updated parameters were very close (~1 unit voor CLa).

2. In that corrrection paper they did not mention a change in the factor (1622) that multiplies the (sum of) the integral(s) in Eq. 1. HOWEVER, the excel calculator released in 2017 and the online calculator show that factor to have a value of 1547.9. The change in values due to the new factor is much larger than their the updated mentioned in note 1!

3. For reasons of consistency the calculator uses the latest model parameters, as could be read from the excel calculator. They values adopted are: multiplier 1547.9, k = 0.2616, a_{b-y} = 0.7 and a_rod = 3.3.

4. The parameter values to convert CLa to CS were also taken from the 2017 excel calculator.

References:

1. LRC Online Circadian stimulus calculator
2. LRC Excel based Circadian stimulus calculator.

3. Rea MS, Figueiro MG, Bierman A, and Hamner R (2012). Modelling the spectral sensitivity of the human circadian system. Light. Res. Technol. 44, 386–396.

4. Rea MS, Figueiro MG, Bierman A, and Hamner R (2012). Erratum: Modeling the spectral sensitivity of the human circadian system (Lighting Research and Technology (2012) 44:4 (386-396) DOI: 10.1177/1477153511430474)). Light. Res. Technol. 44, 516.

4.5.2 indvcmf/

py

- __init__.py
- individual_observer_cmf_model.py

namespace luxpy.indvcmf

Module for Individual Observer lms-CMFs (Asano, 2016)

_INDVCMF_DATA_PATH path to data files

_INDVCMF_DATA Dict with required data

_INDVCMF_STD_DEV_ALL_PARAM Dict with std. dev. model parameters

_INDVCMF_CATOBSPFCTR Categorical observer parameters.

_INDVCMF_M_10d xyz to 10° lms conversion matrix.

_WL_CRIT critical wavelength above which interpolation of S-cone data fails.

_WL wavelengths of spectral data.

cie2006cmfsEx() Generate Individual Observer CMFs (cone fundamentals) based on CIE2006 cone fundamentals and published literature on observer variability in color matching and in physiological parameters.

getMonteCarloParam() Get dict with normally-distributed physiological factors for a population of observers.

getUSCensusAgeDist() Get US Census Age Distribution

genMonteCarloObs() Monte-Carlo generation of individual observer color matching functions (cone fundamentals) for a certain age and field size.

getCatObs() Generate cone fundamentals for categorical observers.

get_lms_to_xyz_matrix() Calculate lms to xyz conversion matrix for a specific field size.

lmsb_to_xyzb() Convert from LMS cone fundamentals to XYZ CMF.

add_to_cmf_dict() Add set of cmfs to _CMF dict.

References

1. Asano Y, Fairchild MD, and Blondé L (2016). Individual Colorimetric Observer Model. PLoS One 11, 1–19.

2. Asano Y, Fairchild MD, Blondé L, and Morvan P (2016). Color matching experiment for highlighting interobserver variability. Color Res. Appl. 41, 530–539.

3. CIE, and CIE (2006). Fundamental Chromaticity Diagram with Physiological Axes - Part I (Vienna: CIE).

4. Asano's Individual Colorimetric Observer Model

Note

Port of Matlab code from: https://www.rit.edu/cos/colorscience/re_AsanoObserverFunctions.php (Accessed April 20, 2018)

`luxpy.toolboxes.indvcmf.`**`cie2006cmfsEx`**(*age=32*, *fieldsize=10*, *wl=None*, *var_od_lens=0*, *var_od_macula=0*, *var_od_L=0*, *var_od_M=0*, *var_od_S=0*, *var_shft_L=0*, *var_shft_M=0*, *var_shft_S=0*, *out='LMS'*, *allow_negative_values=False*)

Generate Individual Observer CMFs (cone fundamentals) based on CIE2006 cone fundamentals and published literature on observer variability in color matching and in physiological parameters.

Args:

age

32 or float or int, optional

Observer age

fieldsize

10, optional

Field size of stimulus in degrees (between 2° and 10°).

wl

None, optional

Interpolation/extraplation of :LMS: output to specified wavelengths.

None: output original _WL = np.array([390,780,5])

var_od_lens

0, optional

Std Dev. in peak optical density [%] of lens.

var_od_macula

0, optional

Std Dev. in peak optical density [%] of macula.

var_od_L

0, optional

Std Dev. in peak optical density [%] of L-cone.

var_od_M

0, optional

Std Dev. in peak optical density [%] of M-cone.

var_od_S

0, optional

Std Dev. in peak optical density [%] of S-cone.

var_shft_L

0, optional

Std Dev. in peak wavelength shift [nm] of L-cone.

var_shft_L

0, optional

Std Dev. in peak wavelength shift [nm] of M-cone.

var_shft_S

0, optional

Std Dev. in peak wavelength shift [nm] of S-cone.

out

'LMS' or , optional

Determines output.

allow_negative_values

False, optional

Cone fundamentals or color matching functions should not have negative values.

If False: X[X<0] = 0.

Returns:

returns

- 'LMS' : ndarray with individual observer area-normalized
  cone fundamentals. Wavelength have been added.

[- 'trans_lens': ndarray with lens transmission
  (no wavelengths added, no interpolation)
- 'trans_macula': ndarray with macula transmission
  (no wavelengths added, no interpolation)
- 'sens_photopig' : ndarray with photopigment sens.
  (no wavelengths added, no interpolation)]

References: 1. Asano Y, Fairchild MD, and Blondé L (2016). Individual Colorimetric Observer Model. PLoS One 11, 1–19.

2. Asano Y, Fairchild MD, Blondé L, and Morvan P (2016). Color matching experiment for highlighting interobserver variability. Color Res. Appl. 41, 530–539.

3. CIE, and CIE (2006). Fundamental Chromaticity Diagram with Physiological Axes - Part I (Vienna: CIE).

4. Asano's Individual Colorimetric Observer Model

luxpy.toolboxes.indvcmf.**getMonteCarloParam**(*n_obs=1*, *stdDevAllParam={'od_L': 17.9, 'od_M': 17.9, 'od_S': 14.7, 'od_lens': 19.1, 'od_macula': 37.2, 'shft_L': 4.0, 'shft_M': 3.0, 'shft_S': 2.5}*)

Get dict with normally-distributed physiological factors for a population of observers.

Args:

n_obs

1, optional

Number of individual observers in population.

stdDevAllParam

_INDVCMF_STD_DEV_ALL_PARAM, optional
Dict with parameters for:
['od_lens', 'od_macula',
'od_L', 'od_M', 'od_S',
'shft_L', 'shft_M', 'shft_S']

Returns:

returns

dict with n_obs randomly drawn parameters.

luxpy.toolboxes.indvcmf.**genMonteCarloObs**(*n_obs=1, fieldsize=10, list_Age=[32], out='LMS', wl=None, allow_negative_values=False*)

Monte-Carlo generation of individual observer cone fundamentals.

Args:

n_obs

1, optional
Number of observer CMFs to generate.

list_Age

list of observer ages or str, optional
Defaults to 32 (cfr. CIE2006 CMFs)
If 'us_census': use US population census of 2010 to generate list_Age.

fieldsize

fieldsize in degrees (between 2° and 10°), optional
Defaults to 10°.

out

'LMS' or str, optional
Determines output.

wl

None, optional
Interpolation/extraplation of :LMS: output to specified wavelengths.
None: output original _WL = np.array([390,780,5])

allow_negative_values

False, optional
Cone fundamentals or color matching functions
should not have negative values.
If False: X[X<0] = 0.

Returns:

returns

LMS [,var_age, vAll]
- LMS: ndarray with population LMS functions.
- var_age: ndarray with population observer ages.
- vAll: dict with population physiological factors (see .keys())

References: 1. Asano Y, Fairchild MD, and Blondé L (2016). Individual Colorimetric Observer Model. PLoS One 11, 1–19.

2. Asano Y, Fairchild MD, Blondé L, and Morvan P (2016). Color matching experiment for highlighting interobserver variability. Color Res. Appl. 41, 530–539.

3. CIE, and CIE (2006). Fundamental Chromaticity Diagram with Physiological Axes - Part I (Vienna: CIE).

4. Asano's Individual Colorimetric Observer Model

luxpy.toolboxes.indvcmf.**getCatObs**(*n_cat=10*, *fieldsize=2*, *out='LMS'*, *wl=None*, *allow_negative_values=False*)

Generate cone fundamentals for categorical observers.

Args:

n_cat

10, optional
Number of observer CMFs to generate.

fieldsize

fieldsize in degrees (between 2° and 10°), optional
Defaults to 10°.

out

'LMS' or str, optional
Determines output.

wl

None, optional
Interpolation/extraplation of :LMS: output to specified wavelengths.
None: output original _WL = np.array([390,780,5])

allow_negative_values

False, optional
Cone fundamentals or color matching functions
should not have negative values.
If False: X[X<0] = 0.

Returns:

returns

LMS [,var_age, vAll]
- LMS: ndarray with population LMS functions.
- var_age: ndarray with population observer ages.
- vAll: dict with population physiological factors (see .keys())

Notes: 1. Categorical observers are observer functions that would represent color-normal populations. They are finite and discrete as opposed to observer functions generated from the individual colorimetric observer model. Thus, they would offer more convenient and practical approaches for the personalized color imaging workflow and color matching analyses. Categorical observers were derived in two steps. At the first step, 10000 observer functions were generated from the individual colorimetric observer model using Monte Carlo simulation. At the second step, the cluster analysis, a modified k-medoids algorithm, was applied to the 10000 observers minimizing the squared Euclidean distance in cone fundamentals space, and categorical observers were derived iteratively. Since the proposed categorical observers are defined by their physiological parameters and ages, their CMFs can be derived for any target field size.

2. Categorical observers were ordered by the importance; the first categorical observer vas the average observer equivalent to CIEPO06 with 38 year-old for a given field size, followed by the second most important categorical observer, the third, and so on.

3. see: https://www.rit.edu/cos/colorscience/re_AsanoObserverFunctions.php

4.5.3 spdbuild/

py

- __init__.py
- spdbuilder.py

namespace luxpy.spdbuild/

Module for building and optimizing SPDs

gaussian_spd() Generate Gaussian spectrum.

butterworth_spd() Generate Butterworth based spectrum.

mono_led_spd() Generate monochromatic LED spectrum based on a Gaussian or butterworth profile or according to Ohno (Opt. Eng. 2005).

spd_builder() Build spectrum based on Gaussians, monochromatic and/or phophor LED spectra.

color3mixer() Calculate fluxes required to obtain a target chromaticity when (additively) mixing 3 light sources.

colormixer() Calculate fluxes required to obtain a target chromaticity when (additively) mixing N light sources.

spd_builder() Build spectrum based on Gaussians, monochromatic and/or phophor LED-type spectra.

get_w_summed_spd() Calculate weighted sum of spds.

fitnessfcn() Fitness function that calculates closeness of solution x to target values for specified objective functions.

spd_constructor_2() Construct spd from spectral model parameters using pairs of intermediate sources.

spd_constructor_3() Construct spd from spectral model parameters using trio's of intermediate sources.

spd_optimizer_2_3() Optimizes the weights (fluxes) of a set of component spectra by combining pairs (2) or trio's (3) of components to intermediate sources until only 3 remain. Color3mixer can then be called to calculate required fluxes to obtain target chromaticity and fluxes are then back-calculated.

get_optim_pars_dict() Setup dict with optimization parameters.

initialize_spd_model_pars() Initialize spd_model_pars (for spd_constructor) based on type of component_data.

initialize_spd_optim_pars() Initialize spd_optim_pars (x0, lb, ub for use with math.minimizebnd) based on type of component_data.

spd_optimizer() Generate a spectrum with specified white point and optimized for certain objective functions from a set of component spectra or component spectrum model parameters.

`luxpy.toolboxes.spdbuild.`**`gaussian_spd`**(*peakwl=530, fwhm=20, wl=[360.0, 830.0, 1.0], with_wl=True*)

Generate Gaussian spectrum.
Args:

peakw

int or float or list or ndarray, optional

Peak wavelength

fwhm

int or float or list or ndarray, optional

Full-Width-Half-Maximum of gaussian.

wl

_WL3, optional

Wavelength range.

with_wl

True, optional

True outputs a ndarray with first row wavelengths.

Returns:

returns

ndarray with spectra.

`luxpy.toolboxes.spdbuild.`**`mono_led_spd`**(*peakwl=530, fwhm=20, wl=[360.0, 830.0, 1.0], with_wl=True, strength_shoulder=2, bw_order=-1*)

Generate monochromatic LED spectrum based on a Gaussian or butterworth profile or according to Ohno (Opt. Eng. 2005).

Args:

peakw

int or float or list or ndarray, optional

Peak wavelength

fwhm

int or float or list or ndarray, optional

Full-Width-Half-Maximum of gaussian used to simulate led.

wl

_WL3, optional

Wavelength range.

with_wl

True, optional

True outputs a ndarray with first row wavelengths.

strength_shoulder

2, optional

Determines the strength of the spectrum shoulders of the mono led.

A value of 1 reduces to a Gaussian model (if bw_order == 0).

bw_order

-1, optional

Order of Butterworth function.

If -1: spd profile is Gaussian.

If (bw_order == 0): spd profile is Gaussian, else Butterworth.

Returns:

returns

ndarray with spectra.

Note:

Gaussian:
g = exp(-0.5*((wl - peakwl)/fwhm)**2)

Butterworth :
bw = 2 / (1 + (((wl - peakwl)/fwhm)**2))

Ohno's model:
ohno = (g + strength_shoulder*g**5)/(1+strength_shoulder)

mono_led_spd = ohno*(bw_order == 0) + bw*(bw_order > 0)

Reference: 1. Ohno Y (2005). Spectral design considerations for white LED color rendering. Opt. Eng. 44, 111302.

luxpy.toolboxes.spdbuild.**phosphor_led_spd**(*peakwl=450, fwhm=20, wl=[360.0, 830.0, 1.0], bw_order=-1, with_wl=True, strength_shoulder=2, strength_ph=0, peakwl_ph1=530, fwhm_ph1=80, strength_ph1=1, peakwl_ph2=560, fwhm_ph2=80, strength_ph2=None, use_piecewise_fcn=False, verbosity=0, out='spd'*)

Generate phosphor LED spectrum with up to 2 phosphors based on Smet (Opt. Expr. 2011).

Model:
1) If strength_ph2 is not None:
phosphor_spd = (strength_ph1*mono_led_spd(peakwl_ph1, . . . , strength_shoulder = 1)
+ strength_ph2)*mono_led_spd(peakwl_ph2, . . . , strength_shoulder = 1))
/ (strength_ph1 + strength_ph2)
else:
phosphor_spd = (strength_ph1*mono_led_spd(peakwl_ph1, . . . , strength_shoulder = 1)
+ (1-strength_ph1)*mono_led_spd(peakwl_ph2, . . . , strength_shoulder = 1))

2) S = (mono_led_spd() + strength_ph*(phosphor_spd/phosphor_spd.max()))/(1 + strength_ph)

3) piecewise_fcn = S for wl < peakwl and 1 for wl >= peakwl

4) phosphor_led_spd = S*piecewise_fcn

Args:

peakw

int or float or list or ndarray, optional
Peak wavelengths of the monochromatic led.

fwhm

int or float or list or ndarray, optional
Full-Width-Half-Maximum of gaussian.

wl

_WL3, optional
Wavelength range.

bw_order

-1, optional
Order of Butterworth function.
If -1: mono_led spd profile is Gaussian.
else: (bw_order == 0): spd profile is Gaussian, else Butterworth.
Note that this only applies to the monochromatic led spds and not
the phosphors spds (these are always gaussian based).

with_wl

True, optional
True outputs a ndarray with first row wavelengths.

strength_shoulder

2, optiona l
Determines the strength of the spectrum shoulders of the mono led.

strength_ph

0, optional
Total contribution of phosphors in mixture.

peakwl_ph1

int or float or list or ndarray, optional
Peak wavelength of the first phosphor.

fwhm_ph1

int or float or list or ndarray, optional
Full-Width-Half-Maximum of gaussian used to simulate first phosphor.

strength_ph1

1, optional
Strength of first phosphor in phosphor mixture.
If :strength_ph2: is None: value should be in the [0,1] range.

peakwl_ph2

int or float or list or ndarray, optional
Peak wavelength of the second phosphor.

fwhm_ph2

int or float or list or ndarray, optional
Full-Width-Half-Maximum of gaussian used to simulate second phosphor.

strength_ph2

None, optional
Strength of second phosphor in phosphor mixture.
If None: strength is calculated as (1-:strength_ph1:)
:target: np2d([100,1/3,1/3]), optional
ndarray with Yxy chromaticity of target.

verbosity

0, optional
If > 0: plots spectrum components (mono_led, ph1, ph2, . . .)

out

'spd', optional
Specifies output.

use_piecewise_fcn

False, optional

True: uses piece-wise function as in Smet et al. 2011. Can give non_smooth spectra optimized from components to which it is applied.

Returns:

returns

spd, component_spds

ndarrays with spectra (and component spds used to build the final spectra)

References: 1. Ohno Y (2005). Spectral design considerations for white LED color rendering. Opt. Eng. 44, 111302.

2. Smet K, Ryckaert WR, Pointer MR, Deconinck G, and Hanselaer P (2011). Optimal colour quality of LED clusters based on memory colours. Opt. Express 19, 6903–6912.

luxpy.toolboxes.spdbuild.**spd_builder**(*flux=None, component_spds=None, peakwl=450, fwhm=20, bw_order=-1, pair_strengths=None, wl=[360.0, 830.0, 1.0], with_wl=True, strength_shoulder=2, strength_ph=0, peakwl_ph1=530, fwhm_ph1=80, strength_ph1=1, peakwl_ph2=560, fwhm_ph2=80, strength_ph2=None, target=None, tar_type='Yuv', cspace_bwtf={}, cieobs='1931_2', use_piecewise_fcn=False, verbosity=0, out='spd', **kwargs*)

Build spectrum based on Gaussian, monochromatic and/or phophor type spectra.

Args:

flux

None, optional

Fluxes of each of the component spectra.

None outputs the individual component spectra.

component_spds

None or ndarray, optional

If None: calculate component spds from input args.

peakw

int or float or list or ndarray, optional

Peak wavelengths of the monochromatic led.

fwhm

int or float or list or ndarray, optional

Full-Width-Half-Maximum of gaussian.

wl

_WL3, optional

Wavelength range.

bw_order

-1, optional

Order of Butterworth function.

If -1: mono_led spd profile is Gaussian.

else: (bw_order == 0): spd profile is Gaussian, else Butterworth.

Note that this only applies to the monochromatic led spds and not the phosphors spds (these are always gaussian based).

pair_strengths

ndarray with pair_strengths of mono_led spds, optional

If None: will be randomly selected, possibly resulting in unphysical (out-of-gamut) solution.

with_wl

True, optional

True outputs a ndarray with first row wavelengths.

strength_shoulder

2, optiona l

Determines the strength of the spectrum shoulders of the mono led.

strength_ph

0, optional

Total contribution of phosphors in mixture.

peakwl_ph1

int or float or list or ndarray, optional

Peak wavelength of the first phosphor.

fwhm_ph1

int or float or list or ndarray, optional

Full-Width-Half-Maximum of gaussian used to simulate first phosphor.

strength_ph1

1, optional

Strength of first phosphor in phosphor mixture.

If :strength_ph2: is None: value should be in the [0,1] range.

peakwl_ph2

int or float or list or ndarray, optional

Peak wavelength of the second phosphor.

fwhm_ph2

int or float or list or ndarray, optional

Full-Width-Half-Maximum of gaussian used to simulate second phosphor.

strength_ph2

None, optional

Strength of second phosphor in phosphor mixture.

If None: strength is calculated as (1-:strength_ph1:)

:target: np2d([100,1/3,1/3]), optional

ndarray with Yxy chromaticity of target.

verbosity

0, optional

If > 0: plots spectrum components (mono_led, ph1, ph2, . . .)

out

'spd', optional

Specifies output.

use_piecewise_fcn

False, optional

True: uses piece-wise function as in Smet et al. 2011. Can give non_smooth spectra optimized from components to which it is applied.

target

None, optional

ndarray with Yxy chromaticity of target.
If None: don't override phosphor strengths, else calculate strength
to obtain :target: using color3mixer().
If not None AND strength_ph is None or 0: components are monochromatic and colormixer is used to optimize fluxes to obtain target chromaticity (N can be > 3 components)

tar_type

'Yxy' or str, optional
Specifies the input type in :target: (e.g. 'Yxy' or 'cct')

cieobs

_CIEOBS, optional
CIE CMF set used to calculate chromaticity values.

cspace_bwtf

{}, optional
Backward (. . . _to_xyz) transform parameters
(see colortf()) to go from :tar_type: to 'Yxy')

Returns:

returns

ndarray with spectra.

Note: 1. Target-optimization is only for phophor_leds with three components (blue pump, ph1 and ph2) spanning a sufficiently large gamut.

References: 1. Ohno Y (2005). Spectral design considerations for white LED color rendering. Opt. Eng. 44, 111302.

2. Smet K, Ryckaert WR, Pointer MR, Deconinck G, and Hanselaer P (2011). Optimal colour quality of LED clusters based on memory colours. Opt. Express 19, 6903–6912.

luxpy.toolboxes.spdbuild.**get_w_summed_spd**(*w*, *spds*)

Calculate weighted sum of spds.

Args:

w

ndarray with weigths (e.g. fluxes)

spds

ndarray with component spds.

Returns:

returns

ndarray with weighted sum.

luxpy.toolboxes.spdbuild.**fitnessfcn**(*x, spd_constructor, spd_constructor_pars=None, F_rss=True, decimals=[3], obj_fcn=[None], obj_fcn_pars=[{}], obj_fcn_weights=[1], obj_tar_vals=[0], verbosity=0, out='F'*)

Fitness function that calculates closeness of solution x to target values for specified objective functions.

Args:

x

ndarray with parameter values

spd_constructor

function handle to a function that constructs the spd from parameter values in :x:.

spd_constructor_pars

None, optional,

Parameters required by :spd_constructor:

F_rss

True, optional

Take Root-Sum-of-Squares of 'closeness' values between target and objective function values.

decimals

3, optional

Rounding decimals of objective function values.

obj_fcn

[None] or list, optional

Function handles to objective function.

obj_fcn_weights

[1] or list, optional.

Weigths for each obj. fcn

obj_fcn_pars

[None] or list, optional

Parameter dicts for each obj. fcn.

obj_tar_vals

[0] or list, optional

Target values for each objective function.

verbosity

0, optional

If > 0: print intermediate results.

out

'F', optional

Determines output.

Returns:

F

float or ndarray with fitness value for current solution :x:.

luxpy.toolboxes.spdbuild.**spd_constructor_2**(*x*, *constructor_pars={}*, ***kwargs*)

Construct spd from model parameters using pairs of intermediate sources.

Pairs (odd,even) of components are selected and combined using 'pair_strength'. This process is continued until only 3 intermediate (combined) sources remain. Color3mixer is then used to calculate the fluxes for the remaining 3 sources, after which the fluxes of all components are back-calculated.

Args:

x

vector of optimization parameters.

constructor_pars

dict with model parameters.

Key 'list' determines which parameters are in :x: and key 'len' (Specifies the number of variables representing each parameter).

Returns:

returns

spd, M, spds
ndarrays with spectrum corresponding to x, M the fluxes of the spectral components of spd and spds the spectral components themselves.

luxpy.toolboxes.spdbuild.**spd_constructor_3**(*x*, *constructor_pars={}*, ***kwargs*)
Construct spd from model parameters using trio's of intermediate sources.

The triangle/trio method creates for all possible combinations of 3 primary component spectra a spectrum that results in the target chromaticity using color3mixer() and then optimizes the weights of each of the latter spectra such that adding them (additive mixing) results in obj_vals as close as possible to the target values.

Args:

x

vector of optimization parameters.

constructor_pars

dict with model parameters.
Key 'list' determines which parameters are in :x: and key 'len' (specifies the number of variables representing each parameter).

Returns:

returns

spd, M, spds
ndarrays with spectrum corresponding to x, M the fluxes of the spectral components of spd and spds the spectral components themselves.

luxpy.toolboxes.spdbuild.**spd_optimizer_2_3**(*optimizer_type='2mixer'*, *spd_constructor=None*, *spd_model_pars=None*, *component_data=4*, *N_components=None*, *wl=[360.0, 830.0, 1.0]*, *allow_butterworth_mono_spds=False*, *Yxy_target=array([[1.0000e+02, 3.3333e-01, 3.3333e-01]])*, *cieobs='1931_2'*, *obj_fcn=[None]*, *obj_fcn_pars=[{}]*, *obj_fcn_weights=[1]*, *obj_tar_vals=[0]*, *decimals=[5]*, *minimize_method='nelder-mead'*, *minimize_opts=None*, *F_rss=True*, *verbosity=0*, ***kwargs*)
Optimizes the weights (fluxes) of a set of component spectra by combining pairs (2) or trio's (3) of components to intermediate sources until only 3 remain. Color3mixer can then be called to calculate required fluxes to obtain target chromaticity and fluxes are then back-calculated.

Args:

optimizer_type

'2mixer' or '3mixer' or 'user', optional
Specifies whether to optimize spectral model parameters by combining pairs or trio's of comonponents.

spd_constructor

None, optional
Function handle to user defined spd_constructor function.
Input: fcn(x, constructor_pars = {}, kwargs)
Output: spd,M,spds
nd array with:

- spd: spectrum resulting from x
- M: fluxes of all component spds
- spds: component spds (in [N+1,wl] format)

(See e.g. spd_constructor_2 or spd_constructor_3)

spd_model_pars

dict with model parameters required by spd_constructor and with optimization parameters required by minimize (x0, lb, ub). .

Only used when :optimizer_type: == 'user'.

component_data

4, optional

Component spectra data:

If int: specifies number of components used in optimization
(peakwl, fwhm and pair_strengths will be optimized).

If dict: generate components based on parameters (peakwl, fwhm, pair_strengths, etc.) in dict.
(keys with None values will be optimized)

If ndarray: optimize pair_strengths of component spectra.

N_components

None, optional

Specifies number of components used in optimization. (only used when :component_data: is dict and user wants to override dict.

Note that shape of parameters arrays must match N_components).

allow_butterworth_mono_spds

False, optional

False: use pure Gaussian based monochrom. spds.

wl

_WL3, optional

Wavelengths used in optimization when :component_data: is not ndarray with spectral data.

Yxy_target

np2d([100,1/3,1/3]), optional

ndarray with Yxy chromaticity of target.

cieobs

_CIEOBS, optional

CIE CMF set used to calculate chromaticity values if not provided in :Yxyi:.

F_rss

True, optional

Take Root-Sum-of-Squares of 'closeness' values between target and objective function values.

decimals

5, optional

Rounding decimals of objective function values.

obj_fcn

[None] or list, optional

Function handles to objective function.

obj_fcn_weights

[1] or list, optional.
Weigths for each obj. fcn

obj_fcn_pars

[None] or list, optional
Parameter dicts for each obj. fcn.

obj_tar_vals

[0] or list, optional
Target values for each objective function.

minimize_method

'nelder-mead', optional
Optimization method used by minimize function.

minimize_opts

None, optional
Dict with minimization options.
None defaults to: {'xtol': 1e-5, 'disp': True, 'maxiter': 1000*Nc,
'maxfev' : 1000*Nc,'fatol': 0.01}

verbosity

0, optional
If > 0: print intermediate results.

Returns:

returns

M, spd_opt, obj_vals
- 'M': ndarray with fluxes for each component spectrum.
- 'spd_opt': optimized spectrum.
- 'obj_vals': values of the obj. fcns for the optimized spectrum.

luxpy.toolboxes.spdbuild.**get_optim_pars_dict**(*target=array([[1.0000e+02, 3.3333e-01, 3.3333e-01]]), tar_type='Yxy', cieobs='1931_2', optimizer_type='2mixer', spd_constructor=None, spd_model_pars=None, cspace='Yuv', cspace_bwtf={}, cspace_fwtf={}, component_spds=None, N_components=None, obj_fcn=[None], obj_fcn_pars=[{}], obj_fcn_weights=[1], obj_tar_vals=[0], decimals=[5], minimize_method='nelder-mead', minimize_opts=None, F_rss=True, peakwl=[450, 530, 610], fwhm=[20, 20, 20], allow_butterworth_mono_spds=False, bw_order=[-1], wl=[360.0, 830.0, 1.0], with_wl=True, strength_shoulder=2, strength_ph=[0], use_piecewise_fcn=False, peakwl_ph1=[530], fwhm_ph1=[80], strength_ph1=[1], peakwl_ph2=[560], fwhm_ph2=[80], strength_ph2=None, verbosity=0, pair_strengths=None, triangle_strengths=None, peakwl_min=[400], peakwl_max=[700], fwhm_min=[5], fwhm_max=[300], bw_order_min=[0], bw_order_max=[100]*)

Setup dict with optimization parameters.

Args: See ?spd_optimizer for more info.

Returns:

opts

dict with keys and values of the function's keywords and values.

luxpy.toolboxes.spdbuild.**initialize_spd_model_pars**(*component_data, N_components=None, allow_butterworth_mono_spds=False, optimizer_type='2mixer', wl=[360.0, 830.0, 1.0]*)

Initialize spd_model_pars dict (for spd_constructor) based on type of component_data.

Args:

component_data

None, optional

Component spectra data:

If int: specifies number of components used in optimization
(peakwl, fwhm and pair_strengths will be optimized).

If dict: generate components based on parameters (peakwl, fwhm,
pair_strengths, etc.) in dict.
(keys with None values will be optimized)

If ndarray: optimize pair_strengths of component spectra.

N_components

None, optional

Specifies number of components used in optimization. (only used when :component_data: is dict and user wants to override dict.

Note that shape of parameters arrays must match N_components).

allow_butterworth_mono_spds

False, optional

- False: use pure Gaussian based monochrom. spds.
- True: also allow butterworth type monochrom. spds while optimizing.

optimizer_type

'2mixer', optional

Type of spectral optimization routine.

(other options: '3mixer', 'search')

wl

_WL3, optional

Wavelengths used in optimization when :component_data: is not an ndarray with spectral data.

Returns:

spd_model_pars

dict with spectrum-model parameters

luxpy.toolboxes.spdbuild.**initialize_spd_optim_pars**(*component_data, N_components=None, allow_butterworth_mono_spds=False, optimizer_type='2mixer', wl=[360.0, 830.0, 1.0]*)

Initialize spd_optim_pars dict based on type of component_data.

Args:

component_data

None, optional

Component spectra data:

If int: specifies number of components used in optimization
(peakwl, fwhm and pair_strengths will be optimized).

If dict: generate components based on parameters (peakwl, fwhm,
pair_strengths, etc.) in dict.
(keys with None values will be optimized)

If ndarray: optimize pair_strengths of component spectra.

N_components

None, optional

Specifies number of components used in optimization. (only used when :component_data: is dict and user wants to override dict.

Note that shape of parameters arrays must match N_components).

allow_butterworth_mono_spds

False, optional

False: use pure Gaussian based monochrom. spds.

optimizer_type

'2mixer', optional

Type of spectral optimization routine. (other options: '3mixer', 'search')

wl

_WL3, optional

Wavelengths used in optimization when :component_data: is not an ndarray with spectral data.

Returns:

spd_optim_pars

dict with optimization parameters (x0, ub, lb)

luxpy.toolboxes.spdbuild.**spd_optimizer**(*target=array([[1.0000e+02, 3.3333e-01, 3.3333e-01]]), tar_type='Yxy', cieobs='1931_2', optimizer_type='2mixer', spd_constructor=None, spd_model_pars=None, cspace='Yuv', cspace_bwtf={}, cspace_fwtf={}, component_spds=None, N_components=None, obj_fcn=[None], obj_fcn_pars=[{}], obj_fcn_weights=[1], obj_tar_vals=[0], decimals=[5], minimize_method='nelder-mead', minimize_opts=None, F_rss=True, peakwl=[450, 530, 610], fwhm=[20, 20, 20], allow_butterworth_mono_spds=False, bw_order=[-1], wl=[360.0, 830.0, 1.0], with_wl=True, strength_shoulder=2, strength_ph=[0], use_piecewise_fcn=False, peakwl_ph1=[530], fwhm_ph1=[80], strength_ph1=[1], peakwl_ph2=[560], fwhm_ph2=[80], strength_ph2=None, verbosity=0, pair_strengths=None, peakwl_min=[400], peakwl_max=[700], fwhm_min=[5], fwhm_max=[300], bw_order_min=0, bw_order_max=100*)

Generate a spectrum with specified white point and optimized for certain objective functions from a set of component spectra or component spectrum model parameters.

Args:

target

np2d([100,1/3,1/3]), optional

ndarray with Yxy chromaticity of target.

tar_type

'Yxy' or str, optional

Specifies the input type in :target: (e.g. 'Yxy' or 'cct')

cieobs

_CIEOBS, optional

CIE CMF set used to calculate chromaticity values, if not provided in :Yxyi:.

optimizer_type

'2mixer', optional

Specifies type of chromaticity optimization

('3mixer' or '2mixer' or 'search')

For help on '2mixer' and '3mixer' algorithms, see notes below.

spd_constructor

None, optional

Function handle to user defined spd_constructor function.

Input: fcn(x, constructor_pars = {}, kwargs)

Output: spd,M,spds

nd array with:

- spd: spectrum resulting from x

- M: fluxes of all component spds
- spds: component spds (in [N+1,wl] format)

(See e.g. spd_constructor_2 or spd_constructor_3)

spd_model_pars

dict with model parameters required by spd_constructor and with optimization parameters required by minimize (x0, lb, ub). .

Only used when :optimizer_type: == 'user'.

cspace

'Yuv', optional

Color space for 'search'-type optimization.

cspace_bwtf

{}, optional

Backward (cspace_to_xyz) transform parameters

(see colortf()) to go from :tar_type: to 'Yxy').

cspace_fwtf

{}, optional

Forward (xyz_to_cspace) transform parameters

(see colortf()) to go from xyz to :cspace:).

component_spds

ndarray of component spectra.

If None: they are built from input args.

N_components

None, optional

Specifies number of components used in optimization. (only used when :component_data: is dict and user wants to override dict value

Note that shape of parameters arrays must match N_components).

allow_butterworth_mono_spds

False, optional

False: use pure Gaussian based monochrom. spds.

wl

_WL3, optional

Wavelengths used in optimization when :component_data: is not an ndarray with spectral data.

F_rss

True, optional

Take Root-Sum-of-Squares of 'closeness' values between target and objective function values.

decimals

5, optional

Rounding decimals of objective function values.

obj_fcn

[None] or list, optional

Function handles to objective function.

obj_fcn_weights

[1] or list, optional.

Weigths for each obj. fcn

obj_fcn_pars

[None] or list, optional

Parameter dicts for each obj. fcn.

obj_tar_vals

[0] or list, optional

Target values for each objective function.

minimize_method

'nelder-mead', optional

Optimization method used by minimize function.

minimize_opts

None, optional

Dict with minimization options.

None defaults to: {'xtol': 1e-5, 'disp': True, 'maxiter': 1000*Nc, 'maxfev' : 1000*Nc,'fatol': 0.01}

verbosity

0, optional

If > 0: print intermediate results.

Note: peakwl:, :fwhm:, ... : see ?spd_builder for more info.

Returns:

returns

spds, M

- 'spds': optimized spectrum.
- 'M': ndarray with fluxes for each component spectrum.

Notes:

Optimization algorithms

1. '2mixer': Pairs (odd,even) of components are selected and combined using 'pair_strength'. This process is continued until only 3 (combined) intermediate sources remain. Color3mixer is then used to calculate the fluxes for the remaining 3 sources, after which the fluxes of all components are back-calculated.

2. '3mixer': The triangle/trio method creates for all possible combinations of 3 primary component spectra a spectrum that results in the target chromaticity using color3mixer() and then optimizes the weights of each of the latter spectra such that adding them (additive mixing) results in obj_vals as close as possible to the target values.

4.5.4 hypspcim/

py

- __init__.py
- hyperspectral_img_simulator.py

namespace luxpy.hypspcim

Module for hyper spectral image simulation

_HYPSPCIM_PATH path to module

_HYPSPCIM_DEFAULT_IMAGE path + filename to default image

xyz_to_rfl() approximate spectral reflectance of xyz based on k nearest neighbour interpolation of samples from a standard reflectance set.

render_image() Render image under specified light source spd.

luxpy.toolboxes.hypspcim.**render_image**(*img=None*, *spd=None*, *rfl=None*, *out='img_hyp'*, *refspd=None*, *D=None*, *cieobs='1931_2'*, *cspace='ipt'*, *cspace_tf={}*, *k_neighbours=4*, *show=True*, *verbosity=0*, *show_ref_img=True*, *stack_test_ref=12*, *write_to_file=None*)

Render image under specified light source spd.

Args:

img

None or str or ndarray with uint8 rgb image.
None load a default image.

spd

ndarray, optional
Light source spectrum for rendering

rfl

ndarray, optional
Reflectance set for color coordinate to rfl mapping.

out

'img_hyp' or str, optional
(other option: 'img_ren': rendered image under :spd:)

refspd

None, optional
Reference spectrum for color coordinate to rfl mapping.
None defaults to D65 (srgb has a D65 white point)

D

None, optional
Degree of (von Kries) adaptation from spd to refspd.

cieobs

_CIEOBS, optional
CMF set for calculation of xyz from spectral data.

cspace

'ipt', optional
Color space for color coordinate to rfl mapping.

cspace_tf

{}, optional
Dict with parameters for xyz_to_cspace and cspace_to_xyz transform.

k_neighbours

4 or int, optional
Number of nearest neighbours for reflectance spectrum interpolation.
Neighbours are found using scipy.cKDTree

show

True, optional
Show images.

verbosity

0, optional

If > 0: make a plot of the color coordinates of original and rendered image pixels.

show_ref_img

True, optional

True: shows rendered image under reference spd. False: shows original image.

write_to_file

None, optional

None: do nothing, else: write to filename(+path) in :write_to_file:

stack_test_ref

12, optional

- 12: left (test), right (ref) format for show and imwrite
- 21: top (test), bottom (ref)
- 1: only show/write test
- 2: only show/write ref
- 0: show both, write test

Returns:

returns

img_hyp, img_ren,
ndarrays with hyperspectral image and rendered images

CHAPTER

FIVE

INDICES AND TABLES

- genindex
- modindex
- search

PYTHON MODULE INDEX

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