LuxPy Documentation

Release 1.12.0

Kevin A.G. Smet

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CONTENTS:

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

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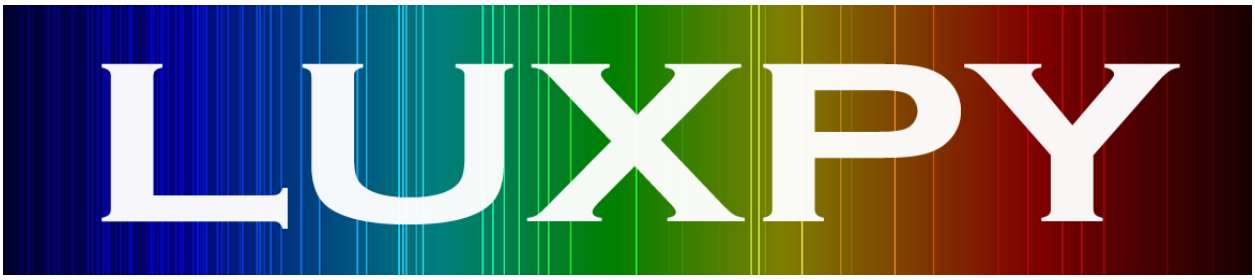

CHAPTER

ONE

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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
    ```

5a. Install luxpy package from pypi:

```
>> pip install luxpy
```

5b. Install luxpy package from anaconda:

```
>> conda install -c ksmet1977 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
- import pathlib
- import importlib
- from collections import OrderedDict as odict
- import colorsys
- import itertools
- import copy
- import time
- import tkinter
- import ctypes
- import platform
- import subprocess
- import cProfile
- import pstats
- import io

3.2 Imported 3e party dependencies :

- numpy (automatic install)
- scipy (stats, optimize, interpolate, . . .)

3.3 Lazily imported 3e party dependencies ():

- matplotlib.pyplot (any graphic output anywhere)
- imageio (imread(), imsave())
- openpyxl (in luxpy.utils: read_excel, write_excel)

3.4 3e party dependencies (automatic install on import)

- import pyswarms (when importing particleswarms from math)
- import pymoo (when importing pymoo_nsga_ii from math)
- import harfang as hg (when importing toolbox.stereoscopicviewer)

3.5 3e party dependencies (requiring manual install)

To control Ocean Optics spectrometers with spectro toolbox:

- import seabreeze (conda install -c poehlmann python-seabreeze)
- pip install pyusb (for use with 'pyseabreeze' backend of python-seabreeze)

CHAPTER

FOUR

LUXPY PACKAGE STRUCTURE

4.1 Utils sub-package

py

- __init__.py
- utilities.py
- folder_tree.py

namespace
luxpy.utils

luxpy.utils.**get_Axes3D_module**()
Get Axes3D module from mpl_toolkits.mplot3d

luxpy.utils.**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.**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.**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.**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.**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.**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.**loadtxt**(*filename*, *header=None*, *sep=','*, *dtype=<class 'float'>*, *missing_values=nan*)

Load data from text file.

Args:

filename

String with filename [+path]

header

None, optional
None: no header present, 'infer' get from file.

sep

',', optional
Delimiter (',' -> csv file)

dtype

float, optional
Try casting output array to this datatype.

missing_values

np.nan, optional

Replace missing values with this.

Returns:

ndarray

loaded data in ndarray of type dtype or object (in case of mixed types)

luxpy.utils.**savetxt**(*filename*, *X*, *header=None*, *sep=','*, *fmt=':1.18f'*, *aw='w'*)

Save data to text file.

Args:

filename

String with filename [+path]

X

ndarray with data

header

None or list, optional
None: no header present.

sep

',', optional
Delimiter (',' -> csv file)

fmt

':1.18f', optional
Format string for numerical data output.
Can be tuple/list for different output formats per column.

aw

'w', optional
options: 'w' -> write or 'a' -> append to file

luxpy.utils.**getdata**(*data*, *dtype=<class 'float'>*, *header=None*, *sep=' '*, *datatype='S'*, *copy=True*, *verbosity=False*, *missing_values=nan*)

Get data from csv-file.

Args:

data

- str with path to file containing data
- ndarray with data

dtype

float, optional
dtype of elements in ndarray data array
If None: mixture of datatypes is expected->dtype of output will be object

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.

copy

True, optional
Return a copy of ndarray

verbosity

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

Returns:

returns

data as ndarray

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

Split data on last axis

Args:

data

ndarray

Returns:

returns

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

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

Join data on last axis.

Args:

data

tuple (ndarray, ndarray, ...)

Returns:

returns

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

luxpy.utils.**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.**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.**read_excel**(*filename*, *sheet_name=None*, *cell_range=None*, *dtype=<class 'float'>*, *force_dictoutput=False*, *out='X'*)

Read excel file using openpyxl.

Args:

filename

string with [path/]filename of Excel file.

sheet_name

None, optional
If None: read all sheets
If string or tuple/list of strings: read these sheets.

cell_range

None, optional
Read all data on sheet(s).
If string range (e.g. 'B2:C4') or tuple/list of cell_ranges: read this range.
If tuple/list: then length must match that of the list of sheet_names!

dtype

float, optional
Try to cast the output data array(s) to this type. In case of failure,
data type will be 'object'.

force_dictoutput

False, optional
If True: output will always be a dictionary (sheet_names are keys)
with the requested data arrays.
If False: in case only a single sheet_name is supplied or only a single
sheet is present, then the output will be an ndarray!

out

'X', optional
String specifying requested output (eg. 'X' or 'X,wb' with wb the loaded workbook)

Returns:

X

dict or ndarray (single sheet and force_dictoutput==False)
with data in requested ranges.

wb

If in :out: the loaded workbook is also output.

`luxpy.utils.write_excel`(*filename*, *X*, *sheet_name=None*, *cell_range=None*)

Write data to an excel file using openpyxl.

Args:

filename

string with [path/]filename of Excel file.

sheet_name

None, optional
If None: use first one (or the keys in :X: when it is a dictionary)
If string: use this sheet.
If tuple/list of strings: use these to write the data in :X: (if :X: is a list/tuple of ndarrays)

X

ndarray, list/tuple or dict
If ndarray/list/tuple: sheet_names must be supplied explicitely in :sheet_names:
If dict: keys must be sheet_names

cell_range

None, optional

Read all data on sheet(s).

If string range (e.g. 'B2:C4') or tuple/list of cell_ranges: read this range.

If tuple/list: then length must match that of the list of sheet_names!

luxpy.utils.**show_luxpy_tree**(*omit=['.pyc', '__pycache__', '.txt', '.dat', '.csv', '.npz', '.png', '.jpg', '.md', '.pdf', '.ini', '.log', '.rar', 'drivers', 'SDK_', 'dll', 'bak']*)

Show luxpy foler tree.

Args:

omit

List of folders and file-extensions to omit.

Returns:

None

luxpy.utils.**is_importable**(*string*, *pip_string=None*, *try_pip_install=False*)

Check if string is importable/loadable. If it doesn't then try to 'pip install' it using subprocess. Returns None if succesful, otherwise throws and error or outputs False.

Args:

string

string with package or module name

pip_string

string with package or module name as known by pip

If None: use the import string

try_pip_install

False, optional

True: try pip installing it using subprocess

Returns:

success

True if importable, False if not.

luxpy.utils.**get_function_kwargs**(*f*)

Get dictionary of a function's keyword arguments and their default values.

Args:

f

function name

Returns:

dict

Dict with the function's keyword arguments and their default values

Is empty if there are no defaults (i.e. f.__defaults__ or f.__kwdefaults__ are None).

luxpy.utils.**profile_fcn**(*fcn*, *profile=True*, *sort_stats='tottime'*, *output_file=None*)

Profile or time a function fcn.

Args:

fcn

function to be profiled or timed (using time.time() difference)

profile

True, optional
Profile the function, otherwise only time it.

sort_stats

'tottime', optional
Sort profile results according to sort_stats ('tottime', 'cumtime',...)

output_file

None, optional
If not None: output result to output_file.

Return:

ps

Profiler output

luxpy.utils.**unique**(*array*, *sort=True*)

Get unique elements from array.

Args:

array

array to get unique elements from.

sort

True, optional
If True: get sorted unique elements.

Returns:

unique_array

ndarray with (sorted) unique elements.

luxpy.utils.**save_pkl**(*filename*, *obj*, *compresslevel=0*)

Save an object in a (gzipped) pickle file.

Args:

filename

str with filename of pickle file.

obj

python object to save

compresslevel

0, optional
If > 0: use gzip to compress pkl file.

Returns:

None

luxpy.utils.**load_pkl**(*filename*, *gzipped=False*)

Load the object in a (gzipped) pickle file.

Args:

filename

str with filename of pickle file.

gzipped

False, optional
If True: '.gz' will be added to filename before opening.

Returns:

obj

loaded python object

luxpy.utils.**imread**(*file*, *use_freeimage=False*)

Read image using imageio

luxpy.utils.**imsave**(*file*, *img*, *use_freeimage=False*)

Save image using imageio

luxpy.utils.**lazy_import**(*name*)

Lazy import of module

luxpy.utils.**tree**(*dir_path: Path*, *level: int = -1*, *limit_to_directories: bool = False*, *length_limit: int = 1000*, *omit=[]*)

Given a directory Path object print a visual tree structure

References:

1. https://stackoverflow.com/questions/9727673/list-directory-tree-structure-in-python

4.2 Math sub-package

py

- __init__.py
- basics.py
- minimizebnd.py
- mupolymodel.py
- Pyswarms_particleswarm.py
- pymoo_nsga_ii.py

namespace
luxpy.math

4.2.1 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(), erfinv()
erf-function and its inverse, imported from scipy.special

cart2pol()
Converts Cartesian to polar coordinates.

pol2cart()
Converts polar to Cartesian coordinates.

cart2spher()
Converts Cartesian to spherical coordinates.

spher2cart()
Converts spherical 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.

v_to_cik()
Calculate 2x2 '(covariance matrix)^-1' elements cik from v-format ellipse descriptor.

cik_to_v()
Calculate v-format ellipse descriptor from 2x2 'covariance matrix'^-1 cik.

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).

vec3
Module for spherical vector coordinates.

fmod()
Floating point modulus, e.g.: fmod(theta, np.pi * 2) would keep an angle in [0, 2pi]b

fit_ellipse()
Fit an ellipse to supplied data points.

fit_cov_ellipse()
Fit an covariance ellipse to supplied data points.

interp1_sprague5()
Perform a 1-dimensional 5th order Sprague interpolation.

linterp()
Perform a 1-dimensional linear interpolation (wrapper around numpy.interp1 with added linear extrapolation).

interp1()
Perform a 1-dimensional linear interpolation (wrapper around scipy.interpolate.InterpolatedUnivariateSpline, scipy.interpolate.interp1d and numpy based linterp).

ndinterp1()
Perform n-dimensional interpolation using Delaunay triangulation.

ndinterp1_scipy()
Perform n-dimensional interpolation using Delaunay triangulation (wrapper around scipy.interpolate.LinearNDInterpolator)

box_m()
Performs a Box M test on covariance matrices.

pitman_morgan()
Pitman-Morgan Test for the difference between correlated variances with paired samples.

mupolymod
Module for Multivariate Polynomial Model Optimization (2D, 3D)

NOT IMPORTED in math-namespace (to minimize dependencies)

pyswarms_particleswarm
Module with particleswarm() function for global minimization using particle swarms (wrapper around pyswarms.single.GlobalBestPSO))

pymoo_nsga_ii
Module with nsga_ii() function for pareto-optimal boundary minimization using Non-Dominated-Sort-Genetic-Algorithm NSGA-II (wrapper around pymoo.NSGAII))

`luxpy.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.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.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.math.**in_hull**(*p*, *hull*)

Test if points in *p* are in *hull*

Args:

p

NxK coordinates of N points in K dimensions

hull

Either a scipy.spatial.Delaunay object or the MxK array of the
coordinates of M points in K dimensions for which Delaunay

triangulation will be computed

Returns:

bool

boolean ndarray with True for in-gamut and False for out-of-gamut points

luxpy.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.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.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.math.erf`(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*, *extobj*])

erf(z) Returns the error function of complex argument.

It is defined as `2/sqrt(pi)*integral(exp(-t**2), t=0..z)`. Args:

x

ndarray
Input array.

Returns:

res

ndarray
The values of the error function at the given points *x*.

See Also:

nerfc, erfinv, erfcinv, wofz, erfcx, erfi

Notes:

1. The cumulative of the unit normal distribution is given by `Phi(z) = 1/2[1 + erf(z/sqrt(2))]`.

References:

1. https://en.wikipedia.org/wiki/Error_function

2. Milton Abramowitz and Irene A. Stegun, eds. Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables. µ New York: Dover, 1972. http://www.math.sfu.ca/~cbm/aands/page_297.htm 3. Steven G. Johnson, Faddeeva W function implementation. http://ab-initio.mit.edu/Faddeeva

Examples:

```
>>> from scipy import special
>>> import matplotlib.pyplot as plt
>>> x = np.linspace(-3, 3)
>>> plt.plot(x, special.erf(x))
>>> plt.xlabel('$x$')
```

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```
>>> plt.ylabel('$erf(x)$')
>>> plt.show()
```

luxpy.math.**erfinv**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*, *extobj*])

Inverse of the error function. Computes the inverse of the error function.

In the complex domain, there is no unique complex number w satisfying erf(w)=z. This indicates a true inverse function would have multi-value. When the domain restricts to the real, -1 < x < 1, there is a unique real number satisfying erf(erfinv(x)) = x.

Args:

y

ndarray

Argument at which to evaluate. Domain: [-1, 1]

Returns:

erfinv

ndarray

The inverse of erf of y, element-wise)

See Also:

- erf : Error function of a complex argument
- erfc : Complementary error function, `1 - erf(x)`
- erfcinv : Inverse of the complementary error function

Examples:

1) **evaluating a float number**

```
>>> from scipy import special
>>> special.erfinv(0.5)
0.4769362762044698
```

2) **evaluating an ndarray**

```
>>> from scipy import special
>>> y = np.linspace(-1.0, 1.0, num=10)
>>> special.erfinv(y)
array([       -inf, -0.86312307, -0.5407314 , -0.30457019, -0.0987901 ,
        0.0987901 ,  0.30457019,  0.5407314 ,  0.86312307,         inf])
```

luxpy.math.**histogram**(*a*, *bins=10*, *bin_center=False*, *range=None*, *weights=None*, *density=False*)

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.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.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.math.**spher2cart**(*theta*, *phi*, *r=1.0*, *deg=True*)

Convert spherical to cartesian coordinates.

Args:

theta

Float, int or ndarray
Angle with positive z-axis.

phi

Float, int or ndarray
Angle around positive z-axis starting from x-axis.

r

1, optional
Float, int or ndarray
radius

Returns:

x, y, z

tuple of floats, ints or ndarrays
Cartesian coordinates

luxpy.math.**cart2spher**(*x*, *y*, *z*, *deg=True*)

Convert cartesian to spherical coordinates.

Args:

x, y, z

tuple of floats, ints or ndarrays
Cartesian coordinates

Returns:

theta

Float, int or ndarray
Angle with positive z-axis.

phi

Float, int or ndarray
Angle around positive z-axis starting from x-axis.

r

1, optional
Float, int or ndarray
radius

luxpy.math.**bvgpdf**(*x*, *y=None*, *mu=None*, *sigmainv=None*)

Evaluate bivariate Gaussian probability density function (BVGPDF)

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.math.**mahalanobis2**(*x*, *y=None*, *z=None*, *mu=None*, *sigmainv=None*)

Evaluate the squared mahalanobis distance

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.

z

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

mu

None or ndarray (.ndim = 1) with center coordinates of the mahalanobis ellipse, optional.
None defaults to zeros(2) or zeros(3).

sigmainv

None or ndarray with 'inverse covariance matrix', optional
Determines the shape and orientation of the PD.
None default to np.eye(2) or eye(3).

Returns:

returns

ndarray with magnitude of mahalanobis2(x,y[,z])

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

Calculates magnitude of vector.

Args:

v

ndarray with vector

Returns:

magnitude

ndarray

luxpy.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.math.**v_to_cik**(*v*, *inverse=False*)

Calculate 2x2 '(covariance matrix)^-1' elements cik

Args:

v

(Nx5) np.ndarray
ellipse parameters [Rmax,Rmin,xc,yc,theta]

inverse

If True: return inverse of cik.

Returns:

cik

'Nx2x2' (covariance matrix)^-1

Notes:

cik is not actually a covariance matrix,
only for a Gaussian or normal distribution!

luxpy.math.**cik_to_v**(*cik*, *xyc=None*, *inverse=False*)

Calculate v-format ellipse descriptor from 2x2 'covariance matrix'^-1 cik

Args:

cik

'Nx2x2' (covariance matrix)^-1

inverse

If True: input is inverse of cik.

Returns:

v

(Nx5) np.ndarray
ellipse parameters [Rmax,Rmin,xc,yc,theta]

Notes:

cik is not actually the inverse covariance matrix,
only for a Gaussian or normal distribution!

luxpy.math.**fmod**(*x*, *y*)

Floating point modulus

e.g., fmod(theta, np.pi * 2) would keep an angle in [0, 2pi]

Args:

x

angle to restrict

y

end of interval [0, y] to restrict to

Returns:

r

floating point modulus

luxpy.math.**remove_outliers**(*data*, *alpha=0.01*)

Remove multivariate outliers from data when outside of alpha-level confidence ellipsoid.

Args:

data

Nxp ndarray with multivariate data (N samples, p variables)

alpha

0.01, optional
Significance level of confidence ellipsoid marking the boundary for outliers.

Return:

data

(N-… x p) ndarray with multivariate data; outliers removed.

luxpy.math.**fit_ellipse**(*xy*, *center_on_mean_xy=False*)

Fit an ellipse to supplied data points.

Args:

xy

coordinates of points to fit (Nx2 array)

center_on_mean_xy

False, optional
Center ellipse on mean of xy
(otherwise it might be offset due to solving
the contrained minization problem: aT*S*a, see ref below.)

Returns:

v

vector with ellipse parameters [Rmax,Rmin, xc,yc, theta (rad.)]

Reference:

1. Fitzgibbon, A.W., Pilu, M., and Fischer R.B., Direct least squares fitting of ellipsees, Proc. of the 13th Internation Conference on Pattern Recognition, pp 253–257, Vienna, 1996.

luxpy.math.**fit_cov_ellipse**(*xy*, *alpha=0.05*, *pdf='chi2'*, *SE=False*, *robust=False*, *robust_alpha=0.01*)

Fit covariance ellipse to xy data.

Args:

xy

coordinates of points to fit (Nx2 array)

alpha

0.05, optional
alpha significance level
(e.g alpha = 0.05 for 95% confidence ellipse)

pdf

chi2, optional
- 'chi2': Rescale using Chi2-distribution

- 't': Rescale using Student t-distribution
- 'norm': Rescale using normal-distribution
- None: don't rescale using pdf, use alpha as scalefactor (cfr. alpha* 1SD or alpha * 1SE)

SE

False, optional
If false, fit standard error ellipse at alpha significance level
If true, fit standard deviation ellipse at alpha significance level

robust

False, optional
If True: remove outliers beyond the confidence ellipsoid before calculating
the covariances.

robust_alpha

0.01, optional
Significance level of confidence ellipsoid marking the boundary for outliers.

Returns:

v

vector with ellipse parameters [Rmax,Rmin, xc,yc, theta (rad.)]

luxpy.math.**linterp**(*X*, *Y*, *Xnew*, *left='ext'*, *right='ext'*, *interp_log=False*, *extrap_log=False*)

Perform linear 1-D interpolation (with linear or constant extrapolation). (wrapper around np.interp)

Args:

X

ndarray with n-dimensional coordinates (last axis represents dimension)

Y

ndarray with values at coordinates in X

Xnew

ndarray of new coordinates (last axis represents dimension)

left

'ext', optional float corresponding to Y.
Value to return for *Xnew* < *X[0]*, None is *Y[0]*.
If 'ext': perform linear extrapolation

right

'ext', optional float corresponding to Y.
Value to return for *Xnew* > *X[-1]*, None is *Y[-1]*.
If 'ext': perform linear extrapolation

interp_log

Perform interpolation method ('linear', 'quadratic', or 'cubic') in log space.

extrap_log

Perform extrapolation method ('linear', 'quadratic', or 'cubic') in log space.

Returns:

Ynew

ndarray with new values at coordinates in Xnew

luxpy.math.**interpolatedunivariatespline**(*X*, *Y*, *Xnew*, *kind='linear'*, *ext='extrapolate'*, *fill_value='extrapolate'*, *w=None*, *bbox=[None, None]*, *check_finite=False*, *interp_log=False*, *extrap_log=False*)

Perform a 1-dimensional interpolation (with extrapolation) (wrapper around scipy.interpolate.InterpolatedUnivariateSpline).

Args:

X

ndarray with n-dimensional coordinates (last axis represents dimension)

Y

ndarray with values at coordinates in X

Xnew

ndarray of new coordinates (last axis represents dimension)

kind

str, optional
supported options for str: 'linear', 'quadratic', 'cubic'

ext

'extrapolate', optional
options:
- 'extrapolate'
- 'zeros': out-of-bounds values are filled with zeros
- 'const': out-of-bounds values are filled with nearest value
- 'fill_value': value of tuple (2,) of values is used to fill out-of-bounds values

fill_value

'extrapolate' or float or int or tupple, optional
If ext == 'fill_value': use fill_value to set lower- and upper-out-of-bounds values when extrapolating

w,bbox,check_finite

see scipy.interpolate.InterpolatedUnivariateSpline()

interp_log

Perform interpolation method ('linear', 'quadratic', or 'cubic') in log space.

extrap_log

Perform extrapolation method ('linear', 'quadratic', or 'cubic') in log space.

Returns:

Ynew

ndarray with new values at coordinates in Xnew

luxpy.math.**interp1_sprague5**(*X*, *Y*, *Xnew*, *extrap='linear'*, *force_scipy_interpolator=False*, *scipy_interpolator='InterpolatedUnivariateSpline'*, *delete_nans=True*, *choose_most_efficient_interpolator=False*, *verbosity=0*)

Perform a 1-dimensional 5th order Sprague interpolation.

Args:

X

ndarray with n-dimensional coordinates.

Y

ndarray with values at coordinates in X.

Xnew

ndarray of new coordinates.

extrap

(np.nan, np.nan) or string, optional
If tuple: fill with values in tuple (<X[0],>X[-1])
If string: ('linear', 'quadratic', 'cubic', 'zeros', 'const')

force_scipy_interpolator

False, optional
If False: numpy.interp function is used for linear interpolation when no or linear extrapolation is used/required (fast!).

scipy_interpolator

'InterpolatedUnivariateSpline', optional
options: 'InterpolatedUnivariateSpline', 'interp1d'

delete_nans

True, optional
If NaNs are present, remove them and (and try to) interpolate without them.

Returns:

Yn

ndarray with values at new coordinates in Xnew.

luxpy.math.**interp1_sprague_cie224_2017**(*X*, *Y*, *Xnew*, *extrap='linear'*, *force_scipy_interpolator=False*, *scipy_interpolator='InterpolatedUnivariateSpline'*, *delete_nans=True*, *choose_most_efficient_interpolator=False*, *verbosity=0*)

Perform a 1-dimensional Sprague interpolation according to CIE-224-2017.

Args:

X

ndarray with n-dimensional coordinates.

Y

ndarray with values at coordinates in X.

Xnew

ndarray of new coordinates.

extrap

(np.nan, np.nan) or string, optional
If tuple: fill with values in tuple (<X[0],>X[-1])
If string: ('linear', 'quadratic', 'cubic', 'zeros', 'const')

force_scipy_interpolator

False, optional
If False: numpy.interp function is used for linear interpolation when no or linear extrapolation is used/required (fast!).

scipy_interpolator

'InterpolatedUnivariateSpline', optional
options: 'InterpolatedUnivariateSpline', 'interp1d'

delete_nans

True, optional
If NaNs are present, remove them and (and try to) interpolate without them.

Returns:

Yn

ndarray with values at new coordinates in Xnew.

luxpy.math.**interp1_lagrange**(*X*, *Y*, *Xnew*, *k=5*, *extrap='linear'*, *force_scipy_interpolator=False*, *scipy_interpolator='InterpolatedUnivariateSpline'*, *delete_nans=True*, *choose_most_efficient_interpolator=False*, *verbosity=0*)

Perform a 1-dimensional k-th order Lagrange interpolation.

Args:

X

ndarray with n-dimensional coordinates.

Y

ndarray with values at coordinates in X.

Xnew

ndarray of new coordinates.

k

5 or int, optional
Order of Lagrange interpolation

extrap

(np.nan, np.nan) or string, optional
If tuple: fill with values in tuple (<X[0],>X[-1])
If string: ('linear', 'quadratic', 'cubic', 'zeros', 'const')

force_scipy_interpolator

False, optional
If False: numpy.interp function is used for linear interpolation when no or linear extrapolation is used/required (fast!).

scipy_interpolator

'InterpolatedUnivariateSpline', optional
options: 'InterpolatedUnivariateSpline', 'interp1d'

delete_nans

True, optional
If NaNs are present, remove them and (and try to) interpolate without them.

Returns:

Yn

ndarray with values at new coordinates in Xnew.

luxpy.math.**interp1**(*X*, *Y*, *Xnew*, *kind='linear'*, *ext='extrapolate'*, *fill_value='extrapolate'*, *force_scipy_interpolator=False*, *scipy_interpolator='InterpolatedUnivariateSpline'*, *delete_nans=True*, *w=None*, *bbox=[None, None]*, *check_finite=False*, *interp_log=False*, *extrap_log=False*, *choose_most_efficient_interpolator=False*, *verbosity=0*)

Perform a 1-dimensional interpolation (wrapper around linterp, interpolateduniviariatespline, interp1d).

Args:

X

ndarray with n-dimensional coordinates (last axis represents dimension)

Y

ndarray with values at coordinates in X

Xnew

ndarray of new coordinates (last axis represents dimension)

kind

str, optional
supported options for str: 'linear', 'quadratic', 'cubic'

ext

'extrapolate', optional
options:
- 'extrapolate', 'ext': use method specified in :kind: to extrapolate.
- 'linear', 'quadratic', 'cubic' extrapolation
- 'zeros': out-of-bounds values are filled with zeros
- 'const','flat','nearest': out-of-bounds values are filled with nearest value
- 'fill_value': value of tuple (2,) of values is used to fill out-of-bounds values

fill_value

'extrapolate' or float or int or tupple, optional
If ext == 'fill_value': use fill_value to set lower- and upper-out-of-bounds values when extrapolating

force_scipy_interpolator

False, optional
If False: numpy.interp function is used for linear interpolation when no or linear extrapolation is used/required (fast!).

scipy_interpolator

'InterpolatedUnivariateSpline', optional
options: 'InterpolatedUnivariateSpline', 'interp1d'

delete_nans

True, optional
If NaNs are present, remove them and (and try to) interpolate without them.

w,bbox,check_finite

see scipy.interpolate.InterpolatedUnivariateSpline()

interp_log

Perform interpolation method ('linear', 'quadratic', or 'cubic') in log space.

extrap_log

Perform extrapolation method ('linear', 'quadratic', or 'cubic') in log space.

Returns:

Ynew

ndarray with new values at coordinates in Xnew

Note:

1. 'numpy.interp' is fastest (but only works for linear interpolation and linear or no extrapolation)
2. For linear interpolation: 'interp1d' is faster for Y (N,...) with N > 1, else 'InterpolatedUnivariateSpline' is faster
3. For 'cubic' interpolation: 'InterpolatedUnivariateSpline' is faster for Y (N,...) with N > 1, else 'interp1d' is faster

luxpy.math.**ndinterp1**(*X*, *Y*, *Xnew*)

Perform nd-dimensional linear interpolation using Delaunay triangulation.

Args:

X

ndarray with n-dimensional coordinates (last axis represents dimension).

Y

ndarray with values at coordinates in X.

Xnew

ndarray of new coordinates (last axis represents dimension).
When outside of the convex hull of X, then a best estimate is
given based on the closest vertices.

Returns:

Ynew

ndarray with new values at coordinates in Xnew.

luxpy.math.**ndinterp1_scipy**(*X*, *Y*, *Xnew*, *fill_value=nan*, *rescale=False*)

Perform a n-dimensional linear interpolation (wrapper around scipy.interpolate.LinearNDInterpolator).

Args:

X

ndarray with n-dimensional coordinates (last axis represents dimension)

Y

ndarray with values at coordinates in X

Xnew

ndarray of new coordinates (last axis represents dimension)

fill_value

float, optional
Value used to fill in for requested points outside of the
convex hull of the input points. If not provided, then
the default is `nan`.

rescale

bool, optional
Rescale points to unit cube before performing interpolation.
This is useful if some of the input dimensions have
incommensurable units and differ by many orders of magnitude.

Returns:

Ynew

ndarray with new values at coordinates in Xnew

`luxpy.math.box_m`(**X*, *ni=None*, *verbosity=0*, *robust=False*, *robust_alpha=0.01*)

Perform Box's M test (p>=2) to check equality of covariance matrices or Bartlett's test (p==1) for equality of variances.

Args:

X

A number (k groups) or list of 2d-ndarrays (rows: samples, cols: variables) with data.
or a number of 2d-ndarrays with covariance matrices (supply ni!)

ni

None, optional
If None: X contains data, else, X contains covariance matrices.

verbosity

0, optional
If 1: print results.

robust

False, optional
If True: remove outliers beyond the confidence ellipsoid before calculating
the covariances.

robust_alpha

0.01, optional
Significance level of confidence ellipsoid marking the boundary for outliers.

Returns:

statistic

F or chi2 value (see len(dfs))

pval

p-value

df

degrees of freedom.
if len(dfs) == 2: F-test was used.
if len(dfs) == 1: chi2 approx. was used.

Notes:

1. If p==1: Reduces to Bartlett's test for equal variances.
2. If (ni>20).all() & (p<6) & (k<6): then a more appropriate chi2 test is used in a some cases.

luxpy.math.**pitman_morgan**(*X*, *Y*, *verbosity=0*)

Pitman-Morgan Test for the difference between correlated variances with paired samples.

Args:

X,Y

ndarrays with data.

verbosity

0, optional
If 1: print results.

Returns:

tval

statistic

pval

p-value

df

degree of freedom.

ratio

variance ratio var1/var2 (with var1 > var2).

Note:

1. Based on Gardner, R.C. (2001). Psychological Statistics Using SPSS for Windows. New Jersey, Prentice Hall.
2. Python port from matlab code by Janne Kauttonen (https://nl.mathworks.com/matlabcentral/fileexchange/67910-pitmanmorgantest-x-y; accessed Sep 26, 2019)

luxpy.math.**stress**(*DE*, *DV*, *axis=0*, *max_scale=100*)

Calculate STandardize-Residual-Sum-of-Squares (STRESS).

Args:

DE, DV

ndarrays of data to be compared.

axis

0, optional
axis with samples

max_scale

100, optional
Maximum of scale.

Returns:

stress

nadarray with stress value(s).

Reference:

1. Melgosa, M., García, P. A., Gómez-Robledo, L., Shamey, R., Hinks, D., Cui, G., & Luo, M. R. (2011). Notes on the application of the standardized residual sum of squares index for the assessment of intra- and inter-observer variability in color-difference experiments. Journal of the Optical Society of America A, 28(5), 949–953.

`luxpy.math.stress_F_test`(*stressA*, *stressB*, *N*, *alpha=0.05*)

Perform F-test on significance of difference between STRESS A and STRESS B.

Args:

stressA, stressB

ndarray with stress(es) values for A and B

N

int or ndarray with number of samples used to determine stress values.

alpha

0.05, optional
significance level

Returns:

Fstats

Dictionary with keys:
- 'p': p-values
- 'F': F-values
- 'Fc': critcal values
- 'H': string reporting on significance of A compared to B.

`luxpy.math.mean_distance_weighted`(*x*, *axis=0*, *keepdims=False*, *center_x=False*, *rtol=0.001*, *max_iter=100*, *cnt=0*, *mu=None*, *mu0=0*)

Recursively calculate distance weighted mean.

Args:

x

ndarray with data

axis

dimension along which to take mean

keepdims

False, optional
If True: keep dimension of original ndarray

center_x

True, optional
Center data first.

rtol

1e-3, optional
Relative tolerance on recursive mean values. If two sequential
mean values differ less than this amount, the recursion stops.

max_iter

100, optional
Maximum amount of recursions. If this number is reached the
recursion stops, even when rtol is not yet achieved. (to avoid
getting stuck in an infinite loop when the recursion doesn't converge)

cnt,mu,mu0

Needed for passing values across recursions to be able to stop them.
DO NOT CHANGE.

Returns:

mu_dw

distance weighted mean of the array

luxpy.math.**round**(*x*, *n=None*)

Round x (int, float, ndarray or tuple) to n significant digits, or n decimals ('to nearest even' or 'halfway from zero').

Args:

x

int, float, ndarray or tuple to be rounded.

n

int or tuple
Number of significant digits, or n decimals.
If int: round to nearest even using numpy's round() function
if Tuple: first element specifies the number of digits, the second element is a string specifying the method:
- 'sigfig': round to n significant digits (uses luxpy.math.round_sigfig function).
- 'dec' or 'nearesteven' or 'numpy' or 'np': round to nearest even using numpy's round function.
- 'halfwayfromzero': rounds halfway from zero (uses luxpy.math.round_awayfromzero function).

Returns:

y

rounded value(s).

Notes:

1. 'sigfig' from: https://stackoverflow.com/questions/18915378/rounding-to-significant-figures-in-numpy
2. 'halfwayfromzero' from: CIETC1-97: https://github.com/ifarup/ciefunctions

luxpy.math.**_interpolate_with_nans**(*fintp*, *X*, *Y*, *Xnew*, *delete_nans=True*, *nan_indices=None*)

Deal with possible NaNs in Y

luxpy.math.**_extrap_y**(*x*, *y*, *xn*, *extrap='linear'*, *force_scipy_interpolator=False*, *scipy_interpolator='InterpolatedUnivariateSpline'*, *delete_nans=True*, *choose_most_efficient_interpolator=False*)

Extrapolate y if needed

luxpy.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.optimize.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'])

4.2.2 vec3/

py

- __init__.py
- vec3.py

namespace
luxpy.math

4.2.3 DEMO/

py

- __init__.py
- DEMO.py
- demo_opt.py

namespace
luxpy.math

4.3 Spectrum sub-package

py

- __init__.py
- spdx_ietm2714.py
- **basics/**
  - __init__.py
  - cmf.py
  - spectral.py
  - spectral_databases.py

namespace
luxpy

4.3.1 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','2015_2','2015_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 array with shape: (3,3)
* luxpy._CMF[x]['N'] = XYZ to RGB conversion matrix for CMF type x.
Matrix is numpy array 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 is no XYZ to LMS conversion matrices defined for the** 1931 2° Judd corrected (1951) cmf sets. The Hunt-Pointer-Estevez conversion matrix of the 1931 2° is therefore used as an approximation!
3. **The XYZ to LMS conversion matrix M for the Judd-Vos XYZ CMFs is the one** that converts to the 1979 Smith-Pokorny cone fundamentals.
4. **The XYZ to LMS conversion matrix for the 1964 10° XYZ CMFs is set** to the one of the CIE 2006 10° cone fundamentals, as not matrix has been officially defined for this CMF set.
4. **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°).
5. **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 has been filled with NaN's.
6. The '2015_x' (with x = 2 or 10) are the same XYZ-CMFs as stored in '2006_x'.
7. **_CMF[x]['M'] for x equal to '2006_2' ('2015_2') or '2006_10' ('2015_10') is NOT** normalized to illuminant E! These are the original matrices as defined by [1] & [2].
8. **_CMF[x]['N'] stores known or calculated conversion matrices from** xyz to rgb. If not available, N has been filled with NaNs.

spectrum/spectral.py

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

_INTERP_REFERENCE
Sets the specific interpolation for spectrum types: ['spd','cmf','rfl','none']

_INTERP_SETTINGS_ALL
Nested Dict with interpolation settings per spectral type ['spd','cmf','rfl','none'] for various interp_reference keys.

_INTERP_SETTINGS
Nested Dict with interpolation settings per spectral type ['spd','cmf','rfl','none'].

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

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 [CIE15:2018, "Colorimetry," CIE, Vienna, Austria, 2018.]

spd()

All-in-one function that can:

1. Read spectral data from data file or take input directly as ndarray.
2. Interpolate spectral data.
3. Normalize spectral data.

xyzbar()
Get color matching functions.

vlbar()
Get Vlambda function.

vlbar_cie_mesopic()
Get CIE mesopic luminous efficiency function Vmesm according to CIE191:2010

get_cie_mesopic_adaptation()
Get the mesopic adaptation state according to CIE191:2010

spd_to_xyz_legacy()
Calculates xyz tristimulus values from spectral data. (luxpy version <= 1.11.4)

spd_to_xyz_barebones()
Calculates xyz tristimulus values from equal wavelength spectral data (no additional processing)

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.

detect_peakwl()
Detect peak wavelengths and fwhm of peaks in spectrum spd.

spectrum/spectral_databases.py

_S_PATH
Path to light source spectra data.

_R_PATH
Path to with spectral reflectance data

_IESTM3015
Database with spectral reflectances related to and light source spectra contained excel calculator of IES TM30-15 publication.

_IESTM3018
Database with spectral reflectances related to and light source spectra contained excel calculator of IES TM30-18 publication.

_IESTM3015_S
Database with only light source spectra contained in the IES TM30-15 excel calculator.

_IESTM3018_S
Database with only light source spectra contained in the IES TM30-18 excel calculator.

_CIE_ILLUMINANTS

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

_CIE_E, _CIE_D65, _CIE_A, _CIE_C, _CIE_F4
Some CIE illuminants for easy use.

_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.

_RFL

Database (dict) with RFLs, including:
* all those in _CRI_RFL,
* the 1269 Matt Munsell samples (see also _MUNSELL),

* the 24 Macbeth ColorChecker samples,

* the 215 samples proposed by Opstelten, J.J. , 1983, The establishment of a representative set of test colours

for the specification of the colour rendering properties of light sources, CIE-20th session, Amsterdam.

* the 114120 RFLs from capbone.com/spectral-reflectance-database/

spectrum/illuminants.py

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

_S012_DAYLIGHTPHASE
ndarray with CIE S0,S1, S2 curves for daylight phase calculation (linearly interpolated to 1 nm).

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

blackbody()
Calculate blackbody radiator spectrum.

_DAYLIGHT_LOCI_PARAMETERS
dict with parameters for daylight loci for various CMF sets; used by daylightlocus().

_DAYLIGHT_M12_COEFFS
dict with coefficients in weights M1 & M2 for daylight phases for various CMF sets.

get_daylightloci_parameters()
Get parameters for the daylight loci functions xD(1000/CCT) and yD(xD); used by daylightlocus().

get_daylightphase_Mi_coeffs()
Get coefficients of Mi weights of daylight phase for specific cieobs following Judd et al. (1964).

_get_daylightphase_Mi_values()
Get daylight phase coefficients M1, M2 following Judd et al. (1964).

_get_daylightphase_Mi()
Get daylight phase coefficients M1, M2 following Judd et al. (1964)

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.

(CIE15:2018, "Colorimetry," CIE, Vienna, Austria, 2018.,
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.

spd_to_indoor()
Convert spd to indoor variant by multiplying it with the CIE spectral transmission for glass.

spectrum/spdx_iestm2714.py

_SPDX_TEMPLATE
template dictionary for SPDX data.

read_spdx()
Read xml file or convert xml string with spdx data to dictionary.

write_spdx()
Convert spdx dictionary to xml string (and write to .spdx file)

References

1. CIE15:2018, "Colorimetry," CIE, Vienna, Austria, 2018.

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.

5. Judd, D. B., MacAdam, D. L., Wyszecki, G., Budde, H. W., Condit, H. R., Henderson, S. T., & Simonds, J. L. (1964). Spectral Distribution of Typical Daylight as a Function of Correlated Color Temperature. J. Opt. Soc. Am., 54(8), 1031–1040. https://doi.org/10.1364/JOSA.54.001031

6. http://www.ies.org/iestm2714

`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'*, *K=None*, *interp_settings=None*)

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
- 'pusa': to :norm_f: photometric units (with Km corrected to standard air, cfr. CIE TN003-2015)
- '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 or ndarray, optional
Type of cmf set to use for normalization using photometric units
(norm_type == 'pu')

K

None, optional
Luminous efficacy of radiation.
Must be supplied if cieobs is an array for norm_type == 'pu'

Returns:

returns

ndarray with normalized data.

luxpy.spectrum.**spectral_interp**(*data*, *wl_new*, *stype='cmf'*, *interp_settings={'cmf': {'etype': 'linear', 'fill_value': None, 'itype': 'linear', 'negative_values_allowed': False}, 'general': {'choose_most_efficient_interpolator': False, 'extrap_log': False, 'force_scipy_interpolator': False, 'interp_log': False, 'scipy_interpolator': 'interp1d', 'sprague_allowed': False, 'sprague_method': 'spargue_cie224_2017'}, 'none': {'etype': 'linear', 'fill_value': None, 'itype': 'cubic', 'negative_values_allowed': False}, 'rfl': {'etype': 'linear', 'fill_value': None, 'itype': 'cubic', 'negative_values_allowed': False}, 'spd': {'etype': 'linear', 'fill_value': None, 'itype': 'cubic', 'negative_values_allowed': False}}*, *itype=None*, *etype=None*, *fill_value=None*, *negative_values_allowed=False*, *delete_nans=True*, *force_scipy_interpolator=False*, *scipy_interpolator='InterpolatedUnivariateSpline'*, *interp_log=False*, *extrap_log=False*, *choose_most_efficient_interpolator=False*, *verbosity=0*)

Perform a 1-dimensional interpolation of spectral data

Args:

data

ndarray with (n+1,N)-dimensional spectral data (0-row: wavelengths, remaining n rows: data)

wl_new

ndarray of new wavelengths (N,)

stype

None, optional

Type of spectral data: None or ('spd', 'cmf', 'rfl')

If None: itype, etype and fill_value kwargs should not be none!

itype

None or str, optional

supported options for str: 'linear', 'quadratic', 'cubic'

If None: use value in interp_settings.

etype

None, or str, optional

options:

- 'extrapolate','ext': use method specified in :itype: to extrapolate.
- 'zeros': out-of-bounds values are filled with zeros
- 'const': out-of-bounds values are filled with nearest value
- 'fill_value': value of tuple (2,) of values is used to fill out-of-bounds values
- 'linear','quadratic','cubic': use of of these methods (slows down function if this method is different from the one in :itype:)

If None: use value in intp_settings.

fill_value

None or str or float or int or tupple, optional

If etype == 'fill_value': use fill_value to set lower- and upper-out-of-bounds values when extrapolating

('extrapolate' when etype requires extrapolation)

If None: use value in interp_settings.

negative_values_allowed

False, optional

If False: negative values are clipped to zero.

delete_nans

True, optional

If NaNs are present, remove them and (and try to) interpolate without them.

force_scipy_interpolator

False, optional

If False: numpy.interp function is used for linear interpolation when no or linear extrapolation is used/required (fast!).

scipy_interpolator

'InterpolatedUnivariateSpline', optional

options: 'InterpolatedUnivariateSpline', 'interp1d'

w,bbox,check_finite

see scipy.interpolate.InterpolatedUnivariateSpline()

interp_log

Perform interpolation method ('linear', 'quadratic', or 'cubic') in log space.

extrap_log

Perform extrapolation method ('linear', 'quadratic', or 'cubic') in log space.

Returns:

data_new

ndarray with interpolated (n+1,N)-dimensional spectral data

(0-row: wavelengths, remaining n rows: interpolated data)

Note:

1. 'numpy.interp' is fastest (but only works for linear interpolation and linear or no extrapolation)
2. For linear interpolation: 'interp1d' is faster for Y (N,...) with N > 1, else 'InterpolatedUnivariateSpline' is faster
3. For 'cubic' interpolation: 'InterpolatedUnivariateSpline' is faster for Y (N,...) with N > 1, else 'interp1d' is faster

`luxpy.spectrum.`**`cie_interp`**(*data*, *wl_new*, *datatype='none'*, *interp_settings={'cmf': {'etype': 'linear', 'fill_value': None, 'itype': 'linear', 'negative_values_allowed': False}, 'general': {'choose_most_efficient_interpolator': False, 'extrap_log': False, 'force_scipy_interpolator': False, 'interp_log': False, 'scipy_interpolator': 'interp1d', 'sprague_allowed': False, 'sprague_method': 'spargue_cie224_2017'}, 'none': {'etype': 'linear', 'fill_value': None, 'itype': 'linear', 'negative_values_allowed': False}, 'rfl': {'etype': 'linear', 'fill_value': None, 'itype': 'cubic', 'negative_values_allowed': False}, 'spd': {'etype': 'linear', 'fill_value': None, 'itype': 'cubic', 'negative_values_allowed': False}}*, *kind=None*, *extrap_kind=None*, *extrap_values=None*, *sprague_allowed=None*, *sprague_method='sprague_cie224_2017'*, *negative_values_allowed=None*, *interp_log=None*, *extrap_log=None*, *force_scipy_interpolator=None*, *scipy_interpolator=None*, *choose_most_efficient_interpolator=None*, *verbosity=0*)

Interpolate / extrapolate spectral data following standard CIE15-2018.

The kind of interpolation depends on the spectrum type defined in :datatype:
(or in :kind: for legacy puprposes-> overrules :datatype:).

Args:

data

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

wl_new

None or ndarray with new wavelengths or [start wavelength, stop wavelength, wavelength interval]
If None: no interpolation is done, a copy of the original data is returned.

datatype

'spd' (light source) or 'rfl' (reflectance) or 'cmf' (color matching functions) or 'none' (undefined), optional
Specifies a type of spectral data.
Is used to select the interpolation and extrapolation defaults, specified
in :interp_settings:.

interp_settings

_INTERP_SETTINGS or dict, optional
Dictionary of dictionaries (see _INTERP_SETTINGS), with at least a key entry
with the interpolation and extrapolation settings for the type specified in
:datatype: (or :kind: if string with spectrum datatype) and one key entry 'none'
('none' is used in case :extrap_kind: is None or 'ext').

kind

None, optional
- If None: the value from interp_settings is used, based on the value of :datatype:.
- If :kind: is a spectrum type (see :interp_settings:), the correct
interpolation type is automatically chosen based on the values in :interp_settings:
(The use of the slow(er) 'sprague5' or 'sprague_cie224_2017' can be
toggled on using :sprague_allowed:).
- Or :kind: can be 'linear', 'quadratic', 'cubic' (or 'sprague5', or 'sprague_cie224_2017, or 'lagrange5').
(see luxpy.spectral_interp?)

sprague_allowed

None, optional
If None: the value from interp_settings is used.
If True: When kind is a spectral data type that corresponds to 'cubic' interpolation,
then a cubic spline interpolation will be used in case of

unequal wavelength spacings, otherwise a 5th order Sprague or Sprague as defined in CIE224-2017 will be used.

If False: always use 'cubic', don't use 'sprague5' or 'sprague_cie224_2017'.
This is the default, as differences are minimal and
use of the 'sprague' functions is a lot slower ('sprague5' = slowest)!

sprague_method

'sprague_cie224_2017', optional

Specific sprague method used for interpolation. (Only for equal spacings, 'sprague_cie224_2017' also on for 5 nm -> 1nm)

- options: 'sprague5' (use luxpy.math.interp1_sprague5), 'sprague_cie224_2017' (use luxpy.interp1_sprague_cie224_2017)

negative_values_allowed

None, optional

If None: the value from interp_settings is used.

If False: negative values are clipped to zero.

extrap_kind

None, optional

If None or 'ext': use the method specified interp_settings[datatype].

If 'kind' or 'itype':
- If possible, use the same method as the interpolation method
(only for 'linear', 'quadratic', 'cubic'),
- otherwise: use the method specified :interp_settings['none']:.

Other options: 'linear' (or 'cie167:2005'), 'quadratic' (or 'cie15:2018'),
'nearest' (or 'cie15:2004' or 'const' or 'flat'), 'cubic', 'fill_value' (use value(s)n in extrap_values)
- If 'linear','quadratic','cubic': slow down of function
in case this method is different from the interpolation method used.

CIE15:2018 states that based on a 2017 paper by Wang that 'quadratic' is 'better'.

However, no significant difference was found between 'quadratic' and 'linear' methods.

Also see note 1 below, for why the CIE67:2005 recommended 'linear' extrapolation is set as the default.

extrap_values

None, optional

If float or list or ndarray, use those values to fill extrapolated value(s) when :extrap_kind:S == 'fill_value'.

extrap_log

None, optional

If None: the value from interp_settings is used.

If True: extrap the log of the spectral values
(not CIE recommended but in most cases seems to give a
more realistic estimate, but can sometimes seriously fail,
especially for the 'quadratic' extrapolation case (see note 1)!!!)

If any zero or negative values are present in a spectrum, then the log is NOT taken.

interp_log

None, optional
If None: the value from interp_settings is used.
Take log before interpolating the spectral data, afterwards take exp of interpolated data.
If any zero or negative values are present in a spectrum, then the log is NOT taken.

force_scipy_interpolator

None, optional
If None: the value from interp_settings is used.
If False: numpy.interp function is used for linear interpolation when no or linear extrapolation is used/required (fast!).

scipy_interpolator

None, optional
If None: the value from interp_settings is used.
options: 'InterpolatedUnivariateSpline', 'interp1d'

Returns:

returns

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

Notes:

1. Type of extrapolation: 'quadratic' vs 'linear'; impact of extrapolating log spectral values:
   Using a 'linear' or 'quadratic' extrapolation, as mentioned in
   CIE167:2005 and CIE15:2018, resp., can lead to extreme large values
   when setting :extrap_log: (not CIE recommended) to True.
   A quick test with the IES TM30 spectra (400 nm - 700 nm, 5 nm spacing)
   shows that 'linear' is better than 'quadratic' in terms of
   mean, median and max DEu'v' with the original spectra (380 nm - 780 nm, 5 nm spacing).
   This conferms the recommendation from CIE167:2005 to use 'linear' extrapolation.
   Setting :extrap_log: to True reduces the median, but inflates the mean due to some
   extremely large DEu'v' values. However, the increase in mean and max DEu'v' is much
   larger for the 'quadratic' case, suggesting that 'linear' extrapolation
   is likely a more suitable recommendation. When using a 1 nm spacing
   'linear' is more similar to 'quadratic' when :extrap_log: is False, otherwise 'linear'
   remains the 'best'. Hence the choice to use the CIE167:2005 recommended linear extrapolation as default!

`luxpy.spectrum.`**`spd`**(*data=None*, *wl=None*, *interp_settings=None*, *kind=None*, *extrap_kind=None*, *extrap_values=None*, *sep=','*, *header=None*, *datatype='spd'*, *norm_type=None*, *norm_f=None*, ***kwargs*)

All-in-one function that can:

1. Read spectral data from data file or take input directly as ndarray.
2. Interpolate spectral data.
3. Normalize spectral data.

Args:

data

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

wl

None, optional
New wavelength range for interpolation.
If None: no interpolation will be done.

kind

None, optional
- None: use defaults in interp_settings for specified datatype.
- str with interpolation type or spectrum type (if spectrum type: overrides anything set in :datatype:)

extrap_kind

None, optional
- None: use defaults in interp_settings for specified datatype.
- str with extrapolation type

extrap_values

None, optional
Controls extrapolation. See cie_interp.

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'

'spd' (light source) or 'rfl' (reflectance) or 'cmf' (color matching functions) or 'none' (undefined), optional
Specifies a type of spectral data.
Is used to determine interpolation and extrapolation defaults.

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
- 'pusa': to :norm_f: photometric units (with Km corrected to standard air, cfr. CIE TN003-2015)
- '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 interpolated and/or normalized spectral data.

`luxpy.spectrum.xyzbar`(*cieobs='1931_2'*, *src='dict'*, *wl_new=None*, *interp_settings=None*, *kind=None*, *extrap_kind=None*, *extrap_values=None*)

Get color matching functions.

Args:

cieobs

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

src

'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.
If None: no interpolation is done.

kind

None, optional
- None: use defaults in interp_settings for "cmf" datatype.
- str with interpolation type

extrap_kind

None, optional
- None: use defaults in interp_settings for specified datatype.
- str with extrapolation type

extrap_values

None, optional
Controls extrapolation. See cie_interp.

Returns:

returns

ndarray with CMFs

References:

1. CIE15:2018, "Colorimetry," CIE, Vienna, Austria, 2018.

luxpy.spectrum.**vlbar**(*cieobs='1931_2'*, *K=None*, *src='dict'*, *wl_new=None*, *interp_settings=None*, *kind=None*, *extrap_kind=None*, *extrap_values=None*, *out=1*)

Get Vlambda functions.

Args:

cieobs

str or ndarray, optional
If str: Sets the type of Vlambda function to obtain.

K

None, optional
Luminous efficacy of radiation.
Must be supplied if cieobs is an array

src

'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.
If None: no interpolation is done.

kind

None, optional
- None: use defaults in interp_settings for "cmf" datatype.
- str with interpolation type

extrap_kind

None, optional
- None: use defaults in interp_settings for specified datatype.
- str with extrapolation type

extrap_values

None, optional
Controls extrapolation. See cie_interp.

out

1 or 2, optional
1: returns Vlambda
2: returns (Vlambda, Km)

Returns:

returns

ndarray with Vlambda of type :cieobs:

References:

1. CIE15:2018, "Colorimetry," CIE, Vienna, Austria, 2018.

luxpy.spectrum.**vlbar_cie_mesopic**(*m=[1]*, *wl_new=None*, *out=1*, *Lp=None*, *Ls=None*, *SP=None*, *interp_settings=None*, *kind=None*, *extrap_kind=None*, *extrap_values=None*)

Get CIE mesopic luminous efficiency function Vmesm according to CIE191:2010

Args:

m

float or list or ndarray with mesopic adaptation coefficients

wl

None, optional
New wavelength range for interpolation.
If None: no interpolation is done.

out

1 or 2, optional
1: returns Vmesm
2: returns (Vmes, Kmesm)

Lp

None, optional
float or ndarray with photopic adaptation luminance
If not None: use this (and SP or Ls) to calculate the
mesopic adaptation coefficient

Ls

None, optional
float or ndarray with scotopic adaptation luminance
If None: SP must be supplied.

SP

None, optional
S/P ratio
If None: Ls must be supplied.

kind

None, optional
- None: use defaults in interp_settings for "cmf" datatype.
- str with interpolation type

extrap_kind

None, optional
- None: use defaults in interp_settings for specified datatype.
- str with extrapolation type

extrap_values

None, optional
Controls extrapolation. See cie_interp.

Returns:

Vmes

ndarray with mesopic luminous efficiency function
for adaptation coefficient(s) m

Kmes

ndarray with luminous efficacies of 555 nm monochromatic light
for for adaptation coefficient(s) m

Reference:

1. CIE 191:2010 Recommended System for Mesopic Photometry Based on Visual Performance. (ISBN 978-3-901906-88-6),

luxpy.spectrum.**get_cie_mesopic_adaptation**(*Lp*, *Ls=None*, *SP=None*)

Get the mesopic adaptation state according to CIE191:2010

Args:

Lp

float or ndarray with photopic adaptation luminance

Ls

None, optional
float or ndarray with scotopic adaptation luminance
If None: SP must be supplied.

SP

None, optional
S/P ratio
If None: Ls must be supplied.

Returns:

Lmes

mesopic adaptation luminance

m

mesopic adaptation coefficient

Reference:

1. CIE 191:2010 Recommended System for Mesopic Photometry Based on Visual Performance. (ISBN 978-3-901906-88-6),

luxpy.spectrum.**spd_to_xyz**(*spds*, *cieobs='1931_2'*, *K=None*, *relative=True*, *rfl=None*, *out=None*, *cie_std_dev_obs=None*, *rounding=None*, *matmul=True*, *interpolate_to='spd'*, *interp_settings={'cmf': {'etype': 'linear', 'fill_value': None, 'itype': 'linear', 'negative_values_allowed': False}, 'general': {'choose_most_efficient_interpolator': False, 'extrap_log': False, 'force_scipy_interpolator': False, 'interp_log': False, 'scipy_interpolator': 'interp1d', 'sprague_allowed': False, 'sprague_method': 'spargue_cie224_2017'}, 'none': {'etype': 'linear', 'fill_value': None, 'itype': 'linear', 'negative_values_allowed': False}, 'rfl': {'etype': 'linear', 'fill_value': None, 'itype': 'cubic', 'negative_values_allowed': False}, 'spd': {'etype': 'linear', 'fill_value': None, 'itype': 'cubic', 'negative_values_allowed': False}}*, *kind=None*, *extrap_kind=None*, *extrap_values=None*, *negative_values_allowed=None*, *sprague_allowed=None*, *sprague_method='sprague_cie224_2017'*, *force_scipy_interpolator=None*, *scipy_interpolator=None*, *choose_most_efficient_interpolator=None*, *verbosity=0*)

Calculate tristimulus values from spectral data.

Args:

spds

ndarray with (N+1,number of wavelengths)-dimensional spectral data (0-row: wavelengths, remaining n rows: data)

cieobs

luxpy._CIEOBS or str or ndarray, optional

Determines the color matching functions to be used in the

calculation of XYZ.

If ndarray: color matching functions (3+1,number of wavelengths). (0-row: spectral wavelengths)

K

None, optional

e.g. K = 683 lm/W for '1931_2' (relative == False)

or K = 100/sum(spd*dl) (relative == True)

relative

True, optional

If False: use K, else calculate K = 100 ./ Yw

rfl

None, optional

If not None, must be ndarray with (M+1,number of wavelengths)-dimensional spectral reflectance data (0-row: wavelengths, remaining n rows: data)

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.

matmul

True, optional

If True: use matrix multiplication and broadcasting to calculate tristimulus values, else use sumproduct with loop over cmfs.

rounding

None, optional

if not None: round xyz output to this many decimals. (see math.round for more options).

interpolate_to

'spd', optional

Interpolate other spectral data to the wavelengths of specified spectral type.

Options: 'spd' or 'cmf'

interp_settings

Nested Dict with interpolation settings per spectral type ['spd','cmf','rfl','none'].

Keys per spectrum type:

- 'itype': str
  - supported options for str: 'linear', 'quadratic', 'cubic'
- 'etype': str
  - supported options:
    - + 'extrapolate'
    - + 'zeros': out-of-bounds values are filled with zeros
    - + 'const': out-of-bounds values are filled with nearest value
    - + 'fill_value': value of tuple (2,) of values is used to fill out-of-bounds values
- 'fill_value': str or float or int or tupple, optional
  - If ext == 'fill_value': use fill_value to set lower- and upper-out-of-bounds values when extrapolating
    - ('extrapolate' when etype requires extrapolation)

negative_values_allowed

None, optional

If False: after interpolation/extrapolation, any negative values are clipped to zero.

If None: use the value in the interp_settings dictionary.

force_scipy_interpolator

None, optional

If False: numpy.interp function is used for linear interpolation when no or linear extrapolation is used/required (fast!).

If None: use the value in the interp_settings dictionary.

scipy_interpolator

None, optional

options: 'InterpolatedUnivariateSpline', 'interp1d'

If None: use the value in the interp_settings dictionary.

choose_most_efficient_interpolator

None, optional

If True: Choose most efficient interpolator

If None: use the value in the interp_settings dictionary.

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. CIE15:2018, "Colorimetry," CIE, Vienna, Austria, 2018.

`luxpy.spectrum.spd_to_xyz_barebones`(*spd*, *cmf*, *K=1.0*, *relative=True*, *rfl=None*, *wl=None*, *matmul=True*)

Calculate tristimulus values from equal wavelength spectral data.

Args:

spd

ndarray with (N+1,number of wavelengths)-dimensional spectral data (0-row: wavelengths, remaining n rows: data)

cmf

color matching functions (3+1,number of wavelengths). (0-row: spectral wavelengths)

K

1.0, optional
e.g. K = 683 lm/W for '1931_2' (relative == False)
or K = 100/sum(spd*dl) (relative == True)

relative

False, optional
If False: use K, else calculate K = 100 ./ Yw

rfl

None, optional
If not None, must be ndarray with (M+1,number of wavelengths)-dimensional spectral reflectance data (0-row: wavelengths, remaining n rows: data)

wl

None, optional

If None: first row of all spectral data are the wavelengths, else wl is ndarray with corresponding wavelengths of shape (number of wavelength,).

matmul

True, optional

If True: use matrix multiplication and broadcasting to calculate tristimulus values, else use sumproduct with loop over cmfs.

Returns:

XYZ, XYZw

ndarrays with tristimulus values (X,Y,Z are on last dimension)

- XYZ: tristim. values of all rfls (if rfl is None: same as XYZw) [M,N,3]
- XYZw: tristim. values of all white points (purely spds are used) [N,3]

luxpy.spectrum.**spd_to_ler**(*data*, *cieobs='1931_2'*, *K=None*, *interp_settings=None*, *kind=None*, *extrap_kind=None*, *extrap_values=None*)

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

Args:

data

ndarray 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 CIE15-2018.

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. CIE15:2018, "Colorimetry," CIE, Vienna, Austria, 2018.

luxpy.spectrum.**spd_to_power**(*data*, *ptype='ru'*, *cieobs='1931_2'*, *K=None*, *interp_settings=None*, *kind=None*, *extrap_kind=None*, *extrap_values=None*)

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

- 'pusa': in photometric units with Km corrected
  to standard air (cfr. CIE TN003-2015)
- 'qu': in quantal energy units

cieobs

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

K

None, optional
Luminous efficacy of radiation, must be supplied if cieobs is an array.

Returns:

returns:

ndarray with normalized spectral data (SI units)

luxpy.spectrum.**detect_peakwl**(*spd*, *n=1*, *verbosity=1*, ***kwargs*)

Detect primary peak wavelengths and fwhm in spectrum spd.

Args:

spd

ndarray with spectral data (2xN).
First row should be wavelengths.

n

1, optional
The number of peaks to try to detect in spd.

verbosity

Make a plot of the detected peaks, their fwhm, etc.

kwargs

Additional input arguments for scipy.signal.find_peaks.

Returns:

prop

list of dictionaries with keys:
- 'peaks_idx' : index of detected peaks
- 'peaks' : peak wavelength values (nm)
- 'heights' : height of peaks
- 'fwhms' : full-width-half-maxima of peaks
- 'fwhms_mid' : wavelength at the middle of the fwhm-range of the peaks (if this is different from the values in 'peaks', then their is some non-symmetry in the peaks)
- 'fwhms_mid_heights' : height at the middle of the peak

luxpy.spectrum.**create_spectral_interpolator**(*S*, *wl=None*, *kind=1*, *ext=0*)

Create an interpolator of kind for spectral data S.

Args:

S

Spectral data array
Row 0 should contain wavelengths if :wl: is None.

wl

None, optional
Wavelengths
If wl is None: row 0 of S should contain wavelengths.

kind

1, optional
Order of spline functions used in interpolator (1<=kind<=5)
Interpolator = scipy.interpolate.InterpolatedUnivariateSpline

Returns:

interpolators

List of interpolator functions for each row in S (minus wl-row if present).

Note:

1. Nan's, +infs, -infs will be ignored when generating the interpolators.

luxpy.spectrum.**wls_shift**(*shfts*, *log_shft=False*, *wl=None*, *S=None*, *interpolators=None*, *kind=1*, *ext=0*)

Wavelength-shift array S over shft wavelengths.

Args:

shfts

array with wavelength shifts.

log_shft

False, optional
If True: shift in log10 wavelength space.

wl

None, optional
Wavelengths to return
If wl is None: S will be used and row 0 should contain wavelengths.

S

None, optional
Spectral data array.
Row 0 should contain wavelengths if :wl: is None.
If None: interpolators should be precalculated + wl must contain wavelength array !

interpolators

None, optional
Pre-calculated interpolators for the (non-wl) rows in S.
If None: will be generated from :S: (which should contain wavelengths on row 0)
with specified :kind: using scipy.interpolate.InterpolatedUnivariateSpline
If not None and S is not None: interpolators take precedence

kind

1, optional
Order of spline functions used in interpolator (1<=kind<=5)

Returns:

wavelength_shifted

array with wavelength-shifted S (or interpolators) evaluated at wl.
(row 0 contains)

Note:

1. Nan's, +infs, -infs will be ignored when generating the interpolators.

luxpy.spectrum.**spd_to_xyz_legacy**(*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 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 CIE15-2018.

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. CIE15:2018, "Colorimetry," CIE, Vienna, Austria, 2018.

luxpy.spectrum.**cri_ref**(*ccts*, *wl3=None*, *ref_type='ciera'*, *mix_range=None*, *cieobs=None*, *cieobs_Y_normalization=None*, *norm_type=None*, *norm_f=None*, *force_daylight_below4000K=False*, *n=None*, *daylight_locus=None*, *round_daylightphase_Mi_to_cie_recommended=False*, *interp_settings=None*)

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

None, optional
Required when calculating daylightphase (adjust locus parameters to cieobs)
If None: value in _CRI_REF_TYPES will be used (with None here corresponding to _CIEOBS).

cieobs_Y_normalization

None, optional
Required for the normalization of the Planckian and Daylight SPDs
when calculating a 'mixed' reference illuminant.
If None: value in _CRI_REF_TYPES will be used,
with None here resulting in the use of the value as specified in :cieobs:

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
- 'pusa': to :norm_f: photometric units (with Km corrected to standard air, cfr. CIE TN003-2015)
- '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.

n

None, optional
Refractive index (for use in calculation of blackbody radiators).
If None: use the one stored in _BB['n']

daylight_locus

None, optional
dict with xD(T) and yD(xD) parameters to calculate daylight locus
for specified cieobs.
If None: use pre-calculated values.
If 'calc': calculate them on the fly.

round_daylightphase_Mi_to_cie_recommended

False, optional
If True: Round M1, M2 values to 3 decimals as recommended by CIE (not that TM30 does not do this, which gives slight errors when calculating a daylight phase (equivalent of around 0.75 K for 6500 K illuminant))
Rounding causes larger errors from target CCT! Therefore, the default is set to False!
Note that neither CIE224-2017 or IES TM30 rounds M1 and M2 to 3 decimals!

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.

`luxpy.spectrum.blackbody(`*cct*, *wl3=None*, *n=None*, *relative=True*`)`

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.

n

None, optional
Refractive index.
If None: use the one stored in _BB['n']

relative

False, optional
True: return relative spectrum normalized to 560 nm
False: return absolute spectral radiance (Planck's law; W/(sr.m^2.nm))

Returns:

returns

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

References:

1. CIE15:2018, "Colorimetry," CIE, Vienna, Austria, 2018.

luxpy.spectrum.**spd_to_indoor**(*spd*, *interp_settings=None*)

Convert spd to indoor variant by multiplying it with the CIE spectral transmission for glass.

luxpy.spectrum.**daylightlocus**(*cct*, *force_daylight_below4000K=False*, *cieobs=None*, *daylight_locus=None*, *use_published_daylightlocus_coeffs_when_cieobs_is_1931_2=True*, *interp_settings=None*)

Calculates daylight chromaticity (xD,yD) 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.

cieobs

CMF set corresponding to xD, yD output.
If None: use default CIE15-20xx locus for '1931_2'
Else: use the locus specified in :daylight_locus:

daylight_locus

None, optional
dict with xD(T) and yD(xD) parameters to calculate daylight locus
for specified cieobs.
If None: use pre-calculated values.
If 'calc': calculate them on the fly.

use_published_daylightlocus_coeffs_when_cieobs_is_1931_2

True, optional
Use published coefficients for CIE 1931 2° CMFs (see CIE015 colorimetry)

Returns:

(xD, yD)

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

References:

1. CIE15:2018, "Colorimetry," CIE, Vienna, Austria, 2018.

`luxpy.spectrum.daylightphase(`*cct*, *wl3=None*, *nominal_cct=False*, *force_daylight_below4000K=False*, *verbosity=None*, *n=None*, *cieobs=None*, *daylight_locus=None*, *daylight_Mi_coeffs=None*, *force_tabulated_xyD_Mi_when_cieobs_is_1931_2=True*, *round_Mi_to_cie_recommended=False*, *interp_settings=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.

nominal_cct

False, optional
If cct is nominal (e.g. when calculating D65): multiply cct first
by 1.4388/1.4380 to account for change in 'c2' in definition of Planckian.

cieobs

None or str or ndarray, optional
CMF set to use when calculating coefficients for daylight locus and for M1, M2 weights.
If None: use standard coefficients for CIE 1931 2° CMFs (for Si at 10 nm).
Else: calculate coefficients following Appendix C of CIE15-2004 and Judd (1964).

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.

n

None, optional
Refractive index (for use in calculation of blackbody radiators).
If None: use the one stored in _BB['n']

daylight_locus

None, optional
dict with xD(T) and yD(xD) parameters to calculate daylight locus

for specified cieobs.

If None: use pre-calculated values.

If 'calc': calculate them on the fly.

daylight_Mi_coeffs

None, optional

dict with coefficients for M1 & M2 weights for specified cieobs.

If None: use pre-calculated values.

If 'calc': calculate them on the fly.

force_tabulated_xyD_Mi_when_cieobs_is_1931_2

True, optional

If cieobs is '1931_2', then use tabulated values for xD, yD and Mi coefficients.

round_daylightphase_Mi_to_cie_recommended

False, optional

If True: Round M1, M2 values to 3 decimals as recommended by CIE (not that TM30 does not do this, which gives slight errors when calculating a daylight phase (equivalent of around 0.75 K for 6500 K illuminant))

Rounding causes larger errors from target CCT! Therefore, the default is set to False!

Note that neither CIE224-2017 or IES TM30 rounds M1 and M2 to 3 decimals!

Returns:

returns

ndarray with daylight phase spectrum

(:returns:[0] contains wavelengths)

References:

1. CIE15:2018, "Colorimetry," CIE, Vienna, Austria, 2018.
2. Judd, MacAdam, Wyszecki, Budde, Condit, Henderson, & Simonds (1964). Spectral Distribution of Typical Daylight as a Function of Correlated Color Temperature. J. Opt. Soc. Am., 54(8), 1031–1040.

luxpy.spectrum.**get_daylightloci_parameters**(*ccts=None*, *cieobs=None*, *wl3=[300, 830, 10]*, *verbosity=0*, *use_1931_2_published_daylightlocus_coeffs=False*, *interp_settings=None*)

Get parameters for the daylight loci functions xD(1000/CCT) and yD(xD).

Args:

ccts

None, optional

ndarray with CCTs, if None: ccts = np.arange(4000,25000,250)

cieobs

None or list of str or list of ndarrays, optional

CMF sets to determine parameters for.

If None: get for all CMFs sets in _CMF (except scoptopic and deviate observer)

wl3

[300,830,10], optional

Wavelength range and spacing of daylight phases to be determined from '1931_2'. The default setting results in parameters very close to that in CIE15-2004/2018.

use_1931_2_published_daylightlocus_coeffs

False, optional

Use published coefficients for CIE 1931 2° CMFs (see CIE015 colorimetry)

verbosity

0, optional
print parameters and make plots.

Returns:

dayloci

dict with parameters for each cieobs
If cieobs contains ndarrays, then keys in dict will be
labeled 'cmf_0', 'cmf_1', …

luxpy.spectrum.**get_daylightphase_Mi_coeffs**(*cieobs=None*, *wl3=None*, *S012_daylightphase=None*, *use_1931_2_published_Mcoeffs=False*, *interp_settings=None*)

Get coefficients of Mi weights of daylight phase for specific cieobs

Args:

cieobs

None or str or ndarray or list of str or list of ndarrays, optional
CMF set to get coefficients for.
If None: get coeffs for all CMFs in _CMF

wl3

None, optional
Wavelength range to interpolate S012_daylightphase to.

S012_daylightphase

None, optional
Daylight phase component functions.
If None: use _S012_DAYLIGHTPHASE

use_1931_2_published_Mcoeffs

False, optional
Use published coefficients of CIE 1931 2° CMFs (see CIE015 colorimetry), even when cieobs is not '1931_2'!

Returns:

Mcoeffs

Dictionary with i,j,k,i1,j1,k1,i2,j2,k2 for each cieobs in :cieobs:
If cieobs contains ndarrays, then keys in dict will be
labeled 'cmf_0', 'cmf_1', …

luxpy.spectrum.**read_spdx**(*spdx*)

Read xml file or convert xml string with spdx data to dictionary.

Args:

spdx

xml string or file with spdx data.

Returns:

spdx_dict

spdx data in a dictionary.

luxpy.spectrum.**write_spdx**(*spdx_dict*, *filename=None*)

Convert spdx dictionary to xml string (and write to .spdx file).

Args:

spdx_dict

dictionary with spdx keys (see _SPDX for keys).

filename

None, optional
string with filename to write xml data to.

Returns:

spdx_xml

string with xml data in spdx dictionary.

4.3.2 SPD class

py

- SPD.py

namespace
luxpy

`class luxpy.spectrum.SPD.SPD(`*spd=None*, *wl=None*, *ax0iswl=True*, *dtype='spd'*, *wl_new=None*, *interp_method='auto'*, *negative_values_allowed=False*, *extrap_values='ext'*, *norm_type=None*, *norm_f=1*, *header=None*, *sep=','*`)`

`read_csv_(`*file*, *header=None*, *sep=','*`)`

Reads spectral data from file.

Args:

file

filename

header

None or 'infer', optional
If 'infer': headers will be inferred from file itself.
If None: no headers are expected from file.

sep

',', optional
Column separator.

Returns:

returns

ndarray with spectral data (first row are wavelengths)

Note:

Spectral data in file should be organized in columns with the first column containing the wavelengths.

`plot(`*ylabel='Spectrum'*, *wavelength_bar=True*, **args*, ***kwargs*`)`

Make a plot of the spectral data in SPD instance.

Returns:

returns

handle to current axes.

`mean()`

Take mean of all spectra in SPD instance.

`sum()`

Sum all spectra in SPD instance.

dot(*S*)

Take dot product with instance of SPD.

add(*S*)

Add instance of SPD.

sub(*S*)

Subtract instance of SPD.

mul(*S*)

Multiply by instance of SPD.

div(*S*)

Divide by instance of SPD.

pow(*n*)

Raise SPD instance to power n.

get_()

Get spd as ndarray in instance of SPD.

setwlv(*spd*)

Store spd ndarray in fields wl and values of instance of SPD.

getwld_()

Get wavelength spacing of SPD instance.

Returns:

returns

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

normalize(*norm_type=None*, *norm_f=1*, *cieobs='1931_2'*, *K=None*, *interp_settings=None*)

Normalize spectral power distributions in SPD instance.

Args:

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
- 'pusa': to :norm_f: photometric units (with Km corrected to standard air, cfr. CIE TN003-2015)
- 'qu': to :norm_f: quantal energy units

norm_f

1, optional
Determines size of normalization for 'max' and 'area' or which wavelength is normalized to 1 for 'lambda' option.

cieobs

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

cie_interp(*wl_new*, *kind='auto'*, *sprague_allowed=False*, *sprague_method='sprague_cie224_2017'*, *negative_values_allowed=False*, *extrap_values='ext'*, *extrap_kind='linear'*, *extrap_log=False*)

Interpolate / extrapolate spectral data following standard CIE15-2018.

The interpolation type depends on the spectrum type defined in :kind:.

Args:

wl_new

ndarray with new wavelengths

kind

'auto', optional
If :kind: is None, return original data.
If :kind: is a spectrum type, the correct
interpolation type if automatically chosen.
(The use of the slow(er) 'sprague5' can be toggled on using :sprague_allowed:).
If kind = 'auto': use self.dtype
Or :kind: can be any interpolation type supported by
luxpy.math.interp1
or can be 'sprague' (uses luxpy.math.interp1_sprague5) or 'sprague_cie224_2017' (uses luxpy.math.interp1_sprague_cie224_2017).

sprague_allowed

None, optional
If None: the value from interp_settings is used.
If True: When kind is a spectral data type that corresponds to 'cubic' interpolation,
then a cubic spline interpolation will be used in case of
unequal wavelength spacings, otherwise a 5th order Sprague or Sprague as defined in CIE224-2017 will be used.
If False: always use 'cubic', don't use 'sprague5' or 'sprague_cie224_2017'.
This is the default, as differences are minimal and
use of the 'sprague' functions is a lot slower ('sprague5' = slowest)!

sprague_method

'sprague_cie224_2017', optional
Specific sprague method used for interpolation. (Only for equal spacings, 'sprague_cie224_2017' also on for 5 nm -> 1nm)
- options: 'sprague5' (use luxpy.math.interp1_sprague5), 'sprague_cie224_2017' (use luxpy.interp1_sprague_cie224_2017)

negative_values_allowed

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

extrap_values

'ext', optional
If 'ext': extrapolate using 'linear' ('cie167:2005' r), 'quadratic' ('cie15:2018')

'nearest' ('cie15:2004') recommended or other (e.g. 'cubic') methods.
If None: use CIE15:2004 recommended 'nearest value' approach when extrapolating.
If float or list or ndarray, use those values to fill extrapolated value(s).

extrap_kind

'linear', optional
Extrapolation method used when :extrap_values: is set to 'ext'.
Options: 'linear' ('cie167:2005'), 'quadratic' ('cie15:2018'),
'nearest' ('cie15:2004'), 'cubic'
CIE15:2018 states that based on a 2017 paper by Wang that 'quadratic' is 'better'.
However, no significant difference was found between 'quadratic' and 'linear' methods.
Also see note 1 below, for why the CIE67:2005 recommended 'linear' extrapolation
is set as the default.

extrap_log

False, optional
If True: extrap the log of the spectral values
(not CIE recommended but in most cases seems to give a
more realistic estimate, but can sometimes seriously fail,
especially for the 'quadratic' extrapolation case (see note 1)!!!)

Returns:

returns

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

Notes:

1. Type of extrapolation: 'quadratic' vs 'linear'; impact of extrapolating log spectral values:
Using a 'linear' or 'quadratic' extrapolation, as mentioned in
CIE167:2005 and CIE15:2018, resp., can lead to extreme large values
when setting :extrap_log: (not CIE recommended) to True.
A quick test with the IES TM30 spectra (400 nm - 700 nm, 5 nm spacing)
shows that 'linear' is better than 'quadratic' in terms of
mean, median and max DEu'v' with the original spectra (380 nm - 780 nm, 5 nm spacing).
This conferms the recommendation from CIE167:2005 to use 'linear' extrapolation.
Setting :extrap_log: to True reduces the median, but inflates the mean due to some
extremely large DEu'v' values. However, the increase in mean and max DEu'v' is much
larger for the 'quadratic' case, suggesting that 'linear' extrapolation
is likely a more suitable recommendation. When using a 1 nm spacing
'linear' is more similar to 'quadratic' when :extrap_log: is False, otherwise 'linear'
remains the 'best'. Hence the choice to use the CIE167:2005 recommended linear
extrapolation as default!

`to_xyz`(*relative=True*, *rfl=None*, *cieobs='1931_2'*, *out=None*)

Calculates xyz tristimulus values from spectral data and return as instance of XYZ.

Args:

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 don't match those of :data:

cieobs

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

out

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

Returns:

returns

luxpy.XYZ instance with ndarray .value field:
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. CIE15:2018, "Colorimetry," CIE, Vienna, Austria, 2018.

4.4 Color sub-package

py

- __init__.py

namespace
luxpy

4.4.1 utils/

py

- __init__.py
- plotters.py

namespace
luxpy

Module with functions related to plotting of color data

get_cmap()
Get an ndarray of rgb values representing a linearly sampled matplotlib colormap

get_subplot_layout()
Calculate layout of multiple subplots.

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.

plotellipse()
Plot one or more ellipses.

plot_chromaticity_diagram_colors()
Plot the chromaticity diagram colors.

plot_spectrum_colors()
Plot spd with spectrum colors.

plot_rfl_color_patches()
Create (and plot) an image with colored patches representing a set of reflectance spectra illuminated by a specified illuminant.

plot_rgb_color_patches()
Create (and plot) an image with patches with specified rgb values.

---

luxpy.color.utils.**get_cmap**(*N*, *cmap_name='jet'*)

Get an ndarray of rgba values representing a linearly sampled matplotlib colormap.

Args:

N

Number of rgba values in returned cmap.

cmap_name

'jet', optional

Matplotlib color map name to sample from.

Returns:

cmap

ndarray with rgba values.

luxpy.color.utils.**get_subplot_layout**(*N*, *min_1xncols=3*)

Calculate layout of multiple subplots.

Args:

N

Number of plots.

min_1xncols

Minimum number of columns before splitting over multiple rows.

Returns:

nrows, ncols

luxpy.color.utils.**plotSL**(*cieobs='1931_2'*, *cspace='Yuv'*, *DL=False*, *BBL=True*, *D65=False*, *EEW=False*, *cctlabels=False*, *axh=None*, *show=True*, *cspace_pars={}*, *formatstr='k-'*, *diagram_colors=False*, *diagram_samples=100*, *diagram_opacity=1.0*, *diagram_lightness=0.25*, ***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())

diagram_colors

False, optional
True: plot colored chromaticity diagram.

diagram_samples

256, optional
Sampling resolution of color space.

diagram_opacity

1.0, optional
Sets opacity of chromaticity diagram

diagram_lightness

0.25, optional
Sets lightness of chromaticity diagram

kwargs

additional keyword arguments for use with matplotlib.pyplot.

Returns:

returns

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 1e11 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

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 1e11 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

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-'*, *legend_loc=None*, ***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 or None, optional
Determines color space / chromaticity diagram to plot data in.
Note that data is expected to be in specified :cspace:
If None: don't do any formatting of x,y [z] axes.

formatstr

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

kwargs

additional keyword arguments for use with matplotlib.pyplot.

Returns:

returns

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*, *axh=None*, ***kwargs*)

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.utils.**plotellipse**(*v*, *cspace_in='Yxy'*, *cspace_out=None*, *nsamples=100*, *show=True*, *axh=None*, *line_color='darkgray'*, *line_style=':'*, *line_width=1*, *line_marker=''*, *line_markersize=4*, *plot_center=False*, *center_marker='o'*, *center_color='darkgray'*, *center_markersize=4*, *show_grid=False*, *llabel=''*, *label_fontname='Times New Roman'*, *label_fontsize=12*, *out=None*)

Plot ellipse(s) given in v-format [Rmax,Rmin,xc,yc,theta].

Args:

v

(Nx5) ndarray

ellipse parameters [Rmax,Rmin,xc,yc,theta]

cspace_in

'Yxy', optional

Color space of v.

If None: no color space assumed. Axis labels assumed ('x','y').

cspace_out

None, optional

Color space to plot ellipse(s) in.

If None: plot in cspace_in.

nsamples

100 or int, optional

Number of points (samples) in ellipse boundary

show

True or boolean, optional
Plot ellipse(s) (True) or not (False)

axh

None, optional
Ax-handle to plot ellipse(s) in.
If None: create new figure with axes.

line_color

'darkgray', optional
Color to plot ellipse(s) in.

line_style

':', optional
Linestyle of ellipse(s).

line_width'

1, optional
Width of ellipse boundary line.

line_marker

'none', optional
Marker for ellipse boundary.

line_markersize

4, optional
Size of markers in ellipse boundary.

plot_center

False, optional
Plot center of ellipse: yes (True) or no (False)

center_color

'darkgray', optional
Color to plot ellipse center in.

center_marker

'o', optional
Marker for ellipse center.

center_markersize

4, optional
Size of marker of ellipse center.

show_grid

False, optional
Show grid (True) or not (False)

llabel

None,optional
Legend label for ellipse boundary.

label_fontname

'Times New Roman', optional
Sets font type of axis labels.

label_fontsize

12, optional
Sets font size of axis labels.

out

None, optional
Output of function
If None: returns None. Can be used to output axh of newly created figure axes or to return Yxys an ndarray with coordinates of ellipse boundaries in cspace_out (shape = (nsamples,3,N))

Returns:

returns

None, or whatever set by :out:.

luxpy.color.utils.**plot_chromaticity_diagram_colors**(*diagram_samples=256*, *diagram_opacity=1.0*, *diagram_lightness=0.25*, *cieobs='1931_2'*, *cspace='Yxy'*, *cspace_pars={}*, *show=True*, *axh=None*, *show_grid=False*, *label_fontname='Times New Roman'*, *label_fontsize=12*, ***kwargs*)

Plot the chromaticity diagram colors.

Args:

diagram_samples

256, optional
Sampling resolution of color space.

diagram_opacity

1.0, optional
Sets opacity of chromaticity diagram

diagram_lightness

0.25, optional
Sets lightness of chromaticity diagram

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:

cspace_pars

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

show_grid

False, optional
Show grid (True) or not (False)

label_fontname

'Times New Roman', optional
Sets font type of axis labels.

label_fontsize

12, optional
Sets font size of axis labels.

kwargs

additional keyword arguments for use with matplotlib.pyplot.

Returns:

luxpy.color.utils.**plot_spectrum_colors**(*spd=None*, *spdmax=None*, *wavelength_height=-0.05*, *wavelength_opacity=1.0*, *wavelength_lightness=1.0*, *cieobs='1931_2'*, *show=True*, *axh=None*, *show_grid=False*, *ylabel='Spectral intensity (a.u.)'*, *xlim=None*, ***kwargs*)

Plot the spectrum colors.

Args:

spd

None, optional
Spectrum

spdmax

None, optional
max ylim is set at 1.05 or (1+abs(wavelength_height)*spdmax)

wavelength_opacity

1.0, optional
Sets opacity of wavelength rectangle.

wavelength_lightness

1.0, optional
Sets lightness of wavelength rectangle.

wavelength_height

-0.05 or 'spd', optional
Determine wavelength bar height
if not 'spd': x% of spd.max()

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.

show_grid

False, optional
Show grid (True) or not (False)

ylabel

'Spectral intensity (a.u.)' or str, optional
Set y-axis label.

xlim

None, optional
list or ndarray with xlimits.

kwargs

additional keyword arguments for use with matplotlib.pyplot.

Returns:

luxpy.color.utils.**plot_rfl_color_patches**(*rfl*, *spd=None*, *cieobs='1931_2'*, *patch_shape=(100, 100)*, *patch_layout=None*, *ax=None*, *show=True*)

Create (and plot) an image with colored patches representing a set of reflectance spectra illuminated by a specified illuminant.

Args:

rfl

ndarray with reflectance spectra

spd

None, optional
ndarray with illuminant spectral power distribution
If None: _CIE_D65 is used.

cieobs

'1931_2', optional
CIE standard observer to use when converting rfl to xyz.

patch_shape

(100,100), optional
shape of each of the patches in the image

patch_layout

None, optional
If None: layout is calculated automatically to give a 'good' aspect ratio

ax

None, optional
Axes to plot the image in. If None: a new axes is created.

show

True, optional
If True: plot image in axes and return axes handle; else: return ndarray with image.

Return:

ax

or :imagae: | Axes is returned if show == True, else: ndarray with rgb image is returned.

luxpy.color.utils.**plot_rgb_color_patches**(*rgb*, *patch_shape=(100, 100)*, *patch_layout=None*, *ax=None*, *show=True*)

Create (and plot) an image with patches with specified rgb values.

Args:

rgb

ndarray with rgb values for each of the patches

patch_shape

(100,100), optional

shape of each of the patches in the image

patch_layout

None, optional

If None: layout is calculated automatically to give a 'good' aspect ratio

ax

None, optional

Axes to plot the image in. If None: a new axes is created.

show

True, optional

If True: plot image in axes and return axes handle; else: return ndarray with image.

Return:

ax

or :imagae: | Axes is returned if show == True, else: ndarray with rgb image is returned.

`luxpy.color.utils.`**`plot_cmfs`**(*cmfs*, *cmf_symbols=['x', 'y', 'z']*, *cmf_label=''*, *ylabel='Sensitivity'*, *wavelength_bar=True*, *colors=['r', 'g', 'b']*, *axh=None*, *legend=True*, ***kwargs*)

Plot CMFs.

Args:

cmfs

ndarray with a set of CMFs.

cmf_symbols

['x,'y','z], optional

Symbols of the CMFs

If not a list but a string, the same label will be used for all CMF

and the same color will be used ('k' if colors is a list)

cmf_label

'', optional

Additional label that will be added in front of the cmf symbols.

ylabel

'Sensitivity', optional

label for y-axis.

wavelength_bar

True, optional

Add a colored wavelength bar with spectral colors.

colors

['r','g','b'], optional

Color for plotting each of the individual CMF.

axh

None, optional

Axes to plot the image in. If None: a new axes is created.

kwargs

additional kwargs for plt.plot().

Returns:

axh

figure axes handle.

4.4.2 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

_IPT_M
Conversion matrix for IPT color space

:_COLORTF_DEFAULT_WHITE_POINT : default white point for colortf (set at Illuminant E)

Supported 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_Yuv76(), Yuv76_to_Yxy(): (X,Y,Z) <-> CIE 1976 (Y,u',v');
* xyz_to_Yuv60(), Yuv60_to_Yxy(): (X,Y,Z) <-> CIE 1960 (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. CIE15:2018, "Colorimetry," CIE, Vienna, Austria, 2018. 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 Y,u',v' chromaticity values.

Args:

xyz

ndarray with tristimulus values

Returns:

Yuv

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

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

Convert CIE 1976 Y,u',v' chromaticity values to XYZ tristimulus values.

Args:

Yuv

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

Returns:

xyz

ndarray with tristimulus values

`luxpy.color.ctf.colortransforms.`**`xyz_to_Yuv76`**(*xyz*, ***kwargs*)

Convert XYZ tristimulus values CIE 1976 Y,u',v' chromaticity values.

Args:

xyz

ndarray with tristimulus values

Returns:

Yuv

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

luxpy.color.ctf.colortransforms.**Yuv76_to_xyz**(*Yuv*, ***kwargs*)

Convert CIE 1976 Y,u',v' chromaticity values to XYZ tristimulus values.

Args:

Yuv

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

Returns:

xyz

ndarray with tristimulus values

luxpy.color.ctf.colortransforms.**xyz_to_Yuv60**(*xyz*, ***kwargs*)

Convert XYZ tristimulus values CIE 1960 Y,u,v chromaticity values.

Args:

xyz

ndarray with tristimulus values

Returns:

Yuv

ndarray with CIE 1960 Y,u,v chromaticity values
(Y value refers to luminance or luminance factor)

luxpy.color.ctf.colortransforms.**Yuv60_to_xyz**(*Yuv60*, ***kwargs*)

Convert CIE 1976 Y,u,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]])*, *flip_axes=False*, *SL_max_lambda=None*, ***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 a single (!) native 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.

flip_axes

False, optional

If True: flip axis 0 and axis 1 in Ydelep to increase speed of loop in function.
(single xyzw with is not flipped!)

SL_max_lambda

None or float, optional

Maximum wavelength of spectrum locus before it turns back on itelf in the high wavelength range (~700 nm)

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]])*, *flip_axes=False*, *SL_max_lambda=None*, ***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 a single (!) native 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.

flip_axes

False, optional

If True: flip axis 0 and axis 1 in Ydelep to increase speed of loop in function.
(single xyzw with is not flipped!)

SL_max_lambda

None or float, optional

Maximum wavelength of spectrum locus before it turns back on itelf in the high wavelength range (~700 nm)

Returns:

xyz

ndarray with tristimulus values

luxpy.color.ctf.colortransforms.**xyz_to_srgb**(*xyz*, *gamma=2.4*, *offset=-0.055*, *use_linear_part=True*, *M=None*, ***kwargs*)

Calculates IEC:61966 sRGB values from xyz.

Args:

xyz

ndarray with relative tristimulus values.

gamma

2.4, optional
Gamma compression in gamma-function gf(x): see notes

offset

-0.055, optional
Offset in gamma-function gf(x): see notes

use_linear_part

True, optional
If False: omit linear part at low RGB values and use gamma function throughout

M

None, optional
xyz to linear srgb conversion matrix.
If None: use predefined matrix

Returns:

rgb

ndarray with R,G,B values (uint8).

Notes:

1. Gamma-function: gf(x) = ((1-offset)*x**gamma + offset)*255
2. dark values use linear function: lf(x) = x[dark] * 12.92 * 255
3. To use a pure gamma function, set offset to zero and use_linear_part to False.

luxpy.color.ctf.colortransforms.**srgb_to_xyz**(*rgb*, *gamma=2.4*, *offset=-0.055*, *use_linear_part=True*, *M=None*, ***kwargs*)

Calculates xyz from IEC:61966 sRGB values.

Args:

rgb

ndarray with srgb values (uint8).

gamma

2.4, optional
Gamma compression in gamma-function gf(x): see notes

offset

-0.055, optional
Offset in gamma-function gf(x): see notes

use_linear_part

True, optional
If False: omit linear part at low RGB values and use gamma function throughout

M

None, optional
xyz to linear srgb conversion matrix
(!!! Don't give inverse matrix as input, function will take inverse of input to M!!!).
If None: use predefined inverse matrix

Returns:

xyz

ndarray with xyz tristimulus values.

Notes:

1. Gamma-function: gf(x) = ((1-offset)*x**gamma + offset)*255
2. dark values use linear function: lf(x) = x[dark] * 12.92 * 255
3. To use a pure gamma function, set offset to zero and use_linear_part to False.

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]

4.4.3 cct/

py

- __init__.py
- cct.py
- cct_legacy.py
- cctduv_ohno_CORM2011.py

namespace
luxpy

cct: Module with functions related to correlated color temperature calculations

These methods supersede earlier methods in cct_legacy.y (prior to Nov 2021)

_CCT_MAX
(= 1e11 K), max. value that does not cause overflow problems.

_CCT_MIN
(= 550 K), min. value that does not cause underflow problems.

_CCT_FALLBACK_N
Number of intervals to divide an ndarray with CCTs.

_CCT_FALLBACK_UNIT
Type of scale (units) an ndarray will be subdivided.

_CCT_LUT_PATH
Folder with Look-Up-Tables (LUT) for correlated color temperature calculations.

_CCT_LUT
Dict with pre-calculated LUTs with structure LUT[mode][cspace][cieobs][lut i].

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

_CCT_LUT_RESOLUTION_REDUCTION_FACTOR
number of subdivisions when performing a cascading lut calculation to zoom-in progressively on the CCT (until a certain tolerance is met)

_CCT_CSPACE
default chromaticity space to calculate CCT and Duv in.

_CCT_CSPACE_KWARGS
nested dict with cspace parameters for forward and backward modes.

get_tcs4()
Get an ndarray of Tc's obtained from a list or tuple of tc4 4-vectors.

calculate_lut()
Function that calculates the LUT for the input ccts.

generate_luts()
Generate a number of luts and store them in a nested dictionary. (Structure: lut[cspace][cieobs][lut type])

xyz_to_cct()
Calculates CCT, Duv from XYZ (wraps a variety of methods)

xyz_to_duv()
Calculates Duv, (CCT) from XYZ (wrapper around xyz_to_cct, but with Duv output.)

cct_to_xyz()
Calculates xyz from CCT, Duv by estimating the line perpendicular to the planckian locus (=iso-T line).

cct_to_xyz()
Calculates xyz from CCT, Duv [_CCT_MIN < CCT < _CCT_MAX]

xyz_to_cct_mcamy1992()

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_hernandez1999()

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_ohno2014()

Calculates CCT, Duv from XYZ using a Ohno's 2014 LUT method.
Ohno Y. (2014) Practical use and calculation of CCT and Duv. Leukos. 2014 Jan 2;10(1):47-55.

xyz_to_cct_zhang2019()

Calculates CCT, Duv from XYZ using Zhang's 2019 golden-ratio search algorithm
Zhang, F. (2019). High-accuracy method for calculating correlated color temperature with a lookup table based on golden section search. Optik, 193, 163018.

xyz_to_cct_robertson1968()

Calculates CCT, Duv from XYZ using a Robertson's 1968 search method.
Robertson, A. R. (1968). Computation of Correlated Color Temperature and Distribution Temperature. Journal of the Optical Society of America, 58(11), 1528–1535.

xyz_to_cct_li2016()

Calculates CCT, Duv from XYZ using a Li's 2019 Newton-Raphson method.
Li, C., Cui, G., Melgosa, M., Ruan, X., Zhang, Y., Ma, L., Xiao, K., & Luo, M. R. (2016). Accurate method for computing correlated color temperature. Optics Express, 24(13), 14066–14078.

xyz_to_cct_fibonacci()

Calculates CCT, Duv from XYZ using a Fibonacci search method.

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

xyz_to_cct_ohno2011()
Calculate cct and Duv from CIE 1931 2° xyz following Ohno (CORM 2011).

_get_ccts_for_lut_bf()
Calculates CCTs for a LUT.

generate_lut_bf()
Calculate a Look-Up-Table for CCT & Duv calculations.

xyz_to_cct_bruteforce
Calculate CCT, Duv from XYZ using a brute-force technique.

---

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_mcamy1992**(*xyzw*, *cieobs='1931_2'*, *wl=None*, *out='cct'*, *cspace='Yuv60'*, *cspace_kwargs={'bwtf': {}, 'fwtf': {}}*)

Convert XYZ tristimulus values to correlated color temperature (CCT) using the mccamy approximation (!!! only valid for CIE 1931 2° input !!!).

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

Args:

xyzw

ndarray of tristimulus values

cieobs

'1931_2', optional
CMF set used to calculated xyzw.
Note: since the parameter values in Mcamy's equation were optimized,
using the 1931 2° CMFs, this is only valid for that CMF set.
It can be changed, but will only impact the calculation of Duv and
thereby causing a potential mismatch/error. Change at own discretion.

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 when determining Duv.
(!!CCT is determined using a fixed set of equations optimized for the 1931 2°
CMFS!!)

cspace

_CCT_SPACE, optional
Color space to do calculations in.
Options:
- cspace string:

e.g. 'Yuv60' for use with luxpy.colortf()
- tuple with forward (i.e. xyz_to..) [and backward (i.e. ..to_xyz)] functions
(and an optional string describing the cspace):
e.g. (forward, backward) or (forward, backward, cspace string) or (forward, cspace string)
- dict with keys: 'fwtf' (foward), 'bwtf' (backward) [, optional: 'str' (cspace string)]
Note: if the backward tf is not supplied, optimization in cct_to_xyz() is done in the CIE 1976 u'v' diagram

cspace_kwargs

_CCT_CSPACE_KWARGS, optional
Parameter nested dictionary for the forward and backward transforms.

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.

`luxpy.color.cct.`**`xyz_to_cct_hernandez1999`**(*xyzw*, *cieobs='1931_2'*, *wl=None*, *out='cct'*, *cspace='Yuv60'*, *cspace_kwargs={'bwtf': {}, 'fwtf': {}}*)

Convert XYZ tristimulus values to correlated color temperature (CCT) using the mccamy approximation (!!! only valid for CIE 1931 2° input !!!).

According to paper small error from 3000 - 800 000 K

Args:

xyzw

ndarray of tristimulus values

cieobs

'1931_2', optional
CMF set used to calculated xyzw.
Note: since the parameter values in the HA equations were optimized,
using the 1931 2° CMFs, this is only valid for that CMF set.
It can be changed, but will only impact the calculation of Duv and
thereby causing a potential mismatch/error. Change at own discretion.

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 when determining Duv.
(!!CCT is determined using a fixed set of equations optimized for the 1931 2° CMFS!!)

cspace

_CCT_SPACE, optional
Color space to do calculations in.
Options:
- cspace string:
e.g. 'Yuv60' for use with luxpy.colortf()
- tuple with forward (i.e. xyz_to..) [and backward (i.e. ..to_xyz)] functions
(and an optional string describing the cspace):
e.g. (forward, backward) or (forward, backward, cspace string) or (forward, cspace string)
- dict with keys: 'fwtf' (foward), 'bwtf' (backward) [, optional: 'str' (cspace string)]
Note: if the backward tf is not supplied, optimization in cct_to_xyz() is done in the CIE 1976 u'v' diagram

cspace_kwargs

_CCT_CSPACE_KWARGS, optional
Parameter nested dictionary for the forward and backward transforms.

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

luxpy.color.cct.**xyz_to_cct_robertson1968**(*xyzw*, *cieobs='1931_2'*, *out='cct'*, *is_uv_input=False*, *wl=None*, *atol=0.1*, *rtol=1e-05*, *force_tolerance=True*, *tol_method='newton-raphson'*, *lut_resolution_reduction_factor=4*, *split_calculation_at_N=25*, *max_iter=10*, *cspace='Yuv60'*, *cspace_kwargs={'bwtf': {}, 'fwtf': {}}*, *lut=None*, *luts_dict=None*, *ignore_wl_diff=False*, *use_fast_duv=True*, ***kwargs*)

Convert XYZ tristimulus values to correlated color temperature (CCT) and Duv(distance above (> 0) or below (< 0) the Planckian locus) using Robertson's 1968 search method (with a 2023 modification to allow for CCTs < 1667 K).

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)

is_uv_input

False, optional
If True: xyzw contain uv input data, not xyz data!

wl

None, optional
Wavelengths used when calculating Planckian radiators.
If None: use same wavelengths as CMFs in :cieobs:.

rtol

1e-5, float, optional
Stop search when cct a relative tolerance is reached.
The relative tolerance is calculated as dCCT/CCT_est,
with CCT_est the current intermediate estimate in the
search and with dCCT the difference between
the present and former estimates.

atol

0.1, optional
Stop search when cct a absolute tolerance (K) is reached.

force_tolerance

True, optional
If False: search only using the list of CCTs in the used lut.
Only one loop of the full algorithm is performed.
Accuracy depends on CCT of test source and the location
and spacing of the CCTs in the list.
If True: search will use adjacent CCTs to test source to create a new LUT,
(repeat the algoritm at higher resolution, progessively zooming in
toward the ground-truth) for tol_method == 'cl'; when
tol_method == 'nr' a newton-raphson method is used.
Because the CCT for multiple source is calculated in one go,
the atol and rtol values have to be met for all!

tol_method

'newton-raphson', optional
(Additional) method to try and achieve set tolerances.
Options:
- 'cl', 'cascading-lut': use increasingly higher CCT-resolution
to 'zoom-in' on the ground-truth.
- 'nr', 'newton-raphson': use the method as described in Li, 2016.

lut_resolution_reduction_factor

_CCT_LUT_RESOLUTION_REDUCTION_FACTOR, optional
Number of times the interval spanned by the adjacent Tc in a search or lut
method is downsampled (the search process will then start again)

max_iter

_CCT_MAX_ITER, optional
Maximum number of iterations used by the cascading-lut or newton-raphson methods.

split_calculation_at_N

_CCT_SPLIT_CALC_AT_N, optional
Split calculation when xyzw.shape[0] > split_calculation_at_N.
Splitting speeds up the calculation. If None: no splitting is done.

lut

None, optional
Look-Up-Table with Ti, u,v,u',v',u'',v'',slope values of Planckians.
Options:
- None: defaults to the lut specified in _CCT_LUT['robertson1968']['lut_type_def'].
- list (lut,lut_kwargs): use this pre-calculated lut
(add additional kwargs for the lut_generator_fcn(), defaults to None if omitted)
- tuple: must be key (label) in :luts_dict: (pre-calculated dict of luts),
if not: then a new lut will be generated from scratch using the info in the tuple.
- str: must be key (label) in :luts_dict: (pre-calculated dict of luts)
- ndarray [Nx1]: list of luts for which to generate a lut
- ndarray [Nxn] with n>3: pre-calculated lut (last col must contain slope of the isotemperature lines).

luts_dict

None, optional
Dictionary of pre-calculated luts for various cspaces and cmf sets.
Must have structure luts_dict[cspace][cieobs][lut_label] with the
lut part of a two-element list [lut, lut_kwargs]. It must contain
at the top-level a key 'wl' containing the wavelengths of the
Planckians used to generate the luts in this dictionary.
If None: luts_dict defaults to _CCT_LUT['robertson1968']['luts'].

cspace

_CCT_SPACE, optional
Color space to do calculations in.
Options:
- cspace string:
e.g. 'Yuv60' for use with luxpy.colortf()
- tuple with forward (i.e. xyz_to..) [and backward (i.e. ..to_xyz)] functions
(and an optional string describing the cspace):
e.g. (forward, backward) or (forward, backward, cspace string) or (forward, cspace string)
- dict with keys: 'fwtf' (foward), 'bwtf' (backward) [, optional: 'str' (cspace string)]
Note: if the backward tf is not supplied, optimization in cct_to_xyz() is done in the CIE 1976 u'v' diagram

cspace_kwargs

_CCT_CSPACE_KWARGS, optional
Parameter nested dictionary for the forward and backward transforms.

ignore_wl_diff

False, optional
When getting a lut from the dictionary, if differences are
detected in the wavelengts of the lut and the ones used to calculate any
plankcians then a new lut should be generated. Seting this to True ignores
these differences and proceeds anyway.

use_fast_duv

_CCT_FAST_DUV, optional
If True: use a fast estimator of the Duv
(one that avoids calculation of Planckians and uses the former
best estimate's u,v coordinates. This method is accurate enough
when the atol is small enough -> as long as abs(T-T_former)<=1K
the Duv estimate should be ok.)

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:

1. Out-of-lut CCTs are encoded as negative CCTs (with as absolute value the value of the closest CCT from the lut.)

References:

1. *Robertson, A. R. (1968). Computation of Correlated Color Temperature and Distribution Temperature. Journal of the Optical Society of America, 58(11), 1528–1535. <https://doi.org/10.1364/JOSA.58.001528>*

2. Baxter, D., Royer, M., & Smet, K. (2023). Modifications of the Robertson Method for Calculating Correlated Color Temperature to Improve Accuracy and Speed. LEUKOS, 20(1), 55–66.

3. Smet, K., Royer, M., Baxter, D., Bretschneider, E., Esposito, T., Houser, K., … Ohno, Y. (2023). Recommended Method for Determining the Correlated Color Temperature and Distance from the Planckian Locus of a Light Source. LEUKOS, 20(2), 223–237.

4. Li, C., Cui, G., Melgosa, M., Ruan, X., Zhang, Y., Ma, L., Xiao, K., & Luo, M. R. (2016). Accurate method for computing correlated color temperature. Optics Express, 24(13), 14066–14078.

`luxpy.color.cct.`**`xyz_to_cct_ohno2014`**(*xyzw*, *cieobs='1931_2'*, *out='cct'*, *is_uv_input=False*, *wl=None*, *atol=0.1*, *rtol=1e-05*, *force_tolerance=True*, *tol_method='newton-raphson'*, *lut_resolution_reduction_factor=4*, *duv_triangular_threshold=0.002*, *split_calculation_at_N=25*, *max_iter=10*, *cspace='Yuv60'*, *cspace_kwargs={'bwtf': {}, 'fwtf': {}}*, *lut=None*, *luts_dict=None*, *ignore_wl_diff=False*, *use_fast_duv=True*, ***kwargs*)

Convert XYZ tristimulus values to correlated color temperature (CCT) and Duv (distance above (>0) or below (<0) the Planckian locus) using Ohno's 2014 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)

is_uv_input

False, optional
If True: xyzw contain uv input data, not xyz data!

wl

None, optional
Wavelengths used when calculating Planckian radiators.
If None: use same wavelengths as CMFs in :cieobs:.

rtol

1e-5, float, optional
Stop search when cct a relative tolerance is reached.
The relative tolerance is calculated as dCCT/CCT_est,
with CCT_est the current intermediate estimate in the
search and with dCCT the difference between
the present and former estimates.

atol

0.1, optional
Stop search when cct a absolute tolerance (K) is reached.

force_tolerance

True, optional
If False: search only using the list of CCTs in the used lut.
Only one loop of the full algorithm is performed.
Accuracy depends on CCT of test source and the location
and spacing of the CCTs in the list.
If True: search will use adjacent CCTs to test source to create a new LUT,
(repeat the algoritm at higher resolution, progessively zooming in
toward the ground-truth) for tol_method == 'cl'; when
tol_method == 'nr' a newton-raphson method is used.
Because the CCT for multiple source is calculated in one go,
the atol and rtol values have to be met for all!

tol_method

'newton-raphson', optional
(Additional) method to try and achieve set tolerances.
Options:
- 'cl', 'cascading-lut': use increasingly higher CCT-resolution
to 'zoom-in' on the ground-truth.
- 'nr', 'newton-raphson': use the method as described in Li, 2016.

lut_resolution_reduction_factor

_CCT_LUT_RESOLUTION_REDUCTION_FACTOR, optional
Number of times the interval spanned by the adjacent Tc in a search or lut
method is downsampled (the search process will then start again)

duv_triangular_threshold

0.002, optional
Threshold for use of the triangular solution.
(if smaller use triangular solution, else use the non-triangular one -> 3e-order
poly)

max_iter

_CCT_MAX_ITER, optional

Maximum number of iterations used by the cascading-lut or newton-raphson methods.

split_calculation_at_N

_CCT_SPLIT_CALC_AT_N, optional

Split calculation when xyzw.shape[0] > split_calculation_at_N.

Splitting speeds up the calculation. If None: no splitting is done.

lut

None, optional

Look-Up-Table with Ti, u,v,u',v',u'',v'',slope values of Planckians.

Options:

- None: defaults to the lut specified in _CCT_LUT['ohno2014']['lut_type_def'].
- list (lut,lut_kwargs): use this pre-calculated lut
  (add additional kwargs for the lut_generator_fcn(), defaults to None if omitted)
- tuple: must be key (label) in :luts_dict: (pre-calculated dict of luts),
  if not: then a new lut will be generated from scratch using the info in the tuple.
- str: must be key (label) in :luts_dict: (pre-calculated dict of luts)
- ndarray [Nx1]: list of luts for which to generate a lut
- ndarray [Nxn] with n>3: pre-calculated lut (last col must contain slope of the isotemperature lines).

luts_dict

None, optional

Dictionary of pre-calculated luts for various cspaces and cmf sets.

Must have structure luts_dict[cspace][cieobs][lut_label] with the lut part of a two-element list [lut, lut_kwargs]. It must contain at the top-level a key 'wl' containing the wavelengths of the Planckians used to generate the luts in this dictionary.

If None: luts_dict defaults to _CCT_LUT['ohno2014']['luts']

cspace

_CCT_SPACE, optional

Color space to do calculations in.

Options:

- cspace string:
  e.g. 'Yuv60' for use with luxpy.colortf()
- tuple with forward (i.e. xyz_to..) [and backward (i.e. ..to_xyz)] functions
  (and an optional string describing the cspace):
  e.g. (forward, backward) or (forward, backward, cspace string) or (forward, cspace string)
- dict with keys: 'fwtf' (foward), 'bwtf' (backward) [, optional: 'str' (cspace string)]

Note: if the backward tf is not supplied, optimization in cct_to_xyz() is done in the CIE 1976 u'v' diagram

cspace_kwargs

_CCT_CSPACE_KWARGS, optional

Parameter nested dictionary for the forward and backward transforms.

ignore_wl_diff

False, optional
When getting a lut from the dictionary, if differences are
detected in the wavelengts of the lut and the ones used to calculate any
plankcians then a new lut should be generated. Seting this to True ignores
these differences and proceeds anyway.

use_fast_duv

_CCT_FAST_DUV, optional
If True: use a fast estimator of the Duv
(one that avoids calculation of Planckians and uses the former
best estimate's u,v coordinates. This method is accurate enough
when the atol is small enough -> as long as abs(T-T_former)<=1K
the Duv estimate should be ok.)

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:

1. Out-of-lut CCTs are encoded as negative CCTs (with as absolute value the value of the closest CCT from the lut.)

References:

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

2. Li, C., Cui, G., Melgosa, M., Ruan, X., Zhang, Y., Ma, L., Xiao, K., & Luo, M. R. (2016). Accurate method for computing correlated color temperature. Optics Express, 24(13), 14066–14078.

luxpy.color.cct.**xyz_to_cct_li2016**(*xyzw*, *cieobs='1931_2'*, *out='cct'*, *is_uv_input=False*, *wl=None*, *atol=0.1*, *rtol=1e-05*, *max_iter=10*, *split_calculation_at_N=25*, *lut=None*, *luts_dict=None*, *ignore_wl_diff=False*, *lut_resolution_reduction_factor=4*, *cspace='Yuv60'*, *cspace_kwargs={'bwtf': {}, 'fwtf': {}}*, *first_guess_mode='robertson2023'*, *fgm_kwargs={}*, *use_fast_duv=True*, ***kwargs*)

Convert XYZ tristimulus values to correlated color temperature (CCT) and Duv(distance above (> 0) or below (< 0) the Planckian locus) using the Newton-Raphson method described in Li et al. (2016).

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)

is_uv_input

False, optional
If True: xyzw contain uv input data, not xyz data!

wl

None, optional
Wavelengths used when calculating Planckian radiators.
If None: use same wavelengths as CMFs in :cieobs:.

rtol

1e-5, float, optional
Stop method when cct a relative tolerance is reached.
The relative tolerance is calculated as dCCT/CCT_est,
with CCT_est the current intermediate estimate in the
search and with dCCT the difference between
the present and former estimates.

atol

0.1, optional
Stop method when cct a absolute tolerance (K) is reached.

max_iter

_CCT_MAX_ITER, optional
Maximum number of iterations used newton-raphson methods.

lut_resolution_reduction_factor

_CCT_LUT_RESOLUTION_REDUCTION_FACTOR, optional
Number of times the interval spanned by the adjacent Tc in a search or lut
method is downsampled (the search process will then start again)

split_calculation_at_N

_CCT_SPLIT_CALC_AT_N, optional
Split calculation when xyzw.shape[0] > split_calculation_at_N.
Splitting speeds up the calculation. If None: no splitting is done.

lut

None, optional
Look-Up-Table with Ti, u,v,u',v',u'',v'',slope values of Planckians.
Options:
- None: defaults to the lut specified in _CCT_LUT[first_guess_mode]['lut_type_def'].
- list (lut,lut_kwargs): use this pre-calculated lut
  (add additional kwargs for the lut_generator_fcn(), defaults to None if omitted)
- tuple: must be key (label) in :luts_dict: (pre-calculated dict of luts),
  if not: then a new lut will be generated from scratch using the info in the tuple.
- str: must be key (label) in :luts_dict: (pre-calculated dict of luts)
- ndarray [Nx1]: list of luts for which to generate a lut
- ndarray [Nxn] with n>3: pre-calculated lut (last col must contain slope of the isotemperature lines).

luts_dict

None, optional

Dictionary of pre-calculated luts for various cspaces and cmf sets.
Must have structure luts_dict[cspace][cieobs][lut_label] with the
lut part of a two-element list [lut, lut_kwargs]. It must contain
at the top-level a key 'wl' containing the wavelengths of the
Planckians used to generate the luts in this dictionary.
If None: luts_dict defaults to _CCT_LUT[first_guess_mode]['luts']

cspace

_CCT_SPACE, optional
Color space to do calculations in.
Options:
- cspace string:
e.g. 'Yuv60' for use with luxpy.colortf()
- tuple with forward (i.e. xyz_to..) [and backward (i.e. ..to_xyz)]
functions
(and an optional string describing the cspace):
e.g. (forward, backward) or (forward, backward, cspace
string) or (forward, cspace string)
- dict with keys: 'fwtf' (foward), 'bwtf' (backward) [, optional: 'str'
(cspace string)]
Note: if the backward tf is not supplied, optimization in cct_to_xyz() is done in
the CIE 1976 u'v' diagram

cspace_kwargs

_CCT_CSPACE_KWARGS, optional
Parameter nested dictionary for the forward and backward transforms.

ignore_wl_diff

False, optional
When getting a lut from the dictionary, if differences are
detected in the wavelengts of the lut and the ones used to calculate any
plankcians then a new lut should be generated. Seting this to True ignores
these differences and proceeds anyway.

first_guess_mode

'robertson2023', optional
Method used to get an approximate (first guess) estimate of the cct,
after which the newton-raphson method is started.
Options: 'robertson2023', 'ohno2014', 'zhang2019'

fgm_kwargs

Dict with keyword arguments for the selected first_guess_mode.

use_fast_duv

_CCT_FAST_DUV, optional
If True: use a fast estimator of the Duv
(one that avoids calculation of Planckians and uses the former
best estimate's u,v coordinates. This method is accurate enough
when the atol is small enough -> as long as abs(T-T_former)<=1K
the Duv estimate should be ok.)

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:

1. Out-of-lut (of first_guess_mode) CCTs are encoded as negative CCTs (with as absolute value the value of the closest CCT from the lut.)

References:

1. Li, C., Cui, G., Melgosa, M., Ruan, X., Zhang, Y., Ma, L., Xiao, K., & Luo, M. R. (2016). Accurate method for computing correlated color temperature. Optics Express, 24(13), 14066–14078.

2. Robertson, A. R. (1968). Computation of Correlated Color Temperature and Distribution Temperature. Journal of the Optical Society of America, 58(11), 1528–1535.

`luxpy.color.cct.`**`xyz_to_cct_li2022`**(*xyzw*, *cieobs='1931_2'*, *out='cct'*, *is_uv_input=False*, *wl=None*, *atol=0.1*, *rtol=1e-05*, *force_tolerance=True*, *tol_method='newton-raphson'*, *lut_resolution_reduction_factor=4*, *duv_triangular_threshold=0.002*, *split_calculation_at_N=25*, *max_iter=10*, *cspace='Yuv60'*, *cspace_kwargs={'bwtf': {}, 'fwtf': {}}*, *lut=None*, *luts_dict=None*, *ignore_wl_diff=False*, *use_fast_duv=True*, ***kwargs*)

Convert XYZ tristimulus values to correlated color temperature (CCT) and Duv (distance above (>0) or below (<0) the Planckian locus) using Li's 2022 update (proposal 2) of Ohno's 2014 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)

is_uv_input

False, optional
If True: xyzw contain uv input data, not xyz data!

wl

None, optional
Wavelengths used when calculating Planckian radiators.
If None: use same wavelengths as CMFs in :cieobs:.

rtol

1e-5, float, optional
Stop search when cct a relative tolerance is reached.
The relative tolerance is calculated as dCCT/CCT_est,
with CCT_est the current intermediate estimate in the
search and with dCCT the difference between
the present and former estimates.

atol

0.1, optional
Stop search when cct a absolute tolerance (K) is reached.

force_tolerance

True, optional
If False: search only using the list of CCTs in the used lut.
Only one loop of the full algorithm is performed.
Accuracy depends on CCT of test source and the location
and spacing of the CCTs in the list.
If True: search will use adjacent CCTs to test source to create a new LUT,
(repeat the algoritm at higher resolution, progessively zooming in
toward the ground-truth) for tol_method == 'cl'; when
tol_method == 'nr' a newton-raphson method is used.
Because the CCT for multiple source is calculated in one go,
the atol and rtol values have to be met for all!

tol_method

'newton-raphson', optional
(Additional) method to try and achieve set tolerances.
Options:
- 'cl', 'cascading-lut': use increasingly higher CCT-resolution
to 'zoom-in' on the ground-truth.
- 'nr', 'newton-raphson': use the method as described in Li, 2016.

lut_resolution_reduction_factor

_CCT_LUT_RESOLUTION_REDUCTION_FACTOR, optional
Number of times the interval spanned by the adjacent Tc in a search or lut
method is downsampled (the search process will then start again)

duv_triangular_threshold

0.002, optional
Threshold for use of the triangular solution
(if smaller use triangular solution, else use the non-triangular (third order
polynomial))

max_iter

_CCT_MAX_ITER, optional
Maximum number of iterations used by the cascading-lut or newton-raphson methods.

split_calculation_at_N

_CCT_SPLIT_CALC_AT_N, optional
Split calculation when xyzw.shape[0] > split_calculation_at_N.
Splitting speeds up the calculation. If None: no splitting is done.

lut

None, optional
Look-Up-Table with Ti, u,v,u',v',u'',v'',slope values of Planckians.
Options:
- None: defaults to the lut specified in _CCT_LUT['li2022']['lut_type_def'].
- list (lut,lut_kwargs): use this pre-calculated lut
(add additional kwargs for the lut_generator_fcn(), defaults to None if
omitted)
- tuple: must be key (label) in :luts_dict: (pre-calculated dict of luts),

if not: then a new lut will be generated from scratch using the info in the tuple.

- str: must be key (label) in :luts_dict: (pre-calculated dict of luts)

- ndarray [Nx1]: list of luts for which to generate a lut

- ndarray [Nxn] with n>3: pre-calculated lut (last col must contain slope of the isotemperature lines).

luts_dict

None, optional

Dictionary of pre-calculated luts for various cspaces and cmf sets.

Must have structure luts_dict[cspace][cieobs][lut_label] with the lut part of a two-element list [lut, lut_kwargs]. It must contain at the top-level a key 'wl' containing the wavelengths of the Planckians used to generate the luts in this dictionary.

If None: luts_dict defaults to _CCT_LUT['li2022']['luts']

cspace

_CCT_SPACE, optional

Color space to do calculations in.

Options:

- cspace string:
  e.g. 'Yuv60' for use with luxpy.colortf()
- tuple with forward (i.e. xyz_to..) [and backward (i.e. ..to_xyz)] functions
  (and an optional string describing the cspace):
  e.g. (forward, backward) or (forward, backward, cspace string) or (forward, cspace string)
- dict with keys: 'fwtf' (foward), 'bwtf' (backward) [, optional: 'str' (cspace string)]

Note: if the backward tf is not supplied, optimization in cct_to_xyz() is done in the CIE 1976 u'v' diagram

cspace_kwargs

_CCT_CSPACE_KWARGS, optional

Parameter nested dictionary for the forward and backward transforms.

ignore_wl_diff

False, optional

When getting a lut from the dictionary, if differences are detected in the wavelengts of the lut and the ones used to calculate any plankcians then a new lut should be generated. Seting this to True ignores these differences and proceeds anyway.

use_fast_duv

_CCT_FAST_DUV, optional

If True: use a fast estimator of the Duv (one that avoids calculation of Planckians and uses the former best estimate's u,v coordinates. This method is accurate enough when the atol is small enough -> as long as abs(T-T_former)<=1K the Duv estimate should be ok.)

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:

1. Out-of-lut CCTs are encoded as negative CCTs (with as absolute value the value of the closest CCT from the lut.)

References:

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

2. Li, Y., Gao, C., Melgosa, M. and Li, C. (2022). Improved methods for computing CCT and Duv. LEUKOS, (in press).

luxpy.color.cct.**xyz_to_cct_zhang2019**(*xyzw*, *cieobs='1931_2'*, *out='cct'*, *is_uv_input=False*, *wl=None*, *atol=0.1*, *rtol=1e-05*, *force_tolerance=True*, *tol_method='newton-raphson'*, *lut_resolution_reduction_factor=4*, *split_calculation_at_N=25*, *max_iter=10*, *cspace='Yuv60'*, *cspace_kwargs={'bwtf': {}, 'fwtf': {}}*, *lut=None*, *luts_dict=None*, *ignore_wl_diff=False*, *use_fast_duv=True*, ***kwargs*)

Convert XYZ tristimulus values to correlated color temperature (CCT) and Duv(distance above (> 0) or below (< 0) the Planckian locus) using the golden-ratio search method described in Zhang et al. (2019).

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)

is_uv_input

False, optional
If True: xyzw contain uv input data, not xyz data!

wl

None, optional
Wavelengths used when calculating Planckian radiators.
If None: use same wavelengths as CMFs in :cieobs:.

rtol

1e-5, float, optional
Stop search when cct a relative tolerance is reached.
The relative tolerance is calculated as dCCT/CCT_est,
with CCT_est the current intermediate estimate in the
search and with dCCT the difference between
the present and former estimates.

atol

0.1, optional
Stop search when cct a absolute tolerance (K) is reached.

force_tolerance

True, optional
If False: search only using the list of CCTs in the used lut.
Only one loop of the full algorithm is performed.
Accuracy depends on CCT of test source and the location
and spacing of the CCTs in the list.
If True: search will use adjacent CCTs to test source to create a new LUT,
(repeat the algoritm at higher resolution, progessively zooming in
toward the ground-truth) for tol_method == 'cl'; when
tol_method == 'nr' a newton-raphson method is used.
Because the CCT for multiple source is calculated in one go,
the atol and rtol values have to be met for all!

tol_method

'newton-raphson', optional
(Additional) method to try and achieve set tolerances.
Options:
- 'cl', 'cascading-lut': use increasingly higher CCT-resolution
to 'zoom-in' on the ground-truth.
- 'nr', 'newton-raphson': use the method as described in Li, 2016.

lut_resolution_reduction_factor

_CCT_LUT_RESOLUTION_REDUCTION_FACTOR, optional
Number of times the interval spanned by the adjacent Tc in a search or lut
method is downsampled (the search process will then start again)

max_iter

_CCT_MAX_ITER, optional
Maximum number of iterations used by the cascading-lut or newton-raphson methods.

split_calculation_at_N

_CCT_SPLIT_CALC_AT_N, optional
Split calculation when xyzw.shape[0] > split_calculation_at_N.
Splitting speeds up the calculation. If None: no splitting is done.

lut

None, optional
Look-Up-Table with Ti, u,v,u',v',u'',v'',slope values of Planckians.
Options:
- None: defaults to the lut specified in
_CCT_LUT['zhang2019']['lut_type_def'].
- list (lut,lut_kwargs): use this pre-calculated lut
(add additional kwargs for the lut_generator_fcn(), defaults to None if
omitted)
- tuple: must be key (label) in :luts_dict: (pre-calculated dict of luts),
if not: then a new lut will be generated from scratch using the info in the
tuple.
- str: must be key (label) in :luts_dict: (pre-calculated dict of luts)
- ndarray [Nx1]: list of luts for which to generate a lut
- ndarray [Nxn] with n>3: pre-calculated lut (last col must contain slope of the
isotemperature lines).

luts_dict

None, optional
Dictionary of pre-calculated luts for various cspaces and cmf sets.
Must have structure luts_dict[cspace][cieobs][lut_label] with the
lut part of a two-element list [lut, lut_kwargs]. It must contain
at the top-level a key 'wl' containing the wavelengths of the
Planckians used to generate the luts in this dictionary.
If None: luts_dict defaults to _CCT_LUT['zhang2019']['luts']

cspace

_CCT_SPACE, optional
Color space to do calculations in.
Options:
- cspace string:
e.g. 'Yuv60' for use with luxpy.colortf()
- tuple with forward (i.e. xyz_to..) [and backward (i.e. ..to_xyz)]
functions
(and an optional string describing the cspace):
e.g. (forward, backward) or (forward, backward, cspace
string) or (forward, cspace string)
- dict with keys: 'fwtf' (foward), 'bwtf' (backward) [, optional: 'str'
(cspace string)]
Note: if the backward tf is not supplied, optimization in cct_to_xyz() is done in
the CIE 1976 u'v' diagram

cspace_kwargs

_CCT_CSPACE_KWARGS, optional
Parameter nested dictionary for the forward and backward transforms.

ignore_wl_diff

False, optional
When getting a lut from the dictionary, if differences are
detected in the wavelengts of the lut and the ones used to calculate any
plankcians then a new lut should be generated. Seting this to True ignores
these differences and proceeds anyway.

use_fast_duv

_CCT_FAST_DUV, optional
If True: use a fast estimator of the Duv
(one that avoids calculation of Planckians and uses the former
best estimate's u,v coordinates. This method is accurate enough
when the atol is small enough -> as long as abs(T-T_former)<=1K
the Duv estimate should be ok.)

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:

1. Out-of-lut CCTs are encoded as negative CCTs (with as absolute value the value of the closest CCT from the lut.)

References:

1. Zhang, F. (2019). High-accuracy method for calculating correlated color temperature with a lookup table based on golden section search. Optik, 193, 163018.

2. Li, C., Cui, G., Melgosa, M., Ruan, X., Zhang, Y., Ma, L., Xiao, K., & Luo, M. R. (2016). Accurate method for computing correlated color temperature. Optics Express, 24(13), 14066–14078.

luxpy.color.cct.**xyz_to_cct_fibonacci**(*xyzw*, *cieobs='1931_2'*, *out='cct'*, *is_uv_input=False*, *wl=None*, *atol=0.1*, *rtol=1e-05*, *force_tolerance=True*, *tol_method='newton-raphson'*, *lut_resolution_reduction_factor=4*, *split_calculation_at_N=25*, *max_iter=10*, *cspace='Yuv60'*, *cspace_kwargs={'bwtf': {}, 'fwtf': {}}*, *lut=None*, *luts_dict=None*, *ignore_wl_diff=False*, *use_fast_duv=True*, ***kwargs*)

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

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)

is_uv_input

False, optional
If True: xyzw contain uv input data, not xyz data!

wl

None, optional
Wavelengths used when calculating Planckian radiators.
If None: use same wavelengths as CMFs in :cieobs:.

rtol

1e-5, float, optional
Stop search when cct a relative tolerance is reached.
The relative tolerance is calculated as dCCT/CCT_est,
with CCT_est the current intermediate estimate in the
search and with dCCT the difference between
the present and former estimates.

atol

0.1, optional
Stop search when cct a absolute tolerance (K) is reached.

force_tolerance

True, optional
If False: search only using the list of CCTs in the used lut.

Only one loop of the full algorithm is performed.
Accuracy depends on CCT of test source and the location
and spacing of the CCTs in the list.
If True: search will use adjacent CCTs to test source to create a new LUT,
(repeat the algoritm at higher resolution, progessively zooming in
toward the ground-truth) for tol_method == 'cl'; when
tol_method == 'nr' a newton-raphson method is used.
Because the CCT for multiple source is calculated in one go,
the atol and rtol values have to be met for all!

tol_method

'newton-raphson', optional
(Additional) method to try and achieve set tolerances.
Options:
- 'cl', 'cascading-lut': use increasingly higher CCT-resolution
to 'zoom-in' on the ground-truth.
- 'nr', 'newton-raphson': use the method as described in Li, 2016.

lut_resolution_reduction_factor

_CCT_LUT_RESOLUTION_REDUCTION_FACTOR, optional
Number of times the interval spanned by the adjacent Tc in a search or lut
method is downsampled (the search process will then start again)

max_iter

_CCT_MAX_ITER, optional
Maximum number of iterations used by the cascading-lut or newton-raphson methods.

split_calculation_at_N

_CCT_SPLIT_CALC_AT_N, optional
Split calculation when xyzw.shape[0] > split_calculation_at_N.
Splitting speeds up the calculation. If None: no splitting is done.

lut

None, optional
Look-Up-Table with Ti, u,v,u',v',u'',v'',slope values of Planckians.
Options:
- None: defaults to the lut specified in _CCT_LUT['fibonacci']['lut_type_def'].
- list (lut,lut_kwargs): use this pre-calculated lut
(add additional kwargs for the lut_generator_fcn(), defaults to None if
omitted)
- tuple: must be key (label) in :luts_dict: (pre-calculated dict of luts),
if not: then a new lut will be generated from scratch using the info in the
tuple.
- str: must be key (label) in :luts_dict: (pre-calculated dict of luts)
- ndarray [Nx1]: list of luts for which to generate a lut
- ndarray [Nxn] with n>3: pre-calculated lut (last col must contain slope of the
isotemperature lines).

luts_dict

None, optional
Dictionary of pre-calculated luts for various cspaces and cmf sets.
Must have structure luts_dict[cspace][cieobs][lut_label] with the

lut part of a two-element list [lut, lut_kwargs]. It must contain at the top-level a key 'wl' containing the wavelengths of the Planckians used to generate the luts in this dictionary.

If None: luts_dict defaults to _CCT_LUT['fibonacci']['luts']

cspace

_CCT_SPACE, optional

Color space to do calculations in.

Options:

- cspace string:
  e.g. 'Yuv60' for use with luxpy.colortf()
- tuple with forward (i.e. xyz_to..) [and backward (i.e. ..to_xyz)] functions
  (and an optional string describing the cspace):
  e.g. (forward, backward) or (forward, backward, cspace string) or (forward, cspace string)
- dict with keys: 'fwtf' (foward), 'bwtf' (backward) [, optional: 'str' (cspace string)]

Note: if the backward tf is not supplied, optimization in cct_to_xyz() is done in the CIE 1976 u'v' diagram

cspace_kwargs

_CCT_CSPACE_KWARGS, optional

Parameter nested dictionary for the forward and backward transforms.

ignore_wl_diff

False, optional

When getting a lut from the dictionary, if differences are detected in the wavelengts of the lut and the ones used to calculate any plankcians then a new lut should be generated. Seting this to True ignores these differences and proceeds anyway.

use_fast_duv

_CCT_FAST_DUV, optional

If True: use a fast estimator of the Duv
(one that avoids calculation of Planckians and uses the former best estimate's u,v coordinates. This method is accurate enough when the atol is small enough -> as long as abs(T-T_former)<=1K the Duv estimate should be ok.)

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:

1. Out-of-lut CCTs (or close to) are encoded as negative CCTs (with as absolute value the value of the closest CCT from the lut.)

luxpy.color.cct.**xyz_to_cct**(*xyzw*, *mode='robertson2023'*, *cieobs='1931_2'*, *out='cct'*, *is_uv_input=False*, *wl=None*, *atol=0.1*, *rtol=1e-05*, *force_tolerance=True*, *tol_method='newton-raphson'*, *lut_resolution_reduction_factor=4*, *split_calculation_at_N=25*, *max_iter=10*, *cspace='Yuv60'*, *cspace_kwargs={'bwtf': {}, 'fwtf': {}}*, *lut=None*, *luts_dict=None*, *ignore_wl_diff=False*, *duv_triangular_threshold=0.002*, *first_guess_mode='robertson2023'*, *fgm_kwargs={}*, *use_fast_duv=True*, ***kwargs*)

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

Args:

xyzw

ndarray of tristimulus values

mode

'robertson2023', optional
String with name of method to use.
Options: 'robertson2023', 'robertson1968', 'ohno2014', 'li2016', 'li2022','zhang2019', 'fibonacci',
(also, but see note below: 'mcamy1992', 'hernandez1999')
Note: first_guess_mode for li2016 can also be specified using a ':' separator,
e.g. 'li2016:robertson1968'

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)

is_uv_input

False, optional
If True: xyzw contain uv input data, not xyz data!

wl

None, optional
Wavelengths used when calculating Planckian radiators.
If None: use same wavelengths as CMFs in :cieobs:.

rtol

1e-5, float, optional
Stop search when cct a relative tolerance is reached.
The relative tolerance is calculated as dCCT/CCT_est,
with CCT_est the current intermediate estimate in the
search and with dCCT the difference between
the present and former estimates.

atol

0.1, optional
Stop search when cct a absolute tolerance (K) is reached.

force_tolerance

True, optional

If False: search only using the list of CCTs in the used lut.
Only one loop of the full algorithm is performed.
Accuracy depends on CCT of test source and the location
and spacing of the CCTs in the list.
If True: search will use adjacent CCTs to test source to create a new LUT,
(repeat the algoritm at higher resolution, progessively zooming in
toward the ground-truth) for tol_method == 'cl'; when
tol_method == 'nr' a newton-raphson method is used.
Because the CCT for multiple source is calculated in one go,
the atol and rtol values have to be met for all!

tol_method

'newton-raphson', optional
(Additional) method to try and achieve set tolerances.
Options:
- 'cl', 'cascading-lut': use increasingly higher CCT-resolution
to 'zoom-in' on the ground-truth. (not for mode == 'li2016')
- 'nr', 'newton-raphson': use the method as described in Li, 2016.

lut_resolution_reduction_factor

_CCT_LUT_RESOLUTION_REDUCTION_FACTOR, optional
Number of times the interval spanned by the adjacent Tc in a search or lut
method is downsampled (the search process will then start again)

max_iter

_CCT_MAX_ITER, optional
Maximum number of iterations used by the cascading-lut or newton-raphson methods.

split_calculation_at_N

_CCT_SPLIT_CALC_AT_N, optional
Split calculation when xyzw.shape[0] > split_calculation_at_N.
Splitting speeds up the calculation. If None: no splitting is done.

lut

None, optional
Look-Up-Table with Ti, u,v,u',v',u'',v'',slope values of Planckians.
Options:
- None: defaults to the lut specified in _CCT_LUT[mode]['lut_type_def'].
- list (lut,lut_kwargs): use this pre-calculated lut
(add additional kwargs for the lut_generator_fcn(), defaults to None if omitted)
- tuple: must be key (label) in :luts_dict: (pre-calculated dict of luts),
if not: then a new lut will be generated from scratch using the info in the tuple.
- str: must be key (label) in :luts_dict: (pre-calculated dict of luts)
- ndarray [Nx1]: list of luts for which to generate a lut
- ndarray [Nxn] with n>3: pre-calculated lut (last col must contain slope of the isotemperature lines).

luts_dict

None, optional
Dictionary of pre-calculated luts for various cspaces and cmf sets.

Must have structure luts_dict[cspace][cieobs][lut_label] with the
lut part of a two-element list [lut, lut_kwargs]. It must contain
at the top-level a key 'wl' containing the wavelengths of the
Planckians used to generate the luts in this dictionary.
If None: the default dict for the mode is used
(e.g. _CCT_LUT['ohno2014']['lut_type_def'], for mode=='ohno2014').

cspace

_CCT_SPACE, optional
Color space to do calculations in.
Options:
- cspace string:
e.g. 'Yuv60' for use with luxpy.colortf()
- tuple with forward (i.e. xyz_to..) [and backward (i.e. ..to_xyz)]
functions
(and an optional string describing the cspace):
e.g. (forward, backward) or (forward, backward, cspace
string) or (forward, cspace string)
- dict with keys: 'fwtf' (foward), 'bwtf' (backward) [, optional: 'str'
(cspace string)]
Note: if the backward tf is not supplied, optimization in cct_to_xyz() is done in
the CIE 1976 u'v' diagram

cspace_kwargs

_CCT_CSPACE_KWARGS, optional
Parameter nested dictionary for the forward and backward transforms.

ignore_wl_diff

False, optional
When getting a lut from the dictionary, if differences are
detected in the wavelengts of the lut and the ones used to calculate any
plankcians then a new lut should be generated. Seting this to True ignores
these differences and proceeds anyway.

duv_triangular_threshold

0.002, optional
Threshold for use of the triangular solution.
(if smaller use triangular solution, else use the non-triangular one:
If mode == 'ohno2014' -> parabolic, if mode == 'li2022' -> 3e-order
poly)

first_guess_mode

'robertson2023', optional (cfr. mode == 'li2016')
Method used to get an approximate (first guess) estimate of the cct,
after which the newton-raphson method is started.
Options: 'robertson2023','robertson1968', 'ohno2014', 'zhang2019','li2022'

use_fast_duv

_CCT_FAST_DUV, optional
If True: use a fast estimator of the Duv
(one that avoids calculation of Planckians and uses the former
best estimate's u,v coordinates. This method is accurate enough
when the atol is small enough -> as long as abs(T-T_former)<=1K

the Duv estimate should be ok.)

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:

1. Using the 'mcamy1992' and 'hernandez1999' options will result in additional errors when cieobs is different from '1931_2' as for these options the CCT is determined using a fixed set of equations optimized for the 1931 2° CMFs!! The only impact will be on the calculation of the Duv from the CCT. That does depend on the settings of cieobs and cspace! Change at own discretion. 2. Out-of-lut CCTs are encoded as negative CCTs (with as absolute value the value of the closest CCT from the lut.)

References:

1. Robertson, A. R. (1968). Computation of Correlated Color Temperature and Distribution Temperature. Journal of the Optical Society of America, 58(11), 1528–1535.

2. Smet K.A.G., Royer M., Baxter D., Bretschneider E., Esposito E., Houser K., Luedtke W., Man K., Ohno Y. (2022), Recommended method for determining the correlated color temperature and distance from the Planckian Locus of a light source (in preparation, LEUKOS?)

3. Baxter D., Royer M., Smet K.A.G. (2022) Modifications of the Robertson Method for Calculating Correlated Color Temperature to Improve Accuracy and Speed (in preparation, LEUKOS?)

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

5. Zhang, F. (2019). High-accuracy method for calculating correlated color temperature with a lookup table based on golden section search. Optik, 193, 163018.

6. Li, C., Cui, G., Melgosa, M., Ruan, X., Zhang, Y., Ma, L., Xiao, K., & Luo, M. R. (2016). Accurate method for computing correlated color temperature. Optics Express, 24(13), 14066–14078.

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

8. 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

9. Li, Y., Gao, C., Melgosa, M. and Li, C. (2022). Improved methods for computing CCT and Duv. LEUKOS, (in press).

`luxpy.color.cct.cct_to_xyz`(*ccts*, *duv=None*, *cct_offset=None*, *cieobs='1931_2'*, *wl=None*, *cspace='Yuv60'*, *cspace_kwargs={'bwtf': {}, 'fwtf': {}}*)

Convert correlated color temperature (550 K <= CCT <= 1e11 K) and Duv (distance above (>0) or below (<0) the Planckian locus) to XYZ tristimulus values.

Finds xyzw_estimated by determining the iso-temperature line

(= line perpendicular to the Planckian locus):

Option 1 (fastest):

First, the angle between the coordinates corresponding to ccts

and ccts-cct_offset are calculated, then 90° is added, and finally

the new coordinates are determined, while taking sign of duv into account.

Option 2 (slowest, about 55% slower):

Calculate the slope of the iso-T-line directly using the Planckian
spectrum and its derivative.

Args:

ccts

ndarray [N,1] of cct values

duv

None or ndarray [N,1] of duv values, optional
Note that duv can be supplied together with cct values in :ccts:
as ndarray with shape [N,2].

cct_offset

None, optional
If None: use option 2 (direct iso-T slope calculation, more accurate,
but slower: about 1.55 slower)
else: use option 1 (estimate slope from 90° + angle of small cct_offset)

cieobs

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

wl

None, optional
Wavelengths used when calculating Planckian radiators.
If None: use same wavelengths as CMFs in :cieobs:.

cspace

_CCT_SPACE, optional
Color space to do calculations in.
Options:
- cspace string:
e.g. 'Yuv60' for use with luxpy.colortf()
- tuple with forward (i.e. xyz_to..) [and backward (i.e. ..to_xyz)]
functions
(and an optional string describing the cspace):
e.g. (forward, backward) or (forward, backward, cspace
string) or (forward, cspace string)
- dict with keys: 'fwtf' (foward), 'bwtf' (backward) [, optional: 'str'
(cspace string)]
Note: if the backward tf is not supplied, optimization in cct_to_xyz() is done in
the CIE 1976 u'v' diagram

cspace_kwargs

_CCT_CSPACE_KWARGS, optional
Parameter nested dictionary for the forward and backward transforms.

Returns:

returns

ndarray with estimated XYZ tristimulus values

Note:

1. If duv is not supplied (:ccts:.shape is (N,1) and :duv: is None), source is assumed to be on the Planckian locus. 2. Minimum CCT is 550 K (lower than 550 K, some negative Duv values will result in coordinates outside of the Spectrum Locus !!!)

luxpy.color.cct.**calculate_lut**(*ccts*, *cieobs*, *wl=None*, *lut_vars=['T', 'uv', 'uvp', 'uvpp', 'iso-T-slope']*, *cspace='Yuv60'*, *cspace_kwargs={'bwtf': {}, 'fwtf': {}}*)

Function that calculates a LUT for the specified calculation method for the input ccts. Calculation is performed for CMF set specified in cieobs and in the chromaticity diagram in cspace.

Args:

ccts

ndarray [Nx1] or str

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

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

cieobs

None or str or ndrarray, optional

str specifying cmf set.

wl

None, optional

Generate luts based on Planckians with wavelengths (range).

If None: use same wavelengths as CMFs in :cieobs:.

lut_vars

['T','uv','uvp','uvpp','iso-T-slope'], optional

Data the lut should contain. Must follow this order

and minimum should be ['T']

cspace

_CCT_SPACE, optional

Color space to do calculations in.

Options:

- cspace string:
  e.g. 'Yuv60' for use with luxpy.colortf()
- tuple with forward (i.e. xyz_to..) [and backward (i.e. ..to_xyz)] functions
  (and an optional string describing the cspace):
  e.g. (forward, backward) or (forward, backward, cspace string) or (forward, cspace string)
- dict with keys: 'fwtf' (foward), 'bwtf' (backward) [, optional: 'str' (cspace string)]

Note: if the backward tf is not supplied, optimization in cct_to_xyz() is done in the CIE 1976 u'v' diagram

cspace_kwargs

_CCT_CSPACE_KWARGS, optional

Parameter nested dictionary for the forward and backward transforms.

Returns:

returns

lut

ndarray with T, u, v, u', v', u'', v'', slope (note ':1st deriv., '':2nd deriv.).

luxpy.color.cct.**generate_luts**(*types=[None], seamless_stitch=True, fallback_unit='K-1', fallback_n=50, cct_min=450, cct_max=100000000000.0, lut_file=None, load=False, lut_path='C:\\Users\\u0032318\\OneDrive - KU Leuven\\Documents\\Github\\luxpy\\luxpy\\data\\cctluts\\', save_luts=True, wl=None, cieobs=['1931_2'], lut_vars=['T', 'uv', 'uvp', 'uvpp', 'iso-T-slope'], cspace=['Yuv60'], cspace_kwargs=[{'bwtf': {}, 'fwtf': {}}], verbosity=0, lut_generator_fcn=<function _generate_lut>, lut_generator_kwargs={}*)

Generate a number of luts and store them in a nested dictionary. Structure: lut[cspace][cieobs][lut type].

Args:

lut_file

None, optional
string specifying the filename to save the lut (as .pkl) to.
If None: don't save anything when generated (i.e. load==False).

load

True, optional
If True: load previously generated dictionary.
If False: generate from scratch.

lut_path

_CCT_LUT_PATH, optional
Path to file.

wl

None, optional
Wavelength for Planckian spectrum generation.
If None: use same wavelengths as CMFs in :cieobs:.

cieobs

[_CIEOBS] or list, optional
Generate a LUT for each one in the list.
If None: generate for all cmfs in _CMF.

types

[None], optional
List of lut specifiers of format [(Tmin,Tmax,Tinterval,unit),...]
If units are in MK-1 then the range is also!
Unit options are:
- '%': equal relative Tc spacing (in %, cfr. (Ti+1 - Ti-1)/Ti-1).
- 'K' equal absolute Tc spacing (in K, cfr. (Ti+1 - Ti-1).
- '%-1': equal relative reciprocal Tc (MK-1 = mired).
- 'K-1': equal absolute reciprocal Tc (MK-1 = mired).
If the last element of the list is a bool, then the way the different
lists of Tcs generated by each list element can be set. If True:
the Tcs will be 'seamlessly' stitched together (this does have an
an impact on the min-max range of each Tc set) so that there are no
discontinuities in terms of the intervals.

seamless_stitch

True, optional
When stitching (creating) LUTs composed of several CCT ranges with different
intervals, these do not always 'match' well, in the sense that discontinuities

might be generated. This can be avoided (at the expense of possibly slightly changed ranges)
by setting the :seamless_stitch: argument to True. Is overriden when
the last element in the lut list is a boolean.

cct_max

_CCT_MAX, optional
Limit Tc's to a maximum value of cct_max

cct_min

_CCT_MIN, optional
Limit Tc's to a minimum value of cct_max

fallback_unit

_CCT_FALLBACK_UNIT, optional
Unit to fall back on when the input unit in tc4 (of first list) is 'au'.
As there is no common distancing of the unit types ['K','%','%-1','K-1']
the Tc's are generated by dividing the min-max range into
a number of divisions, specified by the negative 3 element (or when
positive or NaN, the number of divisions is set by :fallback_divisions:)

fallback_n

_CCT_FALLBACK_N, optional
Number of divisions the min-max range is divided into, in the
fallback case in which unit=='au' and the 3e 4-vector element
is NaN or positive.

lut_vars

['T','uv','uvp','uvpp','iso-T-slope'], optional
Data the lut should contain. Must follow this order
and minimum should be ['T']

cspace,cspace_kwargs

Lists with the cspace and cspace_kwargs for which luts will be generated.
Default is single chromaticity diagram in _CCT_CSPACE.

verbosity

0, optional
If > 0: give some intermediate feedback while generating luts.

lut_generator_fcn

_generate_lut, optional
Lets a user specify his own lut generation function (must output a list of 1 lut).
Default is the general function. There is a specific one for
Ohno's 2014 method as that one requires a different correction factor
for each lut for the parabolic solutions. This optimized value is specified in the
second list index. (see _generate_lut_ohno2014()).

lut_generator_kwargs

{}, optional
Dict with keyword arguments specific to the (user) lut_generator_fcn.
(e.g. {'f_corr':0.9991} for _generate_lut_ohno2014())

Returns:

dict

Dictionary with luts for the specified mode, cieobs(s) and cspace(s).
Structure: lut[cspace][cieobs][lut type]
At the upper dict level there is also a key 'wl' which contains a dict with keys
the cieobs and with values the wavelengths used to calculate the Planckians for
each lut for the specified cieobs; as well as a key with the lut_vars
The luts contains as data the variables as specified in lut_vars:
- T: (in K)
- uv: chromaticity coordinates of planckians
- uvp: chromaticity coordinates of 1st derivative of the planckians.
- uvpp: chromaticity coordinates of 2nd derivative of the planckians.
- iso-T-slope: slope of isotemperature lines (calculated as in Robertson, 1968).

luxpy.color.cct.**get_tcs4**(*tc4*, *uin=None*, *seamless_stitch=True*, *fallback_unit='K-1'*, *fallback_n=50*)

Get an ndarray of Tc's obtained from a list or tuple of tc4 4-vectors.

Args:

tc4

list or tuple of 4-vectors.
e.g. (tc4_1, tc4_2, tc4_3,...) or (tc4_1, tc4_2, tc4_3,..., bool::seamless_stitch)
When the last element of the list/tuple is a bool, then this specifies
how the Tc arrays generated for each of the 4-vector elements need to be
stitched together. This overrides the seamless_stitch input argument.
Vector elements are:
[Tmin, Tmax inclusive, Tinterval(or number of intervals), unit]
Unit specifies unit of the Tc interval, i.e. it determines the
type of scale in which the spacing of the Tc are done.
Unit options are:
- '%': equal relative Tc spacing (in %, cfr. (Ti+1 - Ti-1)/Ti-1).
- 'K' equal absolute Tc spacing (in K, cfr. (Ti+1 - Ti-1).
- '%-1': equal relative reciprocal Tc (MK-1 = mired).
- 'K-1': equal absolute reciprocal Tc (MK-1 = mired).
If the 'interval' element is negative, it actually represents
the number of intervals between Tmin, Tmax (included).

uin

None, optional
Unit of input Tmin, Tmax (by default it is assumed to be the same
as the scale 'unit').

seamless_stitch

True, optional
Determines how the Tc arrays generated for each of the 4-vector
elements are stitched together. Is overriden by the presence of a
bool as last list/tuple element in :tc4:.
For a seamless stitch, all units for all 4-vectors should be the same!!

fallback_unit

_CCT_FALLBACK_UNIT, optional
Unit to fall back on when the input unit in tc4 (of first list) is 'au'.
As there is no common distancing of the unit types ['K','%','%-1','K-1']
the Tc's are generated by dividing the min-max range into

a number of divisions, specified by the negative 3 element (or when positive or NaN, the number of divisions is set by :fallback_divisions:)

fallback_n

_CCT_FALLBACK_N, optional
Number of divisions the min-max range is divided into, in the fallback case in which unit=='au' and the 3e 4-vector element is NaN or positive.

Returns:

tcs

ndarray with Tcs

`luxpy.color.cct._get_lut`(*lut, uin=None, seamless_stitch=True, fallback_unit='K-1', fallback_n=50, resample_ndarray=False, cct_max=100000000000.0, cct_min=450, luts_dict=None, lut_type_def=None, lut_vars=['T', 'uv', 'uvp', 'uvpp', 'iso-T-slope'], cieobs='1931_2', cspace_str=None, wl=None, ignore_unequal_wl=False, lut_generator_fcn=<function _generate_lut>, lut_generator_kwargs={}, cspace='Yuv60', cspace_kwargs={'bwtf': {}, 'fwtf': {}}, **kwargs*)

Get an ndarray LUT from various sources.

Args:

lut

Look-Up-Table with Ti, u,v,u',v',u'',v'',slope values of Planckians, or whatever quantities are specified in lut_vars ('T','uv' is always part of the lut).
Options:
- list: must have two elements: [lut,lut_kwargs]
- None: lut from luts_dict with lut_type_def as key
- str: lut from luts_dict at key :lut:
- ndarray [Nxn, with n>1]: precalculated lut (only processing will be to keep it with cct_min-cct_max range)
- ndarray [Nx1]: list of Tc's from which a new lut will be calculated.
- tuple of 4-vectors: used as key in luts_dict or to generate new lut from scratch

4-vector info:

+ format: e.g. (tc4_1, tc4_2, tc4_3,...) or (tc4_1, tc4_2, tc4_3,..., bool::seamless_stitch)
+ When the last element of the list/tuple is a bool, then this specifies how the Tc arrays generated for each of the 4-vector elements need to be stitched together. This overrides the seamless_stitch input argument.
+ Vector elements are:

[Tmin, Tmax inclusive, Tinterval(or number of intervals), unit]

Unit specifies unit of the Tc interval, i.e. it determines the type of scale in which the spacing of the Tc are done.
Unit options are:

- '%': equal relative Tc spacing (in %, cfr. (Ti+1 - Ti-1)/Ti-1).
- 'K' equal absolute Tc spacing (in K, cfr. (Ti+1 - Ti-1).
- '%-1': equal relative reciprocal Tc (MK-1 = mired).
- 'K-1': equal absolute reciprocal Tc (MK-1 = mired).

If the 'interval' element is negative, it actually represents
the number of intervals between Tmin, Tmax (included).

uin

None, optional
Unit of input Tmin, Tmax (by default it is assumed to be the same
as the scale 'unit') in Tc generation from tuple.

seamless_stitch

True, optional
Determines how the Tc arrays generated for each of the 4-vector
elements are stitched together. Is overriden by the presence of a
bool as last list/tuple element in :tc4:.
For a seamless stitch, all units for all 4-vectors should be the same!!

cct_max

_CCT_MAX, optional
Limit Tc's to a maximum value of cct_max

cct_min

_CCT_MIN, optional
Limit Tc's to a minimum value of cct_max

fallback_unit

_CCT_FALLBACK_UNIT, optional
Unit to fall back on when the input unit in tc4 (of first list) is 'au'.
As there is no common distancing of the unit types ['K','%','%-1','K-1']
the Tc's are generated by dividing the min-max range into
a number of divisions, specified by the negative 3 element (or when
positive or NaN, the number of divisions is set by :fallback_divisions:)

fallback_n

_CCT_FALLBACK_N, optional
Number of divisions the min-max range is divided into, in the
fallback case in which unit=='au' and the 3e 4-vector element
is NaN or positive.

resample_tc4_array

False, optional
If False: do not resample Tc's of an ndarray input for tc4
else: divide min-max range in fallback_n intervals. Uses fallback_unit
to determine the scale for the resampling.

wl

None, optional
Wavelength for Planckian spectrum generation.
If None: use same wavelengths as CMFs in :cieobs:.

cieobs

_CIEOBS or str or ndarray, optional
CMF set used to convert Planckian spectra to chromaticity coordinates

lut_type_def

None, placeholder
Default lut (tuple key) to read from luts_dict.

luts_dict

None, optional
Dictionary of pre-calculated luts for various cspaces and cmf sets.
Must have structure luts_dict[cspace][cieobs][lut_label] with the
lut part of a two-element list [lut, lut_kwargs]. It must contain
at the top-level a key 'wl' containing the wavelengths of the
Planckians used to generate the luts in this dictionary.
If None: the default dict for the mode is used
(e.g. _CCT_LUT['ohno2014']['lut_type_def'], for mode=='ohno2014').

lut_vars

['T','uv','uvp','uvpp','iso-T-slope'], optional
Data the lut should contain. Must follow this order
and minimum should be ['T']

cspace,cspace_kwargs

Lists with the cspace and cspace_kwargs for which luts will be generated.
Default is single chromaticity diagram in _CCT_CSPACE.

ignore_unequal_wl

False, optional
If True: ignore any differences in the wavelengths used to calculate
the lut (cfr. Planckians) from the luts_dict and the requested
wavelengths in :wl:

lut_generator_fcn

_generate_lut, optional
Lets a user specify his own lut generation function (must output a list of 1 lut).
Default is the general function. There is a specific one for
Ohno's 2014 method as that one requires a different correction factor
for each lut for the parabolic solutions. This optimized value is specified in the
second list index. (see _generate_lut_ohno2014()).

lut_generator_kwargs

{}, optional
Dict with keyword arguments specific to the (user) lut_generator_fcn.
(e.g. {'f_corr':0.9991} for _generate_lut_ohno2014())

Returns:

lut

List with an ndarray with in the columns whatever is specified in
lut_vars (Tc and uv are always present!).
Default lut_vars = ['T','uv','uvp','uvpp','iso-T-slope']
- Tc: (in K)
- u,v: chromaticity coordinates of planckians
- u'v': chromaticity coordinates of 1st derivative of the planckians.
- u",v": chromaticity coordinates of 2nd derivative of the planckians.
- slope of isotemperature lines (calculated as in Robertson, 1968).

lut_kwargs

{}
Dictionary with additional parameters related to the generation of the
lut.

luxpy.color.cct.**_generate_tcs**(*tc4*, *uin=None*, *seamless_stitch=True*, *cct_max=100000000000.0*, *cct_min=450*, *fallback_unit='K-1'*, *fallback_n=50*, *resample_ndarray=False*)

Get an ndarray of Tc's obtained from a list or tuple of tc4 4-vectors (or ndarray).

Args:

tc4

list or tuple of 4-vectors or ndarray.
If ndarray: return tc4 limited to a cct_min-cct_max range (do nothing else).
If list/tuple: e.g. (tc4_1, tc4_2, tc4_3,...) or (tc4_1, tc4_2, tc4_3,..., bool::seamless_stitch)
When the last element of the list/tuple is a bool, then this specifies
how the Tc arrays generated for each of the 4-vector elements need to be
stitched together. This overrides the seamless_stitch input argument.
Vector elements are:
[Tmin, Tmax inclusive, Tinterval(or number of intervals), unit]
Unit specifies unit of the Tc interval, i.e. it determines the
type of scale in which the spacing of the Tc are done.
Unit options are:
- '%': equal relative Tc spacing (in %, cfr. (Ti+1 - Ti-1)/Ti-1).
- 'K' equal absolute Tc spacing (in K, cfr. (Ti+1 - Ti-1).
- '%-1': equal relative reciprocal Tc (MK-1 = mired).
- 'K-1': equal absolute reciprocal Tc (MK-1 = mired).
If the 'interval' element is negative, it actually represents
the number of intervals between Tmin, Tmax (included).

uin

None, optional
Unit of input Tmin, Tmax (by default it is assumed to be the same
as the scale 'unit').

seamless_stitch

True, optional
Determines how the Tc arrays generated for each of the 4-vector
elements are stitched together. Is overriden by the presence of a
bool as last list/tuple element in :tc4:.
For a seamless stitch, all units for all 4-vectors should be the same!!

cct_max

_CCT_MAX, optional
Limit Tc's to a maximum value of cct_max

cct_min

_CCT_MIN, optional
Limit Tc's to a minimum value of cct_max

fallback_unit

_CCT_FALLBACK_UNIT, optional
Unit to fall back on when the input unit in tc4 (of first list) is 'au'.
As there is no common distancing of the unit types ['K','%','%-1','K-1']
the Tc's are generated by dividing the min-max range into
a number of divisions, specified by the negative 3 element (or when
positive or NaN, the number of divisions is set by :fallback_divisions:)

fallback_n

_CCT_FALLBACK_N, optional
Number of divisions the min-max range is divided into, in the
fallback case in which unit=='au' and the 3e 4-vector element
is NaN or positive.

resample_ndarray

False, optional
If False: do not resample Tc's of an ndarray input for tc4
else: divide min-max range in fallback_n intervals. Uses fallback_unit
to determine the scale for the resampling.

Returns:

tcs

ndarray with Tcs

luxpy.color.cct.**_generate_lut**(*tc4*, *uin=None*, *seamless_stitch=True*, *fallback_unit='K-1'*, *fallback_n='K-1'*, *resample_ndarray=False*, *cct_max=100000000000.0*, *cct_min=450*, *wl=None*, *cieobs='1931_2'*, *lut_vars=['T', 'uv', 'uvp', 'uvpp', 'iso-T-slope']*, *cspace='Yuv60'*, *cspace_kwargs={'bwtf': {}, 'fwtf': {}}*, ***kwargs*)

Get an ndarray LUT for Tc's obtained from a list or tuple of tc4 4-vectors (or ndarray).

Args:

tc4

list or tuple of 4-vectors or ndarray.
If ndarray: return tc4 limited to a cct_min-cct_max range (do nothing else).
If list/tuple: e.g. (tc4_1, tc4_2, tc4_3,...) or (tc4_1, tc4_2, tc4_3,..., bool::seamless_stitch)
When the last element of the list/tuple is a bool, then this specifies
how the Tc arrays generated for each of the 4-vector elements need to be
stitched together. This overrides the seamless_stitch input argument.
Vector elements are:
[Tmin, Tmax inclusive, Tinterval(or number of intervals), unit]
Unit specifies unit of the Tc interval, i.e. it determines the
type of scale in which the spacing of the Tc are done.
Unit options are:
- '%': equal relative Tc spacing (in %, cfr. (Ti+1 - Ti-1)/Ti-1).
- 'K' equal absolute Tc spacing (in K, cfr. (Ti+1 - Ti-1).
- '%-1': equal relative reciprocal Tc (MK-1 = mired).
- 'K-1': equal absolute reciprocal Tc (MK-1 = mired).
If the 'interval' element is negative, it actually represents
the number of intervals between Tmin, Tmax (included).

uin

None, optional
Unit of input Tmin, Tmax (by default it is assumed to be the same
as the scale 'unit').

seamless_stitch

True, optional
Determines how the Tc arrays generated for each of the 4-vector
elements are stitched together. Is overriden by the presence of a

bool as last list/tuple element in :tc4:.
For a seamless stitch, all units for all 4-vectors should be the same!!

cct_max

_CCT_MAX, optional
Limit Tc's to a maximum value of cct_max

cct_min

_CCT_MIN, optional
Limit Tc's to a minimum value of cct_max

fallback_unit

_CCT_FALLBACK_UNIT, optional
Unit to fall back on when the input unit in tc4 (of first list) is 'au'.
As there is no common distancing of the unit types ['K','%','%-1','K-1']
the Tc's are generated by dividing the min-max range into
a number of divisions, specified by the negative 3 element (or when
positive or NaN, the number of divisions is set by :fallback_divisions:)

fallback_n

_CCT_FALLBACK_N, optional
Number of divisions the min-max range is divided into, in the
fallback case in which unit=='au' and the 3e 4-vector element
is NaN or positive.

resample_tc4_array

False, optional
If False: do not resample Tc's of an ndarray input for tc4
else: divide min-max range in fallback_n intervals. Uses fallback_unit
to determine the scale for the resampling.

wl

None, optional
Wavelength for Planckian spectrum generation.
If None: use same wavelengths as CMFs in :cieobs:.

cieobs

[_CIEOBS] or list of str or ndarrays, optional
Generate a LUT for each one in the list.
If None: generate for all cmfs in _CMF.

lut_vars

['T','uv','uvp','uvpp','iso-T-slope'], optional
Data the lut should contain. Must follow this order
and minimum should be ['T']

cspace,cspace_kwargs

Lists with the cspace and cspace_kwargs for which luts will be generated.
Default is single chromaticity diagram in _CCT_CSPACE.

Returns:

lut

List with an ndarray with in the columns whatever is specified in
lut_vars (Tc and uv are always present!).
Default lut_vars = ['T','uv','uvp','uvpp','iso-T-slope']

- Tc: (in K)
- u,v: chromaticity coordinates of planckians
- u'v': chromaticity coordinates of 1st derivative of the planckians.
- u",v": chromaticity coordinates of 2nd derivative of the planckians.
- slope of isotemperature lines (calculated as in Robertson, 1968).

lut_kwargs

{},
Dictionary with additional parameters related to the generation of the lut.

luxpy.color.cct.**_generate_lut_ohno2014**(*lut*, *uin=None*, *seamless_stitch=True*, *fallback_unit='K-1'*, *fallback_n=50*, *resample_ndarray=False*, *cct_max=100000000000.0*, *cct_min=450*, *luts_dict=None*, *lut_type_def=None*, *lut_vars=['T', 'uv']*, *cieobs='1931_2'*, *cspace_str=None*, *wl=None*, *ignore_unequal_wl=False*, *cspace='Yuv60'*, *cspace_kwargs={'bwtf': {}, 'fwtf': {}}*, *f_corr=None*, *ignore_f_corr_is_None=False*, *duv_triangular_threshold=0.002*, *ignore_wl_diff=False*, ***kwargs*)

Lut generator function for ohno2014.

Args:

…

see docstring for _generate_lut

f_corr

Tc,x correction factor for the parabolic solution in Ohno2014.
If None, it will be recalculated (note that it depends on the lut) for increased accuracy.

ignore_f_corr_is_None

If True, ignore f_corr is None, i.e. don't re-calculate f_corr.

Returns:

lut

an ndarray with the lut

dict

a dictionary with the (re-optmized) value for f_corr and for ignore_f_cor_is_None.)

luxpy.color.cct.**_generate_lut_li2022**(*lut, uin=None, seamless_stitch=True, fallback_unit='K-1', fallback_n=50, resample_ndarray=False, cct_max=100000000000.0, cct_min=450, luts_dict=None, lut_type_def=None, lut_vars=['T', 'uv', 'uvp', 'uvpp'], cieobs='1931_2', cspace_str=None, wl=None, ignore_unequal_wl=False, lut_generator_fcn=<function _generate_lut>, lut_generator_kwargs={}, cspace='Yuv60', cspace_kwargs={'bwtf': {}, 'fwtf': {}}, f_corr=None, ignore_f_corr_is_None=False, duv_triangular_threshold=0.002, ignore_wl_diff=False, **kwargs*)

Lut generator function for li2022 (= updated ohno2014).

Args:

…

see docstring for _generate_lut

f_corr

Tc,x correction factor for the non-triangular solution in Ohno2014.
If None, it will be recalculated (note that it depends on the lut) for increased accuracy.

ignore_f_corr_is_None

If True, ignore f_corr is None, i.e. don't re-calculate f_corr.

Returns:

lut

an ndarray with the lut

dict

a dictionary with the (re-optmized) value for f_corr and for ignore_f_cor_is_None.)

luxpy.color.cct.**calculate_cct_luts**(*wl*, *cmf_list=['1931_2', '1964_10', '2015_2', '2015_10']*, *mode='robertson2023'*, *lut_type=None*, *lut_generator_kwargs={}*, *luts=None*, *load=False*, *save_luts=False*, *lut_path='./'*, *cspace=['Yuv60']*, *cspace_kwargs=[{'bwtf': {}, 'fwtf': {}}]*, *verbosity=1*)

Calculate a lut dictionary for a specified wl and list of color matching functions

luxpy.color.cct.**xyz_to_cct_ohno2011**(*xyz*)

Calculate cct and Duv from CIE 1931 2° xyz following Ohno (2011).

Args:

xyz

ndarray with CIE 1931 2° X,Y,Z tristimulus values

Returns:

cct, duv

ndarrays with correlated color temperatures and distance to blackbody locus in CIE 1960 uv

References:

1. Ohno, Y. (2011). Calculation of CCT and Duv and Practical Conversion Formulae. CORM 2011 Conference, Gaithersburg, MD, May 3-5, 2011

luxpy.color.cct.**_get_ccts_for_lut_bf**(*start=1000*, *end=41000*, *interval=0.25*, *unit='%'*)

luxpy.color.cct.**generate_lut_bf**(*ccts=None*, *start=1000*, *end=41000*, *interval=0.25*, *unit='%'*, *wl=None*, *cmfs='1931_2'*, *cspace='Yuv60'*, *cspace_kwargs={}*)

Calculate a Look-Up-Table for CCT & Duv calculations.

Args:

ccts

None, optional
If not None: use this specific list or ndarray of CCTs.

start

1000, optional
Start in CCT (LUT also has one lower CCT)

end

41000, optional
End at this CCT (LUT also has a higher CCT)

interval

0.25, optional
Interval to go from one to the next CCT in the LUT

(:unit: determines exactly how much this number increases the CCT)

unit

'%', optional

Options:

- '%': cct[i+1] = cct[i]*(1 + interval/100)
- 'K': cct[i+1] = cct[i] + interval
- '%-1': 1e6/cct[i+1] = (1e6/cct[i])*(1 + interval/100)
- 'K-1': 1e6/cct[i+1] = 1e6/cct[i] + interval

wl

None, optional

If None: use same wavelengths as from cmf set to generate blackbody radiators

cmf

"1931_2", optional

String specifying or ndarray with CMF set.

cspace

'Yuv60', optional

String specifying the color or chromaticity space to calculate the distance to the blackbody locus in.

(uses luxpy.colortf)

cspace_kwargs

{}, optional

A dict with any kwargs for the xyz_to_space function

(cfr. luxpy.colortf(xyz, fwtf = cspace_kwargs)).

Returns:

lut

ndarray [nx3] with CCT, u, v coordinates

(or whatever equivalent coordinates for the selected cspace)

luxpy.color.cct.**xyz_to_cct_bruteforce**(*xyz*, *wl=None*, *cmfs='1931_2'*, *atol=1e-15*, *rtol=1e-20*, *n_max=10000.0*, *down_sampling_factor=10*, *ccts=None*, *start=1000*, *end=41000*, *interval=0.25*, *unit='%'*, *cspace='Yuv60'*, *cspace_kwargs={}*, *lut=array([[9.9751e+02, 4.4860e-01, 3.5457e-01], [1.0000e+03, 4.4801e-01, 3.5462e-01], [1.0025e+03, 4.4743e-01, 3.5468e-01], ..., [4.0869e+04, 1.8165e-01, 2.6966e-01], [4.0971e+04, 1.8165e-01, 2.6964e-01], [4.1073e+04, 1.8164e-01, 2.6962e-01]])*, *use_newton_raphson=False*, *fast_duv=True*, *out='cct'*)

Calculates the CCT (and Duv) value for a set of tristimulus values using brute-force approach. The method start by generating a large LUT, finds CCT with a minimum distance to the blackbody locus. Then further iterates over smaller and smaller CCT-ranges by generating new LUTs, until the solution converges to a specified tolerance or until a maximum number of iterations is reached.

Args:

xyz

ndarray of tristimulus values XYZ. [nx3]

wl

None, optional

If None: use same wavelengths as from cmf set to generate blackbody radiators for LUT.

cmf

"1931_2", optional
String specifying or ndarray with CMF set to use for LUT computation.

atol

0.1, optional
Absolute tolerance in Kelvin. If the difference between the two surrounding CCTs is smaller than tol,
the brute-force search stops.

n_max

1000, optional
Maximum number of iterations that a more detailed LUT is generated.
If the number of iterations > n_max, the brute-force search stops.

down_sampling_factor

10, optional
Value by which the original interval is further downsampled at each iteration.

ccts

None, optional
If not None: use this specific list or ndarray of CCTs.

start

1000, optional
Start in CCT (LUT also has one lower CCT)

end

41000, optional
End at this CCT (LUT also has a higher CCT)

interval

0.25, optional
Interval to go from one to the next CCT in the LUT
(:unit: determines exactly how much this number increases the CCT)

unit

'%', optional
Options:
- '%': cct[i+1] = cct[i]*(1 + interval/100)
- 'K': cct[i+1] = cct[i] + interval
- '%-1': 1e6/cct[i+1] = (1e6/cct[i])*(1 + interval/100)
- 'K-1': 1e6/cct[i+1] = 1e6/cct[i] + interval

cspace

'Yuv60', optional
String specifying the color or chromaticity space to calculate
the distance to the blackbody locus in.
(uses luxpy.colortf)

cspace_kwargs

{}, optional
A dict with any kwargs for the xyz_to_space function
(cfr. luxpy.colortf(xyz, fwtf = cspace_kwargs)).

lut

_CCT_LUT_BRUTEFORCE_1931_2_uv60, optonal
Pre-calculated LUT: Lut for CIE uv 1960 coordinates and CIE 1931 2° CMFs.
If not None, this LUT is used instead of generating a new one (= only starting lut).

use_newton_raphson

False, optional
If True: use Newton-Raphson method to find the exact CCT.
Much faster than brute-force search.

fast_duv

True, optional

out

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

Returns:

CCT_Duv

ndarray(s) 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)

4.4.4 cct/robertson1968

py

- __init__.py
- robertson1968.py

namespace
luxpy.color.cct.robertson1968

Standalone (no luxpy required) module with (updated, 2022) Robertson1968 CCT functions

(includes correction near slope-sign-change of iso-temperature-lines)

cct_to_xyz()
Calculates xyz from CCT, Duv by estimating the line perpendicular to the planckian locus (=iso-T line).

cct_to_xyz()
Calculates xyz from CCT, Duv [_CCT_MIN < CCT < _CCT_MAX]

References:

1. Robertson, A. R. (1968). Computation of Correlated Color Temperature and Distribution Temperature. Journal of the Optical Society of America, 58(11), 1528–1535.

2. Smet K.A.G., Royer M., Baxter D., Bretschneider E., Esposito E., Houser K., Luedtke W., Man K., Ohno Y. (2022), Recommended method for determining the correlated color temperature and distance from the Planckian Locus of a light source (in preparation, LEUKOS?)

3. Baxter D., Royer M., Smet K.A.G. (2022) Modifications of the Robertson Method for Calculating Correlated Color Temperature to Improve Accuracy and Speed (in preparation, LEUKOS?)

`luxpy.color.cct.robertson1968.`**`save_pkl`**(*filename*, *obj*)

Save an object in a pickle file.

Args:

filename

str with filename of pickle file.

obj

python object to save

Returns:

None

`luxpy.color.cct.robertson1968.`**`load_pkl`**(*filename*)

Load the object in a pickle file.

Args:

filename

str with filename of pickle file.

Returns:

obj

loaded python object

`luxpy.color.cct.robertson1968.`**`get_tcs4`**(*tc4*, *cct_min=450*, *cct_max=100000000000.0*)

Generate list of Tc of Planckians from (Tmin, Tmax inclusive, Tincrement, unit)

Args:

tc4

4-element list or tuple
Elements are: [Tmin, Tmax inclusive, Tincrement, unit]
Unit specifies unit of the Tc interval, i.e. it determines the type of scale in which the spacing of the Tc are done.
Unit options are:
- '%': equal relative Tc spacing (in %, cfr. (Ti+1 - Ti-1)/Ti-1).
- 'K' equal absolute Tc spacing (in K, cfr. (Ti+1 - Ti-1).

- '%-1': equal relative reciprocal Tc (MK-1 = mired).
- 'K-1': equal absolute reciprocal Tc (MK-1 = mired).

If the 'increment' element is negative, it actually represents
the number of intervals between Tmin, Tmax (included).

cct_min

_CCT_MIN, optional
Limit Tc's to a minimum value of cct_min

cct_max

_CCT_MAX, optional
Limit Tc's to a maximum value of cct_max

Returns:

Tcs

ndarray [N,1] of ccts.

luxpy.color.cct.robertson1968.**calculate_lut**(*ccts*, *cieobs*, *lut_vars=['T', 'uv', 'uvp', 'uvpp', 'iso-T-slope']*, *cct_min=450*, *cct_max=100000000000.0*)

Function that calculates a LUT for the specified calculation method for the input ccts. Calculation is performed for CMF set specified in cieobs and in the chromaticity diagram in cspace.

Args:

ccts

ndarray [Nx1] or str or 4-element tuple
If ndarray: list of ccts for which to (re-)calculate the LUTs.
If str: path to file containing CCTs (no header; sep = ',')
If 4-element tuple: generate ccts from (Tmin, Tmax, increment, unit) specifier

cieobs

None or str, optional
str specifying cmf set.

lut_vars

['T','uv','uvp','uvpp','iso-T-slope'], optional
Data the lut should contain. Must follow this order
and minimum should be ['T']

cct_min

_CCT_MIN, optional
Limit Tc's to a minimum value of cct_min

cct_max

_CCT_MAX, optional
Limit Tc's to a maximum value of cct_max

Returns:

returns

lut

ndarray with T, u, v, u', v', u'', v'', slope (note ':1st deriv., '':2nd deriv.).

luxpy.color.cct.robertson1968.**loadtxt**(*filename*, *header=None*, *sep=', '*, *dtype=<class 'float'>*, *missing_values=nan*)

Load data from text file.

Args:

filename

String with filename [+path]

header

None, optional

None: no header present, 'infer' get from file.

sep

',', optional

Delimiter (',' -> csv file)

dtype

float, optional

Try casting output array to this datatype.

missing_values

np.nan, optional

Replace missing values with this.

Returns:

ndarray

loaded data in ndarray of type dtype or object (in case of mixed types)

luxpy.color.cct.robertson1968.**xyz_to_cct**(*xyzw*, *is_uv_input=False*, *cieobs='1931_2'*, *out='cct'*, *lut=None*, *apply_newton_raphson=False*, *rtol=1e-10*, *atol=0.1*, *max_iter=10*, *split_calculation_at_N=25*, *use_fast_duv=True*)

Convert XYZ tristimulus values to correlated color temperature (CCT) and Duv(distance above (> 0) or below (< 0) the Planckian locus) using Robertson's 1968 search method.

Args:

xyzw

ndarray of tristimulus values

is_uv_input

False, optional

If True: xyzw contain uv input data, not xyz data!

cieobs

_CCT_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)

rtol

1e-10, float, optional

Stop search when cct a relative tolerance is reached.

The relative tolerance is calculated as dCCT/CCT_est,

with CCT_est the current intermediate estimate in the

search and with dCCT the difference between

the present and former estimates.

atol

0.1, optional

Stop search when cct a absolute tolerance (K) is reached.

lut

None, optional
Look-Up-Table with Ti, u,v,u',v',u'',v'',slope values of Planckians.
Options:
- None: defaults to the lut specified in _CCT_LUT['lut_type_def'].
- tuple: new lut will be generated from scratch using the info in the tuple.
- ndarray [Nx1]: list of luts for which to generate a lut
- ndarray [Nxn] with n>3: pre-calculated lut (last col must contain slope of the isotemperature lines).

apply_newton_raphson

False, optional
If False: use only the Robertson1968 base method.
Accuracy depends on CCT of test source and the location
and spacing of the CCTs in the list.
If True: improve estimate of base method using a follow-up
newton-raphson method.
When the CCT for multiple source is calculated in one go,
then the atol and rtol values have to be met for all!

max_iter

_CCT_MAX_ITER, optional
Maximum number of iterations used by the cascading-lut or newton-raphson methods.

split_calculation_at_N

_CCT_SPLIT_CALC_AT_N, optional
Split calculation when xyzw.shape[0] > split_calculation_at_N.
Splitting speeds up the calculation. If None: no splitting is done.

use_fast_duv

_CCT_FAST_DUV, optional
If True: use a fast estimator of the Duv
(one that avoids calculation of Planckians and uses the former
best estimate's u,v coordinates. This method is accurate enough
when the atol is small enough -> as long as abs(T-T_former)<=1K
the Duv estimate should be ok.)

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:

1. Out-of-lut CCTs are encoded as negative CCTs (with as absolute value the value of the closest CCT from the lut.)

References:

1. Robertson, A. R. (1968). Computation of Correlated Color Temperature and Distribution Temperature. Journal of the Optical Society of America, 58(11), 1528–1535.

2. Baxter D., Royer M., Smet K.A.G. (2022) Modifications of the Robertson Method for Calculating

Correlated Color Temperature to Improve Accuracy and Speed (in preparation, LEUKOS?)

3. Li, C., Cui, G., Melgosa, M., Ruan, X., Zhang, Y., Ma, L., Xiao, K., & Luo, M. R. (2016). Accurate method for computing correlated color temperature. Optics Express, 24(13), 14066–14078.

`luxpy.color.cct.robertson1968.`**`xyz_to_duv`**(*xyzw*, *out='duv'*, ***kwargs*)

Wraps xyz_to_cct, but with duv output. For kwargs info, see xyz_to_cct.

`luxpy.color.cct.robertson1968.`**`cct_to_xyz`**(*ccts*, *duv=None*, *cct_offset=None*, *cieobs='1931_2'*)

Convert correlated color temperature (550 K <= CCT <= 1e11 K) and Duv (distance above (>0) or below (<0) the Planckian locus) to XYZ tristimulus values.

Finds xyzw_estimated by determining the iso-temperature line
(= line perpendicular to the Planckian locus):
Option 1 (fastest):
First, the angle between the coordinates corresponding to ccts
and ccts-cct_offset are calculated, then 90° is added, and finally
the new coordinates are determined, while taking sign of duv into account.
Option 2 (slowest, about 55% slower):
Calculate the slope of the iso-T-line directly using the Planckian
spectrum and its derivative.

Args:

ccts

ndarray [N,1] of cct values

duv

None or ndarray [N,1] of duv values, optional
Note that duv can be supplied together with cct values in :ccts:
as ndarray with shape [N,2].

cct_offset

None, optional
If None: use option 2 (direct iso-T slope calculation, more accurate,
but slower: about 1.55 slower)
else: use option 1 (estimate slope from 90° + angle of small cct_offset)

cieobs

_CCT_CIEOBS, optional
CMF set used to calculated xyzw.

wl

None, optional
Wavelengths used when calculating Planckian radiators.
If None: use same wavelengths as CMFs in :cieobs:.

Returns:

returns

ndarray with estimated XYZ tristimulus values

Note:

1. If duv is not supplied (:ccts:.shape is (N,1) and :duv: is None), source is assumed to be on the Planckian locus. 2. Minimum CCT is 550 K (lower than 550 K, some negative Duv values will result in coordinates outside of the Spectrum Locus !!!)

4.4.5 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*)

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

Args:

xyzw

ndarray with white point data (CIE 1964 10° XYZs!!)

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))

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*, *n_step=2*, *catmode=None*, *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)

n_step

2, optional
Number of step in CAT (1: 1-step, 2: 2-step)

catmode

None, optional

- None: use :n_step: to set mode: 1 = '1>2', 2:'1>0>2'

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

-'1>2': One-step CAT
from illuminant 1 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

[_MCAT_DEFAULT], 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

Reference:

1. Smet, K. A. G., & Ma, S. (2020). Some concerns regarding the CAT16 chromatic adaptation transform. Color Research & Application, 45(1), 172–177.

luxpy.color.cat.**apply_vonkries1**(*xyz*, *xyzw1*, *xyzw2*, *D=1*, *mcat=None*, *invmcat=None*, *in_type='xyz'*, *out_type='xyz'*, *use_Yw=False*)

Apply a 1-step von kries chromatic adaptation transform.

Args:

xyz

ndarray with sample tristimulus or cat-sensor values

xyzw1

ndarray with white point tristimulus or cat-sensor values of illuminant 1

xyzw2

ndarray with white point tristimulus or cat-sensor values of illuminant 2

D

1, optional

Degree of chromatic adaptation

mcat

None, optional

Specifies CAT sensor space.

- options:
  - None defaults to luxpy.cat._MCAT_DEFAULT
  - str: see see luxpy.cat._MCATS.keys() for options (details on type, ?luxpy.cat)
  - ndarray: matrix with sensor primaries

invmcat

None,optional

Pre-calculated inverse mcat.

If None: calculate inverse of mcat.

in_type

'xyz', optional

Input type ('xyz', 'rgb') of data in xyz, xyzw1, xyzw2

out_type

'xyz', optional

Output type ('xyz', 'rgb') of corresponding colors

use_Yw

False, optional

Use CAT version with Yw factors included (but this results in potential wrong predictions, see Smet & Ma (2020)).

Returns:

xyzc

ndarray with corresponding colors.

Reference:

1. Smet, K. A. G., & Ma, S. (2020). Some concerns regarding the CAT16 chromatic adaptation transform. Color Research & Application, 45(1), 172–177.

luxpy.color.cat.**apply_vonkries2**(*xyz*, *xyzw1*, *xyzw2*, *xyzw0=None*, *D=1*, *mcat=None*, *invmcat=None*, *in_type='xyz'*, *out_type='xyz'*, *use_Yw=False*)

Apply a 2-step von kries chromatic adaptation transform.

Args:

xyz

ndarray with sample tristimulus or cat-sensor values

xyzw1

ndarray with white point tristimulus or cat-sensor values of illuminant 1

xyzw2

ndarray with white point tristimulus or cat-sensor values of illuminant 2

xyzw0

None, optional
ndarray with white point tristimulus or cat-sensor values of baseline illuminant 0
None: defaults to EEW.

D

[1,1], optional
Degree of chromatic adaptations (Ill.1–>Ill.0, Ill.2.–>Ill.0)

mcat

None, optional
Specifies CAT sensor space.
- options:
    - None defaults to luxpy.cat._MCAT_DEFAULT
    - str: see see luxpy.cat._MCATS.keys() for options
        (details on type, ?luxpy.cat)
    - ndarray: matrix with sensor primaries

invmcat

None,optional
Pre-calculated inverse mcat.
If None: calculate inverse of mcat.

in_type

'xyz', optional
Input type ('xyz', 'rgb') of data in xyz, xyzw1, xyzw2

out_type

'xyz', optional
Output type ('xyz', 'rgb') of corresponding colors

use_Yw

False, optional
Use CAT version with Yw factors included (but this results in
potential wrong predictions, see Smet & Ma (2020)).

Returns:

xyzc

ndarray with corresponding colors.

Reference:

1. Smet, K. A. G., & Ma, S. (2020). Some concerns regarding the CAT16 chromatic adaptation transform. Color Research & Application, 45(1), 172–177.

`luxpy.color.cat.`**`apply_vonkries`**(*xyz*, *xyzw1*, *xyzw2*, *xyzw0=None*, *D=1*, *n_step=2*, *catmode='1>0>2'*, *mcat=None*, *invmcat=None*, *in_type='xyz'*, *out_type='xyz'*, *use_Yw=False*)

Apply a 1-step or 2-step von kries chromatic adaptation transform.

Args:

xyz

ndarray with sample tristimulus or cat-sensor values

xyzw1

ndarray with white point tristimulus or cat-sensor values of illuminant 1

xyzw2

ndarray with white point tristimulus or cat-sensor values of illuminant 2

xyzw0

None, optional
ndarray with white point tristimulus or cat-sensor values of baseline illuminant 0
None: defaults to EEW.

D

[1,1], optional
Degree of chromatic adaptations (Ill.1–>Ill.0, Ill.2.–>Ill.0)

n_step

2, optional
Number of step in CAT (1: 1-step, 2: 2-step)

catmode

None, optional
- None: use :n_step: to set mode: 1 = '1>2', 2:'1>0>2'
-'1>0>2': Two-step CAT
from illuminant 1 to baseline illuminant 0 to illuminant 2.
-'1>2': One-step CAT
from illuminant 1 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.

mcat

None, optional
Specifies CAT sensor space.
- options:
- None defaults to luxpy.cat._MCAT_DEFAULT
- str: see see luxpy.cat._MCATS.keys() for options
(details on type, ?luxpy.cat)
- ndarray: matrix with sensor primaries

invmcat

None,optional
Pre-calculated inverse mcat.
If None: calculate inverse of mcat.

in_type

'xyz', optional
Input type ('xyz', 'rgb') of data in xyz, xyzw1, xyzw2

out_type

'xyz', optional
Output type ('xyz', 'rgb') of corresponding colors

use_Yw

False, optional
Use CAT version with Yw factors included (but this results in
potential wrong predictions, see Smet & Ma (2020)).

Returns:

xyzc

ndarray with corresponding colors.

Reference:

1. Smet, K. A. G., & Ma, S. (2020). Some concerns regarding the CAT16 chromatic adaptation transform. Color Research & Application, 45(1), 172–177.

`luxpy.color.cat.`**`apply_ciecat94`**(*xyz*, *xyzw*, *xyzwr=None*, *E=1000*, *Er=1000*, *Yb=20*, *D=1*, *cat94_old=True*)

Calculate corresponding color tristimulus values using the CIECAT94 chromatic adaptation transform.

Args:

xyz

ndarray with sample 1931 2° XYZ tristimulus values under the test illuminant

xyzw

ndarray with white point tristimulus values of the test illuminant

xyzwr

None, optional
ndarray with white point tristimulus values of the reference illuminant
None defaults to D65.

E

100, optional
Illuminance (lx) of test illumination

Er

63.66, optional
Illuminance (lx) of the reference illumination

Yb

20, optional
Relative luminance of the adaptation field (background)

D

1, optional
Degree of chromatic adaptation.
For object colours D = 1,
and for luminous colours (typically displays) D=0

Returns:

xyzc

ndarray with corresponding tristimlus values.

Reference:

1. CIE160-2004. (2004). A review of chromatic adaptation transforms (Vols. CIE160-200). CIE.

4.4.6 cam/

py

- __init__.py
- colorappearancemodels.py
- helpers.py
- utils.py
- ciecam02.py
- cam02ucs.py
- ciecam16.py
- cam16ucs.py
- cam15u
- sww2016.py
- cam18sl.py
- camjabz.py
- zcam.py
- cmf_translator_sww2021

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, ciecam16, ciecam97s, cam15u, cam18sl)

_SURROUND_PARAMETERS

database of surround param. c, Nc, F and FLL
for ciecam02, ciecam16, ciecam97s and cam15u.

_NAKA_RUSHTON_PARAMETERS

database with parameters (n, sig, scaling and noise)
for the Naka-Rushton function:
NK(x) = sign(x) * scaling * ((abs(x)**n) / ((abs(x)**n) + (sig**n))) + noise

_CAM_UCS_PARAMETERS

database with parameters specifying the conversion
from ciecamX to:
camXucs (uniform color space),
camXlcd (large color diff.),
camXscd (small color diff).

_CAM15U_PARAMETERS
database with CAM15u model parameters.

_CAM_SWW16_PARAMETERS
cam_sww16 model parameters.

_CAM18SL_PARAMETERS
database with CAM18sl model parameters

_CAM_DEFAULT_WHITE_POINT
Default internal reference white point (xyz)

_CAM_DEFAULT_CONDITIONS
Default CAM model parameters for model.

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

deltaH()
Compute a hue difference, dH = 2*C1*C2*sin(dh/2).

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.

ciecam02()

calculates ciecam02 output

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

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.

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.

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.

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.

cam18sl()

calculates the output for the CAM18sl model for self-luminous related stimuli.

Hermans, S., Smet, K. A. G., & Hanselaer, P. (2018). "Color appearance model for self-luminous stimuli." Journal of the Optical Society of America A, 35(12), 2000–2009.

camXucs()

Wraps ciecam02(), ciecam16(), cam02ucs(), cam16ucs().

specific wrappers in the 'xyz_to_cspace()' and 'cpsace_to_xyz()' format

'xyz_to_jabM_ciecam02', 'jabM_ciecam02_to_xyz',
'xyz_to_jabC_ciecam02', 'jabC_ciecam02_to_xyz',
'xyz_to_jabM_ciecam16', 'jabM_ciecam16_to_xyz',
'xyz_to_jabC_ciecam16', 'jabC_ciecam16_to_xyz',
'xyz_to_jabz', 'jabz_to_xyz',
'xyz_to_jabM_camjabz', 'jabM_camjabz_to_xyz',
'xyz_to_jabC_camjabz', 'jabC_camjabz_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',
'xyz_to_qabM_cam18sl', 'qabM_cam18sl_to_xyz',
'xyz_to_qabS_cam18sl', 'qabS_cam18sl_to_xyz',

_update_parameter_dict()

Get parameter dict and update with values in args dict

_setup_default_adaptation_field()

Setup a default illuminant adaptation field with Lw = 100 cd/m^2 for selected CIE observer.

_massage_input_and_init_output()

Redimension input data to ensure most they have the appropriate sizes for easy and efficient looping.

_massage_output_data_to_original_shape()
Massage output data to restore original shape of original CAM input.

_get_absolute_xyz_xyzw()
Calculate absolute xyz tristimulus values of stimulus and white point from spectral input or convert relative xyz values to absolute ones.

_simple_cam()
An example CAM illustration the usage of the functions in luxpy.cam.helpers

Module for CAM "front-end" cmf adaptation

translate_cmfI_to_cmfS()

Using smooth RGB primaries, translate input data (spectral or tristimlus)
for an indivual observer to the expected tristimulus values for a standard observer.

get_conversion_matrix()

Using smooth RGB primaries, get the 'translator' matrix to convert
tristimulus values calculated using an individual observer's
color matching functions (cmfs) to those calculated using the cmfs of
a standard observer.

get_rgb_smooth_prims()
Get smooth R, G, B primaries with specified wavelength range

_R,_G,_B
precalculated smooth primaries with [360,830,1] wavelength range.

`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.`**`naka_rushton`**`(`*data*, *sig=2.0*, *n=0.73*, *scaling=1.0*, *noise=0.0*, *forward=True*`)`

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

NK(x) = sign(x) * scaling * ((abs(x)**n) / ((abs(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.

forward

True, optional
True: do NK(x)
False: do NK(x)**(-1).

Returns:

returns

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

luxpy.color.cam.**deltaH**(*h1*, *C1*, *h2=None*, *C2=None*, *htype='deg'*)

Compute a hue difference, dH = 2*C1*C2*sin(dh/2)

Args:

h1

hue for sample 1 (or hue difference if h2 is None)

C1

chroma of sample 1 (or prod C1*C2 if C2 is None)

h2

hue angle of sample 2 (if None, then h1 contains a hue difference)

C2

chroma of sample 2

htype

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

Returns:

returns

ndarray of deltaH values.

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

Get hue quadrature H from hue h.

Args:

h

float or ndarray [(N,) or (N,1)] with:
- hue angle data in degrees (!) if forward == True.

- Hue quadrature data if forward = False

unique_hue data

None or dict, optional
- None: defaults to:
{'hues': 'red yellow green blue red'.split(),
'i': np.arange(5.0),
'hi':[20.14, 90.0, 164.25,237.53,380.14],
'ei':[0.8,0.7,1.0,1.2,0.8],
'Hi':[0.0,100.0,200.0,300.0,400.0]}
- dict: user specified unique hue data
(same structure as above)

forward

True, optional
If true: input h is hue angle, else it is Hue quadrature

Returns:

H

ndarray of Hue quadrature value(s) (forward == True) or of hue angle values(s) (foward == False).

luxpy.color.cam.**_update_parameter_dict**(*args*, *parameters={}*, *cieobs='2006_10'*, *match_conversionmatrix_to_cieobs=False*, *Mxyz2lms_whitepoint=None*)

Get parameter dict and update with values in args dict.

Also replace the xyz-to-lms conversion matrix with the one corresponding
to cieobs and normalize it to illuminant E.

Args:

args

dictionary with updated values.
(get by placing 'args = locals().copy()' immediately after the start
of the function from which the update is called,
see _simple_cam() code for an example.)

parameters

dictionary with all (adjustable) parameter values used by the model

cieobs

String with the CIE observer CMFs (one of _CMF['types'] of the input data
Is used to get the Mxyz2lms matrix when match_conversionmatrix_to_cieobs == True)

match_conversionmatrix_to_cieobs

False, optional
If False: keep the Mxyz2lms in the parameters dict

Mxyz2lms_whitepoint

None, optional
If not None: update the Mxyz2lms key in the parameters dict
so that the conversion matrix is the one in _CMF[cieobs]['M'],
in other such that it matches the cieobs of the input data.

Returns:

parameters

updated dictionary with model parameters for further use in the CAM.

Notes:

For an example on the use, see code _simple_cam() (type: _simple_cam??)

luxpy.color.cam.**_setup_default_adaptation_field**(*dataw=None*, *Lw=100*, *cie_illuminant='D65'*, *inputtype='xyz'*, *relative=True*, *cieobs='2006_10'*)

Setup a default illuminant adaptation field with Lw = 100 cd/m^2 for selected CIE observer.

Args:

dataw

None or ndarray, optional
Input tristimulus values or spectral data of white point.
None defaults to the use of the illuminant specified in :cie_illuminant:.

cie_illuminant

'D65', optional
String corresponding to one of the illuminants (keys)
in luxpy._CIE_ILLUMINANT
If ndarray, then use this one.
This is ONLY USED WHEN dataw is NONE !!!

Lw

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

inputtype

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

relative

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

cieobs

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

Returns:

dataw

Ndarray with default adaptation field data (spectral or xyz)

Notes:

For an example on the use, see code _simple_cam() (type: _simple_cam??)

luxpy.color.cam.**_massage_input_and_init_output**(*data*, *dataw*, *inputtype='xyz'*, *direction='forward'*, *n_out=3*)

Redimension input data to ensure most they have the appropriate sizes for easy and efficient looping. || 1. Convert data and dataw to atleast_2d ndarrays | 2. Make axis 1 of dataw have 'same' dimensions as data | 3. Make dataw have same lights source axis size as data | 4. Flip light source axis to axis=0 for efficient looping | 5. Initialize output array camout to 'same' shape as data but with camout.shape[-1] == n_out

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.

inputtype

'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
-'inverse': cam -> xyz

n_out

3, optional
output size of last dimension of camout
(e.g. n_out=3 for j,a,b output or n_out = 5 for J,M,h,a,b output)

Returns:

data

ndarray with reshaped data

dataw

ndarray with reshaped dataw

camout

NaN filled ndarray for output of CAMv (camout.shape[-1] == Nout)

originalshape

original shape of data

Notes:

For an example on the use, see code _simple_cam() (type: _simple_cam??)

`luxpy.color.cam.`**`_massage_output_data_to_original_shape`**`(`*data*, *originalshape*`)`

Massage output data to restore original shape of original CAM input.

Notes:

For an example on the use, see code _simple_cam() (type: _simple_cam??)

`luxpy.color.cam.`**`_get_absolute_xyz_xyzw`**`(`*data*, *dataw*, *i=0*, *Lw=100*, *direction='forward'*, *cieobs='2006_10'*, *inputtype='xyz'*, *relative=True*`)`

Calculate absolute xyz tristimulus values of stimulus and white point from spectral input or convert relative xyz values to absolute ones.

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.

i

0, optional
row number in data and dataw ndarrays
(for loops across illuminant dimension after dimension reshape
with _massage_output_data_to_original_shape).

Lw

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

inputtype

'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
-'inverse': cam -> xyz

relative

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

cieobs

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

Returns:

xyzti

in forward mode : ndarray with relative or absolute sample xyz for data[i]
in inverse mode: None

xyzwi

ndarray with relative or absolute white point for dataw[i]

xyzw_abs

ndarray with absolute xyz for white point for dataw[i]

Notes:

For an example on the use, see code _simple_cam() (type: _simple_cam??)

luxpy.color.cam.**_simple_cam**(*data*, *dataw=None*, *Lw=100.0*, *relative=True*, *inputtype='xyz'*, *direction='forward'*, *cie_illuminant='D65'*, *parameters={'Mxyz2lms': array([[3.8971e-01, 6.8898e-01, -7.8680e-02], [-2.2981e-01, 1.1834e+00, 4.6410e-02], [0.0000e+00, 0.0000e+00, 1.0000e+00]]), 'cA': 1, 'ca': array([1, -1, 0]), 'cb': array([1.6667e-01, 1.6667e-01, -3.3333e-01]), 'n': 0.3333333333333333}*, *cieobs='2006_10'*, *match_to_conversionmatrix_to_cieobs=True*)

An example CAM illustration the usage of the functions in luxpy.cam.helpers

Note that this example uses NO chromatic adaptation
and SIMPLE compression, opponent and correlate processing.
THIS IS ONLY FOR ILLUSTRATION PURPOSES !!!

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:

cie_illuminant

'D65', optional
String corresponding to one of the illuminants (keys)
in luxpy._CIE_ILLUMINANT
If ndarray, then use this one.
This is ONLY USED WHEN dataw is NONE !!!

Lw

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

relative

True or False, optional
True: data and dataw input is relative (i.e. Yw = 100)

parameters

{'cA': 1, 'ca':np.array([1,-1,0]), 'cb':(1/3)*np.array([0.5,0.5,-1]),
'n': 1/3, 'Mxyz2lms': _CMF['1931_2']['M'].copy()}
Dict with model parameters
(For illustration purposes of match_conversionmatrix_to_cieobs,
the conversion matrix luxpy._CMF['1931_2']['M'] does NOT match
the default observer specification of the input data in :cieobs: !!!)

inputtype

'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
-'inverse': cam -> 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']

match_conversionmatrix_to_cieobs

True, optional
When changing to a different CIE observer, change the xyz_to_lms
matrix to the one corresponding to that observer.
Set to False to keep the one in the parameter dict!

Returns:

returns

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

luxpy.color.cam.**ciecam02**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=None*, *outin='J,aM,bM'*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *forward=True*, *yellowbluepurplecorrect=False*, *mcat='cat02'*)

Run CIECAM02 color appearance model in forward or backward modes.

Args:

data

ndarray with relative sample xyz values (forward mode) or J'a'b' coordinates (inverse mode)

xyzw

ndarray with relative white point tristimulus values

Yw

None, optional
Luminance factor of white point.
If None: xyz (in data) and xyzw are entered as relative tristimulus values
(normalized to Yw = 100).
If not None: input tristimulus are absolute and Yw is used to
rescale the absolute values to relative ones
(relative to a reference perfect white diffuser
with Ywr = 100).
Yw can be < 100 for e.g. paper as white point. If Yw is None, it
is assumed that the relative Y-tristimulus value in xyzw
represents the luminance factor Yw.

conditions

None, optional
Dictionary with viewing condition parameters for:

La, Yb, D and surround.
surround can contain:
- str (options: 'avg','dim','dark') or
- dict with keys c, Nc, F.
None results in:
{'La':100, 'Yb':20, 'D':1, 'surround':'avg'}

naka_rushton_parameters

None, optional
If None: use _NAKA_RUSHTON_PARAMETERS

unique_hue_data

None, optional
If None: use _UNIQUE_HUE_DATA

forward

True, optional
If True: run in CAM in forward mode, else: inverse mode.

outin

'J,aM,bM', optional
String with requested output (e.g. "J,aM,bM,M,h") [Forward mode]
- attributes: 'J': lightness,'Q': brightness,
'M': colorfulness,'C': chroma, 's': saturation,
'h': hue angle, 'H': hue quadrature/composition,
String with inputs in data [inverse mode].
Input must have data.shape[-1]==3 and last dim of data must have
the following structure for inverse mode:
* data[...,0] = J or Q,
* data[...,1:] = (aM,bM) or (aC,bC) or (aS,bS) or (M,h) or (C, h), ...

yellowbluepurplecorrect

False, optional
If False: don't correct for yellow-blue and purple problems in ciecam02.
If 'brill-suss':
for yellow-blue problem, see:
- Brill [Color Res Appl, 2006; 31, 142-145] and
- Brill and Süsstrunk [Color Res Appl, 2008; 33, 424-426]
If 'jiang-luo':
for yellow-blue problem + purple line problem, see:
- Jiang, Jun et al. [Color Res Appl 2015: 40(5), 491-503]

mcat

'cat02', optional
Specifies CAT sensor space.
- options:
- 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

Returns:

camout

ndarray with color appearance correlates (forward mode)

or

XYZ tristimulus values (inverse mode)

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.**xyz_to_jabM_ciecam02**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *yellowbluepurplecorrect=False*, *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=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *yellowbluepurplecorrect=False*, *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=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *yellowbluepurplecorrect=False*, *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=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *yellowbluepurplecorrect=False*, *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.**cam02ucs**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *ucstype='ucs'*, *forward=True*, *yellowbluepurplecorrect=False*, *mcat='cat02'*)

Run the CAM02-UCS[,-LCD,-SDC] color appearance difference model in forward or backward modes.
Args:

data

ndarray with sample xyz values (forward mode) or J'a'b' coordinates (inverse mode)

xyzw

ndarray with white point tristimulus values

conditions

None, optional
Dictionary with viewing conditions.
None results in:
{'La':100, 'Yb':20, 'D':1, 'surround':'avg'}
For more info see luxpy.cam.ciecam02()?

naka_rushton_parameters

None, optional
If None: use _NAKA_RUSHTON_PARAMETERS

unique_hue_data

None, optional
If None: use _UNIQUE_HUE_DATA

ucstype

'ucs', optional
String with type of color difference appearance space
options: 'ucs', 'scd', 'lcd'

forward

True, optional
If True: run in CAM in forward mode, else: inverse mode.

yellowbluepurplecorrect

False, optional
If False: don't correct for yellow-blue and purple problems in ciecam02.
If 'brill-suss':
for yellow-blue problem, see:
- Brill [Color Res Appl, 2006; 31, 142-145] and
- Brill and Süsstrunk [Color Res Appl, 2008; 33, 424-426]
If 'jiang-luo':
for yellow-blue problem + purple line problem, see:
- Jiang, Jun et al. [Color Res Appl 2015: 40(5), 491-503]

mcat

'cat02', optional
Specifies CAT sensor space.
- options:
- 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

Returns:

camout

ndarray with J'a'b' coordinates (forward mode)

or

XYZ tristimulus values (inverse mode)

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.**xyz_to_jab_cam02ucs**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *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=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *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=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *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=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *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=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *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=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *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.**ciecam16**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=None*, *outin='J,aM,bM'*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *forward=True*, *mcat='cat16'*)

Run CIECAM16 color appearance model in forward or backward modes.

Args:

data

ndarray with relative sample xyz values (forward mode) or J'a'b' coordinates (inverse mode)

xyzw

ndarray with relative white point tristimulus values

Yw

None, optional
Luminance factor of white point.
If None: xyz (in data) and xyzw are entered as relative tristimulus values
(normalized to Yw = 100).
If not None: input tristimulus are absolute and Yw is used to
rescale the absolute values to relative ones
(relative to a reference perfect white diffuser
with Ywr = 100).
Yw can be < 100 for e.g. paper as white point. If Yw is None, it
is assumed that the relative Y-tristimulus value in xyzw
represents the luminance factor Yw.

conditions

None, optional
Dictionary with viewing condition parameters for:
La, Yb, D and surround.
surround can contain:
- str (options: 'avg','dim','dark') or
- dict with keys c, Nc, F.
None results in:
{'La':100, 'Yb':20, 'D':1, 'surround':'avg'}

naka_rushton_parameters

None, optional
If None: use _NAKA_RUSHTON_PARAMETERS

unique_hue_data

None, optional
If None: use _UNIQUE_HUE_DATA

forward

True, optional
If True: run in CAM in forward mode, else: inverse mode.

outin

'J,aM,bM', optional
String with requested output (e.g. "J,aM,bM,M,h") [Forward mode]
- attributes: 'J': lightness,'Q': brightness,
'M': colorfulness,'C': chroma, 's': saturation,
'h': hue angle, 'H': hue quadrature/composition,
String with inputs in data [inverse mode].
Input must have data.shape[-1]==3 and last dim of data must have
the following structure for inverse mode:
* data[...,0] = J or Q,
* data[...,1:] = (aM,bM) or (aC,bC) or (aS,bS) or (M,h) or (C, h), ...

mcat

'cat16', optional
Specifies CAT sensor space.
- options:
- None defaults to 'cat16'
- str: see see luxpy.cat._MCATS.keys() for options
(details on type, ?luxpy.cat)
- ndarray: matrix with sensor primaries

Returns:

camout

ndarray with color appearance correlates (forward mode)
or
XYZ tristimulus values (inverse mode)

References:

1. 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.**xyz_to_jabM_ciecam16**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*, ***kwargs*)

Wrapper function for ciecam16 forward mode with J,aM,bM output.

For help on parameter details: ?luxpy.cam.ciecam16

luxpy.color.cam.**jabM_ciecam16_to_xyz**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*, ***kwargs*)

Wrapper function for ciecam16 inverse mode with J,aM,bM input.

For help on parameter details: ?luxpy.cam.ciecam16

luxpy.color.cam.**xyz_to_jabC_ciecam16**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*, ***kwargs*)

Wrapper function for ciecam16 forward mode with J,aC,bC output.

For help on parameter details: ?luxpy.cam.ciecam16

luxpy.color.cam.**jabC_ciecam16_to_xyz**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*, ***kwargs*)

Wrapper function for ciecam16 inverse mode with J,aC,bC input.

For help on parameter details: ?luxpy.cam.ciecam16

luxpy.color.cam.**cam16ucs**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *ucstype='ucs'*, *forward=True*, *mcat='cat16'*)

Run the CAM16-UCS[,-LCD,-SDC] color appearance difference model in forward or backward modes.
Args:

data

ndarray with sample xyz values (forward mode) or J'a'b' coordinates (inverse mode)

xyzw

ndarray with white point tristimulus values

conditions

None, optional

Dictionary with viewing conditions.

None results in:

{'La':100, 'Yb':20, 'D':1, 'surround':'avg'}

For more info see luxpy.cam.ciecam16()?

naka_rushton_parameters

None, optional

If None: use _NAKA_RUSHTON_PARAMETERS

unique_hue_data

None, optional

If None: use _UNIQUE_HUE_DATA

ucstype

'ucs', optional

String with type of color difference appearance space

options: 'ucs', 'scd', 'lcd'

forward

True, optional

If True: run in CAM in forward mode, else: inverse mode.

mcat

'cat16', optional

Specifies CAT sensor space.

- options:
  - None defaults to 'cat16'
  - str: see see luxpy.cat._MCATS.keys() for options
    (details on type, ?luxpy.cat)
  - ndarray: matrix with sensor primaries

Returns:

camout

ndarray with J'a'b' coordinates (forward mode)

or

XYZ tristimulus values (inverse mode)

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.**xyz_to_jab_cam16ucs**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16ucs forward mode with J,aM,bM output.

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=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16ucs inverse mode with J,aM,bM input.

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=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16ucs forward mode with J,aMp,bMp 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=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16ucs inverse mode with J,aMp,bMp 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=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16ucs forward mode with J,aMp,bMp 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=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*, ***kwargs*)

Wrapper function for cam16ucs inverse mode with J,aMp,bMp input and ucstype = scd.

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

luxpy.color.cam.**zcam**(*data*, *xyzw=None*, *outin='J,aM,bM'*, *cieobs='1931_2'*, *conditions=None*, *forward=True*, *mcat='cat02'*, *apply_cat_to_whitepoint=False*, ***kwargs*)

Run the Jz,az,bz based color appearance model in forward or backward modes.

Args:

data

ndarray with relative sample xyz values (forward mode) or J'a'b' coordinates (inverse mode)

xyzw

ndarray with relative white point tristimulus values

None defaults to D65

cieobs

_CIEOBS, optional

CMF set to use when calculating :xyzw: if this is None.

conditions

None, optional

Dictionary with viewing condition parameters for:

La, Yb, D and surround.

surround can contain:

- str (options: 'avg','dim','dark') or
- dict with keys c, Nc, F.

None results in:

{'La':100, 'Yb':20, 'D':1, 'surround':'avg'}

forward

True, optional

If True: run in CAM in forward mode, else: inverse mode.

outin

'J,aM,bM', optional
String with requested output (e.g. "J,aM,bM,M,h") [Forward mode]
- attributes: 'J': lightness,'Q': brightness,
'M': colorfulness,'C': chroma, 's': saturation,
'h': hue angle, 'H': hue quadrature/composition,
'Wz': whiteness, 'Kz':blackness, 'Sz': saturation, 'V': vividness
String with inputs in data [inverse mode].
Input must have data.shape[-1]==3 and last dim of data must have
the following structure for inverse mode:
* data[...,0] = J or Q,
* data[...,1:] = (aM,bM) or (aC,bC) or (aS,bS) or (M,h) or (C, h), ...

mcat

'cat02', optional
Specifies CAT sensor space.
- options:
- None defaults to 'cat02'
- str: see see luxpy.cat._MCATS.keys() for options
(details on type, ?luxpy.cat)
- ndarray: matrix with sensor primaries

apply_cat_to_whitepoint

False, optional
Apply a CAT to the white point.
However, ZCAM as published doesn't do this for some reason.

Returns:

camout

ndarray with color appearance correlates (forward mode)
or
XYZ tristimulus values (inverse mode)

References:

1. Safdar, M., Cui, G., Kim,Y. J., and Luo, M. R.(2017). Perceptually uniform color space for image signals including high dynamic range and wide gamut. Opt. Express, vol. 25, no. 13, pp. 15131–15151, Jun. 2017.

2. Safdar, M., Hardeberg, J., Cui, G., Kim, Y. J., and Luo, M. R.(2018). A Colour Appearance Model based on Jzazbz Colour Space, 26th Color and Imaging Conference (2018), Vancouver, Canada, November 12-16, 2018, pp96-101.

3. Safdar, M., Hardeberg, J.Y., Luo, M.R. (2021) ZCAM, a psychophysical model for colour appearance prediction, Optics Express. 29(4), 6036-6052, <https://doi.org/10.1364/OE.413659>`_

`luxpy.color.cam.`**`xyz_to_jabz`**(*xyz*, *ztype='jabz'*, *use_zcam_parameters=False*, ***kwargs*)

Convert XYZ tristimulus values to Jz,az,bz color coordinates.

Args:

xyz

ndarray with absolute tristimulus values (Y in cd/m^2!)

ztype

'jabz', optional

String with requested return:
Options: 'jabz', 'iabz'

use_zcam_parameters

False, optional
ZCAM uses a slightly different values (see notes)

Returns:

jabz

ndarray with Jz (or Iz), az, bz color coordinates

Notes:

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

2a. Jz represents the 'lightness' relative to a D65 white with luminance = 10000 cd/m^2
(note that Jz that not exactly equal 1 for this high value, but rather for 102900 cd/m2)

2b. az, bz represent respectively a red-green and a yellow-blue opponent axis
(but note that a D65 shows a small offset from (0,0))

3. ZCAM: calculates Iz as M' - epsilon (instead L'/2 + M'/2 as in Iz,az,bz color space!).

Reference:

1. Safdar, M., Cui, G., Kim,Y. J., and Luo, M. R. (2017). Perceptually uniform color space for image signals including high dynamic range and wide gamut. Opt. Express, vol. 25, no. 13, pp. 15131–15151, June 2017.

2. Safdar, M., Hardeberg, J.Y., Luo, M.R. (2021) ZCAM, a psychophysical model for colour appearance prediction, Optics Express. 29(4), 6036-6052, <https://doi.org/10.1364/OE.413659>`_

`luxpy.color.cam.`**`jabz_to_xyz`**(*jabz*, *ztype='jabz'*, *use_zcam_parameters=False*, ***kwargs*)

Convert Jz,az,bz color coordinates to XYZ tristimulus values.

Args:

jabz

ndarray with Jz,az,bz color coordinates

ztype

'jabz', optional
String with requested return:
Options: 'jabz', 'iabz'

use_zcam_parameters

False, optional
ZCAM uses a slightly different values (see notes)

Returns:

xyz

ndarray with tristimulus values

Note:

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

2a. Jz represents the 'lightness' relative to a D65 white with luminance = 10000 cd/m^2
(note that Jz that not exactly equal 1 for this high value, but rather for 102900 cd/m2)

2b. az, bz represent respectively a red-green and a yellow-blue opponent axis
(but note that a D65 shows a small offset from (0,0))

3. ZCAM: calculates Iz as M' - epsilon (instead L'/2 + M'/2 as in Iz,az,bz color space!).

Reference:

1. Safdar, M., Cui, G., Kim,Y. J., and Luo, M. R. (2017). Perceptually uniform color space for image signals including high dynamic range and wide gamut. Opt. Express, vol. 25, no. 13, pp. 15131–15151, June, 2017.

2. Safdar, M., Hardeberg, J.Y., Luo, M.R. (2021) ZCAM, a psychophysical model for colour appearance prediction, Optics Express. 29(4), 6036-6052, <https://doi.org/10.1364/OE.413659>`_

luxpy.color.cam.**xyz_to_jabM_zcam**(*data*, *xyzw='_CIE_D65'*, *cieobs='1931_2'*, *conditions=None*, *mcat='cat02'*, *apply_cat_to_whitepoint=False*, ***kwargs*)

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

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

luxpy.color.cam.**jabM_zcam_to_xyz**(*data*, *xyzw='_CIE_D65'*, *cieobs='1931_2'*, *conditions=None*, *mcat='cat02'*, *apply_cat_to_whitepoint=False*, ***kwargs*)

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

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

luxpy.color.cam.**xyz_to_jabC_zcam**(*data*, *xyzw='_CIE_D65'*, *cieobs='1931_2'*, *conditions=None*, *mcat='cat02'*, *apply_cat_to_whitepoint=False*, ***kwargs*)

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

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

luxpy.color.cam.**jabC_zcam_to_xyz**(*data*, *xyzw='_CIE_D65'*, *cieobs='1931_2'*, *conditions=None*, *mcat='cat02'*, *apply_cat_to_whitepoint=False*, ***kwargs*)

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

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

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

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

'JOSA' or str or dict, optional
Dict with model parameters.
- str: 'JOSA','best-fit-JOSA' or 'best-fit-all-Munsell'
- dict: user defined model parameters
(dict should have same structure)

inputtype

'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']

match_conversionmatrix_to_cieobs

When changing to a different CIE observer, change the xyz_to_lms matrix to the one corresponding to that observer. If False: use the one set in parameters or _CAM_SWW16_PARAMETERS

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_lab_cam_sww16**(*xyz*, *xyzw=None*, *Yb=20.0*, *Lw=400.0*, *Ccwb=None*, *relative=True*, *parameters='JOSA'*, *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='JOSA'*, *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

luxpy.color.cam.**cam18sl**(*data*, *datab=None*, *Lb=[100]*, *fov=10.0*, *inputtype='xyz'*, *direction='forward'*, *outin='Q,aS,bS'*, *parameters=None*)

Convert between CIE 2006 10° XYZ tristimulus values (or spectral data) and CAM18sl color appearance correlates.

Args:

data

ndarray of CIE 2006 10° absolute XYZ tristimulus values or spectral data

or color appearance attributes of stimulus

datab

ndarray of CIE 2006 10° absolute XYZ tristimulus values or spectral data
of stimulus background

Lb

[100], optional
Luminance (cd/m^2) value(s) of background(s) calculated using the CIE 2006 10° CMFs
(only used in case datab == None and the background is assumed to be an Equal-Energy-White)

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 -> cam18sl
-'inverse': cam18sl -> xyz

outin

'Q,aS,bS' or str, optional
'Q,aS,bS' (brightness and opponent signals for saturation)
other options: 'Q,aM,bM' (colorfulness)
(Note that 'Q,aW,bW' would lead to a Cartesian
a,b-coordinate system centered at (1,0))
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._CAM18SL_PARAMETERS
(see references below)

Returns:

returns

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

Notes:

* Instead of using the CIE 1964 10° CMFs in some places of the model,
the CIE 2006 10° CMFs are used througout, making it more self_consistent.
This has an effect on the k scaling factors (now different those in CAM15u)
and the illuminant E normalization for use in the chromatic adaptation transform.
(see future erratum to Hermans et al., 2018)

* The paper also used an equation for the amount of white W, which is
based on a Q value not expressed in 'bright' ('cA' = 0.937 instead of 123).
This has been corrected for in the luxpy version of the model, i.e.
_CAM18SL_PARAMETERS['cW'][0] has been changed from 2.29 to 1/11672.
(see future erratum to Hermans et al., 2018)
* Default output was 'Q,aW,bW' prior to March 2020, but since this
is an a,b Cartesian system centered on (1,0), the default output
has been changed to 'Q,aS,bS'.

References:

1. Hermans, S., Smet, K. A. G., & Hanselaer, P. (2018). "Color appearance model for self-luminous stimuli." Journal of the Optical Society of America A, 35(12), 2000–2009.

luxpy.color.cam.**xyz_to_qabM_cam18sl**(*xyz*, *xyzb=None*, *Lb=[100]*, *fov=10.0*, *parameters=None*, ***kwargs*)

Wrapper function for cam18sl forward mode with 'Q,aM,bM' output.

For help on parameter details: ?luxpy.cam.cam18sl

luxpy.color.cam.**qabM_cam18sl_to_xyz**(*qab*, *xyzb=None*, *Lb=[100]*, *fov=10.0*, *parameters=None*, ***kwargs*)

Wrapper function for cam18sl inverse mode with 'Q,aM,bM' input.

For help on parameter details: ?luxpy.cam.cam18sl

luxpy.color.cam.**xyz_to_qabS_cam18sl**(*xyz*, *xyzb=None*, *Lb=[100]*, *fov=10.0*, *parameters=None*, ***kwargs*)

Wrapper function for cam18sl forward mode with 'Q,aS,bS' output.

For help on parameter details: ?luxpy.cam.cam18sl

luxpy.color.cam.**qabS_cam18sl_to_xyz**(*qab*, *xyzb=None*, *Lb=[100]*, *fov=10.0*, *parameters=None*, ***kwargs*)

Wrapper function for cam18sl inverse mode with 'Q,aS,bS' input.

For help on parameter details: ?luxpy.cam.cam18sl

luxpy.color.cam.**camXucs**(*data*, *xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *Yw=None*, *outin='J,aM,bM'*, *conditions=None*, *forward=True*, *ucstype='ucs'*, *yellowbluepurplecorrect=False*, *mcat=None*, *camtype='ciecam02'*)

Wraps ciecam02(), ciecam16(), cam02ucs(), cam16ucs().

Args:

camtype

_DEFAULT_TYPE, optional
String specifying the cam-model.

Notes:

1. To call ciecam02() or ciecam16(): set ucstype to None !!!
2. For more info on other input arguments, see doc-strings of those functions.

4.4.7 deltaE/

py

- __init__.py
- colordifferences.py
- discriminationellipses.py
- frieleellipses.py
- macadamellipses.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.

get_macadam_ellipse()
Estimate n-step MacAdam ellipse at CIE x,y coordinates

get_brown1957_ellipse()
Estimate n-step Brown (1957) ellipse at CIE x,y coordinates.

get_gij_fmc()
Get gij matrices describing the discrimination ellipses for Yxy using FMC-1 or FMC-2.

get_fmc_discrimination_ellipse()
Get n-step discrimination ellipse(s) in v-format (R,r, xc, yc, theta) for Yxy using FMC-1 or FMC-2.

`luxpy.color.deltaE.deltaH(`*h1*, *C1*, *h2=None*, *C2=None*, *htype='deg'*`)`

Compute a hue difference, dH = 2*C1*C2*sin(dh/2)
Args:

h1
hue for sample 1 (or hue difference if h2 is None)

C1
chroma of sample 1 (or prod C1*C2 if C2 is None)

h2
hue angle of sample 2 (if None, then h1 contains a hue difference)

C2
chroma of sample 2

htype
'deg' or 'rad', optional

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

Returns:

returns

ndarray of deltaH values.

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=None*, *conditionst={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *Ywr=None*, *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_DEFAULT_TYPE, optional

Str specifier for CAM type to use, options: 'ciecam02' or 'ciecam16'.

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_DEFAULT_TYPE, optional

Str specifier for CAM type to use, options: 'ciecam02' or 'ciecam16'.

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:

luxpy.color.deltaE.**get_discrimination_ellipse**(*Yxy=array([[1.0000e+02, 3.3333e-01, 3.3333e-01]])*, *etype='fmc2'*, *nsteps=10*, *k_neighbours=3*, *average_cik=True*, *Y=None*, *brown1957_weighted=True*)

Get discrimination ellipse(s) in v-format (R,r, xc, yc, theta) for Yxy using an interpolation of the MacAdam ellipses or using FMC-1 or FMC-2.

Args:

Yxy

2D ndarray with [Y,]x,y coordinate centers.

If Yxy.shape[-1]==2: Y is added using the value from the Y-input argument.

etype

'fmc2', optional

Type color discrimination ellipse estimation to use.

options: 'macadam', 'fmc1', 'fmc2'

- 'macadam': interpolate covariance matrices of closest MacAdam ellipses (see: get_macadam_ellipse?).
- 'fmc1': use FMC-1 from ref 2 (see get_fmc_discrimination_ellipse?).
- 'fmc2': use FMC-1 from ref 3 (see get_fmc_discrimination_ellipse?).
- 'brown1957': interpolate covariance matrices of closest Brown1957 ellipses (see: get_brown1957_ellipse?).

nsteps

10, optional

Set multiplication factor for ellipses

(nsteps=1 corresponds to approximately 1 MacAdam step,

for FMC-2, Y also has to be 10.69, see note below).

brown1957_weighted

True, optional

If True: use weighted averages from Table III in Brown 1957 paper, else use the straight averages.

k_neighbours

3, optional

Only for option 'macadam'.

Number of nearest ellipses to use to calculate ellipse at xy

average_cik

True, optional

Only for option 'macadam'.

If True: take distance weighted average of inverse 'covariance ellipse' elements cik.

If False: average major & minor axis lengths and ellipse orientation angles directly.

Y

None, optional

Only for option 'fmc2'(see note below).

If not None: Y = 10.69 and overrides values in Yxy.

Note:

1. FMC-2 is almost identical to FMC-1 is Y = 10.69!; see [3]

References:

1. MacAdam DL. Visual Sensitivities to Color Differences in Daylight*. J Opt Soc Am. 1942;32(5):247-274.
2. Chickering, K.D. (1967), Optimization of the MacAdam-Modified 1965 Friele Color-Difference Formula, 57(4):537-541
3. Chickering, K.D. (1971), FMC Color-Difference Formulas: Clarification Concerning Usage, 61(1):118-122
4. Brown, WRJ. (1957). Color Discrimination of Twelve Observers*. Journal of the Optical Society of America, 47(2), 137–143.

`luxpy.color.deltaE.get_macadam_ellipse`(*xy=None*, *k_neighbours=3*, *nsteps=10*, *average_cik=True*)

Estimate n-step MacAdam ellipse at CIE x,y coordinates xy by calculating average inverse covariance ellipse of

the k_neighbours closest ellipses.

Args:

xy

None or ndarray, optional

If None: output Macadam ellipses, if not None: xy are the CIE xy coordinates for which ellipses will be estimated.

k_neighbours

3, optional

Number of nearest ellipses to use to calculate ellipse at xy

nsteps

10, optional

Set number of MacAdam steps of ellipse.

average_cik

True, optional

If True: take distance weighted average of inverse 'covariance ellipse' elements cik.

If False: average major & minor axis lengths and ellipse orientation angles directly.

Returns:

v_mac_est

estimated MacAdam ellipse(s) in v-format [Rmax,Rmin,xc,yc,theta]

References:

1. MacAdam DL. Visual Sensitivities to Color Differences in Daylight*. J Opt Soc Am. 1942;32(5):247-274.

luxpy.color.deltaE.**get_brown1957_ellipse**(*xy=None*, *weighted=True*, *k_neighbours=3*, *nsteps=10*, *average_cik=True*)

Estimate n-step Brown1957 ellipse at CIE x,y coordinates xy by calculating average inverse covariance ellipse of the k_neighbours closest ellipses.

Args:

xy

None or ndarray, optional

If None: output Brown1957 ellipses, if not None: xy are the CIE xy coordinates for which ellipses will be estimated.

weighted

True, optional

If True: use weighted averages from Table III in Brown 1957 paper, else use the straight averages.

k_neighbours

3, optional

Number of nearest ellipses to use to calculate ellipse at xy

nsteps

10, optional

Set number of steps of ellipse.

average_cik

True, optional

If True: take distance weighted average of inverse

'covariance ellipse' elements cik.
If False: average major & minor axis lengths and
ellipse orientation angles directly.

Returns:

v_brown_est

estimated Brown1957 ellipse(s) in v-format [Rmax,Rmin,xc,yc,theta]

References:

1. Brown, W.R.J. (1957). Color Discrimination of Twelve Observers*. Journal of the Optical Society of America, 47(2), 137–143. https://doi.org/10.1364/JOSA.47.000137

luxpy.color.deltaE.**get_gij_fmc**(*Yxy*, *etype='fmc2'*, *ellipsoid=True*, *Y=None*, *cspace='Yxy'*)

Get gij matrices describing the discrimination ellipses/ellipsoids for Yxy or xyz using FMC-1 or FMC-2.

Args:

Yxy

2D ndarray with [Y,]x,y coordinate centers.
If Yxy.shape[-1]==2: Y is added using the value from the Y-input argument.

etype

'fmc2', optional
Type of FMC color discrimination equations to use (see references below).
options: 'fmc1', fmc2'

Y

None, optional
Only affects FMC-2 (see note below).
If not None: Y = 10.69 and overrides values in Yxy.

ellipsoid

True, optional
If True: return ellipsoids, else return ellipses (only if cspace == 'Yxy')!

cspace

'Yxy', optional
Return coefficients for Yxy-ellipses/ellipsoids ('Yxy') or XYZ ellipsoids ('xyz')

Note:

1. FMC-2 is almost identical to FMC-1 is Y = 10.69!; see [2]

References:

1. Chickering, K.D. (1967), Optimization of the MacAdam-Modified 1965 Friele Color-Difference Formula, 57(4), p.537-541
2. Chickering, K.D. (1971), FMC Color-Difference Formulas: Clarification Concerning Usage, 61(1), p.118-122

luxpy.color.deltaE.**get_fmc_discrimination_ellipse**(*Yxy=array([[1.0000e+02, 3.3333e-01, 3.3333e-01]])*, *etype='fmc2'*, *Y=None*, *nsteps=10*)

Get discrimination ellipse(s) in v-format (R,r, xc, yc, theta) for Yxy using FMC-1 or FMC-2.

Args:

Yxy

2D ndarray with [Y,]x,y coordinate centers.
If Yxy.shape[-1]==2: Y is added using the value from the Y-input argument.

etype

'fmc2', optional
Type of FMC color discrimination equations to use (see references below).
options: 'fmc1', fmc2'

Y

None, optional
Only affects FMC-2 (see note below).
If not None: Y = 10.69 and overrides values in Yxy.

nsteps

10, optional
Set multiplication factor for ellipses
(nsteps=1 corresponds to approximately 1 MacAdam step,
for FMC-2, Y also has to be 10.69, see note below).

Note:

1. FMC-2 is almost identical to FMC-1 is Y = 10.69!; see [2]

References:

1. Chickering, K.D. (1967), Optimization of the MacAdam-Modified 1965 Friele Color-Difference Formula, 57(4), p.537-541
2. Chickering, K.D. (1971), FMC Color-Difference Formulas: Clarification Concerning Usage, 61(1), p.118-122

`luxpy.color.deltaE.`**`discrimination_hotelling_t2`**`(`*Yxy1*, *Yxy2*, *etype='fmc2'*, *ellipsoid=True*, *Y1=None*, *Y2=None*, *cspace='Yxy'*`)`

Check 'significance' of difference using Hotelling's T2 test on the centers Yxy1 and Yxy2 and their associate FMC-1/2 discrimination ellipses.

Args:

Yxy1, Yxy2

2D ndarrays with [Y,]x,y coordinate centers.
If Yxy.shape[-1]==2: Y is added using the value from the Y-input argument.

etype

'fmc2', optional
Type of FMC color discrimination equations to use (see references below).
options: 'fmc1', fmc2'

Y1, Y2

None, optional
Only affects FMC-2 (see note below).
If not None: Yi = 10.69 and overrides values in Yxyi.

ellipsoid

True, optional
If True: return ellipsoids, else return ellipses (only if cspace == 'Yxy')!

cspace

'Yxy', optional
Return coefficients for Yxy-ellipses/ellipsoids ('Yxy') or XYZ ellipsoids ('xyz')

Returns:

p

Chi-square based p-value

T2

T2 test statistic (= mahalanobis distance on summed standard error cov. matrices)

Steps:

1. For each center coordinate, the standard error covariance matrix gij^-1 = Si/ni is determined using the FMC-1 or FMC-2 equations (see refs. 1 & 2). 2. Calculate sum of covariance matrices: SIG = S1/n1

+ S2/n2 = gij1^-1 + gij2^-1 3. These are then used in Hotelling's T2 test: T2 = (xy1 - xy2).T*(SIG^-1)*(xy1_xy2) 4. The T2 statistic is then tested against a Chi-square distribution with 2 or 3 degrees of freedom.

References:

1. Chickering, K.D. (1967), Optimization of the MacAdam-Modified 1965 Friele Color-Difference Formula, 57(4):537-541
2. Chickering, K.D. (1971), FMC Color-Difference Formulas: Clarification Concerning Usage, 61(1):118-122

4.4.8 whiteness/

py

- __init__.py
- smet_white_loci.py

namespace
luxpy

Module with Smet et al. (2018) neutral white loci

_UW_NEUTRALITY_PARAMETERS_SMET2014
dict with parameters of the unique white models in Smet et al. (2014)

xyz_to_neutrality_smet2018()
Calculate degree of neutrality using the unique white model in Smet et al. (2014) or the normalized (max = 1) degree of chromatic adaptation model from Smet et al. (2017).

cct_to_neutral_loci_smet2018()
Calculate the most neutral appearing Duv10 in and the degree of neutrality for a specified CCT using the models in Smet et al. (2018).

References

1. Smet, K. A. G. (2018). Two Neutral White Illumination Loci Based on Unique White Rating and Degree of Chromatic Adaptation. LEUKOS, 14(2), 55–67.

2. Smet, K., Deconinck, G., & Hanselaer, P., (2014), Chromaticity of unique white in object mode. Optics Express, 22(21), 25830–25841.

3. 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.

Added August 02, 2019.

`luxpy.color.whiteness.`**`xyz_to_neutrality_smet2018`**(*xyz10*, *nlocitype='uw'*, *uw_model='Linvar'*)

Calculate degree of neutrality using the unique white model in Smet et al. (2014) or the normalized (max = 1) degree of chromatic adaptation model from Smet et al. (2017).

Args:

xyz10

ndarray with CIE 1964 10° xyz tristimulus values.

nlocitype

'uw', optional

'uw': use unique white models published in Smet et al. (2014).

'ca': use degree of chromatic adaptation model from Smet et al. (2017).

uw_model

'Linvar', optional

Use Luminance invariant unique white model from Smet et al. (2014).

Other options: 'L200' (200 cd/m^2), 'L1000' (1000 cd/m^2) and 'L2000' (2000 cd/m^2).

Returns:

N

ndarray with calculated neutrality

References:

1. Smet, K., Deconinck, G., & Hanselaer, P., (2014), Chromaticity of unique white in object mode. Optics Express, 22(21), 25830–25841.

2. 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.whiteness.`**`cct_to_neutral_loci_smet2018`**(*cct*, *nlocitype='uw'*, *out='duv,D'*)

Calculate the most neutral appearing Duv10 in and the degree of neutrality for a specified CCT using the models in Smet et al. (2018).

Args:

cct10

ndarray CCT

nlocitype

'uw', optional

'uw': use unique white models published in Smet et al. (2014).

'ca': use degree of chromatic adaptation model from Smet et al. (2017).

out

'duv,D', optional

Specifies requested output (other options: 'duv', 'D').

Returns:

duv

ndarray with most neutral Duv10 value corresponding to the cct input.

D

ndarray with the degree of neutrality at (cct, duv).

References:

1. Smet, K.A.G., (2018), Two Neutral White Illumination Loci Based on Unique White Rating and Degree of Chromatic Adaptation. LEUKOS, 14(2), 55–67.

Notes:

1. Duv is specified in the CIE 1960 u10v10 chromatity diagram as the models were developed using CIE 1964 10° tristimulus, chromaticity and CCT values.
2. The parameter +0.0172 in Eq. 4b should be -0.0172.

4.4.9 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
  - cie_wrappers.py
  - iestm30_wrappers.py
  - cri2012.py
  - mcri.py
  - cqs.py
  - fci.py
  - thorntoncpi.py
- **/iestm30/**
  - __init__.py
  - metrics.py
  - graphics.py
  - metrics_fast.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 13 keys (04 Mar, 2025):
- sampleset [str/dict],
- ref_type [str],
- calculation_wavelength_range [list],
- cieobs [Dict],
- cct_mode [str],
- avg [fcn handle],
- rf_from_avg_rounded_rfi [bool],
- round_daylightphase_Mi_to_cie_recommended [bool],
- 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','iesrf-tm30-20','iesrf-tm30-24'
* 'cri2012','cri2012-hl17','cri2012-hl1000','cri2012-real210',
* 'mcri',
* 'cqs-v7.5','cqs-v9.0'
* 'fci'
* 'thornton_cpi'

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

_get_hue_bin_data()
Slice gamut spanned by the sample jabt, jabr and calculate hue-bin data.

_hue_bin_data_to_rxhj()
Calculate hue bin measures: Rcshj, Rhshj, Rfhj, DEhj

_hue_bin_data_to_rfi()
Get sample color differences DEi and calculate color fidelity values Rfi.

_hue_bin_data_to_rg()
Calculates gamut area index, Rg.

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_iesrf_tm30_20(): TM30-20 version (= TM30-18)

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
spd_to_iesrg_tm30_20(): TM30-20 version (= TM30-18)

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/graphics.py

spd_to_ies_tm30_metrics()
Calculates IES TM30 metrics from spectral data

plot_cri_graphics()

Plots graphical information on color rendition
properties based on spectral data input or dict with
pre-calculated measures.

_tm30_process_spd()
Calculate all required parameters for plotting from spd using cri.spd_to_cri()

plot_tm30_cvg()
Plot TM30 Color Vector Graphic (CVG).

plot_tm30_Rfi()
Plot Sample Color Fidelity values (Rfi).

plot_tm30_Rxhj()
Plot Local Chroma Shifts (Rcshj), Local Hue Shifts (Rhshj) and Local Color Fidelity values (Rfhj).

plot_tm30_Rcshj()
Plot Local Chroma Shifts (Rcshj).

plot_tm30_Rhshj()
Plot Local Hue Shifts (Rhshj).

plot_tm30_Rfhj()
Plot Local Color Fidelity values (Rfhj).

plot_tm30_spd()
Plot test SPD and reference illuminant, both normalized to the same luminous power.

plot_tm30_report()
Plot a figure with an ANSI/IES-TM30 color rendition report.

plot_cri_graphics()

Plots graphical information on color rendition
properties based on spectral data input or dict with
pre-calculated measures (cusom design).
Includes Metameric uncertainty index Rt and vector-fields
of color rendition shifts.

iestm30/metrics.py

spd_to_ies_tm30_metrics()
Calculates IES TM30 metrics from spectral data + Metameric Uncertainty + Vector Fields

iestm30/metrics_fast.py

_cri_ref()
Calculate multiple reference illuminant spectra based on ccts for color rendering index calculations.

_xyz_to_jab_cam02ucs()
Calculate CAM02-UCS J'a'b' coordinates from xyz tristimulus values of sample and white point.

spd_to_tm30()
Calculate tm30 measures from spd.

- Created for faster spectral optimization based on ANSI/IES-TM30 measures

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._get_hue_bin_data`(*jabt*, *jabr*, *start_hue=0*, *nhbins=16*, *normalized_chroma_ref=100*)

Slice gamut spanned by the sample jabt, jabr and calculate hue-bin data.

Args:

jabt

ndarray with jab sample data under test illuminant

jabr

ndarray with jab sample data under reference illuminant

start_hue

0.0 or float, optional

Hue angle to start bin slicing

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.

normalized_chroma_ref

100.0 or float, optional

Controls the size (chroma/radius) of the normalization circle/gamut.

Returns:

dict

Dictionary with keys:

- 'jabt', 'jabr': ndarrays with jab sample data under test & ref. illuminants
- 'DEi': ndarray with sample jab color difference between test and ref.
- 'Ct', 'Cr': chroma for each sample under test and ref.
- 'ht', 'hr': hue angles (rad.) for each sample under test and ref.
- 'ht_idx', 'hr_idx': hue bin indices for each sample under test and ref.
- 'jabt_hj', 'jabr_hj': ndarrays with hue-bin averaged jab's under test & ref. illuminants
- 'DE_hj' : ndarray with average sample DE in each hue bin
- 'jabt_hj_closed', 'jabr_hj_closed': ndarrays with hue-bin averaged jab's under test & ref. illuminants (closed gamut: 1st == last)
- 'jabtn_hj', 'jabrn_hj': ndarrays with hue-bin averaged and normalized jab's under test & ref. illuminants
- 'jabtn_hj_closed', 'jabrn_hj_closed': ndarrays with hue-bin and normalized averaged jab's under test & ref. illuminants (closed gamut: 1st == last)
- 'ht_hj', 'hr_hj': hues (rad.) for each hue bin for test and ref.
- 'Ct_hj', 'Cr_hj': chroma for each hue bin for test and ref.
- 'Ctn_hj' : normalized chroma for each hue bin for test (ref = normalized_chroma_ref)
- 'nhbins': number of hue bins
- 'start_hue' : start hue for bin slicing
- 'normalized_chroma_ref': normalized chroma value for ref.
- 'dh': hue-angle arcs (°)
- 'hue_bin_edges': hue bin edge (rad)
- 'hbinnrs': hue bin indices for each sample under ref. (= hr_idx)

luxpy.color.cri.**spd_to_jab_t_r**(*St*, *cri_type='ies-tm30'*, *out='jabt,jabr'*, *wl=None*, *sampleset=None*, *ref_type=None*, *calculation_wavelength_range=None*, *cieobs=None*, *cct_mode=None*, *cspace=None*, *catf=None*, *cri_specific_pars=None*, *round_daylightphase_Mi_to_cie_recommended=False*, *interp_settings=None*)

Calculates jab color values for a sample set illuminated with test source SPD and its reference illuminant.

Args:

St

ndarray with spectral data
(can be multiple SPDs, first axis are the wavelengths)

out

'jabt,jabr' or str, optional
Specifies requested output (e.g.'jabt,jabr' or 'jabt,jabr,cct,duv')

wl

None, optional
Wavelengths (or [start, end, spacing]) to interpolate the spds in St 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

calculation_wavelength_range

None or list, optional
Specifies the range outside of which all values of the SPD will be dropped in the calculations.

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

cct_mode

None or str or (str, dict), optional
Specifies which mode to use when calculating xyz_to_cct().
If tuple: second element is dict with additional kwargs for xyz_to_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']

round_daylightphase_Mi_to_cie_recommended

False, optional
Round M1, M2 values to 3 decimals as recommended by CIE (not that TM30 does not do this, which gives slight errors when calculating a daylight phase (equivalent of around 0.75 K for 6500 K illuminant))

Returns:

returns

(ndarray, ndarray)
with jabt and jabr data for :out: 'jabt,jabr'

Other output is also possible by changing the :out: str value.

`luxpy.color.cri.`**`spd_to_rg`**(*St*, *cri_type='ies-tm30'*, *out='Rg'*, *wl=None*, *sampleset=None*, *ref_type=None*, *calculation_wavelength_range=None*, *round_daylightphase_Mi_to_cie_recommended=None*, *cct_mode=None*, *cieobs=None*, *avg=None*, *cspace=None*, *catf=None*, *cri_specific_pars=None*, *rg_pars=None*, *fit_gamut_ellipse=False*, *interp_settings=None*)

Calculates the color gamut index, Rg, of spectral data.

Args:

St

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

calculation_wavelength_range

None or list, optional
Specifies the range outside of which all values of the SPD will be dropped in the calculations.

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

cct_mode

None or str or (str, dict), optional

Specifies which mode to use when calculating xyz_to_cct().
If tuple: second element is dict with additional kwargs for xyz_to_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']

round_daylightphase_Mi_to_cie_recommended

None or bool, optional
Round M1, M2 values to 3 decimals as recommended by CIE (not that TM30 does not do this, which gives slight errors when calculating a daylight phase (equivalent of around 0.75 K for 6500 K illuminant))

rg_pars

None or dict, optional
Dict containing specifying parameters for slicing the gamut.
Dict structure:
{'nhbins' : None, 'start_hue' : 0,
'normalize_gamut' : False, 'normalized_chroma_ref': 100.0}
- 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.
- key 'use_bin_avg_DEi': True or False
  Note that following IES-TM30 DEhj 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 DEhj (False).

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'.

fit_gamut_ellipse

fit ellipse to normalized color gamut
(extract from function using out; also stored in hue_bin_data['gamut_ellipse_fit'])

Returns:

returns

float or ndarray with Rg for :out: 'Rg'
Other output is also possible by changing the :out: str value.
E.g. out == 'Rg,data' would output an ndarray with Rg values
and a dictionary :data: with keys:
'St', 'Sr', 'cct', 'duv', 'hue_bin_data'
'xyzti', xyzti, 'xyztw', 'xyzri', 'xyzrw'

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_DEi**(*St*, *cri_type='ies-tm30'*, *out='DEi'*, *wl=None*, *sampleset=None*, *ref_type=None*, *calculation_wavelength_range=None*, *round_daylightphase_Mi_to_cie_recommended=None*, *cieobs=None*, *cct_mode=None*, *avg=None*, *cspace=None*, *catf=None*, *cri_specific_pars=None*, *interp_settings=None*)

Calculates color differences (~fidelity), DEi, of spectral data.

Args:

St

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 in St 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']

round_daylightphase_Mi_to_cie_recommended

None or bool, optional
Round M1, M2 values to 3 decimals as recommended by CIE (not that TM30 does not do this, which gives slight errors when calculating a daylight phase (equivalent of around 0.75 K for 6500 K illuminant))

Returns:

returns

float or ndarray with DEi for :out: 'DEi'

Other output is also possible by changing the :out: str value.

luxpy.color.cri.**optimize_scale_factor**(*cri_type*, *opt_scale_factor*, *scale_fcn*, *avg*, *rf_from_avg_rounded_rfi*, *interp_settings=None*)

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').

Args:

cri_type

str or dict
-'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)

opt_scale

True or False
True: optimize scaling-factor, else do nothing and use value of
scaling-factor in :scale: dict.

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)

avg

None or fcn handle
Averaging function (handle) for color differences, DEi
(e.g. numpy.mean, .math.rms, .math.geomean)
None use the one specified in :cri_type: dict.

Returns:

scaling_factor

ndarray

luxpy.color.cri.**spd_to_cri**(*St*, *cri_type='ies-tm30'*, *out='Rf'*, *wl=None*, *sampleset=None*, *ref_type=None*, *calculation_wavelength_range=None*, *round_daylightphase_Mi_to_cie_recommended=None*, *cieobs=None*, *cct_mode=None*, *avg=None*, *rf_from_avg_rounded_rfi=None*, *scale=None*, *opt_scale_factor=False*, *cspace=None*, *catf=None*, *cri_specific_pars=None*, *rg_pars=None*, *fit_gamut_ellipse=False*, *interp_settings=None*)

Calculates the color rendering fidelity index, Rf, of spectral data.

Args:

St

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

calculation_wavelength_range

None or list, optional

Specifies the range outside of which all values of the SPD will be dropped in the calculations.

round_daylightphase_Mi_to_cie_recommended

None or bool, optional

Round M1, M2 values to 3 decimals as recommended by CIE (not that TM30 does not do this, which gives slight errors when calculating a daylight phase (equivalent of around 0.75 K for 6500 K illuminant))

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

cct_mode

None or str or (str, dict), optional

Specifies which mode to use when calculating xyz_to_cct().

If tuple: second element is dict with additional kwargs for xyz_to_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
and calculating hue bin specific indices.
Dict structure:
{'nhbins' : None, 'start_hue' : 0,
'normalize_gamut' : False, 'normalized_chroma_ref': 100.0}
- 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.
- key 'use_bin_avg_DEi': True or False
Note that following IES-TM30 DEhj 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 DEhj (False).

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.

rf_from_avg_rounded_rfi

None, optional
If None: use as specified in the :cri_type: dict
If False: calculate Rf directly from DEa.
If True: round Rfi to integer numbers and average them to Rf
(method used in CIE-13.3-1995 Ra calculation)

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_factor

True or False, optional
True: optimize scaling-factor, else do nothing and use value of
scaling-factor in :scale: dict.

fit_gamut_ellipse

fit ellipse to normalized color gamut
(extract from function using out; also stored in hue_bin_data['gamut_ellipse_fit'])

Returns:

returns

float or ndarray with Rf for :out: 'Rf'
Other output is also possible by changing the :out: str value.
E.g. out == 'Rg,data' would output an ndarray with Rf values

and a dictionary :data: with keys:

- 'St, Sr' : ndarray of test SPDs and corresponding ref. illuminants.
- 'xyz_cct': xyz of white point calculate with cieobs defined for cct calculations in cri_type['cieobs']
- 'cct, duv': CCT and Duv obtained with cieobs in cri_type['cieobs']['cct']
- 'xyzti, xyzri': ndarray tristimulus values of test and ref. samples (obtained with with cieobs in cri_type['cieobs']['xyz'])
- 'xyztw, xyzrw': ndarray tristimulus values of test and ref. white points (obtained with with cieobs in cri_type['cieobs']['xyz'])
- 'DEi, DEa': ndarray with individual sample color differences DEi and average DEa between test and ref.
- 'Rf' : ndarray with general color fidelity index values
- 'Rg' : ndarray with color gamut area index values
- 'Rfi' : ndarray with specific (sample) color fidelity indices

- 'Rfhj' : ndarray with local (hue binned) fidelity indices
- 'DEhj' : ndarray with local (hue binned) color differences
- 'Rcshj': ndarray with local chroma shifts indices
- 'Rhshj': ndarray with local hue shifts indices
- 'hue_bin_data': dict with output from _get_hue_bin_data() [see its help for more info]
- 'cri_type': same as input (for reference purposes)

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.`**`_hue_bin_data_to_rxhj`**(*hue_bin_data*, *cri_type='ies-tm30'*, *scale_factor=None*, *scale_fcn=None*, *use_bin_avg_DEi=True*)

Calculate hue bin measures: Rcshj, Rhshj, Rfhj, DEhj.

Rcshj: local chroma shift
Rhshj: local hue shift
Rfhj: local (hue bin) color fidelity
DEhj: local (hue bin) color differences

(See IES TM30)

Args:

hue_bin_data

Dict with hue bin data obtained with _get_hue_bin_data().

use_bin_avg_DEi

True, optional
Note that following IES-TM30 DEhj 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 DEhj (False).
If None: use value in rg_pars dict in cri_type dict!

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 Rcshj, Rhshj, Rfhj, DEhj

References:

1. IES TM30, Method for Evaluating Light Source Color Rendition. New York, NY: The Illuminating Engineering Society of North America.

`luxpy.color.cri._hue_bin_data_to_rfi`(*hue_bin_data=None*, *cri_type='ies-tm30'*, *scale_factor=None*, *scale_fcn=None*)

Get sample color differences DEi and calculate color fidelity values Rfi.

Rfi: Sample color fidelity
DEi: Sample color differences

(See IES TM30)

Args:

hue_bin_data

Dict with hue bin data obtained with _get_hue_bin_data().

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 Rfi, DEi

References:

1. IES TM30, Method for Evaluating Light Source Color Rendition. New York, NY: The Illuminating Engineering Society of North America.

`luxpy.color.cri._hue_bin_data_to_rg`(*hue_bin_data*, *max_scale=100*, *normalize_gamut=False*)

Calculates gamut area index, Rg.

Args:

hue_bin_data

Dict with hue bin data obtained with _get_hue_bin_data().

max_scale

100.0, optional
Value of Rg when Rf = max_scale (i.e. DEavg = 0)

normalize_gamut

False, optional
True normalizes the gamut of test to that of ref.
(perfect agreement results in circle).

out

'Rg', optional
Specifies which variables to output as ndarray

Returns:

Rg

float or ndarray with gamut area indices Rg.

luxpy.color.cri.**spd_to_ciera**(*SPD*, *out='Rf'*, *wl=None*, *interp_settings=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*, *interp_settings=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*, *interp_settings=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*, *interp_settings=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-tm30-20'*, *interp_settings=None*)

Wrapper function for the 'iesrf' color fidelity index (IES TM30-20 = 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 TM30-20 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-tm30-20'*, *interp_settings=None*)

Wrapper function for the 'spd_to_rg' color gamut area index (IES TM30-18 = TM30-20).

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 TM30-20 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-tm30-20'*, *interp_settings=None*)

Wrapper function for the 'iesrf' color fidelity index (IES TM30-20 = 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 TM30-20 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-tm30-20'*, *interp_settings=None*)

Wrapper function for the 'spd_to_rg' color gamut area index (IES TM30-18 = TM30-20).

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 TM30-20 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'*, *interp_settings=None*)

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'*, *interp_settings=None*)

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'*, *interp_settings=None*)

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 TM30-18 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'*, *interp_settings=None*)

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 TM30-18 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_20**(*SPD*, *out='Rf'*, *wl=None*, *cri_type='iesrf-tm30-20'*, *interp_settings=None*)

Wrapper function for the 'iesrf' color fidelity index (IES TM30-20 = 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 TM30-20 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_20**(*SPD*, *out='Rg'*, *wl=None*, *cri_type='iesrf-tm30-20'*, *interp_settings=None*)

Wrapper function for the 'spd_to_rg' color gamut area index (IES TM30-18 = TM30-20).

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 TM30-20 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*, *interp_settings=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*, *interp_settings=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*, *interp_settings=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*, *interp_settings=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*, *mcri_defaults=None*, *interp_settings=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

mcri_defaults

None, optional
Dictionary with structure of _MCRI_DEFAULTS containing everything
needed to calculate MCRI.
If None: _MCRI_DEFAULTS is used.

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*, *interp_settings=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.**spd_to_fci**(*spd*, *use_cielab=True*)

Calculate Feeling of Contrast Index (FCI).

Args:

spd

ndarray with spectral power distribution(s) of the test light source(s).

use_cielab

True, optional
True: use original formulation of FCI, which adopts a CIECAT94
chromatic adaptation transform followed by a conversion to
CIELAB coordinates before calculating the gamuts.
False: use CIECAM02 coordinates and embedded CAT02 transform.

Returns:

fci

ndarray with FCI values.

References:

1. Hashimoto, K., Yano, T., Shimizu, M., & Nayatani, Y. (2007). New method for specifying color-rendering properties of light sources based on feeling of contrast. Color Research and Application, 32(5), 361–371.

luxpy.color.cri.**spd_to_thornton_cpi**(*spd*, *interp_settings=None*)

Calculate Thornton's Color Preference Index (CPI).

Args:

spd

nd array with spectral power distribution(s) of the test light source(s).

Returns:

cpi

ndarray with CPI values.

Reference:

1. Thornton, W. A. (1974). A Validation of the Color-Preference Index. Journal of the Illuminating Engineering Society, 4(1), 48–52.

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*, *plot_10_20_circles=False*, *axtype='polar'*, *ax=None*, *force_CVG_layout=False*, *hbin_color_map=None*)

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.

plot_10_20_circles

False, optional

If True and :axtype: == 'cart': Plot white circles at

80%, 90%, 100%, 110% and 120% of :scalef:

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.

hbin_color_map

ndarray with predefined RGB color map

If None or hbin_color_map.shape[0]<nhbins: cmap will be created, else use values in ndarray.

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*, *plot_10_20_circles=True*, *plot_vectors=True*, *gamut_line_color=None*, *gamut_line_style='-'*, *gamut_line_marker='o'*, *gamut_line_label=None*, *axtype='polar'*, *ax=None*, *force_CVG_layout=False*, *hbin_color_map=None*, *hvector_color_map=None*, *jabti=None*, *jabri=None*, *hbinnr=None*)

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.

plot_10_20_circles

True, optional
If True and :axtype: == 'cart': Plot white circles at
80%, 90%, 100%, 110% and 120% of :scalef:

plot_vectors

True, optional
True: plot vectors from reference to test colors.

gamut_line_color

'grey', optional
Color to plot the test color gamut in.

gamut_line_style

'-', optional
Line style to plot the test color gamut in.

gamut_line_marker

'o', optional
Markers to plot the test color gamut points for each hue bin in
(only used when plot_vectors = False).

gamut_line_label

None, optional
Label for gamut line. (only used when plot_vectors = False).

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.

hbin_color_map

ndarray with predefined RGB color map for the hue bins

If None or hbin_color_map.shape[0]<nhbins: cmap will be created, else use values in ndarray.

hvector_color_map

ndarray with predefined RGB color map for the color shift vectors in each hue bin.
If None or hvector_color_map.shape[0]<hbins: cmap will be created, else use values in ndarray.

jabti

None, optional
ndarray with jab data of all samples under test SPD (scaled to 'unit' circle)
If not None: plot chromaticity coordinates of test samples relative to
the mean chromaticity of the samples under the reference illuminant.

jabri

None, optional
ndarray with jab data of all samples under reference SPD (scaled to 'unit' circle)
Must be supplied when jabti is not None!

hbinnr

None, optional
ndarray with hue bin number of each sample.
Must be supplied when jabti is not None!

Returns:

returns

gcf(), gca(), list with rgb colors for hue bins (for use in
other plotting fcns)

luxpy.color.cri.**spd_to_ies_tm30_metrics**(*St*, *cri_type=None*, *hbins=16*, *start_hue=0.0*, *scalef=100*, *no_VF_metrics=False*, *vf_model_type='M6'*, *vf_pcolorshift={'Cref': 40, 'href': array([3.7835e+00, 3.3161e+00, 2.8272e+00, 1.9093e+00, 5.2787e+00, 4.3081e+00, 3.7762e-01, 6.2055e+00, 1.4564e+00, 8.8926e-01]), 'labels': array(['5B', '5BG', '5G', '5GY', '5P', '5PB', '5R', '5RP', '5Y', '5YR'], dtype=object), 'sig': 0.3}*, *scale_vf_chroma_to_sample_chroma=False*, *interp_settings=None*)

Calculates IES TM30 metrics from spectral data.

Args:

St

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.

no_VF_metrics

False, optional
If True: don't calculate vector-field based metrics.

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

Dictionary with color rendering data:

- 'St, Sr' : ndarray of test SPDs and corresponding ref. illuminants.
- 'xyz_cct': xyz of white point calculate with cieobs defined for cct calculations in cri_type['cieobs'] and cri_type['cct_mode']
- 'cct, duv': CCT and Duv obtained with cieobs in cri_type['cieobs']['cct'] and using mode in cri_type['cct_mode']
- 'xyzti, xyzri': ndarray tristimulus values of test and ref. samples (obtained with with cieobs in cri_type['cieobs']['xyz'])
- 'xyztw, xyzrw': ndarray tristimulus values of test and ref. white points (obtained with with cieobs in cri_type['cieobs']['xyz'])
- 'DEi, DEa': ndarray with individual sample color differences DEi and average DEa between test and ref.
- 'Rf' : ndarray with general color fidelity index values
- 'Rg' : ndarray with color gamut area index values
- 'Rfi' : ndarray with specific (sample) color fidelity indices
- 'Rfhj' : ndarray with local (hue binned) fidelity indices
- 'DEhj' : ndarray with local (hue binned) color differences
- 'Rcshj': ndarray with local chroma shifts indices
- 'Rhshj': ndarray with local hue shifts indices
- 'hue_bin_data': dict with output from _get_hue_bin_data() [see its help for more info]
- 'cri_type': same as input (for reference purposes)
- 'vf' : dictionary with vector field measures and data. (if no_VF_metrics == False)
  Keys:
  - 'Rt' : ndarray with general metameric uncertainty index Rt
  - 'Rti' : ndarray with specific metameric uncertainty indices Rti
  - 'Rfhj' : ndarray with local (hue binned) fidelity indices
    obtained from VF model predictions at color space

pixel coordinates
- 'DEhj' : ndarray with local (hue binned) color differences
(same as above)
- 'Rcshj': ndarray with local chroma shifts indices for vectorfield coordinates
(same as above)
- 'Rhshj': ndarray with local hue shifts indicesfor vectorfield coordinates
(same as above)
- 'Rfi': ndarray with sample fidelity indices for vectorfield coordinates
(same as above)
- 'DEi': ndarray with sample color differences for vectorfield coordinates
(same as above)
- 'hue_bin_data': dict with output from _get_hue_bin_data() for vectorfield coordinates
- 'dataVF': dictionary with output of cri.VFPX.VF_colorshift_model()

luxpy.color.cri.**_tm30_process_spd**(*spd*, *cri_type='ies-tm30'*, ***kwargs*)

Calculate all required parameters for plotting from spd using cri.spd_to_cri()

Args:

spd

ndarray or dict
If ndarray: single spectral power distribution.
If dict: dictionary with pre-computed parameters.
required keys:
dict_keys(['St', 'Sr', 'xyztw_cct', 'cct', 'duv',
'xyzti', 'xyztw', 'xyzri', 'xyzrw',
'DEi', 'DEa', 'Rf', 'Rg',
'Rcshj', 'Rhshj', 'Rfhj', 'hue_bin_data'])
see cri.spd_to_cri() for more info on parameters.

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 (in kwargs)
to the function will override default values in cri_type dict.

kwargs

Additional optional keyword arguments,
the same as in cri.spd_to_cri()

Returns:

data

dictionary with required parameters for plotting functions.

luxpy.color.cri.**plot_tm30_cvg**(*spd*, *cri_type='ies-tm30'*, *gamut_line_color=None*, *gamut_line_style='-'*, *gamut_line_marker='o'*, *gamut_line_label=None*, *plot_vectors=True*, *plot_index_values=True*, *axh=None*, *axtype='cart'*, *show_annexE_priority=True*, *show_Rcsh1_Rfh1=True*, ***kwargs*)

Plot TM30 Color Vector Graphic (CVG).

Args:

spd

ndarray or dict
If ndarray: single spectral power distribution.
If dict: dictionary with pre-computed parameters (using _tm30_process_spd()).
required keys:
dict_keys(['St', 'Sr', 'xyztw_cct', 'cct', 'duv',
'xyzti', 'xyztw', 'xyzri', 'xyzrw',
'DEi', 'DEa', 'Rf', 'Rg',
'Rcshj', 'Rhshj', 'Rfhj', 'hue_bin_data'])
see cri.spd_to_cri() for more info on parameters.

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 (in kwargs)
to the function will override default values in cri_type dict.

gamut_line_color

'r', optional
Plotting line style for the line connecting the
average test chromaticity in the hue bins.
None defaults to red (240,80,70)/255 (IES-TM30-20 recommended).

gamut_line_style

'-', optional
Plotting color for the line connecting the
average test chromaticity in the hue bins.

gamut_line_marker

'-', optional
Markers to plot the test color gamut points for each hue bin in
(only used when plot_vectors = False).

gamut_line_label

None, optional
Label for gamut line. (only used when plot_vectors = False).

plot_vectors

True, optional
Plot color shift vectors in CVG (True) or not (False).

plot_index_values

True, optional
Print Rf, Rg, CCT and Duv in corners of CVG (True) or not (False).
If False: turns of potential prints of Rcsh1, Rfh1
and annexE_priority levelels as well. This way this argument can be

easily used to turn off all plotting and printing when graphs are
to be generated with gamuts of multiple sources.

axh

None, optional
If None: create new figure with single axes, else plot on specified axes.

axtype

'cart' (or 'polar'), optional
Make Cartesian (default) or polar plot.

show_annexE_priority

True, optional
Add Annex E priority levels for source.

show_Rcsh1_Rfh1

True, optional
Add the local chroma shift (%) and the local color fidelity index
for hue bin 1 at the bottom of the graph.

kwargs

Additional optional keyword arguments,
the same as in cri.spd_to_cri()

Returns:

axh

handle to figure axes.

data

dictionary with required parameters for plotting functions.

`luxpy.color.cri.plot_tm30_Rfi`(*spd*, *cri_type='ies-tm30'*, *axh=None*, *font_size=11*, ***kwargs*)

Plot Sample Color Fidelity values (Rfi).

Args:

spd

ndarray or dict
If ndarray: single spectral power distribution.
If dict: dictionary with pre-computed parameters (using _tm30_process_spd()).
required keys:
dict_keys(['St', 'Sr', 'xyztw_cct', 'cct', 'duv',
'xyzti', 'xyztw', 'xyzri', 'xyzrw',
'DEi', 'DEa', 'Rf', 'Rg',
'Rcshj', 'Rhshj', 'Rfhj', 'hue_bin_data'])
see cri.spd_to_cri() for more info on parameters.

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 (in kwargs)
to the function will override default values in cri_type dict.

axh

None, optional
If None: create new figure with single axes, else plot on specified axes.

font_size

_TM30_FONT_SIZE, optional
Font size of text, axis labels and axis values.

kwargs

Additional optional keyword arguments,
the same as in cri.spd_to_cri()

Returns:

axh

handle to figure axes.

data

dictionary with required parameters for plotting functions.

luxpy.color.cri.**plot_tm30_Rxhj**(*spd*, *cri_type='ies-tm30'*, *axh=None*, *figsize=(6, 15)*, *font_size=11*, ***kwargs*)

Plot Local Chroma Shifts (Rcshj), Local Hue Shifts (Rhshj) and Local Color Fidelity values (Rfhj) (one for each hue-bin).

Args:

spd

ndarray or dict
If ndarray: single spectral power distribution.
If dict: dictionary with pre-computed parameters (using _tm30_process_spd()).
required keys:
dict_keys([‘St’, ‘Sr’, ‘xyztw_cct’, ‘cct’, ‘duv’,
‘xyzti’, ‘xyztw’, ‘xyzri’, ‘xyzrw’,
‘DEi’, ‘DEa’, ‘Rf’, ‘Rg’,
‘Rcshj’, ‘Rhshj’, ‘Rfhj’, ‘hue_bin_data’])
see cri.spd_to_cri() for more info on parameters.

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 (in kwargs)
to the function will override default values in cri_type dict.

axh

None, optional
If None: create new figure with single axes, else plot on specified axes.

figsize

(6,15), optional
Figure size of pyplot figure.

font_size

_TM30_FONT_SIZE, optional
Font size of text, axis labels and axis values.

kwargs

Additional optional keyword arguments,
the same as in cri.spd_to_cri()

Returns:

axh

handle to figure axes.

data

dictionary with required parameters for plotting functions.

luxpy.color.cri.**plot_tm30_Rcshj**(*spd*, *cri_type='ies-tm30'*, *axh=None*, *xlabel=True*, *y_offset=0*, *font_size=11*, ***kwargs*)

Plot Local Chroma Shift values (Rcshj) (one for each hue-bin).

Args:

spd

ndarray or dict
If ndarray: single spectral power distribution.
If dict: dictionary with pre-computed parameters (using _tm30_process_spd()).
required keys:
dict_keys(['St', 'Sr', 'xyztw_cct', 'cct', 'duv',
'xyzti', 'xyztw', 'xyzri', 'xyzrw',
'DEi', 'DEa', 'Rf', 'Rg',
'Rcshj', 'Rhshj', 'Rfhj', 'hue_bin_data'])
see cri.spd_to_cri() for more info on parameters.

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 (in kwargs)
to the function will override default values in cri_type dict.

axh

None, optional
If None: create new figure with single axes, else plot on specified axes.

xlabel

True, optional
If False: don't add label and numbers to x-axis
(useful when plotting plotting all 'Local Rfhi, Rcshi, Rshhi'
values in 3x1 subplots with 'shared x-axis': saves vertical space)

y_offset

0, optional
text-offset from top of bars in barplot.

font_size

_TM30_FONT_SIZE, optional
Font size of text, axis labels and axis values.

kwargs

Additional optional keyword arguments,
the same as in cri.spd_to_cri()

Returns:

axh

handle to figure axes.

data

dictionary with required parameters for plotting functions.

luxpy.color.cri.**plot_tm30_Rhshj**(*spd*, *cri_type='ies-tm30'*, *axh=None*, *xlabel=True*, *y_offset=0*, *font_size=11*, ***kwargs*)

Plot Local Hue Shift values (Rhshj) (one for each hue-bin).

Args:

spd

ndarray or dict
If ndarray: single spectral power distribution.
If dict: dictionary with pre-computed parameters (using _tm30_process_spd()).
required keys:
dict_keys(['St', 'Sr', 'xyztw_cct', 'cct', 'duv',
'xyzti', 'xyztw', 'xyzri', 'xyzrw',
'DEi', 'DEa', 'Rf', 'Rg',
'Rcshj', 'Rhshj', 'Rfhj', 'hue_bin_data'])
see cri.spd_to_cri() for more info on parameters.

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 (in kwargs)
to the function will override default values in cri_type dict.

axh

None, optional
If None: create new figure with single axes, else plot on specified axes.

xlabel

True, optional
If False: don't add label and numbers to x-axis
(useful when plotting plotting all 'Local Rfhi, Rcshi, Rshhi'
values in 3x1 subplots with 'shared x-axis': saves vertical space)

y_offset

0, optional
text-offset from top of bars in barplot.

font_size

_TM30_FONT_SIZE, optional
Font size of text, axis labels and axis values.

kwargs

Additional optional keyword arguments,
the same as in cri.spd_to_cri()

Returns:

axh

handle to figure axes.

data

dictionary with required parameters for plotting functions.

luxpy.color.cri.**plot_tm30_Rfhj**(*spd*, *cri_type='ies-tm30'*, *axh=None*, *xlabel=True*, *y_offset=0*, *font_size=11*, ***kwargs*)

Plot Local Color Fidelity values (Rfhj) (one for each hue-bin).

Args:

spd

ndarray or dict
If ndarray: single spectral power distribution.
If dict: dictionary with pre-computed parameters (using _tm30_process_spd()).
required keys:
dict_keys(['St', 'Sr', 'xyztw_cct', 'cct', 'duv',
'xyzti', 'xyztw', 'xyzri', 'xyzrw',
'DEi', 'DEa', 'Rf', 'Rg',
'Rcshj', 'Rhshj', 'Rfhj', 'hue_bin_data'])
see cri.spd_to_cri() for more info on parameters.

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 (in kwargs)
to the function will override default values in cri_type dict.

axh

None, optional
If None: create new figure with single axes, else plot on specified axes.

xlabel

True, optional
If False: don't add label and numbers to x-axis
(useful when plotting plotting all 'Local Rfhi, Rcshi, Rshhi'
values in 3x1 subplots with 'shared x-axis': saves vertical space)

y_offset

0, optional
text-offset from top of bars in barplot.

font_size

_TM30_FONT_SIZE, optional
Font size of text, axis labels and axis values.

kwargs

Additional optional keyword arguments,
the same as in cri.spd_to_cri()

Returns:

axh

handle to figure axes.

data

dictionary with required parameters for plotting functions.

luxpy.color.cri.**plot_tm30_spd**(*spd*, *cri_type='ies-tm30'*, *axh=None*, *font_size=11*, ***kwargs*)

Plot test SPD and reference illuminant, both normalized to the same luminous power.

Args:

spd

ndarray or dict
If ndarray: single spectral power distribution.
If dict: dictionary with pre-computed parameters (using _tm30_process_spd()).
required keys:
dict_keys(['St', 'Sr', 'xyztw_cct', 'cct', 'duv',
'xyzti', 'xyztw', 'xyzri', 'xyzrw',
'DEi', 'DEa', 'Rf', 'Rg',
'Rcshj', 'Rhshj', 'Rfhj', 'hue_bin_data'])
see cri.spd_to_cri() for more info on parameters.

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 (in kwargs)
to the function will override default values in cri_type dict.

axh

None, optional
If None: create new figure with single axes, else plot on specified axes.

font_size

_TM30_FONT_SIZE, optional
Font size of text, axis labels and axis values.

kwargs

Additional optional keyword arguments,
the same as in cri.spd_to_cri()

Returns:

axh

handle to figure axes.

data

dictionary with required parameters for plotting functions.

luxpy.color.cri.**plot_tm30_report**(*spd*, *cri_type='ies-tm30'*, *report_type='full'*, *source=''*, *manufacturer=''*, *date=''*, *model=''*, *notes=''*, *max_len_notes_line=40*, *figsize=None*, *save_fig_name=None*, *dpi=300*, *plot_report_top=True*, *plot_report_bottom=True*, *show_annexE_priority=True*, *show_Rcsh1_Rfh1=True*, *suptitle='ANSI/IES TM-30-18 Color Rendition Report'*, *font_size=None*, ***kwargs*)

Create TM30 Color Rendition Report.

Args:

spd

ndarray or dict

If ndarray: single spectral power distribution.

If dict: dictionary with pre-computed parameters (using _tm30_process_spd()).

required keys:

dict_keys([‘St’, ‘Sr’, ‘xyztw_cct’, ‘cct’, ‘duv’,
‘xyzti’, ‘xyztw’, ‘xyzri’, ‘xyzrw’,
‘DEi’, ‘DEa’, ‘Rf’, ‘Rg’,
‘Rcshj’, ‘Rhshj’, ‘Rfhj’, ‘hue_bin_data’])

see cri.spd_to_cri() for more info on parameters.

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 (in kwargs)
to the function will override default values in cri_type dict.

report_type

‘full’, optional

Generate a full report as in ANSI/IES-TM30-2020

Options :

- ‘full’: full report with spectrum plot, color vector graphic, local indices, sample indices’simple’, …
- ‘intermediate’: color vector graphic + local chroma and hue shifts
- ‘simple’: color vector graphic only
- ‘spd_cvg’: spectrum plot + color vector graphic

source

string with source name.

manufacturer

string with source manufacturer.

model

string with source model.

date

string with source measurement date.

notes

string to be split

max_len_notes_line

40, optional

Maximum length of a single line when splitting the string.

figsize

None, optional

Figure size of pyplot figure.

If None a default depending on the report_type is used:

- 'full': (7,12)
- 'intermediate' : (14,6)
- 'simple' : (6,6)
- 'spd_cvg': (14,6)

save_fig_name

None, optional

Filename (+path) to which the report will be saved as an image (png).

If None: don't save, just display.

dpi

300, optional

Dots-Per-Inch of image file (PNG).

plot_report_top

execute _plot_tm30_report_top()

plot_report_bottom

execute _plot_tm30_report_bottom()

show_annexE_priority

True, optional

Add Annex E priority levels for source.

show_Rcsh1_Rfh1

True, optional

Add the local chroma shift (%) and the local color fidelity index for hue bin 1 at the bottom of the graph.

suptitle

'ANSI/IES TM-30-18 Color Rendition Report' or str, optional

report title (input for plt.suptitle).

font_size

None, optional

Font size of text, axis labels and axis values (adjust when changing figsizes).

Defaults : ('full': _TM30_FONT_SIZE_FULLREPORT, other options: _TM30_FONT_SIZE)

kwargs

Additional optional keyword arguments, the same as in cri.spd_to_cri()

Returns:

axs

dictionary with handles to each axes.

data

dictionary with required parameters for plotting functions.

luxpy.color.cri.**spd_to_tm30_report**(*spd*, *cri_type='ies-tm30'*, *report_type='full'*, *source=''*, *manufacturer=''*, *date=''*, *model=''*, *notes=''*, *max_len_notes_line=40*, *figsize=None*, *save_fig_name=None*, *dpi=300*, *plot_report_top=True*, *plot_report_bottom=True*, *show_annexE_priority=True*, *show_Rcsh1_Rfh1=True*, *suptitle='ANSI/IES TM-30-18 Color Rendition Report'*, *font_size=None*, ***kwargs*)

Create TM30 Color Rendition Report.

Args:

spd

ndarray or dict

If ndarray: single spectral power distribution.

If dict: dictionary with pre-computed parameters (using _tm30_process_spd()).

required keys:

dict_keys([‘St’, ‘Sr’, ‘xyztw_cct’, ‘cct’, ‘duv’,
‘xyzti’, ‘xyztw’, ‘xyzri’, ‘xyzrw’,
‘DEi’, ‘DEa’, ‘Rf’, ‘Rg’,
‘Rcshj’, ‘Rhshj’, ‘Rfhj’, ‘hue_bin_data’])

see cri.spd_to_cri() for more info on parameters.

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 (in kwargs)
to the function will override default values in cri_type dict.

report_type

‘full’, optional

Generate a full report as in ANSI/IES-TM30-2020

Options :

- ‘full’: full report with spectrum plot, color vector graphic, local indices, sample indices’simple’, …
- ‘intermediate’: color vector graphic + local chroma and hue shifts
- ‘simple’: color vector graphic only
- ‘spd_cvg’: spectrum plot + color vector graphic

source

string with source name.

manufacturer

string with source manufacturer.

model

string with source model.

date

string with source measurement date.

notes

string to be split

max_len_notes_line

40, optional

Maximum length of a single line when splitting the string.

figsize

None, optional

Figure size of pyplot figure.

If None a default depending on the report_type is used:

- 'full': (7,12)
- 'intermediate' : (14,6)
- 'simple' : (6,6)
- 'spd_cvg': (14,6)

save_fig_name

None, optional

Filename (+path) to which the report will be saved as an image (png).

If None: don't save, just display.

dpi

300, optional

Dots-Per-Inch of image file (PNG).

plot_report_top

execute _plot_tm30_report_top()

plot_report_bottom

execute _plot_tm30_report_bottom()

show_annexE_priority

True, optional

Add Annex E priority levels for source.

show_Rcsh1_Rfh1

True, optional

Add the local chroma shift (%) and the local color fidelity index for hue bin 1 at the bottom of the graph.

suptitle

'ANSI/IES TM-30-18 Color Rendition Report' or str, optional

report title (input for plt.suptitle).

font_size

None, optional

Font size of text, axis labels and axis values (adjust when changing figsizes).

Defaults : ('full': _TM30_FONT_SIZE_FULLREPORT, other options: _TM30_FONT_SIZE)

kwargs

Additional optional keyword arguments, the same as in cri.spd_to_cri()

Returns:

axs

dictionary with handles to each axes.

data

dictionary with required parameters for plotting functions.

luxpy.color.cri.**plot_cri_graphics**(*data*, *cri_type=None*, *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=True*, *vf_model_type='M6'*, *vf_pcolorshift={'Cref': 40, 'href': array([3.7835e+00, 3.3161e+00, 2.8272e+00, 1.9093e+00, 5.2787e+00, 4.3081e+00, 3.7762e-01, 6.2055e+00, 1.4564e+00, 8.8926e-01]), 'labels': array(['5B', '5BG', '5G', '5GY', '5P', '5PB', '5R', '5RP', '5Y', '5YR'], dtype=object), 'sig': 0.3}*, *vf_color='k'*, *vf_bin_labels=array(['5B', '5BG', '5G', '5GY', '5P', '5PB', '5R', '5RP', '5Y', '5YR'], dtype=object)*, *vf_plot_bin_colors=True*, *scale_vf_chroma_to_sample_chroma=False*, *plot_VF=True*, *plot_CF=False*, *plot_SF=False*, *plot_test_sample_coord=False*)

Plot graphical information on color rendition properties (custom design).

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

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.

plot_test_sample_coord

Plot the coordinates of the samples under the test illuminant
relative to the mean chromaticity under the reference illuminant (in the CVG plot).

Returns:

returns

(data,
[plt.gcf(),ax_spd, ax_CVG, ax_locC, ax_locH, ax_VF],
cmap)

:data: is a dictionary with color rendering data
with keys:
- 'St, Sr' : ndarray of test SPDs and corresponding ref. illuminants.
- 'xyz_cct': xyz of white point calculate with cieobs defined for cct calculations in cri_type['cieobs']
- 'cct, duv': CCT and Duv obtained with cieobs in cri_type['cieobs']['cct']
- 'xyzti, xyzri': ndarray tristimulus values of test and ref. samples (obtained with with cieobs in cri_type['cieobs']['xyz'])
- 'xyztw, xyzrw': ndarray tristimulus values of test and ref. white points (obtained with with cieobs in cri_type['cieobs']['xyz'])
- 'DEi, DEa': ndarray with individual sample color differences DEi and average DEa between test and ref.
- 'Rf' : ndarray with general color fidelity index values
- 'Rg' : ndarray with color gamut area index values
- 'Rfi' : ndarray with specific (sample) color fidelity indices
- 'Rfhj' : ndarray with local (hue binned) fidelity indices
- 'DEhj' : ndarray with local (hue binned) color differences
- 'Rcshj': ndarray with local chroma shifts indices
- 'Rhshj': ndarray with local hue shifts indices
- 'hue_bin_data': dict with output from _get_hue_bin_data() [see its help for more info]
- 'cri_type': same as input (for reference purposes)
- 'vf' : dictionary with vector field measures and data.
    Keys:
        - 'Rt' : ndarray with general metameric uncertainty index Rt
        - 'Rti' : ndarray with specific metameric uncertainty indices Rti
        - 'Rfhj' : ndarray with local (hue binned) fidelity indices
            obtained from VF model predictions at color space
            pixel coordinates
        - 'DEhj' : ndarray with local (hue binned) color differences
            (same as above)
        - 'Rcshj': ndarray with local chroma shifts indices for vectorfield coordinates
            (same as above)
        - 'Rhshj': ndarray with local hue shifts indicesfor vectorfield coordinates
            (same as above)
        - 'Rfi': ndarray with sample fidelity indices for vectorfield coordinates

(same as above)
- 'DEi': ndarray with sample color differences for vectorfield coordinates
(same as above)
- 'hue_bin_data': dict with output from _get_hue_bin_data() for vectorfield coordinates
- 'dataVF': dictionary with output of cri.VFPX.VF_colorshift_model()

:[...]: list with handles to current figure and 5 axes.

:cmap: list with rgb colors for hue bins (for use in other plotting fcns)

luxpy.color.cri.**spd_to_tm30_fast**(*St*, *interp_settings=None*)

Calculate tm30 measures from spd.

luxpy.color.cri.**cri_ref_fast**(*ccts*, *wl3=array([360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830])*, *ref_type='iestm30'*, *mix_range=[4000, 5000]*, *cieobs=None*, *cieobs_Y_normalization=None*, *force_daylight_below4000K=False*, *n=None*, *daylight_locus=None*, *round_daylightphase_Mi_to_cie_recommended=None*, *interp_settings=None*)

Calculates multiple reference illuminant spectra based on ccts for color rendering index calculations.

luxpy.color.cri.**xyz_to_jab_cam02ucs_fast**(*xyz*, *xyzw*, *ucs=True*, *conditions=None*)

Calculate CAM02-UCS J'a'b' coordinates from xyz tristimulus values of sample and white point.

Args:

xyz

ndarray with sample tristimulus values

xyzw

ndarray with white point tristimulus values

conditions

None, optional
Dictionary with viewing conditions.
None results in:
{'La':100, 'Yb':20, 'D':1, 'surround':'avg'}
For more info see luxpy.cam.ciecam02()?

Returns:

jab

ndarray with J'a'b' coordinates.

4.4.10 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.

luxpy.color.cri.VFPX.**VF_colorshift_model**(*S*, *cri_type='iesrf'*, *model_type='M6'*, *cspace={'Yw': None, 'conditions': {'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}, 'mcat': 'cat02', 'type': 'jab_cam02ucs', 'xyzw': None, 'yellowbluepurplecorrect': None}*, *sampleset=None*, *pool=False*, *pcolorshift={'Cref': 40, 'href': array([3.1416e-01, 9.4248e-01, 1.5708e+00, 2.1991e+00, 2.8274e+00, 3.4558e+00, 4.0841e+00, 4.7124e+00, 5.3407e+00, 5.9690e+00]), 'sig': 0.3}*, *vfcolor='k'*, *verbosity=0*, *interp_settings=None*)

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*, *interp_settings=None*)

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**(*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 around (0,0).

Args:

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.

Returns:

x,y

ndarrays with circle coordinates (only returned if out is 'x,y')

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.

luxpy.color.cri.VFPX.**calculate_VF_PX_models**(*S*, *cri_type='iesrf'*, *sampleset=None*, *pool=False*, *pcolorshift={'Cref': 40, 'href': array([3.1416e-01, 9.4248e-01, 1.5708e+00, 2.1991e+00, 2.8274e+00, 3.4558e+00, 4.0841e+00, 4.7124e+00, 5.3407e+00, 5.9690e+00]), 'labels': '#', 'sig': 0.3}*, *vfcolor='k'*, *verbosity=0*, *interp_settings=None*)

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([[3.6000e+02, 3.6100e+02, 3.6200e+02, 3.6300e+02, 3.6400e+02, 3.6500e+02, 3.6600e+02, 3.6700e+02, 3.6800e+02, 3.6900e+02, 3.7000e+02, 3.7100e+02, 3.7200e+02, 3.7300e+02, 3.7400e+02, 3.7500e+02, 3.7600e+02, 3.7700e+02, 3.7800e+02, 3.7900e+02, 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, 5.5600e+02, 5.5700e+02, 5.5800e+02, 5.5900e+02, 5.6000e+02, 5.6100e+02, 5.6200e+02, 5.6300e+02, 5.6400e+02, 5.6500e+02, 5.6600e+02, 5.6700e+02, 5.6800e+02, 5.6900e+02, 5.7000e+02, 5.7100e+02, 5.7200e+02, 5.7300e+02, 5.7400e+02, 5.7500e+02, 5.7600e+02, 5.7700e+02, 5.7800e+02, 5.7900e+02, 5.8000e+02, 5.8100e+02, 5.8200e+02, 5.8300e+02, 5.8400e+02, 5.8500e+02, 5.8600e+02, 5.8700e+02, 5.8800e+02, 5.8900e+02, 5.9000e+02, 5.9100e+02, 5.9200e+02, 5.9300e+02, 5.9400e+02, 5.9500e+02, 5.9600e+02, 5.9700e+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)

4.4.11 XYZ,LAB classes

py

- CDATA.py

namespace
luxpy

`class luxpy.color.CDATA.XYZ(value=None, relative=True, cieobs='1931_2', dtype='xyz')`

`ctf(dtype='Yuv', **kwargs)`

Convert XYZ tristimulus values to color space coordinates.

Args:

dtype

_CSPACE or str, optional
Convert to this color space.

kwargs

additional input arguments required for
color space transformation.
See specific luxpy function for more info
(e.g. ?luxpy.xyz_to_lab)

Returns:

returns

luxpy.LAB with .value field that is a ndarray
with color space coordinates

`plot(ax=None, title=None, **kwargs)`

Plot tristimulus or cone fundamental values.

Args:

ax

None or axes handles, optional
None: create new figure axes, else use :ax: for plotting.

title

None or str, optional
Give plot a title.

kwargs

additional arguments for use with
matplotlib.pyplot.scatter

Returns:

gca

handle to current axes.

`to_Yxy()`

Convert XYZ tristimulus values CIE Yxy chromaticity values.

Returns:

Yxy

luxpy.LAB with .value field that is a ndarray

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

`to_Yuv`(***kwargs*)

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

Returns:

Yuv

luxpy.LAB with .value field that is a ndarray
with CIE 1976 Yu'v' chromaticity values.
(Y value refers to luminance or luminance factor)

`to_Yuv76`(***kwargs*)

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

Returns:

Yuv

luxpy.LAB with .value field that is a ndarray
with CIE 1976 Yu'v' chromaticity values.
(Y value refers to luminance or luminance factor)

`to_Yuv60`(***kwargs*)

Convert XYZ tristimulus values CIE 1960 Yuv chromaticity values.

Returns:

Yuv

luxpy.LAB with .value field that is a ndarray
with CIE 1960 Yuv chromaticity values.
(Y value refers to luminance or luminance factor)

`to_wuv`(*xyzw=array([1.0000e+02, 1.0000e+02, 1.0000e+02])*)

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

Args:

xyzw

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

Returns:

wuv

luxpy.LAB with .value field that is a ndarray
with W*U*V* values.

`to_lms`()

Convert XYZ tristimulus values or LMS cone fundamental responses to LMS cone fundamental responses.

Returns:

lms

luxpy.XYZ with .value field that is a ndarray
with LMS cone fundamental responses.

`to_xyz`()

Convert XYZ tristimulus values or LMS cone fundamental responses to XYZ tristimulus values.

Returns:

xyz

luxpy.XYZ with .value field that is a ndarray

with XYZ tristimulus values.

to_lab(*xyzw=None*, *cieobs='1931_2'*)

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

Args:

xyzw

None or ndarray with xyz 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

luxpy.LAB with .value field that is a ndarray
with CIE 1976 L*a*b* (CIELAB) color coordinates

to_luv(*xyzw=None*, *cieobs='1931_2'*)

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

Args:

xyzw

None or ndarray with xyz 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

luxpy.LAB with .value field that is a ndarray
with CIE 1976 L*u*v* (CIELUV) color coordinates

to_Vrb_mb(*cieobs='1931_2'*, *scaling=[1, 1]*, *M=None*)

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

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

Args:

cieobs

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

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

luxpy.LAB with .value field that is a ndarray
ndarray with V,r,b (Macleod-Boynton) color coordinates

`to_ipt`(*cieobs='1931_2'*, *xyzw=None*, *M=None*)

Convert XYZ tristimulus values to IPT color coordinates.

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

Args:

xyzw

None or ndarray with xyz 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 conversion matrix determined by :cieobs:

Returns:

ipt

luxpy.LAB with *.value* field that is a ndarray
with IPT color coordinates

Note:

xyz

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

`to_Ydlep`(*cieobs='1931_2'*, *xyzw=array([1.0000e+02, 1.0000e+02, 1.0000e+02])*)

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

Args:

xyzw

None or ndarray with xyz 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

`to_srgb`(*gamma=2.4*)

Calculates IEC:61966 sRGB values from xyz.

Args:

xyz

ndarray with relative tristimulus values.

gamma

2.4, optional
compression in sRGB

Returns:

rgb

ndarray with R,G,B values (uint8).

to_jabz(*ztype='jabz'*)

Convert XYZ tristimulus values to Jz,az,bz color coordinates.

Args:

xyz

ndarray with absolute tristimulus values (Y in cd/m^2!)

ztype

'jabz', optional
String with requested return:
Options: 'jabz', 'iabz'

Returns:

jabz

ndarray with Jz,az,bz color coordinates

Notes:

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

2a. Jz represents the 'lightness' relative to a D65 white with luminance = 10000 cd/m^2
(note that Jz that not exactly equal 1 for this high value, but rather for 102900 cd/m2)

2b. az, bz represent respectively a red-green and a yellow-blue opponent axis
(but note that a D65 shows a small offset from (0,0))

Reference:

1. Safdar, M., Cui, G., Kim,Y. J., and Luo,M. R. (2017). Perceptually uniform color space for image signals including high dynamic range and wide gamut. Opt. Express, vol. 25, no. 13, pp. 15131–15151, Jun. 2017.

to_jabM_ciecam02(*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'}*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *yellowbluepurplecorrect=None*, *mcat='cat02'*)

See ?luxpy.xyz_to_jabM_ciecam02

to_jabC_ciecam02(*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'}*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *yellowbluepurplecorrect=None*, *mcat='cat02'*)

See ?luxpy.xyz_to_jabC_ciecam02

to_jab_cam02ucs(*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'}*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *yellowbluepurplecorrect=None*, *mcat='cat02'*)

See ?luxpy.xyz_to_jab_cam02ucs

to_jab_cam02lcd(*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'}*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *yellowbluepurplecorrect=None*, *mcat='cat02'*)

See ?luxpy.xyz_to_jab_cam02lcd

to_jab_cam02scd(*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'}*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *yellowbluepurplecorrect=None*, *mcat='cat02'*)

See ?luxpy.xyz_to_jab_cam02scd

to_jabM_ciecam16(*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'}*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*)

See ?luxpy.xyz_to_jabM_ciecam16

to_jabC_ciecam16(*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'}*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*)

See ?luxpy.xyz_to_jabC_ciecam16

to_jab_cam16ucs(*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'}*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*)

See ?luxpy.xyz_to_jab_cam02ucs

to_jab_cam16lcd(*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'}*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*)

See ?luxpy.xyz_to_jab_cam16lcd

to_jab_cam16scd(*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'}*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *mcat='cat16'*)

See ?luxpy.xyz_to_jab_cam16scd

to_jabM_zcam(*xyzw=None*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *mcat='cat16'*)

See ?luxpy.xyz_to_jabM_zcam

to_jabC_zcam(*xyzw=array([[1.0000e+02, 1.0000e+02, 1.0000e+02]])*, *conditions={'D': 1.0, 'Dtype': None, 'La': 100.0, 'Yb': 20.0, 'surround': 'avg'}*, *mcat='cat16'*)

See ?luxpy.xyz_to_jabC_zcam

to_qabW_cam15u(*fov=10.0*, *parameters=None*)

See ?luxpy.xyz_to_qabW_cam15u

to_lab_cam_sww_2016(*xyzw=None*, *Yb=20.0*, *Lw=400.0*, *relative=True*, *parameters=None*, *inputtype='xyz'*, *cieobs='2006_10'*)

See ?luxpy.xyz_to_lab_cam_sww_2016

to_qabS_cam18sl(*xyz*, *xyzb=None*, *Lb=[100]*, *fov=10.0*, *parameters=None*)

See ?luxpy.xyz_to_qabS_cam18sl

to_qabM_cam18sl(*xyz*, *xyzb=None*, *Lb=[100]*, *fov=10.0*, *parameters=None*)

See ?luxpy.xyz_to_qabM_cam18sl

class luxpy.color.CDATA.**LAB**(*value=None*, *relative=True*, *cieobs='1931_2'*, *dtype='lab'*, *xyzw=None*, *M=None*, *scaling=None*, *Lw=None*, *Yw=None*, *Yb=None*, *conditions=None*, *naka_rushton_parameters=None*, *unique_hue_data=None*, *yellowbluepurplecorrect=None*, *mcat=None*, *ucstype=None*, *fov=None*, *parameters=None*)

ctf(***kwargs*)

Convert color space coordinates to XYZ tristimulus values.

Args:

dtype

'xyz'
Convert to this color space.

kwargs

additional input arguments required for
color space transformation.
See specific luxpy function for more info
(e.g. ?luxpy.xyz_to_lab)

Returns:

returns

luxpy.XYZ with .value field that is a ndarray
with tristimulus values

plot(*plt_type='3d'*, *ax=None*, *title=None*, ***kwargs*)

Plot color coordinates.

Args:

plt_type

'3d' or 3 or '2d or 2, optional
-'3d' or 3: plot all 3 dimensions (lightness and chromaticity)
-'2d' or 2: plot only chromaticity dimensions.

ax

None or axes handles, optional
None: create new figure axes, else use :ax: for plotting.

title

None or str, optional
Give plot a title.

kwargs

additional arguments for use with
matplotlib.pyplot.scatter

Returns:

gca

handle to current axes.

to_xyz(***kwargs*)

Convert color space coordinates to XYZ tristimulus values.

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 (S026:2018 & TN003:2015) photobiological quantities

(Eelc, Eemc, Eesc, Eer, Eez, and Elc, Emc, Esc, Er, Ez)

Photoreceptor	Photopigment (label,)	Spectral efficiency s()	Quantity (-opic irradiance)	Q-symbol (Ee,)	Unit symbol
l-cone	photopsin (lc)	erythrolabe	erythropic	Ee,lc	W.m2
m-cone	photopsin (mc)	chlorolabe	chloropic	Ee,mc	W.m2
s-cone	photopsin (sc)	cyanolabe	cyanopic	Ee,sc	W.m2
rod	rhodopsin (r)	rhodopic	rhodopic	Ee,r	W.m2
ipRGC	melanopsin (z)	melanopic	melanopic	Ee,z	W.m2

CIE recommends that the -opic irradiance is determined by convolving the spectral
irradiance, Ee,() (Wm2), for each wavelength, with the action spectrum, s(),
where s() is normalized to one at its peak:

Ee, = Ee,() s() d

where the corresponding units are Wm2 in each case.

The equivalent luminance is calculated as:

E, = Km Ee,() s() d V() d / s() d

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() 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 default CIE-S026:2018 alpha-actinic action spectra. (stored in file:
'./data/cie_S026_2018_SI_action_spectra_CIEToolBox_v1.049.dat')

_ACTIONSPECTRA_CIES026

ndarray with alpha-actinic action spectra. (stored in file:
'./data/cie_S026_2018_SI_action_spectra_CIEToolBox_v1.049.dat')

_ACTIONSPECTRA_CIETN003

ndarray with CIE-TN003:2015 alpha-actinic action spectra. (stored in file:
'./data/cie_tn003_2015_SI_action_spectra.dat')

spd_to_aopicE()

Calculate alpha-opic irradiance (Ee,) and equivalent
luminance (E) values for the l-cone, m-cone, s-cone,
rod and iprgc () photoreceptor cells following
CIE S026:2018 (= default actionspectra) or CIE TN003:2015.

spd_to_aopicEDI()

Calculate alpha-opic equivalent daylight (D65) illuminance (lx)
for the l-cone, m-cone, s-cone, rod and iprgc () photoreceptor cells.

spd_to_aopicDER()

Calculate -opic Daylight (D65) Efficacy Ratio
for the l-cone, m-cone, s-cone, rod and iprgc () photoreceptor cells.

spd_to_aopicELR()

Calculate -opic Efficacy of Luminous Radiation
for the l-cone, m-cone, s-cone, rod and iprgc () photoreceptor cells.

References:

1. CIE-S026:E2018 (2018). CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light (Vienna, Austria). (https://files.cie.co.at/CIE%20S%20026%20alpha-opic%20Toolbox%20User%20Guide.pdf)

2. 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.

Module for Blue light hazard calculations

_BLH
Blue Light Hazard function

spd_to_blh_eff()
Calculate Blue Light Hazard efficacy (K) or efficiency (eta) of radiation.

References:

1. IEC 62471:2006, 2006, Photobiological safety of lamps and lamp systems.

2. IEC TR 62778, 2014, Application of IEC 62471 for the assessment of blue light hazard to light sources and luminaires.

`luxpy.toolboxes.photbiochem.`**`spd_to_aopicE`**(*sid*, *Ee=None*, *E=None*, *Q=None*, *cieobs='1931_2'*, *K=None*, *sid_units='W/m2'*, *out='Eeas'*, *actionspectra='CIE-S026'*, *interp_settings=None*)

Calculate alpha-opic irradiance (Ee,) values (W/m^2) for the l-cone, m-cone, s-cone, rod and iprgc () photoreceptor cells following CIE S026:2018.

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:

Note that E is calculate using a Km factor corrected to standard air.

Q

None, optional

If not None: Normalize :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' or str, optional

Determines values to return.

(to get also get equivalent illuminance E set :out: to 'Eeas,Eas')

actionspectra

'CIE-S026', optional

Actionspectra to use in calculation

options:

- 'CIE-S026': will use action spectra as defined in CIE S026
- 'CIE-TN003': will use action spectra as defined in CIE TN003

Returns:

returns

Eeas a numpy.ndarray with the -opic irradiance
of all spectra in :sid: in SI-units (W/m^2).

(other choice can be set using :out:)

References:

1. CIE-S026:E2018 (2018). CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light (Vienna, Austria). (https://files.cie.co.at/CIE%20S%20026%20alpha-opic%20Toolbox%20User%20Guide.pdf)

2. 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)

`luxpy.toolboxes.photbiochem.`**`spd_to_aopicEDI`**(*sid*, *Ee=None*, *E=None*, *Q=None*, *cieobs='1931_2'*, *K=None*, *sid_units='W/m2'*, *actionspectra='CIE-S026'*, *ref='D65'*, *out='a_edi'*, *interp_settings=None*)

Calculate alpha-opic equivalent daylight (D65) illuminance (lux) for the l-cone, m-cone, s-cone, rod and iprgc () photoreceptor cells.

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:
Note that E is calculate using a Km factor corrected to standard air.

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:

actionspectra

'CIE-S026', optional
Actionspectra to use in calculation
options:
- 'CIE-S026': will use action spectra as defined in CIE S026
- 'CIE-TN003': will use action spectra as defined in CIE TN003

ref

'D65', optional
Reference (daylight) spectrum to use. ('D65' or 'E' or ndarray)

out

'Eeas, Eas' or str, optional
Determines values to return.

Returns:

returns

ndarray with the -opic Equivalent Daylight Illuminance (lux) with the
for the l-cone, m-cone, s-cone, rod and iprgc photoreceptors
of all spectra in :sid: in SI-units.

`luxpy.toolboxes.photbiochem.`**`spd_to_aopicDER`**(*sid*, *cieobs='1931_2'*, *K=None*, *sid_units='W/m2'*, *actionspectra='CIE-S026'*, *ref='D65'*, *interp_settings=None*)

Calculate -opic Daylight (D65) Efficacy Ratio (= -opic Daylight (D65) Efficiency) for the l-cone, m-cone, s-cone, rod and iprgc () photoreceptor cells.

Args:

sid

numpy.ndarray with retinal spectral irradiance in :sid_units:
(if 'uW/cm2', sid will be converted to SI units 'W/m2')

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:

actionspectra

'CIE-S026', optional

Actionspectra to use in calculation
options:
- 'CIE-S026': will use action spectra as defined in CIE S026
- 'CIE-TN003': will use action spectra as defined in CIE TN003

ref

'D65', optional
Reference (daylight) spectrum to use. ('D65' or 'E' or ndarray)

Returns:

returns

ndarray with the -opic Daylight Efficacy Ratio with the
for the l-cone, m-cone, s-cone, rod and iprgc photoreceptors
of all spectra in :sid: in SI-units.

luxpy.toolboxes.photbiochem.**spd_to_aopicELR**(*sid*, *cieobs='1931_2'*, *K=None*, *sid_units='W/m2'*, *actionspectra='CIE-S026'*, *interp_settings=None*)

Calculate -opic Efficacy of Luminous Radiation (W/lm) for the l-cone, m-cone, s-cone, rod and iprgc () photoreceptor cells.

Args:

sid

numpy.ndarray with retinal spectral irradiance in :sid_units:
(if 'uW/cm2', sid will be converted to SI units 'W/m2')

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:

actionspectra

'CIE-S026', optional
Actionspectra to use in calculation
options:
- 'CIE-S026': will use action spectra as defined in CIE S026
- 'CIE-TN003': will use action spectra as defined in CIE TN003

Returns:

returns

ndarray with the -opic Efficacy of Luminous Radiation (W/lm) with the
for the l-cone, m-cone, s-cone, rod and iprgc photoreceptors
of all spectra in :sid: in SI-units.

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*, *version='CLa2.0'*, *E=None*, *sum_sources=False*, *interpolate_sources=True*, *t_CS=1.0*, *f_CS=1.0*)

Calculate Circadian Stimulus (CS) and Circadian Light (CLa, CLa2.0).

Args:

El

ndarray, optional
Defaults to D65
light source spectral irradiance distribution

version

'CLa2.0', optional
CLa version to calculate
Options:
- 'CLa1.0': Rea et al. 2012
- 'CLa2.0': Rea et al. 2021, 2022

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 (1.0,2.0) and CLa (1.0, 2.0) 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 CIE15-2018, "Colorimetry").

t_CS

1.0, optional
The duration factor (in hours): a continuous value from 0.5 to 3.0

f_CS

1.0, optional
The spatial distribution factor: a discrete value (2, 1, or 0.5)
depending upon the spatial distribution of the light source.
Default = 1 (for t = 1 h, CS is equal to the 2012 version).
Options:
- 2.0: full visual field, as with a Ganzfeld.
- 1.0: central visual field, as with a discrete light box on a desk.
- 0.5: superior visual field, as from ceiling mounted down-light fixtures.

Returns:

CS

ndarray with Circadian stimulus values

CLa

ndarray with Circadian Light values

Notes on CLa1.0 (2012 version):

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.

Notes on CLa2.0 (2021 version):

1. In the original model, 1000 lux of CIE Illuminant A resulted in a CLA = 1000. In the revised model, a photopic illuminance of 1000 lux from CIE Illuminant A (approximately that of an incandescent lamp operated at 2856 K) results in a CLA 2.0 = 813. The value of 813 CLA 2.0 should be used by those wishing to calibrate instrumentation designed to report CLA 2.0 and CS. CLA 2.0 values can still be used to approximate the photopic illuminance, in lux, from a nonspecific "white" light source. For comparison, CLA 2.0 values should be multiplied by 1.23 to estimate the equivalent photopic illuminance from CIE Illuminant A, or by 0.66 to estimate the equivalent photopic illuminance from CIE Illuminant D65 (an approximation of daylight with a CCT of 6500 K).

2. Nov. 6, 2021: To get a value of CLa2.0 = 813, Eq. 3 from the paper must be adjusted to also divide by the transmision of the macula ('mp' in paper) the S-cone and Vlambda functions prior to calculating the integrals in the denominators of the first factor after the a_rod_1 and a_rod_2 scalars! Failure to do so results in a CLa2.0 of 800, instead of the reported 813 by the online calculator. Verification of the code on github shows indeed that these denominators are calculated by using the macular transmission divided S-cone and Vlambda functions. Is this an error in the code or in the paper?

3. Feb. 22, 2022: A corrigendum has been released for Eq. 3 in the original paper, where the normalization is indeed done.

4. Feb. 22, 2022: While the rodsat value in the corrigendum is defined as 6.50 W/m^2, this calculator uses the value as used in the online calculator: 6.5215 W/m^2. (see code base on github:)

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)). Light. Res. Technol. 44, 516.

5. Rea, M. S., Nagare, R., & Figueiro, M. G. (2021). Modeling Circadian Phototransduction: Quantitative Predictions of Psychophysical Data. Frontiers in Neuroscience, 15, 44.

6. Rea, M. S., Nagare, R., & Figueiro, M. G. (2022). Corrigendum: Modeling Circadian Phototransduction: Quantitative Predictions of Psychophysical Data. Frontiers in Neuroscience, 16.

7. LRC Online Circadian stimulus calculator (CLa2.0, 2021)

8. Github code: LRC Online Circadian stimulus calculator (CLa2.0, accessed Nov. 5, 2021)

`luxpy.toolboxes.photbiochem.`**`CLa_to_CS`**(*CLa*, *t=1*, *f=1*, *forward=True*)

Convert Circadian Light to Circadian Stimulus (and back).

Args:

CLa

ndarray with Circadian Light values
or Circadian Stimulus values (if forward == False)

t

1.0, optional
The duration factor (in hours): a continuous value from 0.5 to 3.0

f

1.0, optional
The spatial distribution factor: a discrete value (2, 1, or 0.5)
depending upon the spatial distribution of the light source.
Default = 1 (for t = 1 h, CS is equal to the 2012 version).
Options:
- 2.0: full visual field, as with a Ganzfeld.
- 1.0: central visual field, as with a discrete light box on a desk.
- 0.5: superior visual field, as from ceiling mounted down-light fixtures.

forward

True, optional
If True: convert CLa to CS values.

If False: convert CS values to CLa values.

Returns:

CS

ndarray with CS values or with CLa values (if forward == False)

References:

1. 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.

2. 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)). Light. Res. Technol. 44, 516.

3. Rea, M. S., Nagare, R., & Figueiro, M.G. (2021). Modeling Circadian Phototransduction: Quantitative Predictions of Psychophysical Data. Frontiers in Neuroscience, 15, 44.

4. LRC Online Circadian Stimulus calculator (CLa2.0, 2021)

`luxpy.toolboxes.photbiochem.`**`spd_to_blh_eff`**(*spd*, *efficacy=True*, *cieobs='1931_2'*, *src='dict'*, *K=None*)

Calculate Blue Light Hazard efficacy (K) or efficiency (eta) of radiation.

Args:

S

ndarray with spectral data

cieobs

str, optional

Sets the type of Vlambda function to obtain.

src

'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.

K

None, optional

e.g. K = 683 lm/W for '1931_2' (relative == False)

or K = 100/sum(spd*dl) (relative == True)

Returns:

eff

ndarray with blue light hazard efficacy or efficiency of radiation values.

References:

1. IEC 62471:2006, 2006, Photobiological safety of lamps and lamp systems.
2. IEC TR 62778, 2014, Application of IEC 62471 for the assessment of blue light hazard to light sources and luminaires.

4.5.2 indvcmf/

py

- __init__.py
- individual_observer_cmf_model.py

namespace
luxpy.indvcmf

Module for Individual Observer lms-CMFs (Asano, 2016 and CIE TC1-97)

_DATA_PATH
path to data files

_DATA
Dict with required data

_DSRC_STD_DEF
default data source for stdev of physiological data ('matlab', 'germany')

_DSRC_LMS_ODENS_DEF
default data source for lms absorbances and optical densities ('asano', 'cietc197')

_LMS_TO_XYZ_METHOD
default method to calculate lms to xyz conversion matrix ('asano', 'cietc197')

_WL_CRIT
critical wavelength above which interpolation of S-cone data fails.

_WL
default wavelengths of spectral data in INDVCMF_DATA.

load_database()
Load a database with parameters and data required by the Asano model.

init()
Initialize: load database required for Asano Individual Observer Model into the default _DATA dict and set some options for rounding, sign. figs and chopping small value to zero; for source data to use for spectral data for LMS absorp. and optical densities, ...

query_state()
print current settings for global variables.

compute_cmfs()
Generate Individual Observer CMFs (cone fundamentals) based on CIE2006 cone fundamentals and published literature on observer variability in color matching and in physiological parameters (Use of Asano optical data and model; or of CIE TC1-91 data and 'variability'-extended model possible).

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. (Use of Asano optical data and model; or of CIE TC1-91 data and 'variability'-extended model possible)

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 determined as a weighted combination of the 2° and 10° matrices.

lmsb_to_xyzb()
Convert from LMS cone fundamentals to XYZ CMFs using conversion matrix determined as a weighted combination of the 2° and 10° matrices.

add_to_cmf_dict()
Add set of cmfs to _CMF dict.

plot_cmfs()
Plot cmf set.

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 TC1-36 (2006). Fundamental Chromaticity Diagram with Physiological Axes - Part I (Vienna: CIE).

4. Asano's Individual Colorimetric Observer Model

5. CIE TC1-97 cmf functions python code developed by Ivar Farup and Jan Hendrik Wold.

Notes

1. Port of Matlab code from: https://www.rit.edu/cos/colorscience/re_AsanoObserverFunctions.php (Accessed April 20, 2018) 2. Adjusted/extended following CIE TC1-97 Python code (and data): github.com/ifarup/ciefunctions (Copyright (C) 2012-2017 Ivar Farup and Jan Henrik Wold) (Accessed Dec 18, 2019)

`luxpy.toolboxes.indvcmf.load_database(`*wl=None*, *dsrc_std=None*, *dsrc_lms_odens=None*, *path=None*`)`

Load database required for Asano Individual Observer Model.

Args:

wl

None, optional

Wavelength range to interpolate data to.

None defaults to the wavelength range associated with data in :dsrc_lms_odens:

path

None, optional

Path where data files are stored (If None: look in ./data/ folder under toolbox path)

dsrc_std

None, optional

Data source ('matlab' code, or 'germany') for stdev data on physiological factors.

None defaults to string in _DSRC_STD_DEF

dsrc_lms_odens

None, optional

Data source ('asano', 'cietc197') for LMS absorbance and optical density data.

None defaults to string in _DSRC_LMS_ODENS_DEF

Returns:

data

dict with data for:

- 'LMSa': LMS absorbances

- 'rmd': relative macular pigment density

- 'docul': ocular media optical density

- 'USCensus2010population': data (age and numbers) on a 2010 US Census

- 'CatObsPfctr': dict with iteratively derived Categorical Observer physiological stdevs.

- 'M2d': Asano 2° lms to xyz conversion matrix

- 'M10d': Asano 10° lms to xyz conversion matrix

- standard deviations on physiological parameters: 'od_lens', 'od_macula', 'od_L', 'od_M', 'od_S', 'shft_L', 'shft_M', 'shft_S'

`luxpy.toolboxes.indvcmf.init`(*wl=None*, *dsrc_std=None*, *dsrc_lms_odens=None*, *lms_to_xyz_method=None*, *use_sign_figs=True*, *use_my_round=True*, *use_chop=True*, *path=None*, *out=None*, *verbosity=1*)

Initialize: load database required for Asano Individual Observer Model into the default _DATA dict and set some options for rounding, sign. figs and chopping small value to zero; for source data to use for spectral data for LMS absorp. and optical desnities, …

Args:

wl

None, optional

Wavelength range to interpolate data to.

None defaults to the wavelength range associated with data in :dsrc_lms_odens:

dsrc_std

None, optional

Data source ('matlab' code, or 'germany') for stdev data on physiological factors.

None defaults to string in _DSRC_STD_DEF

dsrc_lms_odens

None, optional

Data source ('asano', 'cietc197') for LMS absorbance and optical density data.

None defaults to string in _DSRC_LMS_ODENS_DEF

lms_to_xyz_method

None, optional

Method to use to determine lms-to-xyz conversion matrix (options: 'asano', 'cietc197')

use_my_round

True, optional

If True: use my_rounding() conform CIE TC1-91 Python code 'ciefunctions'. (slows down code)

by setting _USE_MY_ROUND.

use_sign_figs

True, optional

If True: use sign_figs() conform CIE TC1-91 Python code 'ciefunctions'. (slows down code)

by setting _USE_SIGN_FIGS.

use_chop

True, optional

If True: use chop() conform CIE TC1-91 Python code 'ciefunctions'. (slows down code)

by setting _USE_CHOP.

path

None, optional

Path where data files are stored (If None: look in ./data/ folder under toolbox path)

out

None, optional

If None: only set global variables, do not output _DATA.copy()

verbosity

1, optional

Print new state of global settings.

Returns:

data

if out is not None: return a dict with dict with data for:

- 'LMSa': LMS absorbances

- 'rmd': relative macular pigment density

- 'docul': ocular media optical density

- 'USCensus2010population': data (age and numbers) on a 2010 US Census

- 'CatObsPfctr': dict with iteratively derived Categorical Observer physiological stdevs.

- 'M2d': Asano 2° lms to xyz conversion matrix

- 'M10d': Asano 10° lms to xyz conversion matrix

- standard deviations on physiological parameters: 'od_lens', 'od_macula', 'od_L', 'od_M', 'od_S', 'shft_L', 'shft_M', 'shft_S'

luxpy.toolboxes.indvcmf.**query_state**()

Print current settings for 'global variables'.

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*, *norm_type=None*, *out='lms'*, *base=False*, *strategy_2=True*, *odata0=None*, *lms_to_xyz_method=None*, *allow_negative_values=False*, *normalize_lms_to_xyz_matrix=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

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.

norm_type

None, optional
- 'max': normalize LMSq functions to max = 1
- 'area': normalize to area
- 'power': normalize to power

out

'lms' or 'xyz', optional
Determines output.

base

False, boolean, optional
The returned energy-based LMS cone fundamentals given to the
precision of 9 sign. figs. if 'True', and to the precision of

6 sign. figs. if 'False'.

strategy_2

True, bool, optional

Use strategy 2 in github.com/ifarup/ciefunctions issue #121 for computing the weighting factor. If false, strategy 3 is applied.

odata0

None, optional

Dict with uncorrected ocular media and macula density functions and LMS absorptance functions

None defaults to the ones stored in _DATA

lms_to_xyz_method

None, optional

Method to use to determine lms-to-xyz conversion matrix (options: 'asano', 'cietc197')

allow_negative_values

False, optional

Cone fundamentals or color matching functions should not have negative values.

If False: X[X<0] = 0.

normalize_lms_to_xyz_matrix

False, optional

Normalize that EEW is always at [100,100,100] in XYZ and LMS system.

Returns:

returns

- 'LMS' [or 'XYZ']: ndarray with individual observer equal area-normalized cone fundamentals. Wavelength have been added.

[- 'M': lms to xyz conversion matrix
- 'trans_lens': ndarray with lens transmission (no interpolation)
- 'trans_macula': ndarray with macula transmission (no interpolation)
- 'sens_photopig' : ndarray with photopigment sens. (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 TC1-36, (2006), Fundamental Chromaticity Diagram with Physiological Axes - Part I (Vienna: CIE).

4. Asano's Individual Colorimetric Observer Model

5. CIE TC1-97 Python code for cone fundamentals and XYZ cmf calculations (by Ivar Farup and Jan Henrik Wold, (c) 2012-2017)

`luxpy.toolboxes.indvcmf.`**`getMonteCarloParam`**(*n_obs=1*, *stdDevAllParam={'dsrc': 'matlab', '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

_DATA['stdev'], 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]*, *wl=None*, *norm_type=None*, *out='lms'*, *base=False*, *strategy_2=True*, *odata0=None*, *lms_to_xyz_method=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°.

wl

None, optional
Interpolation/extraplation of :LMS: output to specified wavelengths.
None: output original _WL

norm_type

None, optional
- 'max': normalize LMSq functions to max = 1
- 'area': normalize to area
- 'power': normalize to power

out

'lms' or 'xyz', optional
Determines output.

base

False, boolean, optional

The returned energy-based LMS cone fundamentals given to the precision of 9 sign. figs. if 'True', and to the precision of 6 sign. figs. if 'False'.

strategy_2

True, bool, optional
Use strategy 2 in github.com/ifarup/ciefunctions issue #121 for computing the weighting factor. If false, strategy 3 is applied.

odata0

None, optional
Dict with uncorrected ocular media and macula density functions and LMS absorptance functions
None defaults to the ones stored in _DATA

lms_to_xyz_method

None, optional
Method to use to determine lms-to-xyz conversion matrix (options: 'asano', 'cietc197')

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 M.D., 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 TC1-36, (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*, *wl=None*, *norm_type=None*, *out='lms'*, *base=False*, *strategy_2=True*, *odata0=None*, *lms_to_xyz_method=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

norm_type

None, optional
- 'max': normalize LMSq functions to max = 1
- 'area': normalize to area
- 'power': normalize to power

out

'lms' or 'xyz', optional
Determines output.

base

False, boolean, optional
The returned energy-based LMS cone fundamentals given to the
precision of 9 sign. figs. if 'True', and to the precision of
6 sign. figs. if 'False'.

strategy_2

True, bool, optional
Use strategy 2 in github.com/ifarup/ciefunctions issue #121 for
computing the weighting factor. If false, strategy 3 is applied.

odata0

None, optional
Dict with uncorrected ocular media and macula density functions and LMS absorptance functions
None defaults to the ones stored in _DATA

lms_to_xyz_method

None, optional
Method to use to determine lms-to-xyz conversion matrix (options: 'asano', 'cietc197')

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 imag-

ing 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

luxpy.toolboxes.indvcmf.**compute_cmfs**(*fieldsize=10*, *age=32*, *wl=None*, *var_od_lens=0*, *var_od_macula=0*, *var_shft_LMS=[0, 0, 0]*, *var_od_LMS=[0, 0, 0]*, *norm_type=None*, *out='lms'*, *base=False*, *strategy_2=True*, *odata0=None*, *lms_to_xyz_method=None*, *allow_negative_values=False*, *normalize_lms_to_xyz_matrix=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

var_od_lens

0, optional

Variation of optical density of lens.

var_od_macula

0, optional

Variation of optical density of macula.

var_shft_LMS

[0, 0, 0] optional

Variation (shift) of LMS peak absorptance.

var_od_LMS

[0, 0, 0] optional

Variation of LMS optical densities.

norm_type

None, optional

- 'max': normalize LMSq functions to max = 1
- 'area': normalize to area
- 'power': normalize to power

out

'lms' or 'xyz', optional

Determines output.

base

False, boolean, optional
The returned energy-based LMS cone fundamentals given to the precision of 9 sign. figs. if 'True', and to the precision of 6 sign. figs. if 'False'.

strategy_2

True, bool, optional
Use strategy 2 in github.com/ifarup/ciefunctions issue #121 for computing the weighting factor. If false, strategy 3 is applied.

odata0

None, optional
Dict with uncorrected ocular media and macula density functions and LMS absorptance functions
None defaults to the ones stored in _DATA

lms_to_xyz_method

None, optional
Method to use to determine lms-to-xyz conversion matrix (options: 'asano', 'cietc197')

allow_negative_values

False, optional
Cone fundamentals or color matching functions should not have negative values.
If False: X[X<0] = 0.

normalize_lms_to_xyz_matrix

False, optional
Normalize that EEW is always at [100,100,100] in XYZ and LMS system.

Returns:

returns

- 'LMS' [or 'XYZ']: ndarray with individual observer equal area-normalized cone fundamentals. Wavelength have been added.

[- 'M': lms to xyz conversion matrix
- 'trans_lens': ndarray with lens transmission (no interpolation)
- 'trans_macula': ndarray with macula transmission (no interpolation)
- 'sens_photopig' : ndarray with photopigment sens. (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, TC1-36, (2006). Fundamental Chromaticity Diagram with Physiological Axes - Part I (Vienna: CIE).

4. Asano's Individual Colorimetric Observer Model

5. CIE TC1-97 Python code for cone fundamentals and XYZ cmf calculations (by Ivar Farup and Jan Henrik Wold, (c) 2012-2017)

luxpy.toolboxes.indvcmf.**add_to_cmf_dict**(*bar=None*, *cieobs='indv'*, *K=683*, *M=array([[1.0000e+00, 0.0000e+00, 0.0000e+00], [0.0000e+00, 1.0000e+00, 0.0000e+00], [0.0000e+00, 0.0000e+00, 1.0000e+00]])*)

Add set of cmfs to _CMF dict.

Args:

bar

None, optional

Set of CMFs. None: initializes to empty ndarray.

cieobs

'indv' or str, optional

Name of CMF set.

K

683 (lm/W), optional

Conversion factor from radiometric to photometric quantity.

M

np.eye, optional

Matrix for lms to xyz conversion.

luxpy.toolboxes.indvcmf.**plot_cmfs**(*cmf*, *axh=None*, ***kwargs*)

Plot cmf set.

luxpy.toolboxes.indvcmf.**my_round**(*x*, *n=0*)

Round array x to n decimal points using round half away from zero. This function is needed because the rounding specified in the CIE recommendation is different from the standard rounding scheme in python (which is following the IEEE recommendation).

Args:

x

ndarray

Array to be rounded

n

int

Number of decimal points

Returns:

y

ndarray

Rounded array

luxpy.toolboxes.indvcmf.**chop**(*arr*, *epsilon=1e-14*)

Chop values smaller than epsilon in absolute value to zero. Similar to Mathematica function.

Args:

arr

float or ndarray

Array or number to be chopped.

epsilon

float

Minimum number.

Returns:

chopped

float or ndarray

Chopped numbers.

luxpy.toolboxes.indvcmf.**sign_figs**(*x*, *n=0*)

Round x to n significant figures (not decimal points). This function is needed because the rounding specified in the CIE recommendation is different from the standard rounding scheme in python (which is following the IEEE recommendation). Uses my_round (above).

Args:

x

int, float or ndarray

Number or array to be rounded.

Returns:

t

float or ndarray

Rounded number or array.

4.5.3 spdbuild/

py

- __init__.py
- spdbuilder.py
- spdbuilder2020.py
- spdoptimzer2020.py

namespace

luxpy.spdbuild/

Module for building and optimizing SPDs

spdbuilder.py

Functions

gaussian_spd()

Generate Gaussian spectrum.

butterworth_spd()

Generate Butterworth based spectrum.

lorentzian2_spd()

Generate 2nd order Lorentzian based spectrum.

roundedtriangle_spd()

Generate a rounded triangle 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.

colormixer_pinv()
Additive color mixer of N primaries using using Moore-Penrose pseudo-inverse matrix.

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.

Module for building and optimizing SPDs (2)

This module implements a class based spectral optimizer. It differs from the spdoptimizer function in spdbuild.py, in that it can use several different minimization algorithms, as well as a user defined method. It is also written such that the user can easily write his own primary constructor function. It supports the '3mixer' algorithm (but no '2mixer') and a 'no-mixer' algorithm (chromaticity as part of the list of objectives) for calculating the mixing contributions of the primaries.

Functions

gaussian_prim_constructor()
constructs a gaussian based primary set.

_setup_wlr()
Initialize the wavelength range for use with PrimConstructor.

_extract_prim_optimization_parameters()
Extract the primary parameters from the optimization vector x and the pdefs dict for use with PrimConstructor.

_stack_wlr_spd()
Stack the wavelength range 'on top' of the spd values for use with PrimConstructor.

PrimConstructor
class for primary (spectral) construction

Minimizer
class for minimization of fitness of each of the objective functions

ObjFcns
class to specify one or more objective functions for minimization

SpectralOptimizer
class for spectral optimization (initialization and run)

spd_optimizer2()
Generate a spectrum with specified white point and optimized for certain objective functions from a set of component spectra or component spectrum model parameters (functional wrapper around SpectralOptimizer class).

Notes

1. See examples below (in spdoptimizer2020.'__main__') for use.

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='xyz'*, *cspace_tf={}*, *CSF=None*, *interp_type='nd'*, *k_neighbours=4*, *show=True*, *verbosity=0*, *show_ref_img=True*, *stack_test_ref=12*, *write_to_file=None*, *csf_based_rgb_rounding=6*)

Render image under specified light source spd.

Args:

img

None or str or ndarray with float (max = 1) rgb image.
None load a default image.

spd

ndarray, optional
Light source spectrum for rendering
If None: use CIE illuminant F4

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

'xyz', optional
Color space for color coordinate to rfl mapping.
Tip: Use linear space (e.g. 'xyz', 'Yuv',…) for (interp_type == 'nd'),
and perceptually uniform space (e.g. 'ipt') for (interp_type == 'nearest')

cspace_tf

{}, optional
Dict with parameters for xyz_to_cspace and cspace_to_xyz transform.

CSF

None, optional
RGB camera response functions.
If None: input :xyz: contains raw rgb values. Override :cspace:
argument and perform estimation directly in raw rgb space!!!

interp_type

'nd', optional
Options:
- 'nd': perform n-dimensional linear interpolation using Delaunay triangulation.
- 'nearest': perform nearest neighbour interpolation.

k_neighbours

4 or int, optional
Number of nearest neighbours for reflectance spectrum interpolation.
Neighbours are found using scipy.spatial.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

csf_based_rgb_rounding

_ROUNDING, optional
Int representing the number of decimals to round the RGB values (obtained from not-None CSF input) to before applying the search algorithm.
Smaller values increase the search speed, but could cause fatal error that causes python kernel to die. If this happens increase the rounding int value.

Returns:

returns

img_hyp, img_ren,
ndarrays with float hyperspectral image and rendered images

luxpy.toolboxes.hypspcim.**xyz_to_rfl**(*xyz*, *CSF=None*, *rfl=None*, *out='rfl_est'*, *refspd=None*, *D=None*, *cieobs='1931_2'*, *cspace='xyz'*, *cspace_tf={}*, *interp_type='nd'*, *k_neighbours_nd=1*, *k_neighbours=4*, *verbosity=0*, *csf_based_rgb_rounding=6*)

Approximate spectral reflectance of xyz values based on nd-dimensional linear interpolation or k nearest neighbour interpolation of samples from a standard reflectance set.

Args:

xyz

ndarray with xyz values of target points.

CSF

None, optional
RGB camera response functions.
If None: input :xyz: contains raw rgb (float) values. Override :cspace:
argument and perform estimation directly in raw rgb space!!!

rfl

ndarray, optional
Reflectance set for color coordinate to rfl mapping.

out

'rfl_est' or str, optional

refspd

None, optional
Refer ence spectrum for color coordinate to rfl mapping.
None defaults to D65.

cieobs

_CIEOBS, optional
CMF set used for calculation of xyz from spectral data.

cspace

'xyz', optional
Color space for color coordinate to rfl mapping.
Tip: Use linear space (e.g. 'xyz', 'Yuv',...) for (interp_type == 'nd'),
and perceptually uniform space (e.g. 'ipt') for (interp_type == 'nearest')

cspace_tf

{}, optional
Dict with parameters for xyz_to_cspace and cspace_to_xyz transform.

interp_type

'nd', optional
Options:
- 'nd': perform n-dimensional linear interpolation using Delaunay triangulation.
- 'nearest': perform nearest neighbour interpolation.

k_neighbours

4 or int, optional
Number of nearest neighbours for reflectance spectrum interpolation.
Neighbours are found using scipy.spatial.cKDTree

k_neighbours_nd

1, optional

Number of nearest neighbours for reflectance spectrum interpolation when interp_type 'nd' fails.$

If None: use the value set in :k_neighbours:

verbosity

0, optional

If > 0: make a plot of the color coordinates of original and

rendered image pixels.

csf_based_rgb_rounding

_ROUNDING, optional

Int representing the number of decimals to round the RGB values (obtained from not-None CSF input) to before applying the search algorithm.

Smaller values increase the search speed, but could cause fatal error that causes python kernel to die. If this happens increase the rounding int value.

Returns:

returns

:rfl_est:

ndarrays with estimated reflectance spectra.

`luxpy.toolboxes.hypspcim.`**`get_superresolution_hsi`**(*lrhsi*, *hrci*, *CSF*, *wl=[380, 780, 1]*, *csf_based_rgb_rounding=6*, *interp_type='nd'*, *k_neighbours=4*, *verbosity=0*)

Get a HighResolution HyperSpectral Image (super-resolution HSI) based on a LowResolution HSI and a High-Resolution Color Image.

Args:

lrhsi

ndarray with float (max = 1) LowResolution HSI [m,m,L].

hrci

ndarray with float (max = 1) HighResolution HSI [M,N,3].

CSF

None, optional

ndarray with camera sensitivity functions

If None: use Nikon D700

wl

[380,780,1], optional

Wavelength range and spacing or ndarray with wavelengths of HSI image.

interp_type

'nd', optional

Options:

- 'nd': perform n-dimensional linear interpolation using Delaunay triangulation.

- 'nearest': perform nearest neighbour interpolation.

k_neighbours

4 or int, optional

Number of nearest neighbours for reflectance spectrum interpolation.

Neighbours are found using scipy.spatial.cKDTree

verbosity

0, optional

Verbosity level for sub-call to render_image().
If > 0: make a plot of the color coordinates of original and
rendered image pixels.

csf_based_rgb_rounding

_ROUNDING, optional
Int representing the number of decimals to round the RGB values (obtained from not-None CSF input) to before applying the search algorithm.
Smaller values increase the search speed, but could cause fatal error that causes python kernel to die. If this happens increase the rounding int value.

Returns:

hrhsi

ndarray with HighResolution HSI [M,N,L].

Procedure:

Call render_image(hrci, rfl = lrhsi_2, CSF = ...) to estimate a hyperspectral image
from the high-resolution color image hrci with the reflectance spectra
in the low-resolution hyper-spectral image as database for the estimation.
Estimation is done in raw RGB space with the lrhsi converted using the
camera sensitivity functions in CSF.

`luxpy.toolboxes.hypspcim.`**`hsi_to_rgb`**(*hsi*, *spd=None*, *cieobs='1931_2'*, *srgb=False*, *linear_rgb=False*, *CSF=None*, *normalize_to_white=True*, *wl=[380, 780, 1]*)

Convert HyperSpectral Image to rgb.

Args:

hsi

ndarray with hyperspectral image [M,N,L]

spd

None, optional
ndarray with illumination spectrum

cieobs

_CIEOBS, optional
CMF set to convert spectral data to xyz tristimulus values.

srgb

False, optional
If False: Use xyz_to_srgb(spd_to_xyz(...)) to convert to srgb values
If True: use camera sensitivity functions.

linear_rgb

False, optional
If False: use gamma = 2.4 in xyz_to_srgb, if False: use gamma = 1 and set :use_linear_part: to False.

CSF

None, optional
ndarray with camera sensitivity functions
If None: use Nikon D700

normalize_to_white

True, optional
If True & CSF is not None: white-balance output rgb to a perfect white diffuser.

wl

[380,780,1], optional
Wavelength range and spacing or ndarray with wavelengths of HSI image.

Returns:

rgb

ndarray with rgb image [M,N,3]

luxpy.toolboxes.hypspcim.**rfl_to_rgb**(*rfl*, *spd=None*, *CSF=None*, *wl=None*, *normalize_to_white=True*)

Convert spectral reflectance functions (illuminated by spd) to Camera Sensitivity Functions.

Args:

rfl

ndarray with spectral reflectance functions (1st row is wavelengths if wl is None).

spd

None, optional
ndarray with illumination spectrum

CSF

None, optional
ndarray with camera sensitivity functions
If None: use Nikon D700

normalize_to_white

True, optional
If True: white-balance output rgb to a perfect white diffuser.

Returns:

rgb

ndarray with rgb values for each spectral reflectance functions

4.5.5 dispcal/

py

- __init__.py
- displaycalibration.py

namespace
luxpy.dispcal

Module for display characterization

_PATH_DATA
path to package data folder

_RGB
set of RGB values that work quite well for display characterization

_XYZ
example set of measured XYZ values corresponding to the RGB values in _RGB

find_index_in_rgb()
Find the index/indices of a specific r,g,b combination k in the ndarray rgb.

find_pure_rgb()
Find the indices of all pure r,g,b (single channel on) in the ndarray rgb.

correct_for_black
Correct xyz for black level (flare)

TR_ggo(),TRi_ggo()
Forward (rgblin-to-xyz) and inverse (xyz-to-rgblin) GGO Tone Response models.

TR_gog(),TRi_gog()
Forward (rgblin-to-xyz) and inverse (xyz-to-rgblin) GOG Tone Response models.

TR_gogo(),TRi_gogo()
Forward (rgblin-to-xyz) and inverse (xyz-to-rgblin) GOGO Tone Response models.

TR_sigmoid(),TRi_sigmoid()
Forward (rgblin-to-xyz) and inverse (xyz-to-rgblin) SIGMOID Tone Response models.

estimate_tr()
Estimate Tone Response curves.

optimize_3x3_transfer_matrix()
Optimize the 3x3 rgb-to-xyz transfer matrix.

get_3x3_transfer_matrix_from_max_rgb()
Get the rgb-to-xyz transfer matrix from the maximum R,G,B single channel outputs

calibrate()
Calculate TR parameters/lut and conversion matrices

calibration_performance()
Check calibration performance (cfr. individual and average color differences for each stimulus).

rgb_to_xyz()
Convert input rgb to xyz

xyz_to_rgb()
Convert input xyz to rgb

DisplayCalibration()
Calculate TR parameters/lut and conversion matrices and store in object.

generate_training_data()
Generate RGB training pairs by creating a cube of RGB values.

generate_test_data()
Generate XYZ test values by creating a cube of CIELAB L*a*b* values, then converting these to XYZ values.

plot_rgb_xyz_lab_of_set()
Make 3d-plots of the RGB, XYZ and L*a*b* cubes of the data in rgb_xyz_lab.

split_ramps_from_cube()
Split a cube data set in pure RGB (ramps) and non-pure (remainder of cube).

is_random_sampling_of_pure_rgbs()
Return boolean indicating if the RGB cube axes (=single channel ramps) are sampled (different increment) independently from the remainder of the cube.

ramp_data_to_cube_data()
Create a RGB and XYZ cube from the single channel ramps in the training data.

GGO_GOG_GOGO_PLI
Class for characterization models that combine a 3x3 transfer matrix and a GGO, GOG, GOGO, SIGMOID, PLI and 1-D LUT Tone response curve | - Tone Response curve

models: | * GGO: gain-gamma-offset model: y = gain*x**gamma + offset | * GOG: gain-offset-gamma model: y = (gain*x + offset)**gamma | * GOG: gain-offset-gamma-offset model: y = (gain*x + offset)**gamma + offset | * SIGMOID: sigmoid (S-shaped) model: y = offset + gain* [1 / (1 + q*exp(-a/gamma*(x - m)))]**(gamma) | * PLI: Piece-wise Linear Interpolation | * LUT: 1-D Look-Up-Tables for the TR | - RGB-to-XYZ / XYZ-to-RGB transfer matrices: | * M fixed: derived from tristimulus values of maximum single channel output | * M optimized: by minimizing the RMSE between measured and predicted XYZ values

MLPR
Class for Multi-Layer Perceptron Regressor based model.

POR
Class for POlynomial Regression based model.

LUTNNLI
Class for LUT-Nearest-Neighbour-distance-weighted-Linear-Interpolation based models.

LUTQHLI
Class for LUT-QHul-Linear-Interpolation based models (cfr. scipt.interpolate.LinearNDInterpolator)

luxpy.toolboxes.dispcal.**_parse_rgbxyz_input**(*rgb*, *xyz=None*, *sep=','*, *header=None*)

Parse the rgb and xyz inputs

luxpy.toolboxes.dispcal.**find_index_in_rgb**(*rgb*, *k=[255, 255, 255]*, *as_bool=False*)

Find the index/indices of a specific r,g,b combination k in the ndarray rgb. (return a boolean array indicating the positions if as_bool == True)

luxpy.toolboxes.dispcal.**_plot_target_vs_predicted_lab**(*labtarget*, *labpredicted*, *cspace='lab'*, *verbosity=1*)

Make a plot of target vs predicted color coordinates

luxpy.toolboxes.dispcal.**_plot_DEs_vs_digital_values**(*DEslab*, *DEsl*, *DEsab*, *rgbcal*, *avg=<function <lambda>>*, *nbit=8*, *verbosity=1*)

Make a plot of the lab, l and ab color differences for the different calibration stimulus types.

luxpy.toolboxes.dispcal.**calibrate**(*rgbcal*, *xyzcal*, *black_correct=True*, *tr_L_type='lms'*, *tr_type='lut'*, *tr_par_lower_bounds=(0, -0.1, 0, -0.1)*, *cieobs='1931_2'*, *nbit=8*, *cspace='lab'*, *avg=<function <lambda>>*, *tr_ensure_increasing_lut_at_low_rgb=0.2*, *tr_force_increasing_lut_at_high_rgb=True*, *tr_rms_break_threshold=0.01*, *tr_smooth_window_factor=None*, *verbosity=1*, *sep=' '*, *header=None*, *optimize_M=True*)

Calculate TR parameters/lut and conversion matrices.

Args:

rgbcal

ndarray [Nx3] or string with filename of RGB values

rgcal must contain at least the following type of settings:

- pure R,G,B: e.g. for pure R: (R != 0) & (G==0) & (B == 0)
- white(s): R = G = B = 2**nbit-1
- gray(s): R = G = B
- black(s): R = G = B = 0
- binary colors: cyan (G = B, R = 0), yellow (G = R, B = 0), magenta (R = B, G = 0)

xyzcal

ndarray [Nx3] or string with filename of measured XYZ values for
the RGB settings in rgbcal.

black_correct

True, optional
If True: correct xyz for black -> xyz - xyz_black

tr_L_type

'lms', optional
Type of response to use in the derivation of the Tone-Response curves.
options:
- 'lms': use cone fundamental responses: L vs R, M vs G and S vs B
(reduces noise and generally leads to more accurate characterization)
- 'Y': use the luminance signal: Y vs R, Y vs G, Y vs B

tr_type

'lut', optional
options:
- 'lut': Derive/specify Tone-Response as a look-up-table
- 'ggo': Derive/specify Tone-Response as a gain-gamma-offset function: y = gain*x**gamma + offset
- 'gog': Derive/specify Tone-Response as a gain-offset-gamma function: y = (gain*x + offset)**gamma
- 'gogo': Derive/specify Tone-Response as a gain-offset-gamma-offset function: y = (gain*x + offset)**gamma + offset
- 'sigmoid': Derive/specify Tone-Response as a sigmoid function: y = offset + gain * [1 / (1 + q*exp(-(a/gamma)*(x - m)))]**(gamma)
- 'pli': Derive/specify Tone-Response as a piecewise linear interpolation function

tr_par_lower_bounds

(0,-0.1,0,-0.1), optional
Lower bounds used when optimizing the parameters of the GGO, GOG, GOGO tone response functions. Try different set of fit fails.
Tip for GOG & GOGO: try changing -0.1 to 0 (0 is not default,
because in most cases this leads to a less goog fit)

cieobs

'1931_2', optional
CIE CMF set used to determine the XYZ tristimulus values
(needed when tr_L_type == 'lms': determines the conversion matrix to
convert xyz to lms values)

nbit

8, optional
RGB values in nbit format (e.g. 8, 16, ...)

cspace

color space or chromaticity diagram to calculate color differences in
when optimizing the xyz_to_rgb and rgb_to_xyz conversion matrices.

avg

lambda x: ((x**2).mean()**0.5), optional
Function used to average the color differences of the individual RGB settings

in the optimization of the xyz_to_rgb and rgb_to_xyz conversion matrices.

tr_ensure_increasing_lut_at_low_rgb

0.2 or float (max = 1.0) or None, optional
Ensure an increasing lut by setting all values below the RGB with the maximum zero-crossing of np.diff(lut) and RGB/RGB.max() values of :tr_ensure_increasing_lut_at_low_rgb:
(values of 0.2 are a good rule of thumb value)
Non-strictly increasing lut values can be caused at low RGB values due to noise and low measurement signal.
If None: don't force lut, but keep as is.

tr_force_increasing_lut_at_high_rgb

True, optional
If True: ensure the tone response curves in the lut are monotonically increasing.
by finding the first 1.0 value and setting all values after that also to 1.0.

tr_rms_break_threshold

0.01, optional
Threshold for breaking a loop that tries different bounds for the gain in the TR optimization for the GGO, GOG, GOGO models.
(for some input the curve_fit fails, but succeeds on using different bounds)

tr_smooth_window_factor

None, optional
Determines window size for smoothing of data using scipy's savgol_filter prior to determining the TR curves.
window_size = x.shape[0]//tr_smooth_window_factor
If None: don't apply any smoothing

verbosity

1, optional
> 0: print and plot optimization results

sep

',', optional
separator in files with rgbcal and xyzcal data

header

None, optional
header specifier for files with rgbcal and xyzcal data
(see pandas.read_csv)

optimize_M

True, optional
If True: optimize transfer matrix M
Else: use column matrix of tristimulus values of R,G,B channels at max.

Returns:

M

linear rgb to xyz conversion matrix

N

xyz to linear rgb conversion matrix

tr

Tone Response function parameters or lut or piecewise linear interpolation functions (forward and backward)

xyz_black

ndarray with XYZ tristimulus values of black

xyz_white

ndarray with tristimlus values of white

luxpy.toolboxes.dispcal.**calibration_performance**(*rgb*, *xyztarget*, *M*, *N*, *tr*, *xyz_black*, *xyz_white*, *tr_type='lut'*, *cspace='lab'*, *avg=<function <lambda>>*, *rgb_is_xyz=False*, *is_verification_data=False*, *nbit=8*, *verbosity=1*, *sep=', '*, *header=None*)

Check calibration performance. Calculate DE for each stimulus.

Args:

rgb

ndarray [Nx3] or string with filename of RGB values

(or xyz values if argument rgb_to_xyz == True!)

xyztarget

ndarray [Nx3] or string with filename of target XYZ values corresponding

to the RGB settings (or the measured XYZ values, if argument rgb_to_xyz == True).

M

linear rgb to xyz conversion matrix

N

xyz to linear rgb conversion matrix

tr

Tone Response function represented by GGO, GOG, GOGO, LUT or PLI (piecewise linear function) models

xyz_black

ndarray with XYZ tristimulus values of black

xyz_white

ndarray with tristimlus values of white

tr_type

'lut', optional

Type of Tone Response in tr input argument

options:

- 'lut': Derive/specify Tone-Response as a look-up-table
- 'ggo': Derive/specify Tone-Response as a gain-gamma-offset function: y = gain*x**gamma + offset
- 'gog': Derive/specify Tone-Response as a gain-offset-gamma function: y = (gain*x + offset)**gamma
- 'gogo': Derive/specify Tone-Response as a gain-offset-gamma-offset function: y = (gain*x + offset)**gamma + offset
- 'sigmoid': Derive/specify Tone-Response as a sigmoid function: y = offset + gain * [1 / (1 + q*exp(-(a/gamma)*(x - m)))]**(gamma)
- 'pli': Derive/specify Tone-Response as a piecewise linear interpolation function

cspace

color space or chromaticity diagram to calculate color differences in.

avg

lambda x: ((x**2).mean()**0.5), optional
Function used to average the color differences of the individual RGB settings in the optimization of the xyz_to_rgb and rgb_to_xyz conversion matrices.

rgb_is_xyz

False, optional
If True: the data in argument rgb are actually measured XYZ tristimulus values and are directly compared to the target xyz.

is_verification_data

False, optional
If False: the data is assumed to be corresponding to RGB value settings used in the calibration (i.e. containing whites, blacks, grays, pure and binary mixtures)
If True: no assumptions on content of rgb, so use this settings when checking the performance for a set of measured and target xyz data different than the ones used in the actual calibration measurements.

nbit

8, optional
RGB values in nbit format (e.g. 8, 16, ...)

verbosity

1, optional
> 0: print and plot optimization results

sep

',', optional
separator in files with rgbcal and xyzcal data

header

None, optional
header specifier for files with rgbcal and xyzcal data
(see pandas.read_csv)

Returns:

M

linear rgb to xyz conversion matrix

N

xyz to linear rgb conversion matrix

tr

Tone Response function parameters or lut or piecewise linear interpolation functions (forward and backward)

xyz_black

ndarray with XYZ tristimulus values of black

xyz_white

ndarray with tristimlus values of white

`luxpy.toolboxes.dispcal.`**`rgb_to_xyz`**(*rgb*, *M*, *tr*, *xyz_black*, *tr_type='lut'*, *nbit=8*)

Convert input rgb to xyz.

Args:

rgb

ndarray [Nx3] with RGB values

M

linear rgb to xyz conversion matrix

tr

Tone Response function represented by GGO, GOG, GOGO, LUT or PLI (piecewise linear function) models

xyz_black

ndarray with XYZ tristimulus values of black

tr_type

'lut', optional

Type of Tone Response in tr input argument

options:

- 'lut': Derive/specify Tone-Response as a look-up-table
- 'ggo': Derive/specify Tone-Response as a gain-gamma-offset function: y = gain*x**gamma + offset
- 'gog': Derive/specify Tone-Response as a gain-offset-gamma function: y = (gain*x + offset)**gamma
- 'gogo': Derive/specify Tone-Response as a gain-offset-gamma-offset function: y = (gain*x + offset)**gamma + offset
- 'sigmoid': Derive/specify Tone-Response as a sigmoid function: y = offset + gain * [1 / (1 + q*exp(-(a/gamma)*(x - m)))]**(gamma)
- 'pli': Derive/specify Tone-Response as a piecewise linear interpolation function

nbit

8, optional

RGB values in nbit format (e.g. 8, 16, ...)

Returns:

xyz

ndarray [Nx3] of XYZ tristimulus values

luxpy.toolboxes.dispcal.**xyz_to_rgb**(*xyz*, *N*, *tr*, *xyz_black*, *tr_type='lut'*, *nbit=8*)

Convert xyz to input rgb.

Args:

xyz

ndarray [Nx3] with XYZ tristimulus values

N

xyz to linear rgb conversion matrix

tr

Tone Response function represented by GGO, GOG, GOGO, LUT or PLI (piecewise linear function) models

xyz_black

ndarray with XYZ tristimulus values of black

tr_type

'lut', optional

Type of Tone Response in tr input argument

options:

- 'lut': Derive/specify Tone-Response as a look-up-table
- 'ggo': Derive/specify Tone-Response as a gain-gamma-offset function: y = gain*x**gamma + offset
- 'gog': Derive/specify Tone-Response as a gain-offset-gamma function: y = (gain*x + offset)**gamma
- 'gogo': Derive/specify Tone-Response as a gain-offset-gamma-offset function: y = (gain*x + offset)**gamma + offset
- 'sigmoid': Derive/specify Tone-Response as a sigmoid function: y = offset + gain * [1 / (1 + q*exp(-(a/gamma)*(x - m)))]**(gamma)
- 'pli': Derive/specify Tone-Response as a piecewise linear interpolation function

nbit

8, optional

RGB values in nbit format (e.g. 8, 16, ...)

Returns:

rgb

ndarray [Nx3] of display RGB values

class luxpy.toolboxes.dispcal.**DisplayCalibration**(*rgbcal*, *xyzcal=None*, *tr_L_type='lms'*, *cieobs='1931_2'*, *tr_type='lut'*, *nbit=8*, *cspace='lab'*, *avg=<function DisplayCalibration.<lambda>>*, *tr_ensure_increasing_lut_at_low_rgb=0.2*, *tr_force_increasing_lut_at_high_rgb=True*, *tr_rms_break_threshold=0.01*, *tr_smooth_window_factor=None*, *verbosity=1*, *sep=', '*, *header=None*, *optimize_M=True*)

Class for display_calibration.

Args:

rgbcal

ndarray [Nx3] or string with filename of RGB values

rgcal must contain at least the following type of settings:

- pure R,G,B: e.g. for pure R: (R != 0) & (G==0) & (B == 0)
- white(s): R = G = B = 2**nbit-1
- gray(s): R = G = B
- black(s): R = G = B = 0
- binary colors: cyan (G = B, R = 0), yellow (G = R, B = 0), magenta (R = B, G = 0)

xyzcal

None, optional

ndarray [Nx3] or string with filename of measured XYZ values for

the RGB settings in rgbcal.

if None: rgbcal is [Nx6] ndarray containing rgb (columns 0-2) and xyz data (columns 3-5)

tr_L_type

'lms', optional

Type of response to use in the derivation of the Tone-Response curves.

options:

- 'lms': use cone fundamental responses: L vs R, M vs G and S vs B
  (reduces noise and generally leads to more accurate characterization)

- 'Y': use the luminance signal: Y vs R, Y vs G, Y vs B

tr_type

'lut', optional

options:

- 'lut': Derive/specify Tone-Response as a look-up-table
- 'ggo': Derive/specify Tone-Response as a gain-gamma-offset function: y = gain*x**gamma + offset
- 'gog': Derive/specify Tone-Response as a gain-offset-gamma function: y = (gain*x + offset)**gamma
- 'gogo': Derive/specify Tone-Response as a gain-offset-gamma-offset function: y = (gain*x + offset)**gamma + offset
- 'sigmoid': Derive/specify Tone-Response as a sigmoid function: y = offset + gain * [1 / (1 + q*exp(-(a/gamma)*(x - m)))]**(gamma)
- 'pli': Derive/specify Tone-Response as a piecewise linear interpolation function

cieobs

'1931_2', optional

CIE CMF set used to determine the XYZ tristimulus values

(needed when tr_L_type == 'lms': determines the conversion matrix to

convert xyz to lms values)

nbit

8, optional

RGB values in nbit format (e.g. 8, 16, ...)

cspace

color space or chromaticity diagram to calculate color differences in

when optimizing the xyz_to_rgb and rgb_to_xyz conversion matrices.

avg

lambda x: ((x**2).mean()**0.5), optional

Function used to average the color differences of the individual RGB settings

in the optimization of the xyz_to_rgb and rgb_to_xyz conversion matrices.

tr_ensure_increasing_lut_at_low_rgb

0.2 or float (max = 1.0) or None, optional

Ensure an increasing lut by setting all values below the RGB with the maximum

zero-crossing of np.diff(lut) and RGB/RGB.max() values of

:tr_ensure_increasing_lut_at_low_rgb:

(values of 0.2 are a good rule of thumb value)

Non-strictly increasing lut values can be caused at low RGB values due

to noise and low measurement signal.

If None: don't force lut, but keep as is.

tr_force_increasing_lut_at_high_rgb

True, optional

If True: ensure the tone response curves in the lut are monotonically increasing.

by finding the first 1.0 value and setting all values after that also to 1.0.

tr_rms_break_threshold

0.01, optional

Threshold for breaking a loop that tries different bounds

for the gain in the TR optimization for the GGO, GOG, GOGO models.
(for some input the curve_fit fails, but succeeds on using different bounds)

tr_smooth_window_factor

None, optional
Determines window size for smoothing of data using scipy's savgol_filter prior to determining the TR curves.
window_size = x.shape[0]//tr_smooth_window_factor
If None: don't apply any smoothing

verbosity

1, optional
> 0: print and plot optimization results

sep

',', optional
separator in files with rgbcal and xyzcal data

header

None, optional
header specifier for files with rgbcal and xyzcal data
(see pandas.read_csv)

optimize_M

True, optional
If True: optimize transfer matrix M
Else: use column matrix of tristimulus values of R,G,B channels at max.

Return:

calobject

attributes are:
- M: linear rgb to xyz conversion matrix
- N: xyz to linear rgb conversion matrix
- TR: Tone Response function parameters for GGO, GOG, GOGO models or lut or piecewise linear interpolation functions (forward and backward)
- xyz_black: ndarray with XYZ tristimulus values of black
- xyz_white: ndarray with tristimlus values of white

as well as:
- rgbcal, xyzcal, cieobs, avg, tr_type, nbit, cspace, verbosity
- performance: dictionary with various color differences set to np.nan
- (run calobject.performance() to fill it with actual values)

`check_performance`(*rgb=None*, *xyz=None*, *verbosity=None*, *sep=','*, *header=None*, *rgb_is_xyz=False*, *is_verification_data=True*)

Check calibration performance (if rgbcal is None: use calibration data).

Args:

rgb

None, optional
ndarray [Nx3] or string with filename of RGB values
(or xyz values if argument rgb_to_xyz == True!)
If None: use self.rgbcal

xyz

None, optional

ndarray [Nx3] or string with filename of target XYZ values corresponding to the RGB settings (or the measured XYZ values, if argument rgb_to_xyz == True).
If None: use self.xyzcal

verbosity

None, optional
if None: use self.verbosity
if > 0: print and plot optimization results

sep

‘,’, optional
separator in files with rgb and xyz data

header

None, optional
header specifier for files with rgb and xyz data
(see pandas.read_csv)

rgb_is_xyz

False, optional
If True: the data in argument rgb are actually measured XYZ tristimulus values and are directly compared to the target xyz.

is_verification_data

False, optional
If False: the data is assumed to be corresponding to RGB value settings used in the calibration (i.e. containing whites, blacks, grays, pure and binary mixtures)
Performance results are stored in self.performance.
If True: no assumptions on content of rgb, so use this settings when checking the performance for a set of measured and target xyz data different than the ones used in the actual calibration measurements.

Return:

performance

dictionary with various color differences.

`to_xyz`(*rgb*)

Convert display rgb to xyz.

`to_rgb`(*xyz*)

Convert xyz to display rgb.

`luxpy.toolboxes.dispcal.TR_ggo`(*x*, **p*)

Forward GGO tone response model (x = rgb; p = [gain,offset,gamma]).
Notes:
1. GGO model: y = gain*x**gamma + offset

`luxpy.toolboxes.dispcal.TRi_ggo`(*x*, **p*)

Inverse GGO tone response model (x = xyz; p = [gain,offset,gamma]).
Notes:
1. GGO model: y = gain*x**gamma + offset

`luxpy.toolboxes.dispcal.TR_gog`(*x*, **p*)

Forward GOG tone response model (x = rgb; p = [gain,offset,gamma]).

Notes:

1. GOG model: y = (gain*x + offset)**gamma

luxpy.toolboxes.dispcal.**TRi_gog**(*x*, **p*)

Inverse GOG tone response model (x = xyz; p = [gain,offset,gamma]).

Notes:

1. GOG model: y = (gain*x + offset)**gamma

luxpy.toolboxes.dispcal.**TR_gogo**(*x*, **p*)

Forward GOGO tone response model (x = rgb; p = [gain,offset,gamma,offset2]).

Notes:

1. GOGO model: y = (gain*x + offset)**gamma + offset2

luxpy.toolboxes.dispcal.**TRi_gogo**(*x*, **p*)

Inverse GOGO tone response model (x = xyz; p = [gain,offset,gamma,offset2]).

Notes:

1. GOGO model: y = (gain*x + offset)**gamma + offset2

luxpy.toolboxes.dispcal.**TR_sigmoid**(*x*, **p*)

Forward SIGMOID tone response model (x = rgb; p = [gain, offset, gamma, m, a, q]).

Notes:

1. SIGMOID model: y = offset + gain * [1 / (1 + q*exp(-a/gamma*(x - m)))]**(gamma)]

luxpy.toolboxes.dispcal.**TRi_sigmoid**(*x*, **p*)

Inverse SIGMOID tone response model (x = xyz; p = [gain, offset, gamma, m, a, q]).

Notes:

1. SIGMOID model: y = offset + gain * [1 / (1 + q*exp(-a/gamma*(x - m)))]**(gamma)]

luxpy.toolboxes.dispcal.**correct_for_black**(*xyz*, *rgb*, *xyz_black=None*)

Correct xyz for black level (flare)

luxpy.toolboxes.dispcal.**_rgb_linearizer**(*rgb*, *tr*, *tr_type='lut'*, *nbit=8*)

Linearize rgb using tr tone response function represented by a GGO, GOG, GOGO, LUT or PLI (cfr. piecewise linear interpolator) model

luxpy.toolboxes.dispcal.**_rgb_delinearizer**(*rgblin*, *tr*, *tr_type='lut'*, *nbit=8*)

De-linearize linear rgblin using tr tone response function represented by GGO, GOG, GOGO, LUT or PLI (cfr. piecewise linear interpolator) model

luxpy.toolboxes.dispcal.**estimate_tr**(*rgb*, *xyz*, *black_correct=True*, *xyz_black=None*, *tr_L_type='lms'*, *tr_type='lut'*, *tr_par_lower_bounds=(0, -0.1, 0, -0.1)*, *cieobs='1931_2'*, *nbit=8*, *tr_ensure_increasing_lut_at_low_rgb=0.2*, *tr_force_increasing_lut_at_high_rgb=True*, *verbosity=1*, *tr_rms_break_threshold=0.01*, *tr_smooth_window_factor=None*)

Estimate tone response functions.

Args:

rgb

ndarray [Nx3] of RGB values

rgcal must contain at least the following type of settings:

- pure R,G,B: e.g. for pure R: (R != 0) & (G==0) & (B == 0)
- white(s): R = G = B = 2**nbit-1
- black(s): R = G = B = 0

xyz

ndarray [Nx3] of measured XYZ values for the RGB settings in rgb.

black_correct

True, optional
If True: correct xyz for black -> xyz - xyz_black

xyz_black

None or ndarray, optional
If None: determine xyz_black from input data (must contain rgb = [0,0,0]!)

tr_L_type

'lms', optional
Type of response to use in the derivation of the Tone-Response curves.
options:
- 'lms': use cone fundamental responses: L vs R, M vs G and S vs B
(reduces noise and generally leads to more accurate characterization)
- 'Y': use the luminance signal: Y vs R, Y vs G, Y vs B

tr_type

'lut', optional
options:
- 'lut': Derive/specify Tone-Response as a look-up-table
- 'ggo': Derive/specify Tone-Response as a gain-gamma-offset function: y = gain*x**gamma + offset
- 'gog': Derive/specify Tone-Response as a gain-offset-gamma function: y = (gain*x + offset)**gamma
- 'gogo': Derive/specify Tone-Response as a gain-offset-gamma-offset function: y = (gain*x + offset)**gamma + offset
- 'sigmoid': Derive/specify Tone-Response as a sigmoid function: y = offset + gain * [1 / (1 + q*exp(-(a/gamma)*(x - m)))]**(gamma)
- 'pli': Derive/specify Tone-Response as a piecewise linear interpolation function

tr_par_lower_bounds

(0,-0.1,0,-0.1), optional
Lower bounds used when optimizing the parameters of the GGO, GOG, GOGO tone response functions. Try different set of fit fails.
Tip for GOG & GOGO: try changing -0.1 to 0 (0 is not default,
because in most cases this leads to a less goog fit)

cieobs

'1931_2', optional
CIE CMF set used to determine the XYZ tristimulus values
(needed when tr_L_type == 'lms': determines the conversion matrix to
convert xyz to lms values)

nbit

8, optional
RGB values in nbit format (e.g. 8, 16, ...)

tr_ensure_increasing_lut_at_low_rgb

0.2 or float (max = 1.0) or None, optional
Ensure an increasing lut by setting all values below the RGB with the maximum zero-crossing of np.diff(lut) and RGB/RGB.max() values of
:tr_ensure_increasing_lut_at_low_rgb:
(values of 0.2 are a good rule of thumb value)

Non-strictly increasing lut values can be caused at low RGB values due
to noise and low measurement signal.
If None: don't force lut, but keep as is.

tr_force_increasing_lut_at_high_rgb

True, optional
If True: ensure the tone response curves in the lut are monotonically increasing.
by finding the first 1.0 value and setting all values after that also to 1.0.

verbosity

1, optional
> 0: print and plot optimization results

tr_rms_break_threshold

0.01, optional
Threshold for breaking a loop that tries different bounds
for the gain in the TR optimization for the GGO, GOG, GOGO models.
(for some input the curve_fit fails, but succeeds on using different bounds)

tr_smooth_window_factor

None, optional
Determines window size for smoothing of data using scipy's savgol_filter prior to determining the TR curves.
window_size = x.shape[0]//tr_smooth_window_factor
If None: don't apply any smoothing

Returns:

tr

Tone Response function parameters or lut or piecewise linear interpolation functions (forward and backward)

xyz_black

ndarray with XYZ tristimulus values of black

p_pure

ndarray with positions in xyz and rgb that contain data corresponding to the black level (rgb = [0,0,0]).

`luxpy.toolboxes.dispcal.`**`optimize_3x3_transfer_matrix`**(*xyz*, *rgb*, *black_correct=True*, *xyz_black=None*, *rgblin=None*, *nbit=8*, *cspace='lab'*, *avg=<function <lambda>>*, *tr=None*, *tr_type=None*, *verbosity=0*)

Optimize the 3x3 rgb-to-xyz transfer matrix

Args:

xyz

ndarray with measured XYZ tristimulus values (not correct for the black-level)

rgb

device RGB values.

black_correct

True, optional
If True: correct xyz for black -> xyz - xyz_black

xyz_black

None or ndarray, optional
If None: determine xyz_black from input data (must contain rgb = [0,0,0]!)

nbit

8, optional
RGB values in nbit format (e.g. 8, 16, ...)

cspace

color space or chromaticity diagram to calculate color differences in
when optimizing the xyz_to_rgb and rgb_to_xyz conversion matrices.

avg

lambda x: ((x**2).mean()**0.5), optional
Function used to average the color differences of the individual RGB settings
in the optimization of the xyz_to_rgb and rgb_to_xyz conversion matrices.

tr

None, optional
Tone Response function parameters or lut or piecewise linear interpolation functions
(forward and backward)
If None -> :rgblin: must be provided !

tr_type

'lut', optional
options:
- 'lut': Derive/specify Tone-Response as a look-up-table
- 'ggo': Derive/specify Tone-Response as a gain-gamma-offset function: y = gain*x**gamma + offset
- 'gog': Derive/specify Tone-Response as a gain-offset-gamma function: y = (gain*x + offset)**gamma
- 'gogo': Derive/specify Tone-Response as a gain-offset-gamma-offset function: y = (gain*x + offset)**gamma + offset
- 'sigmoid': Derive/specify Tone-Response as a sigmoid function: y = offset + gain * [1 / (1 + q*exp(-(a/gamma)*(x - m)))]**(gamma)
- 'pli': Derive/specify Tone-Response as a piecewise linear interpolation function

verbosity

1, optional
> 0: print and plot optimization results

Returns:

M

linear rgb-to-xyz conversion matrix

luxpy.toolboxes.dispcal.**get_3x3_transfer_matrix_from_max_rgb**(*xyz*, *rgb*, *black_correct=True*, *xyz_black=None*)

Get the rgb-to-xyz transfer matrix from the maximum R,G,B single channel outputs

Args:

xyz

ndarray with measured XYZ tristimulus values (not correct for the black-level)

rgb

device RGB values.

black_correct

True, optional
If True: correct xyz for black -> xyz - xyz_black

xyz_black

None or ndarray, optional
If None: determine xyz_black from input data (must contain rgb = [0,0,0]!)

Returns:

M

linear rgb-to-xyz conversion matrix

luxpy.toolboxes.dispcal.**generate_training_data**(*inc=[10]*, *inc_offset=0*, *nbit=8*, *seed=0*, *randomize_order=True*, *verbosity=0*, *fig=None*)

Generate RGB training pairs by creating a cube of RGB values.

Args:

inc

[10], optional
Increment along each channel (=R,G,B) axes in the RGB cube.
If inc is a list with 2 different values the RGB cube axes
are sampled independently from the remainder of the cube.
–> inc = [inc_remainder, inc_axes]

inc_offset

0, optional
The offset along each channel axes from which to start incrementing.

nbit

8, optional
RGB values in nbit format (e.g. 8, 16, ...)

include_max

True, optional
If True: ensure all combinations of max value (e.g. 255 for nbit = 8) are included in RGB cube.

include_min

True, optional
If True: ensure all combinations of min value 0 are included in RGB cube.

seed

0, optional
Seed for setting the state of numpy's random number generator.

randomize_order

True, optional
Randomize the order of the (xyz,rgb) pairs before output.

verbosity

0, optional
Level of output.

Returns:

rgb

ndarray with RGB values.

luxpy.toolboxes.dispcal.**generate_test_data**(*dlab=[10, 10, 10]*, *nbit=8*, *seed=0*, *xyzw=None*, *cieobs='1931_2'*, *xyzrgb_hull=None*, *randomize_order=True*, *verbosity=0*, *fig=None*)

Generate XYZ test values by creating a cube of CIELAB L*a*b* values, then converting these to XYZ values.

Args:

dlab

[10,10,10], optional

Increment along each CIELAB (=L*,a*,b*) axes in the Lab cube.

nbit

8, optional

RGB values in nbit format (e.g. 8, 16, ...)

seed

0, optional

Seed for setting the state of numpy's random number generator.

xyzw

None, optional

White point xyz to convert from lab to xyz

If None: use the white in xyzrgb_hull. If this is also None: use _CIE_D65 white.

cieobs

_CIEOBS, optional

CIE standard observer used to convert _CIE_D65 to XYZ when xyzw needs to be determined from the illuminant spectrum.

xyzrgb_hull

None, optional

ndarray with (XYZ,RGB) pairs from which the hull (= display gamut) can be determined.

If None: test XYZ might fall outside of display gamut !

randomize_order

True, optional

Randomize the order of the test xyz before output.

verbosity

0, optional

Level of output.

Returns:

xyz

ndarray with XYZ values.

luxpy.toolboxes.dispcal.**split_ramps_from_cube**(*rgb*, *xyz=None*, *rgb_only=False*)

Split a cube data set in pure RGB (ramps) and non-pure (remainder of cube).

luxpy.toolboxes.dispcal.**is_random_sampling_of_pure_rgbs**(*inc*)

Return boolean indicating if the RGB cube axes (=single channel ramps) are sampled (different increment) independently from the remainder of the cube.

Note:

1. Independent sampling is indicated when :inc: is a list with 2 different values.

luxpy.toolboxes.dispcal.**plot_rgb_xyz_lab_of_set**(*rgb_xyz_lab*, *subscript=''*, *data_contains=['rgb', 'xyz', 'lab']*, *nrows=1*, *row=1*, *fig=None*, *axs=None*, *figsize=(14, 7)*, *marker='.'*)

Make 3d-plots of the RGB, XYZ and L*a*b* cubes of the data in rgb_xyz_lab.

Args:

rgb_xyz_lab

ndarray with RGB, XYZ, Lab data.

subscript

‘’, optional

subscript to add to the axis labels.

data_contains

[‘rgb’,’xyz’,’lab’], optional

specifies what is in rgb_xyz_lab

nrows

1, optional

Number of rows in (nx3) figure.

row

1, optional

Current row number to plot to (when using the function to plot nx3 figures)

fig

None, optional

Figure handle.

If None: generate new figure.

axs

None, optional

Axes handles: (3,) or None

If None: add new axes for each of the RGB, XYZ, Lab subplots.

figsize

(14,7), optional

Figure size.

marker

‘.’, optional

Marker symbol used for plotting.

Return:

fig, axs

Handles to the figure and the three axes in that figure.

`luxpy.toolboxes.dispcal.`**`ramp_data_to_cube_data`**(*training_data*, *black_correct=True*, *nbit=8*)

Create a RGB and XYZ cube from the single channel ramps in the training data.

Args:

training_data

tuple (xyz_train, rgb_train) of ndarrays

black_correct

True, optional

If True: apply black correction before creating the cubes

If False: the black level will be added 3 times as the XYZ of the R, G, B channels are summed)

class luxpy.toolboxes.dispcal.**GGO_GOG_GOGO_PLI**(*training_data=None*, *single_channel_ramp_only_data=False*, *cspace='lab'*, *nbit=8*, *xyzw=None*, *xyzb=None*, *black_correct=True*, *tr=None*, *tr_type=None*, *tr_L_type='Y'*, *tr_par_lower_bounds=(0, -0.1, 0, -0.1)*, *M=None*, *optimize_M=True*, *N=None*, *cieobs='1931_2'*, *avg=<function GGO_GOG_GOGO_PLI.<lambda>>*, *tr_ensure_increasing_lut_at_low_rgb=0.2*, *tr_force_increasing_lut_at_high_rgb=True*, *tr_rms_break_threshold=0.01*, *tr_smooth_window_factor=None*)

train(*training_data=None*, *single_channel_ramp_only_data=None*, *EPS=1e-300*)

to_rgb(*xyz*)

to_xyz(*rgb*)

class luxpy.toolboxes.dispcal.**MLPR**(*training_data=None*, *single_channel_ramp_only_data=False*, *cspace='lab'*, *nbit=8*, *xyzw=None*, *xyzb=None*, *black_correct=False*, *linearize_rgb=False*, *tr_par_lower_bounds=(0, -0.1, 0, -0.1)*, *tr_L_type='Y'*, *tr_type='pli'*, *cieobs='1931_2'*, *tr_ensure_increasing_lut_at_low_rgb=0.2*, *tr_force_increasing_lut_at_high_rgb=True*, *tr_rms_break_threshold=0.01*, *tr_smooth_window_factor=None*, *mode=['bw']*, *use_StandardScaler=True*, *hidden_layer_sizes=(500,)*, *activation='relu'*, *max_iter=100000*, *tol=0.0001*, *learning_rate='adaptive'*, ***kwargs*)

class luxpy.toolboxes.dispcal.**POR**(*training_data=None*, *single_channel_ramp_only_data=False*, *cspace='lab'*, *nbit=8*, *xyzw=None*, *xyzb=None*, *black_correct=True*, *linearize_rgb=True*, *tr_par_lower_bounds=(0, -0.1, 0, -0.1)*, *tr_L_type='Y'*, *tr_type='pli'*, *cieobs='1931_2'*, *tr_ensure_increasing_lut_at_low_rgb=0.2*, *tr_force_increasing_lut_at_high_rgb=True*, *tr_rms_break_threshold=0.01*, *tr_smooth_window_factor=None*, *mode=['bw']*, *polyfeat_degree=5*, *polyfeat_include_bias=True*, *polyfeat_interaction_only=False*, *linreg_fit_intercept=False*, *linreg_positive=False*)

class luxpy.toolboxes.dispcal.**LUTNNLI**(*training_data=None*, *single_channel_ramp_only_data=False*, *cspace='lab'*, *nbit=8*, *xyzw=None*, *xyzb=None*, *black_correct=True*, *linearize_rgb=True*, *tr_par_lower_bounds=(0, -0.1, 0, -0.1)*, *tr_L_type='Y'*, *tr_type='pli'*, *cieobs='1931_2'*, *tr_ensure_increasing_lut_at_low_rgb=0.2*, *tr_force_increasing_lut_at_high_rgb=True*, *tr_rms_break_threshold=0.01*, *tr_smooth_window_factor=None*, *mode=['bw']*, *number_of_nearest_neighbours=4*, ***kwargs*)

predict(*x*, *mode*, *ckdtree=None*, *x_train=None*, *y_train=None*)

class luxpy.toolboxes.dispcal.**LUTQHLI**(*training_data=None*, *single_channel_ramp_only_data=False*, *cspace='lab'*, *nbit=8*, *xyzw=None*, *xyzb=None*, *black_correct=True*, *linearize_rgb=True*, *tr_par_lower_bounds=(0, -0.1, 0, -0.1)*, *tr_L_type='Y'*, *tr_type='pli'*, *cieobs='1931_2'*, *tr_ensure_increasing_lut_at_low_rgb=0.2*, *tr_force_increasing_lut_at_high_rgb=True*, *tr_rms_break_threshold=0.01*, *tr_smooth_window_factor=None*, *rescale=False*, *mode=['bw']*)

class luxpy.toolboxes.dispcal.**VirtualDisplay**(*model='kwak2000_SII'*, *seed=-1*, *nbit=None*, *channel_dependence=None*, ***model_pars*)

to_rgb(*xyz*, ***kwargs*)

to_xyz(*rgb*, ***kwargs*)

4.5.6 rgb2spec/

py

- __init__.py
- smits_mitsuba.py

namespace
luxpy.rgb2spec

Module for RGB to spectrum conversions

_BASESPEC_SMITS
Default dict with base spectra for white, cyan, magenta, yellow, blue, green and red for each intent ('rfl' or 'spd')

rgb_to_spec_smits()
Convert an array of (linearized) RGB values to a spectrum using a smits like conversion as implemented in mitsuba (July 10, 2019)

convert()
Convert an array of (linearized) RGB values to a spectrum (wrapper around rgb_to_spec_smits(), future: implement other methods)

luxpy.toolboxes.rgb2spec.**rgb_to_spec_smits**(*rgb*, *intent='rfl'*, *linearized_rgb=True*, *bitdepth=8*, *wlr=[360.0, 830.0, 1.0]*, *rgb2spec=None*)

Convert an array of (linearized) RGB values to a spectrum using a Smits like conversion as implemented in Mitsuba.

Args:

rgb

ndarray of list of (linearized) rgb values

linearized_rgb

True, optional

If False: RGB values will be linearized using:

rgb_lin = xyz_to_srgb(srgb_to_xyz(rgb), gamma = 1, use_linear_part = False)

If True: user has entered pre-linearized RGB values.

intent

'rfl' (or 'spd'), optional
type of requested spectrum conversion.

bitdepth

8, optional
bit depth of rgb values

wlr

_WL3, optional
desired wavelength (nm) range of spectrum.

rgb2spec

None, optional
Dict with base spectra for white, cyan, magenta, yellow, blue, green and red for each intent.
If None: use _BASESPEC_SMITS.

Returns:

spec

ndarray with spectrum or spectra (one for each rgb value, first row are the wavelengths)

luxpy.toolboxes.rgb2spec.**convert**(*rgb*, *linearized_rgb=True*, *method='smits_mtsb'*, *intent='rfl'*, *bitdepth=8*, *wlr=[360.0, 830.0, 1.0]*, *rgb2spec=None*)

Convert an array of RGB values to a spectrum.

Args:

rgb

ndarray of list of rgb values

linearized_rgb

True, optional
If False: RGB values will be linearized using:
rgb_lin = xyz_to_srgb(srgb_to_xyz(rgb), gamma = 1, use_linear_part = False)
If True: user has entered pre-linearized RGB values.

method

'smits_mtsb', optional
Method to use for conversion:
- 'smits_mtsb': use a smits like conversion as implemented in mitsuba.

intent

'rfl' (or 'spd'), optional
type of requested spectrum conversion .

bitdepth

8, optional
bit depth of rgb values

wlr

_WL3, optional
desired wavelength (nm) range of spectrum.

rgb2spec

None, optional
Dict with base spectra for white, cyan, magenta, yellow, blue, green and red for each intent.
If None: use _BASESPEC_SMITS.

Returns:

spec

ndarray with spectrum or spectra (one for each rgb value, first row are the wavelengths)

4.5.7 iolidfiles/

py

- __init__.py
- io_lid_files.py

namespace

luxpy.iolidfiles

Module for reading and writing IES and LDT files.

read_lamp_data

Read in light intensity distribution and other lamp data from LDT or IES files.

Notes:

1.Only basic support. Writing is not yet implemented. 2.Reading IES files is based on Blender's ies2cycles.py 3.This was implemented to build some uv-texture maps for rendering and only tested for a few files. 4. Use at own risk. No warranties.

luxpy.toolboxes.iolidfiles.**read_lamp_data**(*datasource*, *multiplier=1.0*, *verbosity=0*, *normalize='I0'*, *only_common_keys=False*)

Read in light intensity distribution and other lamp data from LDT or IES files.

Args:

datasource

Filename of LID file or StringIO object or string with LID data.

multiplier

1.0, optional

Scaler for candela values.

verbosity

0, optional

Display messages while reading file.

normalize

'I0', optional

If 'I0': normalize LID to intensity at (theta,phi) = (0,0)

If 'max': normalize to max = 1.

If None: do not normalize.

only_common_keys

False, optional

If True, output only common dict keys related to angles, values and such of LID.

read_lid_lamp_data(?) for print of common keys and return empty dict with common keys.

Returns:

lid

dict with IES or LDT file data. | | If LIDtype == 'ies': | dict_keys(| ['datasource', 'version', 'lamps_num', 'lumens_per_lamp', | 'candela_mult', 'v_angles_num', 'h_angles_num', 'photometric_type', | 'units_type', 'width', 'length', 'height', 'ballast_factor', | 'future_use', 'input_watts', 'v_angs', 'h_angs', 'lamp_cone_type', | 'lamp_h_type', 'candela_values', 'candela_2d', 'v_same', 'h_same', | 'intensity', 'theta', 'values', 'phi', 'map','Iv0'] |) | | If LIDtype == 'ldt': | dict_keys(| ['datasource', 'version', 'manufacturer', 'Ityp','Isym', | 'Mc', 'Dc', 'Ng', 'name', Dg', 'cct/cri', 'tflux', 'lumens_per_lamp', | 'candela_mult', 'tilt', lamps_num', | 'cangles', 'tangles','candela_values', 'candela_2d', | 'intensity', 'theta', 'values', 'phi', 'map', 'Iv0'] |)

Notes:

1. if only_common_keys: output is dictionary with keys: ['datasource', 'version', 'intensity', 'theta', 'phi', 'values', 'map', 'Iv0', 'candela_values', 'candela_2d']
2. 'theta','phi', 'values' (='candela_2d') contain the original theta angles, phi angles and normalized candelas as specified in file.
3. 'map' contains a dicionary with keys 'thetas', 'phis', 'values'. This data has been complete to full angle ranges thetas: [0,180]; phis: [0,360]
4. LDT map completion only supported for Isymm == 4 (since 31/10/2018), and Isymm == 1 (since, 02/10/2021), Map will be filled with original 'theta', 'phi' and normalized 'candela_2d' values !
5. LIDtype is checked by looking for the presence of 'TILT=' in datasource content (if True->'IES' else 'LDT')
6. IES files with TILT=INCLUDE or TILT=<filename> are not supported!

`luxpy.toolboxes.iolidfiles.`**`get_uv_texture`**(*theta*, *phi=None*, *values=None*, *input_types=('array', 'array')*, *method='linear'*, *theta_min=0*, *angle_res=1*, *close_phi=False*, *deg=True*, *r=1*, *show=True*, *out='values_map'*)

Create a uv-texture map. | with specified angular resolution (°) and with positive z-axis as normal. | u corresponds to phi [0° - 360°] | v corresponds to theta [0° - 180°], (or [-90° - 90°])

Args:

theta

Float, int or ndarray

Angle with positive z-axis.

Values corresponding to 0 and 180° must be specified!

phi

None, optional

Float, int or ndarray

Angle around positive z-axis starting from x-axis.

If not None: values corresponding to 0 and 360° must be specified!

values

None

ndarray or mesh of values at (theta, phi) locations.

input_types

('array','array'), optional

Specification of type of input of (angles,values)

method

'linear', optional

Interpolation method.

(supported scipy.interpolate.griddata methods:

'nearest', 'linear', 'cubic')

theta_min

0, optional

If 0: [0, 180]; If -90: theta range = [-90,90]

close_phi

False, optional

Make phi angles array closed (full circle).

angle_res

1, optional

Resolution in degrees.

deg

True, optional

Type of angle input (True: degrees, False: radians).

r

1, optional

Float, int or ndarray

radius

show

True, optional

Plot results.

out

'values_map', optional

Specifies output: "return eval(out)"

Returns:

returns

as specified by :out:.

`luxpy.toolboxes.iolidfiles.`**`save_texture`**(*filename*, *tex*, *bits=16*, *transpose=True*)

Save 16 bit grayscale PNG image of uv-texture.

Args:

filename

Filename of output image.

tex

ndarray float uv-texture.

transpose

True, optional

If True: transpose tex (u,v) to set u as columns and v as rows

in texture image.

Returns:

None

Note:

Texture is rescaled to max = 1 and saved as uint16.

–> Before using uv_map: rescale back to set 'normal' to 1.

luxpy.toolboxes.iolidfiles.**draw_lid**(*LID*, *grid_interp_method='linear'*, *theta_min=0*, *angle_res=1*, *ax=None*, *projection='2d'*, *polar_plot_Cx_planes=[0, 90]*, *use_scatter_plot=False*, *plot_colorbar=True*, *legend_on=True*, *plot_luminaire_position=True*, *plot_diagram_top=0.001*, *out='ax'*, ***plottingkwargs*)

Draw the light intensity distribution.

Args:

LID

dict with IES or LDT file data.
(obtained with iolidfiles.read_lamp_data())

grid_interp_method

'linear', optional
Interpolation method for (theta,phi)-grid of normalized luminous intensity values.
(supported scipy.interpolate.griddata methods:
'nearest', 'linear', 'cubic')

theta_min

0, optional
If 0: [0, 180]; If -90: theta range = [-90,90]

angle_res

1, optional
Resolution in degrees.

ax

None, optional
If None: create new 3D-axes for plotting.

projection

'2d', optional
If '3d' make 3 plot
If '2d': make polar plot(s). [not yet implemented (25/03/2021)]

polar_plot_Cx_planes

[0,90], optional
Plot (Cx)-(Cx+180) planes; eg. [0,90] will plot C0-C180 and C90-C270 planes in 2D polar plot.

use_scatter_plot

False, optional
If True: use plt.scatter for plotting intensity values in 3D plot.
If False: use plt.plot_surface for plotting in 3D plot.

plot_colorbar

True, optional
Plot colorbar representing the normalized luminous intensity values in the LID 3D plot.

legend_on

True, optional
If True: plot legend on polar plot (no legend for 3D plot!).

plot_luminaire_position

True, optional
Plot the position of the luminaire (0,0,0) in the 3D graph as a red diamond.

plot_diagram_top

1e-3, optional
Plot the top of the polar diagram (True).
If None: automatic detection of non-zero intensity values in top part.
If float: automatic detection of intensity values larger than max__intensity*float in top part.
(if smaller: don't plot top.)

out

'ax', optional
string with variable to return
default: ax handle to plot.

Returns:

returns

Whatever requested as determined by the string in :out:

luxpy.toolboxes.iolidfiles.**render_lid**(*LID='./data/luxpy_test_lid_file.ies'*, *sensor_resolution=100*, *sensor_position=[0, -1, 0.8]*, *sensor_n=[0, 1, -0.2]*, *fov=(90, 90)*, *Fd=2*, *luminaire_position=[0, 1.3, 2]*, *luminaire_n=[0, 0, -1]*, *wall_center=[0, 2, 1]*, *wall_n=[0, -1, 0]*, *wall_width=4*, *wall_height=2*, *wall_rho=1*, *floor_center=[0, 1, 0]*, *floor_n=[0, 0, 1]*, *floor_width=4*, *floor_height=2*, *floor_rho=1*, *grid_interp_method='linear'*, *angle_res=5*, *theta_min=0*, *ax3D=None*, *ax2D=None*, *join_axes=True*, *legend_on=True*, *plot_luminaire_position=True*, *plot_lumiaire_rays=False*, *plot_luminaire_lid=True*, *plot_sensor_position=True*, *plot_sensor_pixels=True*, *plot_sensor_rays=False*, *plot_wall_edges=True*, *plot_wall_luminance=True*, *plot_wall_intersections=False*, *plot_floor_edges=True*, *plot_floor_luminance=True*, *plot_floor_intersections=False*, *out='Lv2D'*)

Render a light intensity distribution.

Args:

LID

dict with IES or LDT file data or string with path/filename;
or String or StringIO object with IES or LDT data.
(dict should be obtained with iolidfiles.read_lamp_data())

sensor_resolution

100, optional
Number of sensor 'pixels' along each dimension.

sensor_position

[0,-1,0.8], optional
x,y,z position of the sensor 'focal' point (is located Fd meters behind actual sensor plane)

sensor_n

[0,1,-0.2], optional
Sensor plane surface normal

fov

(90,90), optional

Field of view of sensor image in degrees.

Fd

2, optional
'Focal' distance in meter. Sensor center is located Fd meter away from
:sensor_position:

luminaire_position

[0,1.3,2], optional
x,y,z position of the photometric equivalent point source

luminaire_n

[0,0,-1], optional
Orientation of lumaire LID (default points downward along z-axis away from source)

wall_center

[0,2,1], optiona
x,y,z position of the back wall

wall_n

[0,-1,0], optional
surface normal of wall

wall_width

4, optional
width of wall (m)

wall_height

2, optional
height of wall (m)

wall_rho

1, optional
Diffuse (Lambertian) reflectance of wall.

floor_center

[0,1,0], optiona
x,y,z position of the floor

floor_n

[0,0,1], optional
surface normal of floor

floor_width

4, optional
width of floor (m)

floor_height

2, optional
height of floor (m)

floor_rho

1, optional
Diffuse (Lambertian) reflectance of floor.

grid_interp_method

'linear', optional
Interpolation method for (theta,phi)-grid of normalized luminous intensity values.

(supported scipy.interpolate.griddata methods:
'nearest', 'linear', 'cubic')

theta_min

0, optional
If 0: [0, 180]; If -90: theta range = [-90,90]
Only used when generating a plot of the LID in the 3D graphs.

angle_res

1, optional
Angle resolution in degrees of LID sampling.
Only used when generating a plot of the LID in the 3D graphs.

ax3D,ax2D

None, optional
If None: create new 3D- or 2D- axes for plotting.
If join_axes == True: try and combine two axes on same figure.
If False: don't plot..

legend_on

False, optional
plot legend.

plot_luminaire_position

True, optional
Plot the position of the luminaire (0,0,0) in the graph as a red diamond.

plot_X...

VArious options to customize plotting. Mainly allows for plotting of
additional info such as plane-ray intersection points, sensor pixels,
sensor-to-plane rays, plane-to-luminaire rays, 3D plot of LID, etc.

out

'Lv2D', optional
string with variable to return
default: variable storing an grayscale image of the rendered LID.

Returns:

returns

Whatever requested as determined by the string in :out:

luxpy.toolboxes.iolidfiles.**luminous_intensity_to_luminous_flux**(*phis*, *thetas*, *I*, *interp=False*, *dp=1*, *dt=1*, *use_RBFInterpolator=True*)

Calculate luminous flux from luminous intensity values.

Args:

phis

Array [N,] of Phi angles in degrees for which intensity values are available.

thetas

Array [M,] of Theta angles in degrees for which intensity values are available.

I

Array [N,M] of luminous intensity values (in cd).

interp

False, optional

If True interpolate I for new phis [0,360] with :dp: spacing and new thetas [0,360] with :dt: spacing

dp

Angle spacing of new phi angles upon interpolation.

dt

Angle spacing of new theta angles upon interpolation.

use_RBFInterpolator

If True: use slower more smooth scipy.interpolate.RBFInterpolator
If False: use scipy.interpolate.LinearNDInterpolator

Returns:

flux

Luminous flux (in lm).

4.5.8 spectro/

py

- __init__.py
- spectro.py

namespace
luxpy.spectro

Package for spectral measurements

Supported devices:

- JETI: specbos 1211, etc.
- OceanOptics: QEPro, QE65Pro, QE65000, USB2000, USB650,etc.

get_spd()
wrapper function to measure a spectral power distribution using a spectrometer of one of the supported manufacturers.

Notes

1. For info on the input arguments of get_spd(), see help for each identically named function in each of the sub-packages.
2. The use of jeti spectrometers requires access to some dll files (delivered with this package).
3. The use of oceanoptics spectrometers requires the manual installation of pyseabreeze, as well as some other 'manual' settings. See help for oceanoptics sub-package.

`luxpy.toolboxes.spectro.init(`*manufacturer*`)`

Import module for specified manufacturer. Make sure everything (drivers, external packages, ...) required is installed!

luxpy.toolboxes.spectro.**get_spd**(*manufacturer='jeti'*, *dvc=0*, *Tint=0*, *autoTint_max=None*, *close_device=True*, *out='spd'*, ***kwargs*)

Measure a spectral power distribution using a spectrometer of one of the supported manufacturers.

Args:

manufacturer

'jeti' or 'oceanoptics', optional
Manufacturer of spectrometer (ensures the correct module is loaded).

dvc

0 or int or spectrometer handle, optional
If int: function will try to initialize the spectrometer to
obtain a handle. The int represents the device
number in a list of all detected devices of the manufacturer.

Tint

0 or Float, optional
Integration time in seconds. (if 0: find best integration time, but < autoTint_max).

autoTint_max

Limit Tint to this value when Tint = 0.

close_device

True, optional
Close spectrometer after measurement.
If 'dvc' not in out.split(','): always close!!!

out

"spd" or e.g. "spd,dvc,Errors", optional
Requested return.

kwargs

For info on additional input (keyword) arguments of get_spd(),
see help for each identically named function in each of the subpackages.

Returns:

spd

ndarray with spectrum. (row 0: wavelengths, row1: values)

dvc

Device handle, if succesfull open (_ERROR: failure, nan: closed)

Errors

Dict with error messages.

4.5.9 sherbrooke_spectral_indices/

py

- __init__.py
- sherbrooke_spectral_indices_2013.py

namespace

luxpy.sherbrooke_spectral_indices

Module for the calculation of the Melatonin Suppression Index (MSI), the Induced Photosynthesis Index (IPI) and the Star Light Index (SLI) ——————————————————————————

spd_to_msi()
calculate Melatonin Suppression Index from spectrum.

spd_to_ipi()
calculate Induced Photosynthesis Index from spectrum.

spd_to_sli()
calculate Star Light Index from spectrum.

References:

1. Aubé M, Roby J, Kocifaj M (2013) Evaluating Potential Spectral Impacts of Various Artificial Lights on Melatonin Suppression, Photosynthesis, and Star Visibility. PLoS ONE 8(7): e67798 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0067798

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@author: ksmet1977 [at] gmail dot com

luxpy.toolboxes.sherbrooke_spectral_indices.**spd_to_msi**(*spd*, *force_5nm_interval=True*)

Calculate Melatonin Suppression Index from spectrum.

Args:

spd

ndarray with spectral data (first row are wavelengths)

force_5nm_interval

True, optional

If True: interpolate spd to 5nm wavelengths intervals, else: keep as in spd.

Returns:

msi

ndarray with Melatonin Suppression Index values for each input spectrum.

luxpy.toolboxes.sherbrooke_spectral_indices.**spd_to_ipi**(*spd*, *force_5nm_interval=True*)

Calculate Induced Photosynthesis Index from spectrum.

Args:

spd

ndarray with spectral data (first row are wavelengths)

force_5nm_interval

True, optional

If True: interpolate spd to 5nm wavelengths intervals, else: keep as in spd.

Returns:

msi

ndarray with Induced Photosynthesis Index values for each input spectrum.

luxpy.toolboxes.sherbrooke_spectral_indices.**spd_to_sli**(*spd*, *force_5nm_interval=True*)

Calculate Star Light Index from spectrum.

Args:

spd

ndarray with spectral data (first row are wavelengths)

force_5nm_interval

True, optional

If True: interpolate spd to 5nm wavelengths intervals, else: keep as in spd.

Returns:

msi

ndarray with Star Light Index values for each input spectrum.

4.5.10 spectral_mismatch_and_uncertainty/

py

- __init__.py
- detector_spectral_mismatch.py

namespace
luxpy.spectral_mismatch_and_uncertainty

Toolbox for spectral mismatch and measurement uncertainty calculations

spectral_mismatch_and_uncertainty/detector_spectral_mismatch.py

f1prime()
Determine the f1prime spectral mismatch index.

get_spectral_mismatch_correct_factors()
Determine the spectral mismatch factors.

Reference

1. Krüger, U. et al. GENERAL V() MISMATCH - INDEX HISTORY, CURRENT STATE, NEW IDEAS (TechnoTeam)

Created on Tue Aug 31 10:46:02 2021

@author: ksmet1977 [at] gmail.com

luxpy.toolboxes.spectral_mismatch_and_uncertainty.**f1prime**(*s_detector*, *S_C='A'*, *cieobs='1931_2'*, *s_target_index=2*, *wlr=None*, *interp_kind='linear'*, *out='f1p'*)

Determine the f1prime spectral mismatch index.
Args:

s_detector

ndarray with detector spectral responsivity (first row = wavelengths)

S_C

'A', optional
Standard 'calibration' illuminant.
string specifying the illuminant to use from the luxpy._CIE_ILLUMINANTS dict
or ndarray with standard illuminant spectral data.

cieobs

'1931_2', optional
string with CIE standard observer color matching functions to use (from luxpy._CMF)
or ndarray with CMFs (s_target_index > 0)
or target spectral responsivity (s_target_index == 0)
(first row contains the wavelengths).

s_target_index

2, optional
if > 0: index into CMF set (1->'xbar', 2->'ybar'='Vlambda', 3->'zbar')
if == 0: cieobs is expected to contain an ndarray with the target spectral responsivity.

wlr

None, optional
Wavelength range (None, ndarray or [start, stop, spacing]).
If None: the wavelengths of the detector are used throughout.

interp_kind

'linear', optional
Interpolation type to use when interpolating function to specified wavelength range.

out

'f1p', optional
Specify requested output of function,
e.g. 'f1p,s_rel' also outputs the normalized target spectral responsitivity.

Returns:

f1p

ndarray (vector) with f1prime values for each of the spectral responsivities in s_detector.

luxpy.toolboxes.spectral_mismatch_and_uncertainty.**get_spectral_mismatch_correction_factors**(*S_Z*, *s_detector*, *S_C='A'*, *cieobs='1931_2*, *s_target_index=*, *wlr=None*, *interp_kind='linea*, *out='F'*)

Determine the spectral mismatch factors.

Args:

S_Z

ndarray with spectral power distribution of measured light source (first row = wavelengths).

s_detector

ndarray with detector spectral responsivity (first row = wavelengths)

S_C

'A', optional
Standard 'calibration' illuminant.
string specifying the illuminant to use from the luxpy._CIE_ILLUMINANTS dict
or ndarray with standard illuminant spectral data.

cieobs

'1931_2', optional
string with CIE standard observer color matching functions to use (from luxpy._CMF)
or ndarray with CMFs (s_target_index > 0)
or target spectral responsivity (s_target_index == 0)
(first row contains the wavelengths).

s_target_index

2, optional
if > 0: index into CMF set (1->'xbar', 2->'ybar'='Vlambda', 3->'zbar')
if == 0: cieobs is expected to contain an ndarray with the target spectral responsivity.

wlr

None, optional
Wavelength range (ndarray or [start, stop, spacing]).
If None: use the wavelength range of S_Z.

interp_kind

'linear', optional
Interpolation type to use when interpolating function to specified wavelength range.

out

'F', optional
Specify requested output of function,
e.g. 'F,f1p' also outputs the f1prime spectral mismatch index.

Returns:

F

ndarray with correction factors for each of the mesured spectra (rows)
and spectral responsivities in s_detector (columns).

4.5.11 technoteamlmk/

py

- __init__.py
- TechnoTeamLMK.py

namespace
luxpy.technoteamlmk

Created on Sat Nov 26 10:32:55 2022

@author: ksmet1977

luxpy.toolboxes.technoteamlmk.**get_labsoft_path**()

luxpy.toolboxes.technoteamlmk.**define_lens**(*lens_type*, *name*, *focusFactors=None*)

Define a technoteam lens

class luxpy.toolboxes.technoteamlmk.**lmkActiveX**(*camera*, *lens*, *focusfactor=None*, *autoscan=True*, *autoexposure=True*, *modfrequency=60*, *maxtime=10*, *labsoft_camera_path='C:/TechnoTeam/LabSoft/Camera/'*, *verbosity=None*)

Class for TechnoTeam LMK camera basic control

All supported camera/lens combinations are defined in: _CAMERAS To add new ones (or new lenses): edit the_CAMERAS dict

lmk = None

```
verbosity_levels = {0:  'none', 1:  'minimal', 2:  'moderate (default)', 3:
'Detailed', 4:  'All'}

workingImage = None

errorFlag = None

colorSpace = {'C*h*_ab':  2048, 'C*h*s*_uv':  512, 'CIE-RGB': 1, 'EBU-RGB': 4,
'HSI': 8192, 'HSV': 4096, 'L*a*b*':  1024, 'L*u*v*':  256, 'LWS': 65536, 'Lrg':
32768, 'Lu_v_':  128, 'Luv':  64, 'Lxy':  32, 'S-RGB': 2, 'WST': 16384, 'XYZ': 16}

imageType = {'Camera':  -3, 'Color':  -1, 'Evaluation[1]':  0, 'Evaluation[2]':  1,
'Evaluation[3]':  2, 'Evaluation[4]':  3, 'Evaluation[5]':  4, 'Luminance':  -2}

regionType = {'AND': {'identifier':  9, 'points':  2}, 'Circle':  {'identifier':  2,
'points':  2}, 'CircularRing':  {'identifier':  6, 'points':  3}, 'Ellipse':
{'identifier':  5, 'points':  3}, 'Line':  {'identifier':  1, 'points':  2}, 'OR':
{'identifier':  7, 'points':  2}, 'Polygon':  {'identifier':  3, 'points':  3},
'Polyline':  {'identifier':  4, 'points':  3}, 'Rectangle':  {'identifier':  0,
'points':  2}, 'XOR': {'identifier':  8, 'points':  2}}

statisticType = {'bitHistogramGrey':  6, 'bitHistorgramColor':  7,
'chromaticityAreaColor':  33, 'chromaticityLineColor':  31, 'contrastGrey':  40,
'histogramColor':  5, 'histogramGrey':  4, 'integralColor':  23, 'integralGrey':
22, 'integralNegativeColor':  38, 'integralNegativeGrey':  36, 'lightArcGrey':  26,
'luminanceGrey':  20, 'projectionColor':  9, 'projectionGrey':  8, 'sectionalColor':
3, 'sectionalGrey':  2, 'spiralWoundGrey':  28, 'standardColor':  1, 'standardGrey':
0, 'symbolColor':  25, 'symbolGrey':  24, 'symbolNegativeColor':  39,
'threeDviewGrey':  34}

captureStartRatio = 10

captureMaxTries = 3

captureFactor = 3

captureCountPic = 1

captureDefaultMaxTries = 3

boolStr = ['False', 'True']
```

camera = {'ttf8847': {'lenses': {'x12mm': {'focusFactors': {'TTScale0_3': 0, 'TTScale0_5': 1, 'TTScale1': 2, 'TTScale3': 3, 'TTScaleInfinite': 4}, 'name': 'o95653f12'}, 'x25mm': {'focusFactors': {'TTScale00': 0, 'TTScale01': 1, 'TTScale02': 2, 'TTScale03': 3, 'TTScale04': 4, 'TTScale05': 5, 'TTScale06': 6, 'TTScale07': 7, 'TTScale08': 8, 'TTScale09': 9, 'TTScale10': 10, 'TTScale11': 11, 'TTScale12': 12, 'TTScale13': 13, 'TTScale14': 14, 'TTScale15': 15, 'TTScale16': 16, 'TTScale17': 17, 'TTScale18': 18, 'TTScale19': 19}, 'name': 'oB225463f25'}, 'x50mm': {'focusFactors': {'TTScale00': 0, 'TTScale01': 1, 'TTScale02': 2, 'TTScale03': 3, 'TTScale04': 4, 'TTScale05': 5, 'TTScale06': 6, 'TTScale07': 7, 'TTScale08': 8, 'TTScale09': 9, 'TTScale10': 10, 'TTScale11': 11, 'TTScale12': 12, 'TTScale13': 13, 'TTScale14': 14, 'TTScale15': 15, 'TTScale16': 16, 'TTScale17': 17, 'TTScale18': 18, 'TTScale19': 19}, 'name': 'oC216813f50'}, 'x6_5mm': {'name': 'o13196f6_5'}}, 'name': 'ttf8847'}, 'tts20035': {'lenses': {'x12f50mm_2mm': {'name': 'oTTNED-12_50_2mmEP'}, 'x12f50mm_4mm': {'name': 'oTTNED-12_50_4mmEP'}, 'x12mm_TTC_163': {'name': 'oTTC-163_D0224'}, 'x50mm_M00442': {'focusFactors': {'TTScale00': 0, 'TTScale01': 1, 'TTScale02': 2, 'TTScale03': 3, 'TTScale04': 4, 'TTScale05': 5, 'TTScale06': 6, 'TTScale07': 7, 'TTScale08': 8, 'TTScale09': 9, 'TTScale10': 10, 'TTScale11': 11, 'TTScale12': 12, 'TTScale13': 13, 'TTScale14': 14, 'TTScale15': 15, 'TTScale16': 16, 'TTScale17': 17, 'TTScale18': 18, 'TTScale19': 19, 'TTScale20': 20, 'TTScale21': 21, 'TTScale22': 22, 'TTScale23': 23}, 'name': 'oM00442f50'}, 'xvr': {'name': 'oTTC-163_D0224'}}, 'name': 'tts20035'}}

verbosity = 2

classmethod show_labsoft_gui(*show=3*)

classmethod open_lmk_labsoft_connection(*objectiveCalibrationPath=None*, *show_gui=3*)

Initializes a connection to LMK LabSoft.

Input:

- objectiveCalibrationPath: path to calibration file

Output:

- answer: 0=no error, other=error code

classmethod close_lmk_labsoft_connection(*open_dialog=0*)

Closes the connection to LMK LabSoft and LabSoft itself.

Input:

- **open_dialog:**

  If 0: | No dialog window. Else: | Opens a dialog window in the Labsoft application. The user can choose whether they wish to save the current state or not or or cancel the closing of LabSoft.

Output:

- answer: 0=no error, other=error code

classmethod delete(*open_dialog=0*)

Delete lmk class object (close connection to labsoft)

classmethod setWorkingImage(*w*)

Set the current working image

classmethod display_error_info(*err_code*, *process_id=''*)

Get the info for err_code and print

classmethod get_filter_wheel_info()

Get max. number of filter wheels and their names.

classmethod measureColorMultipic(*countPic=None*, *defaultMaxTries=None*)

Capture a ColorMultiPicture

classmethod saveImage(*folderXYZ*, *fileNameXYZ*)

Save the captured image currently as workingImage to the specified file and folder

classmethod loadImage(*pathXYZ*)

Load a previously captured image from a specific path

classmethod getStatistic(*statisticType*, *regionName*, *colorSpace*)

Get Cmin, Cmax, Cmean, Cvar for specified colorSpace for a specific region

classmethod get_color_autoscan_times()

classmethod capture_X_map(*folder*, *fileName*, *X_type='XYZ'*, *startRatio=None*, *factor=None*, *countPic=None*, *defaultMaxTries=None*, *autoscan=None*, *autoexposure=None*, *modfrequency=None*, *maxtime=None*)

Measure XYZ / Y image and save as .pcf / .pf image. (parameters as set in class attributes)

classmethod captureXYZmap(*folderXYZ*, *fileNameXYZ*, *startRatio=None*, *factor=None*, *countPic=None*, *defaultMaxTries=None*, *autoscan=None*, *autoexposure=None*, *modfrequency=None*, *maxtime=None*)

Measure XYZ image and save as .pcf image. (parameters as set in class attributes)

classmethod captureYmap(*folderY*, *fileNameY*, *startRatio=None*, *factor=None*, *countPic=None*, *defaultMaxTries=None*, *autoscan=None*, *autoexposure=None*, *modfrequency=None*, *maxtime=None*)

Measure Y image and save as .pf image. (parameters as set in class attributes)

classmethod createEllips(*centerPt*, *width*, *height*, *regionName*)

Create an ellips with a: | - centerPoint defined by centerPt (contains x and y value) | - certain width (horizontal axis) | - certain height (vertical axis) | - give the ellips region a regionName (string)

Function returns the regionIndex of the ellips

classmethod createPolygon(*pointsXY*, *regionName*)

Create a polygon with: | - vertices specified in pointsXY (x->width, y->height) | - give the polygon region a regionName (string)

Function returns the regionIndex of the polygon

classmethod createRectangle(*topleftXY*, *bottomrightXY*, *regionName*)

Create a Rectangle spanning: | - the top-left and bottom-right vertices | - give the rectangle region a regionName (string)

Function returns the regionIndex of the rectangle

classmethod deleteRegionByName(*regionName*)

Delete a Region by regioName

classmethod getRegionIndexByName(*regionName*)

Return the index of a region with a region name set to regionName.

classmethod createStatisticObjectOfRegion(*regionName*, *statisticType*)

Create a color statistic object | call as follows: createStatisticObjectOfRegion('regionTestName',statisticType['standardColor'])

classmethod selectRegionByIndex(*ind*, *s*)

Select a region by its index number s defines wether the region is selected or deselected (true or false)

classmethod selectRegionByName(*regionName*, *s*)

Select a region by its region name, s defines wether the region is selected or deselected (true or false)

classmethod setIntegrationTime(*wishedTime*)

Set integration time. | [int32, double] LMKAxServer::iSetIntegrationTime (double _dWishedTime, double & _drRealizedTime)

Parameters:

_dWishedTime
Wished integration time :_drRealizedTime: Realized integration time

classmethod getIntegrationTime()

Get integration time. | [int32, double, double, double, double, double] LMKAxServer::iGetIntegrationTime | (handle, double _drCurrentTime, double & _drPreviousTime, | double & _drNextTime, double & _drMinTime, double & _drMaxTime) | | Determine current exposure time and other time parameters.

Parameters:

_drCurrentTime
Current integration time

_drPreviousTime
Next smaller (proposed) time

_drNextTime
Next larger (proposed) time

_drMinTime
Minimal possible time

_drMaxTime
Maximal possible time

classmethod set_autoscan(*autoscan=None*)

Set auto scan.

If the option Autoscan is on, then the exposure time of the camera is automatically determined before each capture by the autoscan algorithm. In the case of a color capture the autoscan algorithm is applied to each color filter separately.

classmethod get_autoscan()

Get auto scan.

classmethod set_autoexposure(*autoexposure=None*)

Set Automatic-Flag for all exposure times.

If this flag is set, all exposure times will automatically adjusted if camera exposure time is reduced or enlarged.

classmethod get_autoexposure()

Get Automatic-Flag for all exposure times.

classmethod set_focusfactor(*focusfactor=None*)

Set focus factor of lens

classmethod get_focusfactor()

Get focus factor of lens

classmethod set_max_exposure_time(*maxtime=None*)

Set the maximum possible exposure time. | int LMKAxServer::iSetMaxCameraTime (double _dMaxCameraTime) | | The maximum values is of course restricted by camera properties. | But you can use an even smaller time to avoid to long meausrement times.

Parameters:

_dMaxCameraTime
Wished value

maxCameraTime

classmethod get_max_exposure_time()

Get the maximum possible exposure time.

classmethod set_mod_frequency(*modfrequency=None*)

Set the frequency of modulated light. | int LMKAxServer::iSetModulationFrequency (double _dModFrequency) | | If the light source is driven by alternating current, | there are some restriction for the exposure times. | Please inform the program about the modulation frequency.

Parameters:

_dModFrequency
Frequency of light source. 0 if no modulation is to be concerend

classmethod get_mod_frequency()

Get the frequency setting of modulated light.

classmethod init()

init lmk ActiveX

classmethod set_converting_units(*units_name='L'*, *units='cd/m^2'*, *units_factor=1*)

Set the converting units (units_name, units, units_factor)

classmethod get_converting_units()

Get the converting units (units_name, units, units_factor)

classmethod set_verbosity(*value*)

classmethod checkForError()

luxpy.toolboxes.technoteamlmk.**kill_lmk4_process**(*verbosity=1*)

luxpy.toolboxes.technoteamlmk.**read_pcf**(*fname*)

Read a TechnoTeam PCF image. (!!! output = float32 CIE-RGB !!!)

luxpy.toolboxes.technoteamlmk.**write_pcf**(*fname*, *data*)

Write a basic TechnoTeam PCF image. (!!! output = float32 CIE-RGB !!!)

luxpy.toolboxes.technoteamlmk.**plot_pcf**(*img*, *to_01_range=True*, *ax=None*)

Plot a TechnoTeam PCF image.

luxpy.toolboxes.technoteamlmk.**pcf_to_xyz**(*pcf_image*)

Convert a TechnoTeam PCF image to XYZ

luxpy.toolboxes.technoteamlmk.**xyz_to_pcf**(*xyz*)

Convert an xyz image to a TechnoTeam PCF

luxpy.toolboxes.technoteamlmk.**ciergb_to_xyz**(*rgb*)

Convert CIE-RGB to XYZ

luxpy.toolboxes.technoteamlmk.**xyz_to_ciergb**(*xyz*)

Convert XYZ to CIE-RGB

class luxpy.toolboxes.technoteamlmk.**Defisheye**(*infile*, ***kwargs*)

fov: fisheye field of view (aperture) in degrees pfov: perspective field of view (aperture) in degrees xcenter: x center of fisheye area ycenter: y center of fisheye area radius: radius of fisheye area angle: image rotation in degrees clockwise dtype: linear, equalarea, orthographic, stereographic format: circular, fullframe

_map(*i*, *j*, *ofocinv*, *dim*)

convert(*image=None*, *outfile=None*)

_start_att(*vkwargs*, *kwargs*)

Starting atributes

4.5.12 stereoscopicviewer/

py

- __init__.py
- /harfang/
- harfang_viewer.py

namespace

luxpy.stereoscopicviewer

luxpy.toolboxes.stereoscopicviewer.**CreateSphereModel**(*decl: ~.VertexLayout = None*, *radius: float = 1*, *subdiv_x: int = 256*, *subdiv_y: int = 256*, *flip_normals=False*)

Create a Sphere Model.

Args:

decl

VertexLayout declaration
If None: the following is created: PosFloatNormalFloatTexCoord0Float
(if using texture images: this is the one that is required)

radius

1, optional
Radius of sphere

subdiv_x

256, optional
Number of subdivisions along sphere axis

subdiv_y

256, optional
Number of subdivision along sphere circumference.

flip_normals

False, optional
If True: flip the direction of the normals of the vertices.

Returns:

Model

Harfang Sphere Model

luxpy.toolboxes.stereoscopicviewer.**CreatePlaneModel**(*decl: ~.VertexLayout = None*, *width: float = 1*, *height: float = 1*, *subdiv_x: int = 256*, *subdiv_y: int = 256*, *flip_normals=False*)

Create a Plane (Quad) Model.

Args:

decl

VertexLayout declaration

If None: the following is created: PosFloatNormalFloatTexCoord0Float

(if using texture images: this is the one that is required)

width

1, optional

Width of plane

height

1, optional

height of plane

subdiv_x

256, optional

Number of subdivisions along plane height

subdiv_y

256, optional

Number of subdivision along plane width.

flip_normals

False, optional

If True: flip the direction of the normals of the vertices.

Returns:

Model

Harfang Plane Model

luxpy.toolboxes.stereoscopicviewer.**create_material**(*prg_ref*, *res*, *ubc=None*, *orm=None*, *slf=None*, *tex=None*, *blend_mode=5*, *faceculling=2*)

Create a Harfang material with specified color and texture properties.

Args:

prg_ref

shader program from assets (ref)

res

resources

ubc

uBaseOpacityColor

orm

uOcclusionRoughnessMetalnessColor

slf

uSelfColor

tex

uSelfMap texture (if not None: any color input is ignored !)

blendmode

hg.BM_Opaque, optional

Blend mode

faceculling

hg.FC_CounterClockwise

Sets face culling (hg.FC_CounterClockwise, hg.FC_Clockwise, hg.FC_Disabled)

Returns:

mat

Harfang material (note that material program variant has been updated accordingly; see: hg.UpdateMaterialPipelineProgramVariant)

luxpy.toolboxes.stereoscopicviewer.**update_material_texture**(*node*, *res*, *tex*, *mat_idx=0*, *name='uSelfMap'*, *stage=4*, *texListPreloaded=None*)

Update the texture of a Harfang material.

Args:

node

Node to which material belongs

res

Pipeline resources

tex

New texture

mat_idx

0, optional

index of material in material table of object

name

"uSelfMap", optional

name of material type (depends on shader used; the default is for the pbr shader)

stage

4, optional

Render stage: depends on features, shader, … (see "writing a pipeline shader" in Harfang documentation)

texListPreloaded

None, optional

List with preloaded textures (to speed up texture update as it doesn't need to be read from file anymore while looping over frames)

Returns:

mat

Harfang material (note that material program variant has been updated accordingly; see: hg.UpdateMaterialPipelineProgramVariant)

luxpy.toolboxes.stereoscopicviewer.**makeColorTex**(*color*, *texHeight=100*, *texWidth=100*, *save=None*)

Make a full single-color texture.

Args:

color

uint8 RGB(A; ignored) color

texHeight,texWidth

Height and width of texture

save

None, optional
File path to save texture to.
If not None: save texture in supplied filepath.

Returns:

text

numpy ndarray with RGB texture.

luxpy.toolboxes.stereoscopicviewer.**split_SingleSphericalTex**(*file*, *left_layout_pos='bottom'*)

Split Image into left eye and right eye subimages

Args:

file

Image file path

left_layout_pos

Position of left eye sub-image in image specified in file.
options: 'bottom', 'top', 'left', 'right', None
If None: there is no left and right subimage in
the image specified in filePath -> don't split

Returns:

file_L, file_R

filepaths to left and right eye sub-images
(each indicated respectively by '_L', '_R' appended to the filename.)

class luxpy.toolboxes.stereoscopicviewer.**Shader**(*resources*, *assetPath='core/shader/pbr.hps'*)

class luxpy.toolboxes.stereoscopicviewer.**Scene**(*canvasColorI=[0, 0, 0, 255]*, *ambientEnvColorI=[0, 0, 0, 0]*)

class luxpy.toolboxes.stereoscopicviewer.**Camera**(*scene*, *position=[0, 0, 0]*, *rotation=[0, 0, 0]*, *zNear=0.01*, *zFar=5000*, *fov=60*)

class luxpy.toolboxes.stereoscopicviewer.**Material**(*shader_prgRef*, *resources*, *uSelfMapTexture=None*, *uSelfMapTextureListPreloaded=None*, *uBaseOpacityColor=[1.0, 1.0, 1.0, 1.0]*, *uSelfColor=[1.0, 1.0, 1.0, 1.0]*, *uOcclusionRoughnessMetalnessColor=[0.0, 0.0, 0.0, 1.0]*, *blend_mode=5*, *faceculling=2*)

createMaterial(*uSelfMapTexture=None*, *uBaseOpacityColor=None*, *uSelfColor=None*, *uOcclusionRoughnessMetalnessColor=None*, *blend_mode=None*, *faceculling=None*)

Create a Harfang material with specified color and texture properties.

Args:

ubc

uBaseOpacityColor

orm

uOcclusionRoughnessMetalnessColor

slf

uSelfColor

tex

uSelfMap texture (if not None: any color input is ignored !)

blendmode

hg.BM_Opaque, optional
Blend mode

faceculling

hg.FC_CounterClockwise
Sets face culling (hg.FC_CounterClockwise, hg.FC_Clockwise, hg.FC_Disabled)

`LoadTexturesFromFiles`(*texFileList*, *return_type=<class 'list'>*)

Load textures specified in texFileList (return_type is either a list or dict)

class luxpy.toolboxes.stereoscopicviewer.**Screen**(*scene*, *shader_prgRef*, *resources*, *geometry='sphere'*, *aspect_ratio=[19, 16]*, *radius=4*, *subdiv_x=256*, *subdiv_y=256*, *uSelfMapTexture=None*, *uSelfMapTextureListPreloaded=None*, *uBaseOpacityColor=[1.0, 1.0, 1.0, 1.0]*, *uSelfColor=[1.0, 1.0, 1.0, 1.0]*, *uOcclusionRoughnessMetalnessColor=[0.0, 0.0, 0.0, 1.0]*, *blend_mode=5*, *position=[0, 0, 0]*, *rotation=[0, 0, 0]*)

`updateScreenMaterial`(*uSelfMapTexture=None*, *uSelfColor=None*, *uBaseOpacityColor=None*, *uOcclusionRoughnessMetalnessColor=None*, *blend_mode=None*)

Update Screen Material

Args:

uBaseOpacityColor

None, optional
uBaseOpacityColor

uOcclusionRoughnessMetalnessColor

None, optional
uOcclusionRoughnessMetalnessColor

uSelfColor

None, optional
uSelfColor

uSelfMapTexture

None, optional
uSelfMap texture (if not None: any color input is ignored !)

blend_mode

None, optional
Blend mode

Note:

- If None: defaults set at initialization are used.

`updateScreenMaterialTexture`(*uSelfMapTexture=None*, *uSelfMapTextureListPreloaded=None*)

Update the texture of the Harfang material.

Args:

uSelfMapTexture

New texture (string with filename)

uSelfMapTextureListPreloaded

None, optional

List with preloaded textures (to speed up texture update as it doesn't need to be read from file anymore while looping over frames)

class luxpy.toolboxes.stereoscopicviewer.**Eye**(*eye*, *vrFlag=True*, *shader_assetPath='core/shader/pbr.hps'*, *scene_canvasColorI=[0, 0, 0, 255]*, *scene_ambientEnvColorI=[0, 0, 0, 0]*, *cam_pos=[0, 0, 0]*, *cam_rot=[0, 0, 0]*, *cam_zNear=0.01*, *cam_zFar=100*, *cam_fov=60*, *screen_geometry='sphere'*, *screen_aspectRatio=1*, *screen_radius=10*, *screen_subdiv_x=256*, *screen_subdiv_y=256*, *screen_uSelfMapTexture=None*, *screen_uSelfMapTextureListPreloaded=None*, *screen_uBaseOpacityColor=[1.0, 1.0, 1.0, 1.0]*, *screen_uSelfColor=[1.0, 1.0, 1.0, 0]*, *screen_uOcclusionRoughnessMetalnessColor=[0.5, 0.0, 0.0, 1.0]*, *screen_blend_mode=5*, *screen_pos=[0, 0, 0]*, *screen_rot=[0, 0, 0]*)

updateScreenMaterial(*uSelfMapTexture=None*, *uBaseOpacityColor=None*, *uSelfColor=None*, *uOcclusionRoughnessMetalnessColor=None*, *blend_mode=None*)

Update Screen Material (see Screen.updateScreenMaterial.__doc__)

updateScreenMaterialTexture(*uSelfMapTexture=None*, *uSelfMapTextureListPreloaded=None*)

Update Screen MaterialTexture (see Screen.updtateScreenMaterialTexture.__doc__)

SceneForwardPipelinePassViewId_PrepareSceneForwardPipelineCommonRenderData(*vid=0*)

PrepareSceneForwardPipelineViewDependentRenderData_SubmitSceneToForwardPipeline(*vs*, *vr_eye_rect*, *isMainScreen=False*)

DestroyForwardPipeline()

class luxpy.toolboxes.stereoscopicviewer.**HmdStereoViewer**(*vrFlag=False*, *vsync=True*, *multisample=4*, *cam_fov=60*, *windowWidth=800*, *windowHeight=600*, *windowTitle='Harfang3d - Stereoscopic Viewer'*, *mainScreenIdx=0*, *screen_geometry='sphere'*, *screen_aspectRatio=[1, 1]*, *screen_radius=10*, *screen_subdiv_x=256*, *screen_subdiv_y=256*, *equiRectImageLeftPos='bottom'*, *equiRectImageLeftIsRight=False*, *screen_uSelfMapTexture=[None]*, *screen_uSelfMapTextureListPreloaded=[None]*, *screen_uBaseOpacityColor=[[1.0, 1.0, 1.0, 1.0]]*, *screen_uSelfColor=[[1.0, 1.0, 1.0, 1.0]]*, *screen_uOcclusionRoughnessMetalnessColor=[[0.0, 0.0, 0.0, 1.0]]*, *screen_blend_mode=5*, *screen_position=[0, 0, 0]*, *screen_rotation=[0, 0, 0]*, *pipeFcns=None*)

set_texture(*screen_uSelfMapTexture*, *equiRectImageLeftPos=None*, *equiRectImageLeftIsRight=None*, *screen_uSelfMapTextureListPreloaded=None*)

init_main()

Initialize Input and Window, add folder with compiled assets

shutdown()

Shutdown Pipelines for left and right eyes, Shutdown Render and destroy Window

updateScreenMaterial(*uSelfMapTexture=None*, *equiRectImageLeftIsRight=None*, *equiRectImageLeftPos=None*, *uBaseOpacityColor=None*, *uSelfColor=None*, *uOcclusionRoughnessMetalnessColor=None*, *blend_mode=None*)

Update Screen Material

Args:

uSelfMapTexture

None, optional

uSelfMap texture (if not None: any color input is ignored !)

equiRectImageLeftPos

'bottom', optional

Specifier for where in the texture image the left sub-image is located.

options: 'bottom', 'top', 'left', 'right', None

If None: there are no separate left/right sub-images in the texture image file.

equiRectImageLeftIsRight

False, optional

If True: the image for the left and right eye is the same.

uBaseOpacityColor

None, optional

uBaseOpacityColor

uOcclusionRoughnessMetalnessColor

None, optional

uOcclusionRoughnessMetalnessColor

uSelfColor

None, optional

uSelfColor

blend_mode

None, optional

Blend mode

Note:

- If None: defaults set at initialization are used.

updateScreenMaterialTexture(*uSelfMapTexture=None*, *equiRectImageLeftIsRight=None*, *equiRectImageLeftPos=None*, *uSelfMapTextureListPreloaded=None*)

Update the texture of the Harfang material.

Args:

uSelfMapTexture

New texture (string with filename)

equiRectImageLeftPos

'bottom', optional
Specifier for where in the texture image the left sub-image is located.
options: 'bottom', 'top', 'left', 'right', None
If None: there are no separate left/right sub-images in the texture image file.

equiRectImageLeftIsRight

False, optional
If True: the image for the left and right eye is the same.

uSelfMapTextureListPreloaded

None, optional
List with preloaded textures (to speed up texture update as it doesn't need to be read from file anymore while looping over frames)

`resetFrameNumber()`

Reset the frame number

`getFrameNumber()`

Get the current frame number

`display()`

Display the texture (first one from list, use run() to loop through all of them)

`run(`*pipeFcns=None*, *pipeFcnsUpdate=None*, *only_once=False*, *u_delay=None*, *a_delay=None*, *autoShutdown=True*`)`

Run through all textures specified at initialization (and do some action) .
Args:

pipeFcns

None, optional
list of piped functions, one executed after the other
If None: use the defaults. This will cause all textures
specified at initialization to be shown one after the other, with
delay time set by :delay:.
If not None: use this set of user-defined pipeFcns (see code for example use)

pipeFcnsUpdate

None, optional
Use this list or dictionary to update the pipeFcns specified by :pipeFcns:
This exists to keep e.g. the defaults but only change the 'action' part, e.g. to
do a measurement.

only_once

False, optional
If True: loop through the set of textures once and then stop and shutdown.

u_delay

None, optional
Delay in seconds for the update function in the pipeFcns.
This delays the initialization of the action function after
an update of the texture (e.g. to give some time display the update on the HMD)
If None: use whatever is set in the (default) pipeFcns update function.
Else override delay if update function as such a kwarg!

a_delay

None, optional

Delay in seconds for the action function in the pipeFcns.
This delays the update to the next texture after the action
has been started (e.g. to simulate some action duration)
If None: use whatever is set in the (default) pipeFcns action function.
Else override delay if action function as such a kwarg!

frame()

Run everything required to update a frame

generate_defaultPipeFcns(*pipeFcnDef=None*)

Generate default pipeline functions (if pipeFcnDef not None: use these)

luxpy.toolboxes.stereoscopicviewer.**generate_stimulus_tex_list**(*stimulus_list=None*, *equiRectImageLeftIsRight=False*, *equiRectImageLeftPos='bottom'*, *rgba_save_folder=None*)

Generate a list of textures Args:

stimulus_list

None or str or list, optional
If None: generate a preset list of rgb colors:
np.array([[1,0,0,1],[0,1,0,1],[0,0,1,1],[1,1,0,1],[1,0,1,1],[0,1,1,1]])*255
If str:
- filename of texture
- or, filename of .iml file with a list of filenames to textures
(first line in path should be: "path" followed by the path to the images in the file list)
If list:
- list of filenames to image textures.
(if not None: any color input is ignored !)
If ndarray with rgba stimuli :
- (equiRectImageLeftIsRight, equiRectImageLeftPos) will be updated to (True, None)
- texture files will be generated in folder

rgba_save_folder

Folder to save the generated full single-color textures in when stimulus_list is an ndarray or None.

Returns:

stimulus_list

list of stimuli file textures

(equiRectImageLeftIsRight, equiRectImageLeftPos)

- equiRectImageLeftIsRight: bool (left image = right image)
- equiRectImageLeftPos: string or None

luxpy.toolboxes.stereoscopicviewer.**generate_rgba_texs_iml**(*rgb*, *rgba_save_folder*)

Generate rgba texture images, save them in a folder and return a list of texFiles and a .iml file with the paths to the texFiles

luxpy.toolboxes.stereoscopicviewer.**get_rgbFromTexPaths**(*rgbatexFiles*)

Get rgb values read from the filenames of the tex-files

luxpy.toolboxes.stereoscopicviewer.**getRectMask**(*roi*, *shape*)

Get a boolean rectangular mask with mask-area determined by the (row,col) coordinates of the top-left & bottom-right corners of the ROI

luxpy.toolboxes.stereoscopicviewer.**getRoiImage**(*img*, *roi*)

luxpy.toolboxes.stereoscopicviewer.**get_xyz_from_xyzmap_roi**(*xyzmap*, *roi*)

Get xyz values of Region-Of-Interest in XYZ-map

luxpy.toolboxes.stereoscopicviewer.**get_rgb_from_rgbtexpath**(*path*)

Get rgb values from filename

CHAPTER

FIVE

INDICES AND TABLES

- genindex
- modindex
- search

PYTHON MODULE INDEX