python-colormath Documentation

Release 3.0.0

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python-colormath is a simple Python module that spares the user from directly dealing with color math. Some features include:

- Support for a wide range of color spaces. A good chunk of the CIE spaces, RGB, HSL/HSV, CMY/CMYK, and many more.
- *Conversions* between the various color spaces. For example, XYZ to sRGB, Spectral to XYZ, CIE Lab to Adobe RGB.
- Calculation of *color difference*. All CIE Delta E functions, plus CMC.
- Chromatic adaptations (changing illuminants).
- RGB to hex and vice-versa.
- 16-bit RGB support.
- Runs on Python 2.7 and Python 3.3+.

**License:** python-colormath is licensed under the BSD License.
CHAPTER 1

Assorted Info

• Issue tracker - Report bugs, ask questions, and share ideas here.
• GitHub project - Source code and issue tracking.
• @getaylor Twitter - Tweets from the maintainer.
• Greg Taylor's blog - Occasional posts about color math and software development.
2.1 Installation

python-colormath currently requires Python 2.7 or Python 3.3+. There are no plans to add support for earlier versions of Python 2 or 3. The only other requirements are NumPy and networkx.

For those on Linux/Unix Mac OS, the easiest route will be pip or easy_install:

```
pip install colormath
```

If you are on Windows, you’ll need to visit NumPy, download their binary distribution, then install colormath.

2.2 Color Objects

python-colormath has support for many of the commonly used color spaces. These are represented by Color objects.
2.2.1 SpectralColor

class colormath.color_objects.SpectralColor(
    spec_340nm=0.0, spec_350nm=0.0,
    spec_360nm=0.0, spec_370nm=0.0,
    spec_380nm=0.0, spec_390nm=0.0,
    spec_400nm=0.0, spec_410nm=0.0,
    spec_420nm=0.0, spec_430nm=0.0,
    spec_440nm=0.0, spec_450nm=0.0,
    spec_460nm=0.0, spec_470nm=0.0,
    spec_480nm=0.0, spec_490nm=0.0,
    spec_500nm=0.0, spec_510nm=0.0,
    spec_520nm=0.0, spec_530nm=0.0,
    spec_540nm=0.0, spec_550nm=0.0,
    spec_560nm=0.0, spec_570nm=0.0,
    spec_580nm=0.0, spec_590nm=0.0,
    spec_600nm=0.0, spec_610nm=0.0,
    spec_620nm=0.0, spec_630nm=0.0,
    spec_640nm=0.0, spec_650nm=0.0,
    spec_660nm=0.0, spec_670nm=0.0,
    spec_680nm=0.0, spec_690nm=0.0,
    spec_700nm=0.0, spec_710nm=0.0,
    spec_720nm=0.0, spec_730nm=0.0,
    spec_740nm=0.0, spec_750nm=0.0,
    spec_760nm=0.0, spec_770nm=0.0,
    spec_780nm=0.0, spec_790nm=0.0,
    spec_800nm=0.0, spec_810nm=0.0,
    spec_820nm=0.0, spec_830nm=0.0,
    observer='2', illuminant='d50')

Bases: colormath.color_objects.IlluminantMixin, colormath.color_objects.ColorBase

A SpectralColor represents a spectral power distribution, as read by a spectrophotometer. Our current implementation has wavelength intervals of 10nm, starting at 340nm and ending at 830nm.

Spectral colors are the lowest level, most “raw” measurement of color. You may convert spectral colors to any other color space, but you can’t convert any other color space back to spectral.

See Spectral power distribution on Wikipedia for some higher level details on how these work.

Parameters

- **observer** (str) – Observer angle. Either ‘2’ or ‘10’ degrees.
- **illuminant** (str) – See Observers and Illuminants for valid values.

calc_density(density_standard=None)

Calculates the density of the SpectralColor. By default, Status T density is used, and the correct density distribution (Red, Green, or Blue) is chosen by comparing the Red, Green, and Blue components of the spectral sample (the values being red in via “filters”).

get_illuminant_xyz(observer=None, illuminant=None)

Parameters

- **observer** (str) – Get the XYZ values for another observer angle. Must be either ‘2’ or ‘10’.
- **illuminant** (str) – Get the XYZ values for another illuminant.

Returns the color’s illuminant’s XYZ values.
get_numpy_array()
Dump this color into NumPy array.

get_value_tuple()
Returns a tuple of the color’s values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

set_illuminant(illuminant)
Validates and sets the color’s illuminant.

Note: This only changes the illuminant. It does no conversion of the color’s coordinates. For this, you’ll want to refer to XYZColor.apply_adaptation.

Tip: Call this after setting your observer.

Parameters illuminant (str) – One of the various illuminants.

set_observer(observer)
Validates and sets the color’s observer angle.

Note: This only changes the observer angle value. It does no conversion of the color’s coordinates.

Parameters observer (str) – One of ‘2’ or ‘10’.

illuminant = None
The color’s illuminant. Set with set_illuminant().

observer = None
The color’s observer angle. Set with set_observer().

2.2.2 LabColor

class colormath.color_objects.LabColor(lab_l, lab_a, lab_b, observer='2', illuminant='d50')
Bases: colormath.color_objects.IlluminantMixin, colormath.color_objects.ColorBase

Represents a CIE Lab color. For more information on CIE Lab, see Lab color space on Wikipedia.

Parameters

• lab_l (float) – L coordinate.
• lab_a (float) – a coordinate.
• lab_b (float) – b coordinate.
• observer (str) – Observer angle. Either ’2′ or ’10′ degrees.
• illuminant (str) – See Observers and Illuminants for valid values.

get_illuminant_xyz(observer=None, illuminant=None)
• **observer** *(str)* – Get the XYZ values for another observer angle. Must be either ‘2’ or ‘10’.

• **illuminant** *(str)* – Get the XYZ values for another illuminant.

    **Returns**  the color’s illuminant’s XYZ values.

**get_value_tuple()**

Returns a tuple of the color’s values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

**set_illuminant**(illuminant)

Validates and sets the color’s illuminant.

**Note:** This only changes the illuminant. It does no conversion of the color’s coordinates. For this, you’ll want to refer to `XYZColor.apply_adaptation`.

**Tip:** Call this after setting your observer.

**Parameters illuminant** *(str)* – One of the various illuminants.

**set_observer**(observer)

Validates and sets the color’s observer angle.

**Note:** This only changes the observer angle value. It does no conversion of the color’s coordinates.

**Parameters observer** *(str)* – One of ‘2’ or ‘10’.

**illuminant = None**

The color’s illuminant. Set with `set_illuminant()`.

**lab_a = None**

a coordinate

**lab_b = None**

b coordinate

**lab_l = None**

L coordinate

**observer = None**

The color’s observer angle. Set with `set_observer()`.

### 2.2.3 LCHabColor

**class** colormath.color_objects.LCHabColor(lch_l, lch_c, lch_h, observer='2', illuminant='d50')

**Bases:**  colormath.color_objects.IlluminantMixin, colormath.color_objects.ColorBase

Represents an CIE LCH color that was converted to LCH by passing through CIE Lab. This differs from `LCHuvColor`, which was converted to LCH through CIE Luv.

See Introduction to Colour Spaces by Phil Cruse for an illustration of how CIE LCH differs from CIE Lab.
Parameters

- `lch_l (float)` – L coordinate.
- `lch_c (float)` – C coordinate.
- `lch_h (float)` – H coordinate.
- `observer (str)` – Observer angle. Either '2' or '10' degrees.
- `illuminant (str)` – See Observers and Illuminants for valid values.

`get_illuminant_xyz (observer=None, illuminant=None)`

Parameters

- `observer (str)` – Get the XYZ values for another observer angle. Must be either ‘2’ or ‘10’.
- `illuminant (str)` – Get the XYZ values for another illuminant.

Returns the color’s illuminant’s XYZ values.

`get_value_tuple ()`

Returns a tuple of the color’s values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

`set_illuminant (illuminant)`

Validates and sets the color’s illuminant.

**Note:** This only changes the illuminant. It does no conversion of the color’s coordinates. For this, you’ll want to refer to `XYZColor.apply_adaptation`.

**Tip:** Call this after setting your observer.

Parameters **illuminant (str)** – One of the various illuminants.

`set_observer (observer)`

Validates and sets the color’s observer angle.

**Note:** This only changes the observer angle value. It does no conversion of the color’s coordinates.

Parameters **observer (str)** – One of ‘2’ or ‘10’.

`illuminant = None`

The color’s illuminant. Set with `set_illuminant ()`.

`lch_c = None`

C coordinate

`lch_h = None`

H coordinate

`lch_l = None`

L coordinate
observer = None

The color’s observer angle. Set with set_observer().

2.2.4 LCHuvColor

class colormath.color_objects.LCHuvColor(lch_l, lch_c, lch_h, observer='2', illuminant='d50')

Bases: colormath.color_objects.IlluminantMixin, colormath.color_objects.ColorBase

Represents an CIE LCH color that was converted to LCH by passing through CIE Luv. This differs from LCHabColor, which was converted to LCH through CIE Lab.

See Introduction to Colour Spaces by Phil Cruse for an illustration of how CIE LCH differs from CIE Lab.

Parameters

• lch_l (float) – L coordinate.
• lch_c (float) – C coordinate.
• lch_h (float) – H coordinate.
• observer (str) – Observer angle. Either '2' or '10' degrees.
• illuminant (str) – See Observers and Illuminants for valid values.

get_illuminant_xyz (observer=None, illuminant=None)

Parameters

• observer (str) – Get the XYZ values for another observer angle. Must be either ‘2’ or ‘10’.
• illuminant (str) – Get the XYZ values for another illuminant.

Returns the color’s illuminant’s XYZ values.

get_value_tuple()

Returns a tuple of the color’s values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

set_illuminant (illuminant)

Validates and sets the color’s illuminant.

Note: This only changes the illuminant. It does no conversion of the color’s coordinates. For this, you’ll want to refer to XYZColor.apply_adaptation.

Tip: Call this after setting your observer.

Parameters illuminant (str) – One of the various illuminants.

set_observer (observer)

Validates and sets the color’s observer angle.

Note: This only changes the observer angle value. It does no conversion of the color’s coordinates.
Parameters **observer** *(str)* – One of ‘2’ or ‘10’.

**illuminant** = None
The color’s illuminant. Set with *set_illuminant()*.

**lch_c** = None
C coordinate

**lch_h** = None
H coordinate

**lch_l** = None
L coordinate

**observer** = None
The color’s observer angle. Set with *set_observer()*.

### 2.2.5 LuvColor

**class** colormath.color_objects.LuvColor *(luv_l, luv_u, luv_v, observer='2', illuminant='d50')*

**Bases:** colormath.color_objects.IlluminantMixin, colormath.color_objects.ColorBase

Represents an Luv color.

**Parameters**

- **luv_l** *(float)* – L coordinate.
- **luv_u** *(float)* – u coordinate.
- **luv_v** *(float)* – v coordinate.
- **observer** *(str)* – Observer angle. Either '2' or '10' degrees.
- **illuminant** *(str)* – See *Observers and Illuminants* for valid values.

**get_illuminant_xyz** *(observer=None, illuminant=None)*

**Parameters**

- **observer** *(str)* – Get the XYZ values for another observer angle. Must be either ‘2’ or ‘10’.
- **illuminant** *(str)* – Get the XYZ values for another illuminant.

**Returns** the color’s illuminant’s XYZ values.

**get_value_tuple** ()

Returns a tuple of the color’s values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

**set_illuminant** *(illuminant)*

Validates and sets the color’s illuminant.

**Note:** This only changes the illuminant. It does no conversion of the color’s coordinates. For this, you’ll want to refer to *XYZColor.apply_adaptation*.

**Tip:** Call this after setting your observer.
Parameters **illuminant** *(str)* – One of the various illuminants.

**set_observer** *(observer)*
Validates and sets the color's observer angle.

Note: This only changes the observer angle value. It does no conversion of the color's coordinates.

Parameters **observer** *(str)* – One of ‘2’ or ‘10’.

illuminant = None
The color's illuminant. Set with *set_illuminant()*.

luv_l = None
L coordinate
luv_u = None
u coordinate
luv_v = None
v coordinate
observer = None
The color's observer angle. Set with *set_observer()*.

### 2.2.6 XYZColor

class colormath.color_objects.XYZColor(xyz_x, xyz_y, xyz_z, observer='2', illuminant='d50')
Bases: colormath.color_objects.IlluminantMixin, colormath.color_objects.ColorBase

Represents an XYZ color.

Parameters

- **xyz_x** *(float)* – X coordinate.
- **xyz_y** *(float)* – Y coordinate.
- **xyz_z** *(float)* – Z coordinate.
- **observer** *(str)* – Observer angle. Either '2' or '10' degrees.
- **illuminant** *(str)* – See Observers and Illuminants for valid values.

**apply_adaptation** *(target_illuminant, adaptation='bradford')*
This applies an adaptation matrix to change the XYZ color's illuminant. You'll most likely only need this during RGB conversions.

**get_illuminant_xyz** *(observer=None, illuminant=None)*

Parameters

- **observer** *(str)* – Get the XYZ values for another observer angle. Must be either ‘2’ or ‘10’.
- **illuminant** *(str)* – Get the XYZ values for another illuminant.

Returns the color's illuminant's XYZ values.
get_value_tuple()  
Returns a tuple of the color's values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

set_illuminant(illuminant)  
Validates and sets the color's illuminant.

Note: This only changes the illuminant. It does no conversion of the color's coordinates. For this, you'll want to refer to XYZColor.apply_adaptation.

Tip: Call this after setting your observer.

Parameters illuminant(str) – One of the various illuminants.

set_observer(observer)  
Validates and sets the color's observer angle.

Note: This only changes the observer angle value. It does no conversion of the color's coordinates.

Parameters observer(str) – One of ‘2’ or ‘10’.

illuminant = None  
The color's illuminant. Set with set_illuminant().

observer = None  
The color's observer angle. Set with set_observer().

xyz_x = None  
X coordinate

xyz_y = None  
Y coordinate

xyz_z = None  
Z coordinate

2.2.7 xyYColor

class colormath.color_objects.xyYColor(xyy_x, xyy_y, xyy_Y, observer='2', illuminant='d50')
Bases: colormath.color_objects.IlluminantMixin, colormath.color_objects.ColorBase

Represents an xyY color.

Parameters

* xyy_x(float) – x coordinate.
* xyy_y(float) – y coordinate.
* xyy_Y(float) – Y coordinate.
* observer(str) – Observer angle. Either ’2’ or ’10’ degrees.
• **illuminant** *(str)* – See *Observers and Illuminants* for valid values.

**get_illuminant_xyz** *(observer=None, illuminant=None)*

**Parameters**

• **observer** *(str)* – Get the XYZ values for another observer angle. Must be either ‘2’ or ‘10’.

• **illuminant** *(str)* – Get the XYZ values for another illuminant.

**Returns** the color’s illuminant’s XYZ values.

**get_value_tuple** ()

Returns a tuple of the color’s values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

**set_illuminant** *(illuminant)*

Validates and sets the color’s illuminant.

**Note:** This only changes the illuminant. It does no conversion of the color’s coordinates. For this, you’ll want to refer to *XYZColor.apply_adaptation*.

**Tip:** Call this after setting your observer.

**Parameters** **illuminant** *(str)* – One of the various illuminants.

**set_observer** *(observer)*

Validates and sets the color’s observer angle.

**Note:** This only changes the observer angle value. It does no conversion of the color’s coordinates.

**Parameters** **observer** *(str)* – One of ‘2’ or ‘10’.

**illuminant = None**

The color’s illuminant. Set with **set_illuminant()**.

**observer = None**

The color’s observer angle. Set with **set_observer()**.

**xyy_Y = None**

Y coordinate

**xyy_x = None**

x coordinate

**xyy_y = None**

y coordinate

### 2.2.8 sRGBColor

**class** *colormath.color_objects.sRGBColor*(rgb_r, rgb_g, rgb_b, is_upscaled=False)*

**Bases:** *colormath.color_objects.BaseRGBColor*

Represents an sRGB color.
Note: If you pass in upscaled values, we automatically scale them down to 0.0-1.0. If you need the old upscaled values, you can retrieve them with `get_upscaled_value_tuple()`.

Variables

- `rgb_r (float)` – R coordinate
- `rgb_g (float)` – G coordinate
- `rgb_b (float)` – B coordinate
- `is_upscaled (bool)` – If True, RGB values are between 1-255. If False, 0.0-1.0.

Parameters

- `rgb_r (float)` – R coordinate. 0…1. 1-255 if is_upscaled=True.
- `rgb_g (float)` – G coordinate. 0…1. 1-255 if is_upscaled=True.
- `rgb_b (float)` – B coordinate. 0…1. 1-255 if is_upscaled=True.
- `is_upscaled (bool)` – If False, RGB coordinate values are between 0.0 and 1.0. If True, RGB values are between 1 and 255.

`get_rgb_hex()`  
Converts the RGB value to a hex value in the form of: #RRGGBB

Return type  `str`

`get_upscaled_value_tuple()`  
Scales an RGB color object from decimal 0.0-1.0 to int 0-255.

`get_value_tuple()`  
Returns a tuple of the color’s values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

`classmethod new_from_rgb_hex (hex_str)`  
Converts an RGB hex string like #RRGGBB and assigns the values to this sRGBColor object.

Return type  `sRGBColor`

`clamped_rgb_b`  
The clamped (0.0-1.0) B value.

`clamped_rgb_g`  
The clamped (0.0-1.0) G value.

`clamped_rgb_r`  
The clamped (0.0-1.0) R value.

`native_illuminant = ‘d65’`  
The RGB space’s native illuminant. Important when converting to XYZ.

`rgb_gamma = 2.2`  
RGB space’s gamma constant.

### 2.2.9 BT2020Color

```py
class colormath.color_objects.BT2020Color (rgb_r, rgb_g, rgb_b, is_upscaled=False)  
Bases: colormath.color_objects.BaseRGBColor
```
Represents a ITU-R BT.2020 color.

**Note:** If you pass in upscaled values, we automatically scale them down to 0.0-1.0. If you need the old upscaled values, you can retrieve them with `get_upscaled_value_tuple()`.

### Variables
- `rgb_r (float)` – R coordinate
- `rgb_g (float)` – G coordinate
- `rgb_b (float)` – B coordinate
- `is_upscaled (bool)` – If True, RGB values are between 1-255. If False, 0.0-1.0.

### Parameters
- `rgb_r (float)` – R coordinate. 0...1. 1-255 if is_upscaled=True.
- `rgb_g (float)` – G coordinate. 0...1. 1-255 if is_upscaled=True.
- `rgb_b (float)` – B coordinate. 0...1. 1-255 if is_upscaled=True.
- `is_upscaled (bool)` – If False, RGB coordinate values are between 0.0 and 1.0. If True, RGB values are between 1 and 255.

### get_rgb_hex()
Converts the RGB value to a hex value in the form of: #RRGGBB

**Return type** `str`

### get_upscaled_value_tuple()
Scales an RGB color object from decimal 0.0-1.0 to int 0-255.

### get_value_tuple()
Returns a tuple of the color’s values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

### classmethod new_from_rgb_hex (hex_str)
Converts an RGB hex string like #RRGGBB and assigns the values to this sRGBColor object.

**Return type** `sRGBColor`

### clamped_rgb_b
The clamped (0.0-1.0) B value.

### clamped_rgb_g
The clamped (0.0-1.0) G value.

### clamped_rgb_r
The clamped (0.0-1.0) R value.

### native_illuminant = 'd65'
The RGB space’s native illuminant. Important when converting to XYZ.

### rgb_gamma = 2.4
RGB space’s gamma constant.
2.2.10 AdobeRGBColor

class colormath.color_objects.AdobeRGBColor(rgb_r, rgb_g, rgb_b, is_upscaled=False)
Bases: colormath.color_objects.BaseRGBColor

Represents an Adobe RGB color.

**Note:** If you pass in upscaled values, we automatically scale them down to 0.0-1.0. If you need the old upscaled values, you can retrieve them with `get_upscaled_value_tuple()`.

**Variables**

- `rgb_r (float)` – R coordinate
- `rgb_g (float)` – G coordinate
- `rgb_b (float)` – B coordinate
- `is_upscaled (bool)` – If True, RGB values are between 1-255. If False, 0.0-1.0.

**Parameters**

- `rgb_r (float)` – R coordinate. 0…1. 1-255 if `is_upscaled=True`.
- `rgb_g (float)` – G coordinate. 0…1. 1-255 if `is_upscaled=True`.
- `rgb_b (float)` – B coordinate. 0…1. 1-255 if `is_upscaled=True`.
- `is_upscaled (bool)` – If False, RGB coordinate values are between 0.0 and 1.0. If True, RGB values are between 1 and 255.

**get_rgb_hex()**

Converts the RGB value to a hex value in the form of: #RRGGBB

**Return type** str

**get_upscaled_value_tuple()**

Scales an RGB color object from decimal 0.0-1.0 to int 0-255.

**get_value_tuple()**

Returns a tuple of the color’s values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

**classmethod new_from_rgb_hex(hex_str)**

Converts an RGB hex string like #RRGGBB and assigns the values to this sRGBColor object.

**Return type** sRGBColor

**clamped_rgb_b**

The clamped (0.0-1.0) B value.

**clamped_rgb_g**

The clamped (0.0-1.0) G value.

**clamped_rgb_r**

The clamped (0.0-1.0) R value.

**native_illuminant = 'd65'**

The RGB space’s native illuminant. Important when converting to XYZ.

**rgb_gamma = 2.2**

RGB space’s gamma constant.
2.2.11 HSLColor

class colormath.color_objects.HSLColor(hsl_h, hsl_s, hsl_l)
    Bases: colormath.color_objects.ColorBase

    Represents an HSL color.

    Parameters
    • hsl_h(float) – H coordinate.
    • hsl_s(float) – S coordinate.
    • hsl_l(float) – L coordinate.

    get_value_tuple()
    Returns a tuple of the color’s values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

    hsl_h = None
    H coordinate

    hsl_l = None
    L coordinate

    hsl_s = None
    S coordinate

2.2.12 HSVColor

class colormath.color_objects.HSVColor(hsv_h, hsv_s, hsv_v)
    Bases: colormath.color_objects.ColorBase

    Represents an HSV color.

    Parameters
    • hsv_h(float) – H coordinate.
    • hsv_s(float) – S coordinate.
    • hsv_v(float) – V coordinate.

    get_value_tuple()
    Returns a tuple of the color’s values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

    hsv_h = None
    H coordinate

    hsv_s = None
    S coordinate

    hsv_v = None
    V coordinate

2.2.13 CMYColor

class colormath.color_objects.CMYColor(cmy_c, cmy_m, cmy_y)
    Bases: colormath.color_objects.ColorBase

    Represents a CMY color.
Parameters

- **cmy_c** (float) – C coordinate.
- **cmy_m** (float) – M coordinate.
- **cmy_y** (float) – Y coordinate.

`get_value_tuple()`

Returns a tuple of the color’s values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

```python
cmy_c = None
    C coordinate

cmy_m = None
    M coordinate

cmy_y = None
    Y coordinate
```

### 2.2.14 CMYKColor

```python
class colormath.color_objects.CMYKColor(cmyk_c, cmyk_m, cmyk_y, cmyk_k)
    Bases: colormath.color_objects.ColorBase

Represents a CMYK color.

Parameters

- **cmyk_c** (float) – C coordinate.
- **cmyk_m** (float) – M coordinate.
- **cmyk_y** (float) – Y coordinate.
- **cmyk_k** (float) – K coordinate.

`get_value_tuple()`

Returns a tuple of the color’s values (in order). For example, an LabColor object will return (lab_l, lab_a, lab_b), where each member of the tuple is the float value for said variable.

```python
cmyk_c = None
    C coordinate

cmyk_k = None
    K coordinate

cmyk_m = None
    M coordinate

cmyk_y = None
    Y coordinate
```

### 2.2.15 IPTColor

```python
class colormath.color_objects.IPTColor(ipt_i, ipt_p, ipt_t)
    Bases: colormath.color_objects.ColorBase

Represents an IPT color.

```

2.2. Color Objects
Parameters

- \( \text{ipt\_i} \) – I coordinate.
- \( \text{ipt\_p} \) – P coordinate.
- \( \text{ipt\_t} \) – T coordinate.

**get_value_tuple()**

Returns a tuple of the color’s values (in order). For example, an `LabColor` object will return \((\text{l}, \text{a}, \text{b})\), where each member of the tuple is the float value for said variable.

```python
ipt\_i = None
I coordinate

ipt\_p = None
P coordinate

ipt\_t = None
T coordinate
```

## 2.3 Observers and Illuminants

Illuminants and observer angles are used in all color spaces that use reflective (instead of transmissive) light. Here are a few brief overviews of what these are and what they do:

- Understanding Standard Illuminants in Color Measurement - Konica Minolta
- What is Meant by the Term “Observer Angle”? - XRite

To adjust the illuminants and/or observer angles on a color:

```python
lab = LabColor(0.1, 0.2, 0.3, observer='10', illuminant='d65')
```

### 2.3.1 Two-degree observer angle

These illuminants can be used with `observer='2'`, for the color spaces that require illuminant/observer:

- 'a'
- 'b'
- 'c'
- 'd50'
- 'd55'
- 'd65'
- 'd75'
- 'e'
- 'f2'
- 'f7'
- 'f11'
2.3.2 Ten-degree observer angle

These illuminants can be used with observer='10', for the color spaces that require illuminant/observer:

- 'd50'
- 'd55'
- 'd65'
- 'd75'

2.4 Color Conversions

Converting between color spaces is very simple with python-colormath. To see a full list of supported color spaces, see Color Objects.

All conversions happen through the convert_color function shown below. The original Color instance is passed in as the first argument, and the desired Color class (not an instance) is passed in as the second argument. If the conversion can be made, a new Color instance will be returned.

```python
from colormath.color_conversions import convert_color

lab = LabColor(0.903, 16.296, -2.22)
xyz = convert_color(lab, XYZColor)
```

2.4.1 Example

This is a simple example of a CIE Lab to CIE XYZ conversion. Refer to Color Objects for a full list of different color spaces that can be instantiated and converted between.
Some color spaces require a trip through RGB during conversion. For example, to get from XYZ to HSL, we have to convert XYZ->RGB->HSL. The same could be said for XYZ to CMYK (XYZ->RGB->CMY->CMYK). Different RGB color spaces have different gamut sizes and capabilities, which can affect your converted color values. sRGB is the default RGB color space due to its ubiquity. If you would like to use a different RGB space for a conversion, you can do something like this:

```python
from colormath.color_objects import XYZColor, HSLColor, AdobeRGBColor
from colormath.color_conversions import convert_color

xyz = XYZColor(0.1, 0.2, 0.3)
hsl = convert_color(xyz, HSLColor, through_rgb_type=AdobeRGBColor)
# If you are going to convert back to XYZ, make sure you use the same RGB color space on the way back.
xyz2 = convert_color(hsl, XYZColor, through_rgb_type=AdobeRGBColor)
```

### 2.4.2 RGB conversions and native illuminants

When converting RGB colors to any of the CIE spaces, we have to pass through the XYZ color space. This serves as a crossroads for conversions to basically all of the reflective color spaces (CIE Lab, LCH, Luv, etc). The RGB spaces are reflective, where the illumination is provided. In the case of a reflective space like XYZ, the illuminant must be supplied by a light source.

Each RGB space has its own native illuminant, which can vary from space to space. To see some of these for yourself, check out Bruce Lindbloom’s XYZ to RGB matrices.

To cite the most commonly used RGB color space as an example, sRGB has a native illuminant of D65. When we convert RGB to XYZ, that native illuminant carries over unless explicitly overridden. If you aren’t expecting this behavior, you’ll end up with variations in your converted color’s numbers.

To explicitly request a specific illuminant, provide the `target_illuminant` keyword when using `colormath.color_conversions.convert_color()`.

```python
from colormath.color_objects import XYZColor, sRGBColor
from colormath.color_conversions import convert_color

rgb = RGBColor(0.1, 0.2, 0.3)
xyz = convert_color(rgb, XYZColor, target_illuminant='d50')
```

### 2.4.3 RGB conversions and out-of-gamut coordinates

RGB spaces tend to have a smaller gamut than some of the CIE color spaces. When converting to RGB, this can cause some of the coordinates to end up being out of the acceptable range (0.0-1.0 or 1-255, depending on whether your RGB color is upsampled).

Rather than clamp these for you, we leave them as-is. This allows for more accurate conversions back to the CIE color spaces. If you require the clamped (0.0-1.0 or 1-255) values, use the following properties on any RGB color:

- `clamped_rgb_r`
- `clamped_rgb_g`
- `clamped_rgb_b`
2.5 Delta E Equations

Delta E equations are used to put a number on the visual difference between two `LabColor` instances. While different lighting conditions, substrates, and physical condition can all introduce unexpected variables, these equations are a good rough starting point for comparing colors.

Each of the following Delta E functions has different characteristics. Some may be more suitable for certain applications than others. While it’s outside the scope of this module’s documentation to go into much detail, we link to relevant material when possible.

2.5.1 Example

```python
from colormath.color_objects import LabColor
from colormath.color_diff import delta_e_cie1976

# Reference color.
color1 = LabColor(lab_l=0.9, lab_a=16.3, lab_b=-2.22)
# Color to be compared to the reference.
color2 = LabColor(lab_l=0.7, lab_a=14.2, lab_b=-1.80)
# This is your delta E value as a float.
delta_e = delta_e_cie1976(color1, color2)
```

2.5.2 Delta E CIE 1976

`colormath.color_diff.delta_e_cie1976(color1, color2)`

Calculates the Delta E (CIE1976) of two colors.

2.5.3 Delta E CIE 1994

`colormath.color_diff.delta_e_cie1994(color1, color2, K_L=1, K_C=1, K_H=1, K_I=0.045, K_2=0.015)`

Calculates the Delta E (CIE1994) of two colors.

- **K_L**: 0.045 graphic arts 0.048 textiles
- **K_2**: 0.015 graphic arts 0.014 textiles
- **K_L**: 1 default 2 textiles

2.5.4 Delta E CIE 2000

`colormath.color_diff.delta_e_cie2000(color1, color2, Kl=1, Kc=1, Kh=1)`

Calculates the Delta E (CIE2000) of two colors.

2.5.5 Delta E CMC

`colormath.color_diff.delta_e_cmc(color1, color2, pl=2, pc=1)`

Calculates the Delta E (CMC) of two colors.

- **CMC values**  Acceptability: pl=2, pc=1 Perceptability: pl=1, pc=1
2.6 ANSI and ISO Density

Density may be calculated from \emph{LabColor} instances.

\begin{verbatim}
colormath.density.auto_density(color)
\end{verbatim}

Given a SpectralColor, automatically choose the correct ANSI T filter. Returns a tuple with a string representation of the filter the calculated density.

**Parameters**

- **color** (SpectralColor) – The SpectralColor object to calculate density for.

**Return type** float

**Returns** The density value, with the filter selected automatically.

\begin{verbatim}
colormath.density.ansi_density(color, density_standard)
\end{verbatim}

Calculates density for the given SpectralColor using the spectral weighting function provided. For example, ANSI_STATUS_T_RED. These may be found in `colormath.density_standards`.

**Parameters**

- **color** (SpectralColor) – The SpectralColor object to calculate density for.
- **density_standard** (numpy.ndarray) – NumPy array of filter of choice from `colormath.density_standards`.

**Return type** float

**Returns** The density value for the given color and density standard.

2.6.1 Example

```python
from colormath.color_objects import SpectralColor
from colormath.density import auto_density, ansi_density
from colormath.density_standards import ANSI_STATUS_T_RED

# Omitted the full spectral kwargs for brevity.
color = SpectralColor(spec_340nm=0.08, ...)
# ANSI T Density for the spectral color.
density = auto_density(color)

# Or maybe we want to specify which filter to use.
red_density = ansi_density(color, ANSI_STATUS_T_RED)
```

2.6.2 Valid Density Constants

The following density constants within `colormath.density_standards` can be passed to `colormath.density.ansi_density()`:

- ANSI_STATUS_A_RED
- ANSI_STATUS_A_GREEN
- ANSI_STATUS_A_BLUE
- ANSI_STATUS_E_RED
- ANSI_STATUS_E_GREEN
- ANSI_STATUS_E_BLUE
2.7 Color Appearance Models

Color appearance models allow the prediction of perceptual correlates (e.g., lightness, chroma or hue) of a given surface color under certain viewing conditions (e.g., a certain illuminant, surround or background). The complexity of color appearance models can range from very low, e.g., CIELAB can technically be considered a color appearance model, to very complex models that take into account a large number color appearance phenomena.

Each of the classes in this module represents a specific model and its computation, yielding the predicted perceptual correlates as instance attributes. Discussing the details of each model go beyond this documentation, but we provide references to the relevant literature for each model and would advice familiarising yourself with it, before using a given models.

2.7.1 Example

```python
# Color stimulus
color = XYZColor(19.01, 20, 21.78)

# The two illuminants that will be compared.
illuminant_d65 = XYZColor(95.05, 100, 108.88)
illuminant_a = XYZColor(109.85, 100, 35.58)

# Background relative luminance
y_b = 20

# Adapting luminance
l_a = 328.31

# Surround condition assumed to be average (see CIECAM02 documentation for values)
c = 0.69
n_c = 1
f = 1

model = CIECAM02(color.xyz_x, color.xyz_y, color.xyz_z,
                  illuminant_d65.xyz_x, illuminant_d65.xyz_y, illuminant_d65.xyz_z,
                  y_b, l_a, c, n_c, f)
```
2.7.2 Nayatani95 et al. Model

```python
class colormath.color_appearance_models.Nayatani95(x, y, z, x_n, y_n, z_n, y_ob, e_o, e_or, n=1)
```

**Bases:** `object`

**References**

**Parameters**
- `x` – X value of test sample $X$.
- `y` – Y value of test sample $Y$.
- `z` – Z value of test sample $Z$.
- `x_n` – X value of reference white $X_n$.
- `y_n` – Y value of reference white $Y_n$.
- `z_n` – Z value of reference white $Z_n$.
- `y_ob` – Luminance factor of achromatic background as percentage $Y_0$. Required to be larger than 0.18.
- `e_o` – Illuminance of the viewing field $E_o$ in lux.
- `e_or` – Normalising illuminance $E_or$ in lux.
- `n` – Noise term $n$.

**brightness**
- Predicted brightness $B_r$.

**chroma**
- Predicted chroma $C$.

**colorfulness**
- Predicted colorfulness $M$.

**hue_angle**
- Predicted hue angle $\theta$.

**saturation**
- Predicted saturation $S$.

2.7.3 Hunt Model

```python
class colormath.color_appearance_models.Hunt(x, y, z, x_b, y_b, z_b, x_w, y_w, z_w, l_a, n_c, n_b, l_as=None, cct_w=None, n_cb=None, n_bb=None, x_p=None, y_p=None, z_p=None, p=None, helson_judd=False, discount_illuminant=False, s=None, s_w=None)
```

**Bases:** `object`

**References**
Parameters

- \(x\) – X value of test sample \(X\).
- \(y\) – Y value of test sample \(Y\).
- \(z\) – Z value of test sample \(Z\).
- \(x_b\) – X value of background \(X_b\).
- \(y_b\) – Y value of background \(Y_b\).
- \(z_b\) – Z value of background \(Z_b\).
- \(x_w\) – X value of reference white \(X_W\).
- \(y_w\) – Y value of reference white \(Y_W\).
- \(z_w\) – Z value of reference white \(Z_W\).
- \(l_a\) – Adapting luminance \(L_A\).
- \(n_c\) – Chromatic surround induction factor \(N_c\).
- \(n_b\) – Brightness surround induction factor \(N_b\).
- \(l_{as}\) – Scotopic luminance of the illuminant \(L_{AS}\). Will be approximated if not supplied.
- \(cct_w\) – Correlated color temperature of illuminant \(T\). Will be used to approximate \(l_{as}\) if not supplied.
- \(n_{cb}\) – Chromatic background induction factor \(N_{cb}\). Will be approximated using \(y_w\) and \(y_b\) if not supplied.
- \(n_{bb}\) – Brightness background induction factor \(N_{bb}\). Will be approximated using \(y_w\) and \(y_b\) if not supplied.
- \(x_p\) – X value of proxima field \(X_p\). If not supplied, will be assumed to equal background.
- \(y_p\) – Y value of proxima field \(Y_p\). If not supplied, will be assumed to equal background.
- \(z_p\) – Z value of proxima field \(Z_p\). If not supplied, will be assumed to equal background.
- \(p\) – Simultaneous contrast/assimilation parameter.
- \(helson_judd\) – Truth value indicating whether the Heslon-Judd effect should be accounted for. Default False.
- \(discount_illuminant\) – Truth value whether discount-the-illuminant should be applied. Default True.
- \(s\) – Scotopic response to the stimulus.
- \(s_w\) – Scotopic response for th reference white.

Raises `ValueError` – if illegal parameter combination is supplied.

`brightness`
- Predicted brightness \(Q\).

`chroma`
- Predicted chroma \(C_{94}\).
colorfulness
   Predicted colorfulness $M_{94}$.

hue_angle
   Predicted hue angle $h_s$.

lightness
   Predicted colorfulness $J$.

saturation
   Predicted saturation $s$.

### 2.7.4 RLAB Model

class colormath.colorappearance_models.RLAB(x, y, z, x_n, y_n, z_n, y_n_abs, sigma, d)
Bases: object

References


Parameters

- $x$ – X value of test sample $X$.
- $y$ – Y value of test sample $Y$.
- $z$ – Z value of test sample $Z$.
- $x_n$ – X value of reference white $X_n$.
- $y_n$ – Y value of reference white $Y_n$.
- $z_n$ – Z value of reference white $Z_n$.
- $y_n\_abs$ – Absolute luminance $Y_n$ of a white object in cd/m^2.
- $sigma$ – Relative luminance parameter $\sigma$. For average surround set $\sigma = 1/2.3$, for dim surround $\sigma = 1/2.9$ and for dark surround $\sigma = 1/3.5$.
- $d$ – Degree of adaptation $D$.

a
   Predicted red-green chromatic response $a^R$.

b
   Predicted yellow-blue chromatic response $b^R$.

chroma
   Predicted chroma $C^R$.

hue_angle
   Predicted hue angle $h^R$.

lightness
   Predicted colorfulness $L^R$.

saturation
   Predicted saturation $s^R$. 
2.7.5 ATD95 Model

class colormath.color_appearance_models.ATD95(x, y, z, x_0, y_0, z_0, y_0_abs, k_1, k_2, sigma=300)

Bases: object

References

Parameters
  • x – X value of test sample X.
  • y – Y value of test sample Y.
  • z – Z value of test sample Z.
  • x_0 – X value of reference white X0.
  • y_0 – Y value of reference white Y0.
  • z_0 – Z value of reference white Z0.
  • y_0_abs – Absolute adapting luminance Y0 in cd/m^2.
  • k_1
  • k_2
  • sigma – σ

brightness
  Predicted brightness Br.

hue
  Predicted hue H.

saturation
  Predicted saturation C.

2.7.6 LLAB Model

class colormath.color_appearance_models.LLAB(x, y, z, x_0, y_0, z_0, y_b, f_s, f_l, f_c, l, d=1)

Bases: object

References

Parameters
• $x$ – X value of test sample $X$.
• $y$ – Y value of test sample $Y$.
• $z$ – Z value of test sample $Z$.
• $x_0$ – X value of reference white $X_0$.
• $y_0$ – Y value of reference white $Y_0$.
• $z_0$ – Z value of reference white $Z_0$.
• $y_b$ – Luminance factor of the background $Y_b$ in $\text{cd/m}^2$.
• $f_s$ – Surround induction factor $F_S$.
• $f_l$ – Lightness induction factor $F_L$.
• $f_c$ – Chroma induction factor $F_C$.
• $l$ – Absolute luminance of reference white $L$ in $\text{cd/m}^2$.
• $d$ – Discounting-the-Illuminant factor $D$.

```
a_l
    Predicted red-green chromatic response $A_L$.
```

```
b_l
    Predicted yellow-blue chromatic response $B_L$.
```

```
croma
    Predicted chroma $Ch_L$.
```

```
hue_angle
    Predicted hue angle $h_L$.
```

```
lightness
    Predicted colorfulness $L_L$.
```

```
saturation
    Predicted saturation $s_L$.
```

### 2.7.7 CIECAM02 Model

```python
class colormath.color_appearance_models.CIECAM02 (x, y, z, x_w, y_w, z_w, y_b, l_a, c, n_c,
f, d=False)
Bases: object
```

References


Parameters

• $x$ – X value of test sample $X$.
• $y$ – Y value of test sample $Y$.
• $z$ – Z value of test sample $Z$.
• $x_w$ – X value of reference white $X_W$.  

• \textbf{y}_w – Y value of reference white \(Y_W\).
• \textbf{z}_w – Z value of reference white \(Z_W\).
• \textbf{y}_b – Background relative luminance \(Y_b\).
• \textbf{l}_a – Adapting luminance \(L_A\) in cd/m^2.
• \textbf{c} – Exponential nonlinearity \(c\). (Average/Dim/Dark) (0.69/0.59/0.525).
• \textbf{n}_c – Chromatic induction factor \(N_c\). (Average/Dim/Dark) (1.0,0.9,0.8).
• \textbf{f} – Maximum degree of adaptation \(F\). (Average/Dim/Dark) (1.0/0.9/0.8).
• \textbf{d} – Discount-the-Illuminant factor \(D\).

\(a\)
Predicted red-green chromatic response \(a\).

\(b\)
Predicted yellow-blue chromatic response \(b\).

\textbf{brightness}
Predicted colorfulness \(Q\).

\textbf{chroma}
Predicted chroma \(C\).

\textbf{colorfulness}
Predicted colorfulness \(M\).

\textbf{hue_angle}
Predicted hue angle \(h\).

\textbf{lightness}
Predicted colorfulness \(J\).

\textbf{saturation}
Predicted saturation \(s_L\).

\textbf{2.7.8 CIECAM02-m1 Model}

\texttt{class} \texttt{colormath.color\_appearance\_models.CIECAM02m1}(x, y, z, x_w, y_w, z_w, x_b, y_b, z_b, l_a, c, n_c, f, p, d=False)

\texttt{Bases:} \texttt{colormath.color\_appearance\_models.CIECAM02}

\textbf{References}
• Wu, R. C., & Wardman, R. H. (2007). Proposed modification to the CIECAM02 colour appearance model to include the simultaneous contrast effects. \textit{Color Research & Application}, 32(2), 121-129.

\textbf{Parameters}
• \textbf{x} – X value of test sample \(X\).
• \textbf{y} – Y value of test sample \(Y\).
• \textbf{z} – Z value of test sample \(Z\).
• \textbf{x}_w – X value of reference white \(X_W\).
• \textbf{y}_w – Y value of reference white \(Y_W\).
• \textbf{z}_w – Z value of reference white \(Z_W\).
• \(x_b\) – X value of background \(X_b\).
• \(y_b\) – Y value of background \(Y_b\).
• \(z_b\) – Z value of background \(Z_b\).
• \(l_a\) – Adapting luminance \(L_A\) in cd/m^2.
• \(c\) – Exponential nonlinearity \(c\). (Average/Dim/Dark) (0.69/0.59/5.25).
• \(n_c\) – Chromatic induction factor \(N_c\). (Average/Dim/Dark) (1.0,0.9,0.8).
• \(f\) – Maximum degree of adaptation \(F\). (Average/Dim/Dark) (1.0/0.9/0.8).
• \(p\) – Simultaneous contrast/assimilation parameter.
• \(d\) – Discount-the-Illuminant factor \(D\).

\[a\]
Predicted red-green chromatic response \(a\).

\[b\]
Predicted yellow-blue chromatic response \(b\).

\[\text{brightness}\]
Predicted colorfulness \(Q\).

\[\text{chroma}\]
Predicted chroma \(C\).

\[\text{colorfulness}\]
Predicted colorfulness \(M\).

\[\text{hue_angle}\]
Predicted hue angle \(h\).

\[\text{lightness}\]
Predicted colorfulness \(J\).

\[\text{saturation}\]
Predicted saturation \(s_L\).

### 2.8 Release Notes

#### 2.8.1 3.0.0

**Features**

- Python 3.5 and 3.6 are now supported.

**Backwards-Incompatible Changes**

- Python 3.3 and 3.4 are no longer supported.
- networkx>=2.0 is now required.
Bug Fixes

- Add NodeNotFound to GraphConversionManager.get_conversion_path().

2.8.2 2.2.0

Features

- AppleRGBColor added. (jan-warchol)
- Added compatibility with NetworkX 2.0. (Erotemic)

Bug Fixes

- \texttt{IPT\_to\_XYZ} docstring corrected. (mumbleskates)

2.8.3 2.1.1

Bug Fixes

- Add 	exttt{network} to install\_requires. (Ed-von-Schleck)

2.8.4 2.1.0

Features

- Added new NetworkX graph-based resolution of conversions between color spaces. Reduces boilerplate and makes it much easier to add additional color spaces going forward. (MichaelMauderer)
- Added the IPT color space. (MichaelMauderer)
- Added Color Appearance Models. Natayani95, Hunt, RLAB, ATD95, LLAB, CIECAM02, CIECAM02-m1. (MichaelMauderer)

Bug Fixes

- \texttt{xyY} conversions now correctly avoid division by zero. (dwbullok)
- Un-transposed adaptation matrices. Has no effect on conversions, but if you use these directly you may see different numbers. (JasonTam)
- During XYZ\textrightarrow{}RGB, linear channel values are now clamped in order to avoid domain errors. Output should now always be between 0 and 1.

Backwards Incompatible changes

- If any of your code directly referenced the color adaptation matrices that were un-inverted, you’ll need to adjust your math.
2.8.5 2.0.2

Bug Fixes

• Apparently I didn’t add the function body for the clamped RGB properties. Yikes.

2.8.6 2.0.1

Features

• Lots of documentation improvements.

• `convert_color()` now has an explicitly defined/documented `target_illuminant` kwarg, instead of letting this fall through to its `**kwargs`. This should make IDE auto-complete better and provide more clarity.

• Added `clamped_rgb_r`, `clamped_rgb_g`, and `clamped_rgb_b` to RGB color spaces. Use these if you have to have in-gamut, potentially compressed coordinates.

Bug Fixes

• Direct conversions to non-sRGB colorspace returned sRGBColor objects. Reported by Cezary Wagner.

2.8.7 2.0.0

Backwards Incompatible changes

• Minimum Python version is now 2.7.

• `ColorBase.convert_to()` is no more. Use `colormath.color_conversions.convert_color()` instead. API isn’t as spiffy looking, but it’s a lot less magical now.

• Completely re-worked RGB handling. Each RGB space now has its own class, inheriting from `BaseRGBColor`. Consequently, RGBColor is no more. In most cases, you can substitute RGBColor with sRGBColor during your upgrade.

• RGB channels are now [0..1] instead of [1..255]. Can use `BaseRGBColor.get_upscaled_value_tuple()` to get the upscaled values.

• `BaseRGBColor.set_from_rgb_hex()` was replaced with a `BaseRGBColor.new_from_rgb_hex()`, which returns a properly formed sRGBColor object.

• BaseRGBColor no longer accepts observer or illuminant kwarg.

• HSL no longer accepts observer, illuminant or rgb_type kwarg.

• HSV no longer accepts observer, illuminant or rgb_type kwarg.

• CMY no longer accepts observer, illuminant or rgb_type kwarg.

• CMYK no longer accepts observer, illuminant or rgb_type kwarg.

• Removed ‘debug’ kwarg in favor of Python’s logging.

• Completely re-worked exception list. Eliminated some redundant exceptions, re-named basically everything else.
Features

- Python 3.3 support added.
- Added tox.ini with supported environments.
- Removed the old custom test runner in favor of nose.
- Replacing simplified RGB->XYZ conversions with Bruce Lindbloom’s.
- A round of PEP8 work.
- Added a BaseColorConversionTest test class with some greatly improved color comparison. Much more useful in tracking down breakages.
- Eliminated non-matrix delta E computations in favor of the matrix equivalents. No need to maintain duplicate code, and the matrix stuff is faster for bulk operations.

Bug Fixes

- Corrected delta_e CMC example error. Should now run correctly.
- color_diff_matrix.delta_e_cie2000 had an edge case where certain angles would result in an incorrect delta E.
- Un-hardcoded XYZColor.apply_adaptation()’s adaptation and observer angles.

2.8.8 1.0.9

Features

- Added an optional vectorized deltaE function. This uses NumPy array/matrix math for a very large speed boost. (Eddie Bell)
- Added this changelog.

Bug Fixes

- Un-hardcode the observer angle in adaptation matrix. (Bastien Dejean)

2.8.9 1.0.8

- Initial GitHub release.
Useful color math resources

- Bruce Lindbloom - Lots of formulas, calculators, and standards.
- John the Math Guy - Useful tutorials and explanations of color theory.
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