Exploring image processing pipelines with scikit-image, joblib, ipywidgets and dash

A bag of tricks for processing images faster

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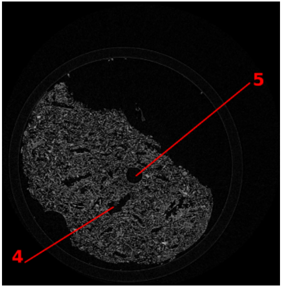
and the `scikit-image` team

`@EGouillart`

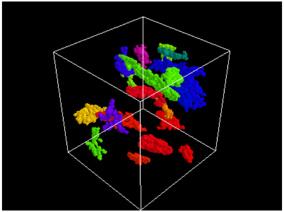
From images to science

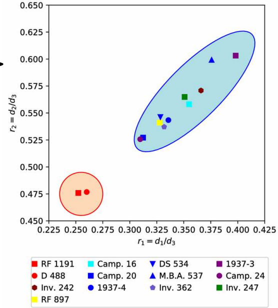


courtesy F. Beaugnon

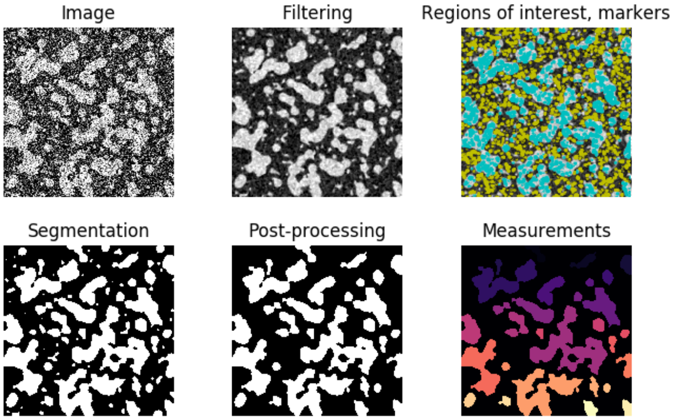
?

⇒

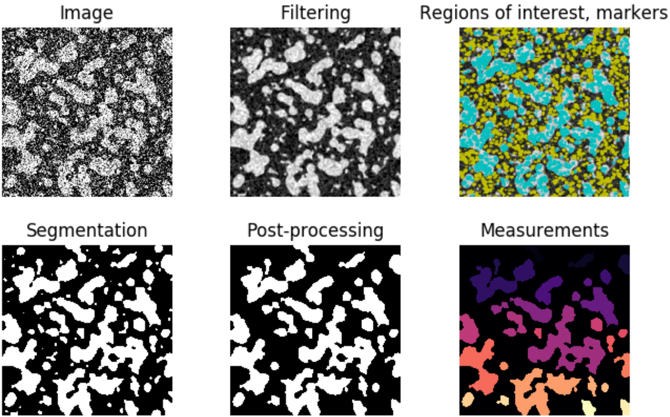




A typical pipeline



A typical pipeline



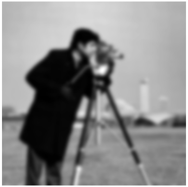
- How to discover & select the different algorithms?
- How to iterate quickly towards a satisfying result?
- How to verify processing results?

Introducing scikit-image

A NumPy-ic image processing library for science

```
>>> from skimage import io, filters
>>> camera_array = io.imread('camera_image.png')
>>> type(camera_array)
<type 'numpy.ndarray'>
>>> camera_array.dtype
dtype('uint8')
>>> filtered_array = filters.gaussian(camera_array, ↩
    sigma=5)
>>> type(filtered_array)
<type 'numpy.ndarray'>
```

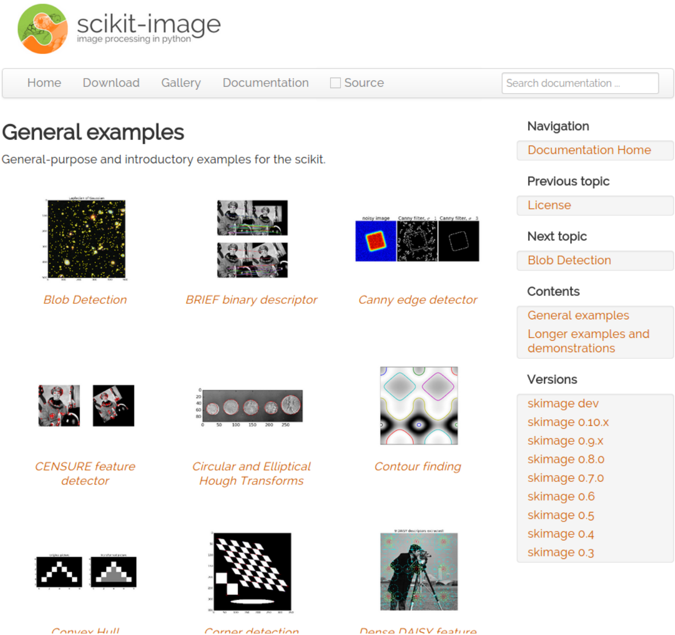
X



Submodules correspond to different tasks: I/O, filtering, segmentation...

Compatible with 2D and 3D images

Documentation at a glance: galleries of examples



scikit-image
image processing in python

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Search documentation ...

General examples

General-purpose and introductory examples for the scikit.

Blob Detection

BRIEF binary descriptor

Canny edge detector

CENSURE feature detector

Circular and Elliptical Hough Transforms

Contour finding

Convex Hull

Corner detection

Dense DAISY feature

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Longer examples and demonstrations

Versions

skimage dev

skimage 0.10.x

skimage 0.9.x

skimage 0.8.0

skimage 0.7.0

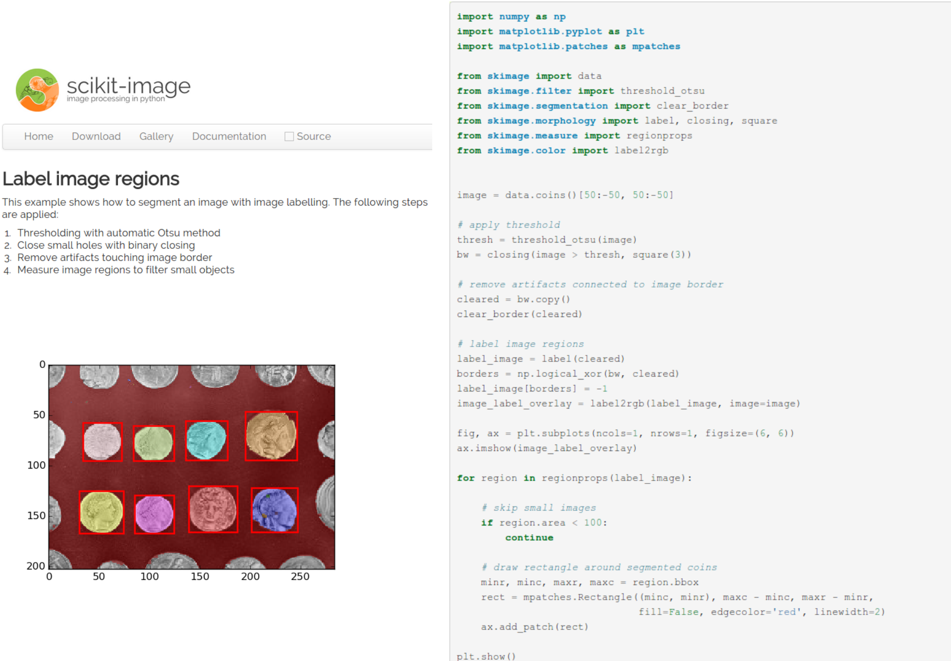
skimage 0.6

skimage 0.5

skimage 0.4

skimage 0.3

Getting started: finding documentation



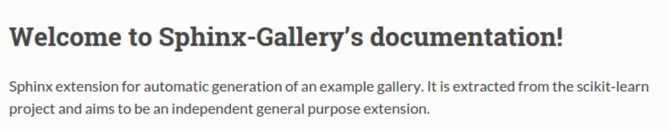
Label image regions

This example shows how to segment an image with image labelling. The following steps are applied:

1. Thresholding with automatic Otsu method
2. Close small holes with binary closing
3. Remove artifacts touching image border
4. Measure image regions to filter small objects

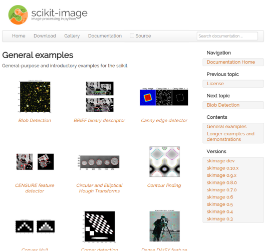
```
import numpy as np
import matplotlib.pyplot as plt
import matplotlib.patches as mpatches

from skimage import data
from skimage.filter import threshold_otsu
from skimage.segmentation import clear_border
from skimage.morphology import label, closing, square
from skimage.measure import regionprops
from skimage.color import label2rgb


image = data.coins()[50:-50, 50:-50]

# apply threshold
thresh = threshold_otsu(image)
bw = closing(image > thresh, square(3))

# remove artifacts connected to image border
cleared = bw.copy()
clear_border(cleared)

# label image regions
label_image = label(cleared)
borders = np.logical_xor(bw, cleared)
label_image[borders] = -1
image_label_overlay = label2rgb(label_image, image=image)

fig, ax = plt.subplots(ncols=1, nrows=1, figsize=(6, 6))
ax.imshow(image_label_overlay)

for region in regionprops(label_image):

    # skip small images
    if region.area < 100:
        continue

    # draw rectangle around segmented coins
    minr, minc, maxr, maxc = region.bbox
    rect = mpatches.Rectangle((minc, minr), maxc - minc, maxr - minr,
                              fill=False, edgecolor='red', linewidth=2)
    ax.add_patch(rect)

plt.show()
```

Galleries as a sphinx-extension: `sphinx-gallery`



Welcome to Sphinx-Gallery's documentation!

Sphinx extension for automatic generation of an example gallery. It is extracted from the scikit-learn project and aims to be an independent general purpose extension.



scikit-image
image processing in python

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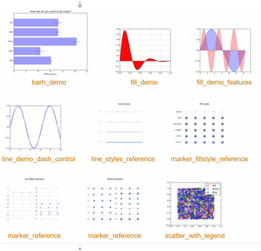


barh_demo

fill_demo

fill_demo_features

line_demo_dash_control

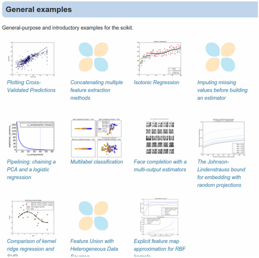
line_styles_reference

marker_fillstyle_reference

marker_reference

marker_reference

scatter_with_legend



General examples

General-purpose and introductory examples for the scikit.

Plotting Cross-Validated Predictions

Concatenating multiple feature extraction methods

Isotonic Regression

Imputing missing values before building an estimator

Pipelining: chaining a PCA and a logistic regression

Multilabel classification

Face completion with a multi-output estimators

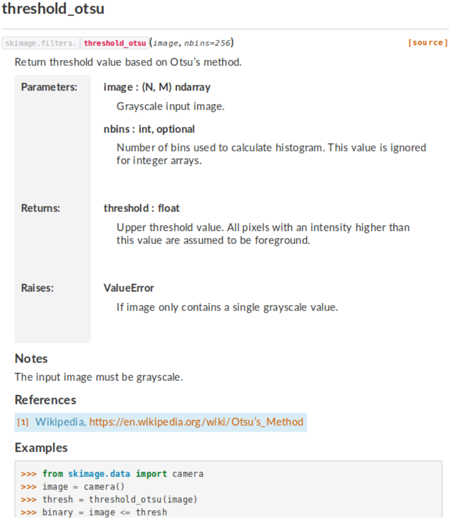
The Johnson-Lindenstrauss bound for embedding with random projections

Comparison of kernel ridge regression and SVR

Feature Union with Heterogeneous Data Sources

Explicit feature map approximation for RBF kernels

Auto documenting your API with links to examples



threshold_otsu

`skimage.filters.threshold_otsu(image, nbins=256)` [source]

Return threshold value based on Otsu's method.

Parameters:

image : (N, M) ndarray

Grayscale input image.

nbins : int, optional

Number of bins used to calculate histogram. This value is ignored for integer arrays.

Returns:

threshold : float

Upper threshold value. All pixels with an intensity higher than this value are assumed to be foreground.

Raises:

ValueError

If image only contains a single grayscale value.

Notes

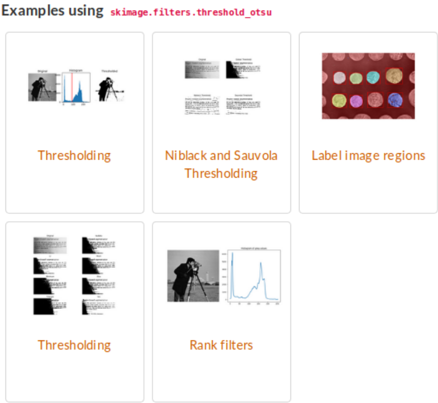
The input image must be grayscale.

References

[1] Wikipedia, https://en.wikipedia.org/wiki/Otsu's_Method

Examples

```
>>> from skimage.data import camera
>>> image = camera()
>>> thresh = threshold_otsu(image)
>>> binary = image <= thresh
```



Examples using `skimage.filters.threshold_otsu`

Thresholding

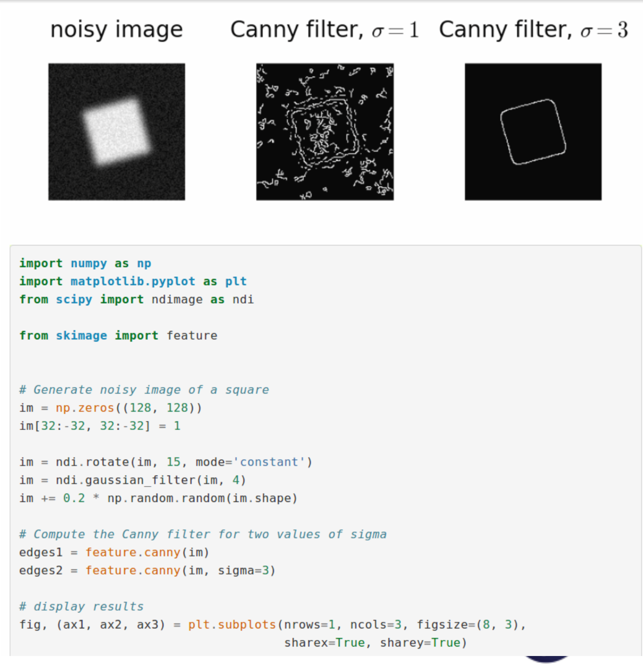
Niblack and Sauvola Thresholding

Label image regions

Thresholding

Rank filters

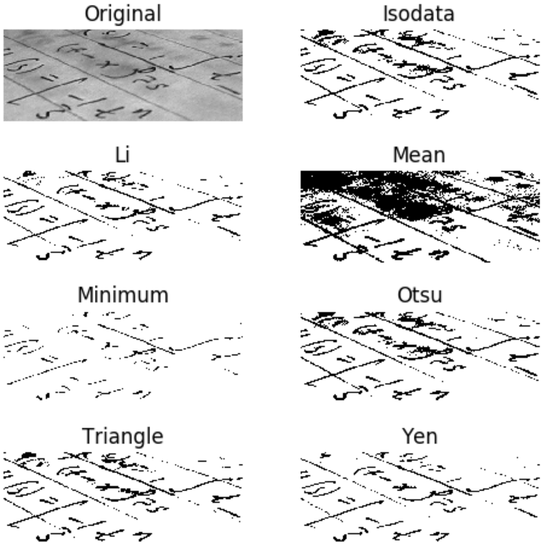
Auto documenting your API with links to examples



```
import numpy as np
import matplotlib.pyplot as plt
from scipy import ndimage as ndi

from skimage import feature


# Generate noisy image of a square
im = np.zeros((128, 128))
im[32:-32, 32:-32] = 1

im = ndi.rotate(im, 15, mode='constant')
im = ndi.gaussian_filter(im, 4)
im += 0.2 * np.random.random(im.shape)

# Compute the Canny filter for two values of sigma
edges1 = feature.canny(im)
edges2 = feature.canny(im, sigma=3)

# display results
fig, (ax1, ax2, ax3) = plt.subplots(nrows=1, ncols=3, figsize=(8, 3),
                                    sharex=True, sharey=True)
```

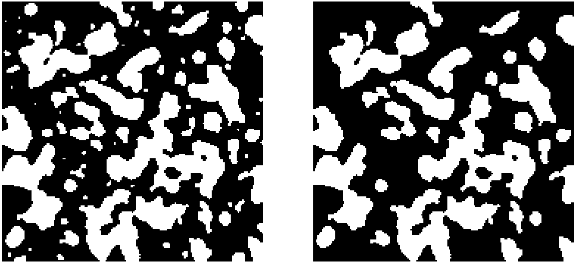
Learning by yourself

`filters.try_all_threshold`



Convenience functions: Numpy operations as one-liners

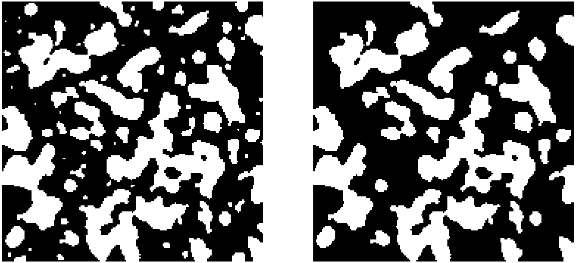
```
labels = measure.label(im)
sizes = np.bincount(labels.ravel())
sizes[0] = 0
keep_only_large = (sizes > 1000)[labels]
```



Convenience functions: Numpy operations as one-liners

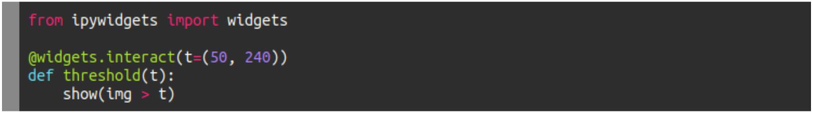
```
labels = measure.label(im)
sizes = np.bincount(labels.ravel())
sizes[0] = 0
keep_only_large = (sizes > 1000)[labels]
```

```
morphology.remove_small_objects(im))
```

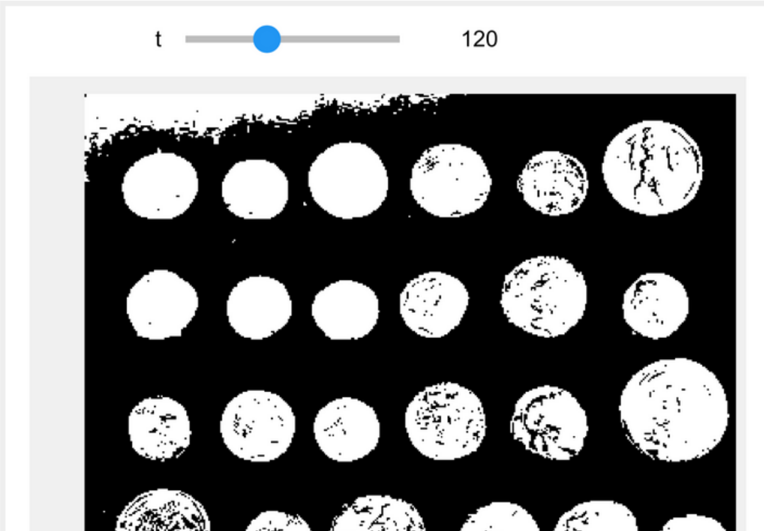


```
clear_border, relabel_sequential, find_boundaries, ↩
join_segmentations
```

More interaction for faster discovery: widgets

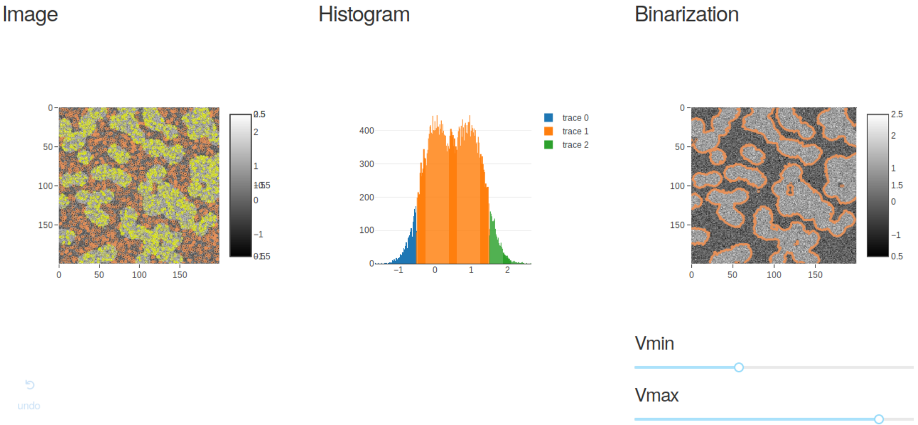


```
from ipywidgets import widgets

@widgets.interact(t=(50, 240))
def threshold(t):
    show(img > t)
```



t 120

More interaction for faster discovery: web applications made easy



`https://dash.plot.ly/`

cnrs

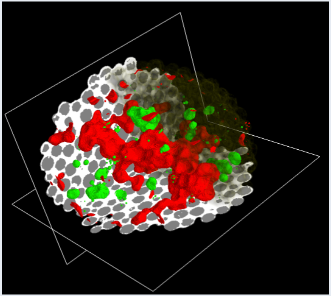
SAINT-GOBAIN

More interaction for faster discovery: web applications made easy

```python
@app.callback(
    dash.dependencies.Output('image-seg', 'figure'),
    [dash.dependencies.Input('slider_min', 'value'),
     dash.dependencies.Input('slider_max', 'value')])
def update_figure(v_min, v_max):
    mask = np.zeros(img.shape, dtype=np.uint8)
    mask[img < v_min] = 1
    mask[img > v_max] = 2
    seg = segmentation.random_walker(img, mask, mode='cg_mg')
    return {'data': [
                go.Heatmap(
                    z=img, colorscale='Greys'
                    ),
        go.Contour(
                    z=seg, ncontours=1,
                    contours=dict(start=1.5, end=1.5,
                                coloring='lines',),
                    line=dict(width=3)
            )
                ]
    }
```

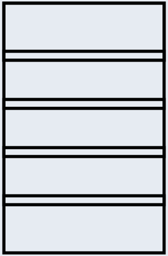
Keeping interaction easy for large data

```python
from joblib import Memory
memory = Memory(cachedir='./cachedir', verbose=0)

@memory.cache
def mem_label(x):
    return measure.label(x)

@memory.cache
def mem_threshold_otsu(x):
    return filters.threshold_otsu(x)

[...]
val = mem_threshold_otsu(dat)
objects = dat > val

median_dat = mem_median_filter(dat, 3)
val2 = mem_threshold_otsu(median_dat[objects])
liquid = median_dat > val2
segmentation_result = np.copy(objects).astype(np.uint8)
segmentation_result[liquid] = 2

aggregates = mem_binary_fill_holes(objects)
aggregates_ds = np.copy(aggregates[::4, ::4, ::4])
cores = mem_binary_erosion(aggregates_ds, np.ones((10, 10,↩
    10)))
```

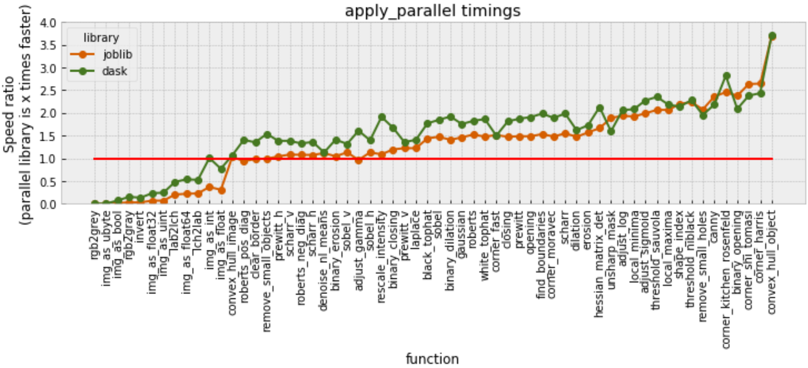


joblib: easy simple parallel computing + lazy re-evaluation

```python
import numpy as np
from sklearn.externals.joblib import Parallel, delayed

def apply_parallel(func, data, *args, chunk=100, overlap=10, n_jobs=4,
                                        **kwargs):
    """
    Apply a function in parallel to overlapping chunks of an array.
    joblib is used for parallel processing.

    [...]
    Examples
    --------
    >>> from skimage import data, filters
    >>> coins = data.coins()
    >>> res = apply_parallel(filters.gaussian, coins, 2)
    """
    sh0 = data.shape[0]
    nb_chunks = sh0 // chunk
    end_chunk = sh0 % chunk
    arg_list = [data[max(0, i*chunk - overlap):
                     min((i+1)*chunk + overlap, sh0)]
                            for i in range(0, nb_chunks)]
    if end_chunk > 0:
        arg_list.append(data[-end_chunk - overlap:])
    res_list = Parallel(n_jobs=n_jobs)(delayed(func)(sub_im, *args, **kwargs)
                        for sub_im in arg_list)
    output_dtype = res_list[0].dtype
    out_data = np.empty(data.shape, dtype=output_dtype)
    for i in range(1, nb_chunks):
        out_data[i*chunk:(i+1)*chunk] = res_list[i][overlap:overlap+chunk]
    out_data[:chunk] = res_list[0][:-overlap]
    if end_chunk > 0:
        out_data[-end_chunk:] = res_list[-1][overlap:]
    return out_data
```

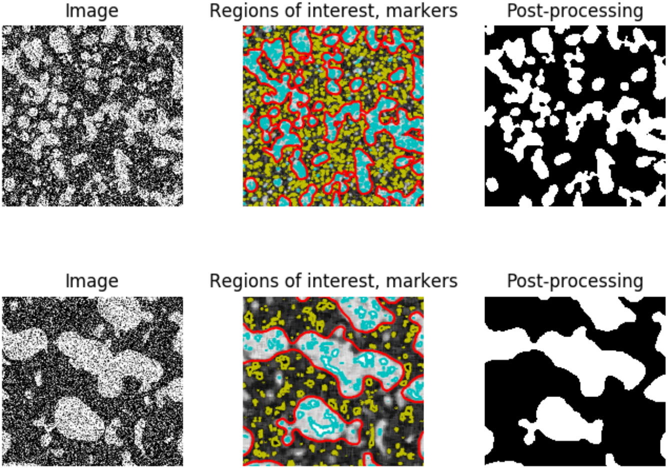


Experimental chunking and parallelization



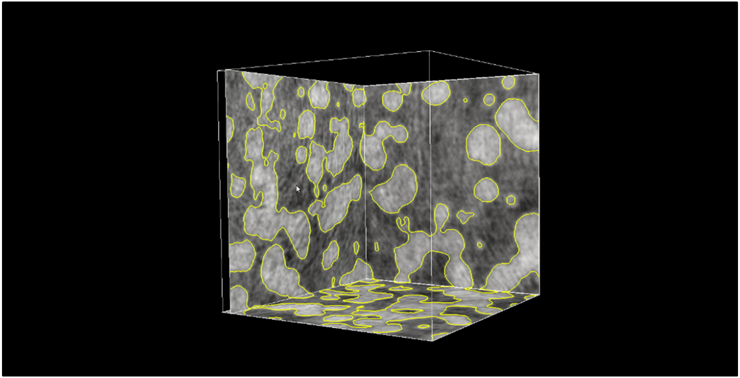
Synchronized `matplotlib` subplots

```
fig, ax = plt.subplots(1, 3, sharex=True, sharey=True)
```



Synchronizing mayavi visualization modules

```
mayavi_module.sync_trait('trait', other_module)
```

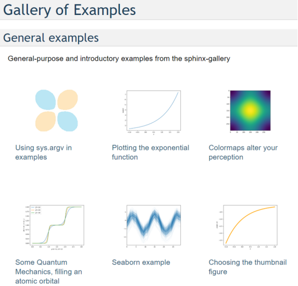


Conclusions

- Explore as much as possible
  Take advantage of documentation
  (maybe improve it!)

- Keep the pipeline interactive

- Check what you're doing,
  use meaningful visualizations



Gallery of Examples

General examples

General-purpose and introductory examples from the sphinx-gallery

Using sys.argv in examples

Plotting the exponential function

Colormaps alter your perception

Some Quantum Mechanics, filling an atomic orbital

Seaborn example

Choosing the thumbnail figure