Bio-image Analysis using cupy

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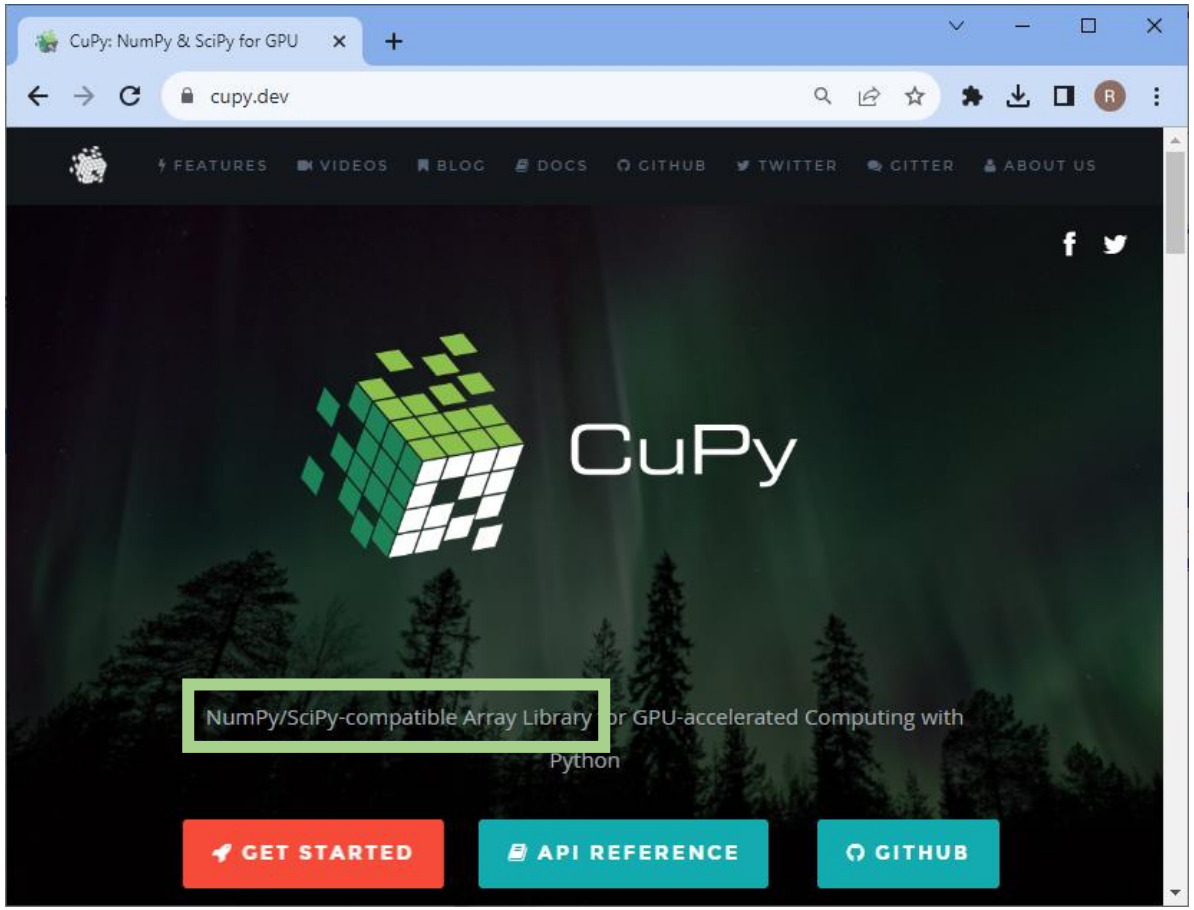
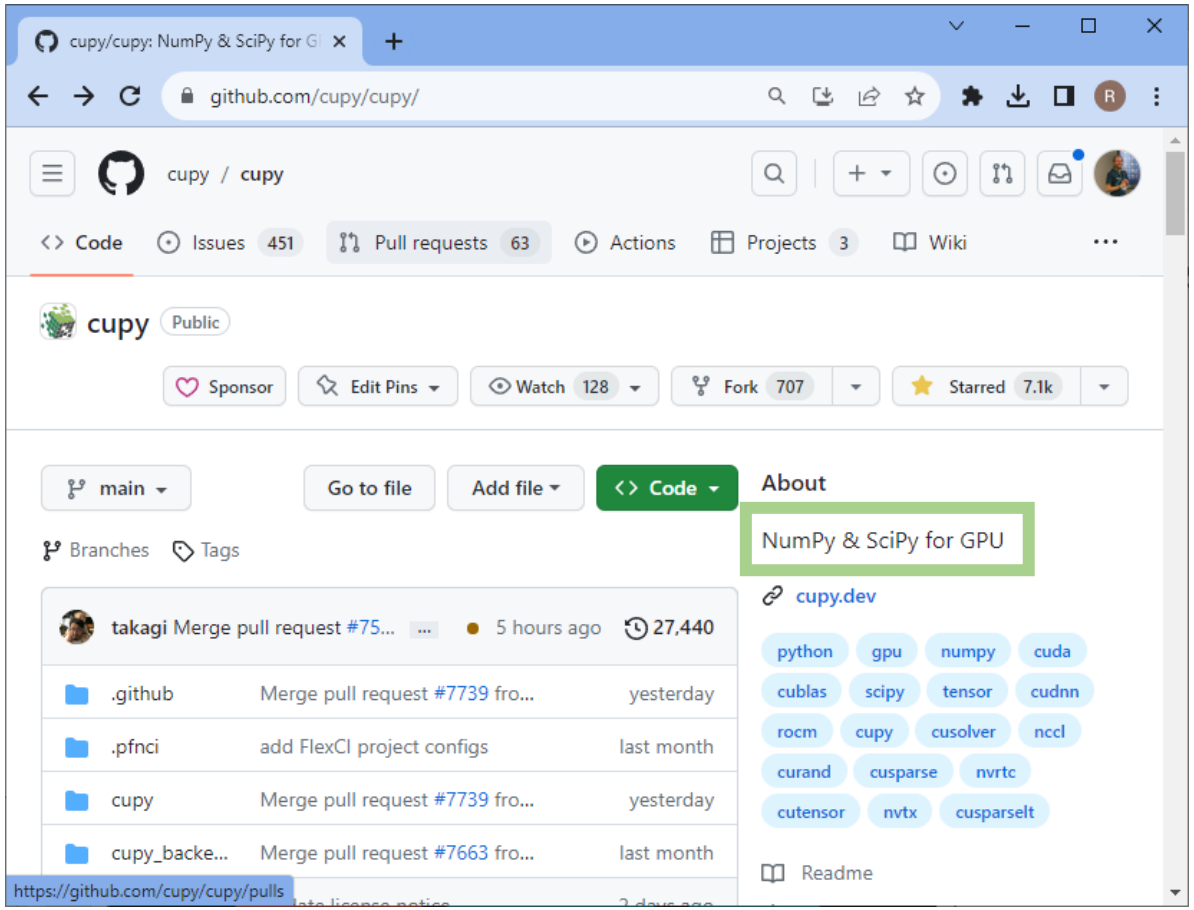
cupy

- CUDA-based GPU-accelerated [image] data processing in Python





drop-in replacement for numpy and scipy

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- The API of some cupy packages is close to the scipy/numpy API.
- This allows *easy* switching from scipy to cupy.

```
import scipy.ndimage as ndi
```

```
import cupyx.scipy.ndimage as xdi
```

- However, image data still needs to be pushed to GPU memory.

```
xp_image = xp.asarray(image)
```

```
ndi.gaussian_filter(image, sigma=5)
```

```
xdi.gaussian_filter(xp_image, sigma=5)
```

Common patterns

- To make code independent from cupy availablity, while minimizing if-else blocks, some common design patterns emerged:

```
try:
    import cupy as xp
except:
    import numpy as xp

import numpy as np
```

If this fails because cupy is not installed,

This will execute and xp will be available.

We can still use np anyway.

- The same pattern works with scipy.ndimage

```
try:
    import cupyx.scipy.ndimage as xdi
except:
    import scipy.ndimage as xdi

import scipy.ndimage as ndi
```

Common patterns

- You can then call magic code like this, which will do different things depending on cupy-availability.

- If cupy is available:

```
[3]: image = imread("../../data/blobs.tif")

     xp_image = xp.asarray(image)

     type(xp_image)

[3]: cupy.ndarray
```

- If cupy is not available:

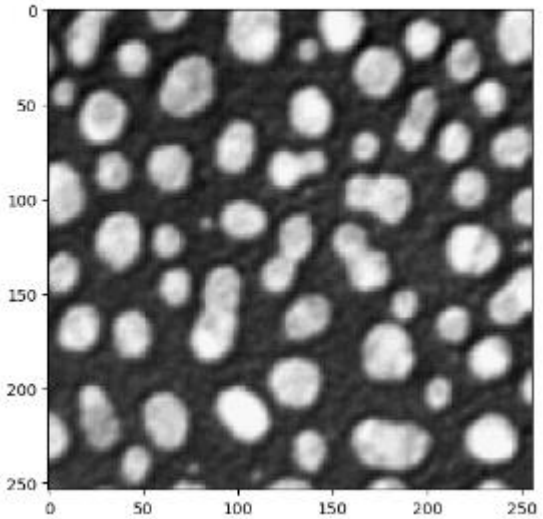
```
[3]: image = imread("../../data/blobs.tif")

     xp_image = xp.asarray(image)

     type(xp_image)

[3]: numpy.ndarray
```

Common patterns

- Some if-else blocks are hard to avoid

```
[7]: if np == xp:
         np_image = xp_image
     else:
         np_image = xp.asnumpy(xp_image)

     imshow(np_image)
```

```
[7]: <matplotlib.image.AxesImage at
     0x24692ef85e0>
```

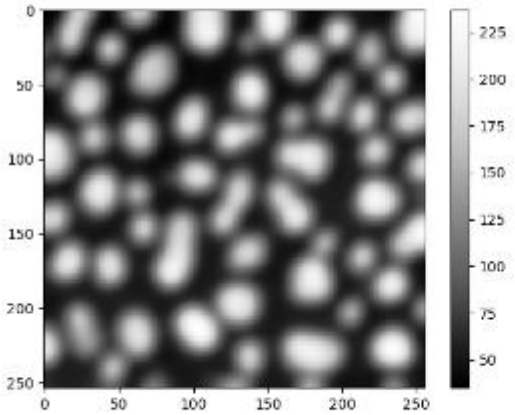


- *Our* libraries aim to be cupy/numpy agnostic

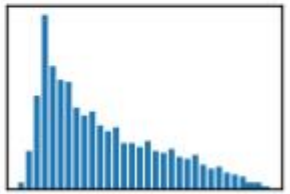
```
[4]: xp_blurred = xdi.gaussian_filter(xp_image, sigma=5)
```

```
[5]: stackview.insight(xp_blurred)
```

[5]:



shape	(254, 256)
dtype	uint8
size	63.5 kB
min	35
max	237



Custom kernels

- CUDA is also just C. You can write custom cupy kernels using simple syntax.
- T represents the image type

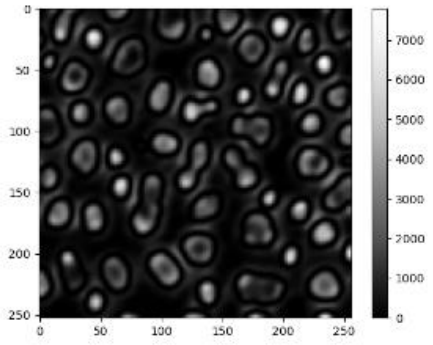
```
squared_difference = cp.ElementwiseKernel(
    'T x, T y',
    'T z',
    'z = (x - y) * (x - y)',
    'squared_difference')
```

Input, output parameters

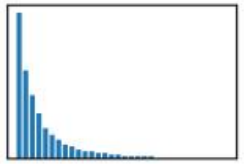
Math / CUDA code

Function call using cupy-arrays as parameters

```
[3]: cp_image = cp.asarray(image[1:], dtype=np.float32)
     image1 = gaussian_filter(cp_image, sigma=3)
     image2 = gaussian_filter(cp_image, sigma=7)

[5]: sqdiff = squared_difference(image1, image2)

[6]: stackview.insight(sqdiff)

[6]:
```



shape	(253, 256)
dtype	float32
size	253.0 kB
min	3.0791853e-08
max	7801.2026



Read more: https://docs.cupy.dev/en/stable/user_guide/kernel.html

Convenience for Napari users

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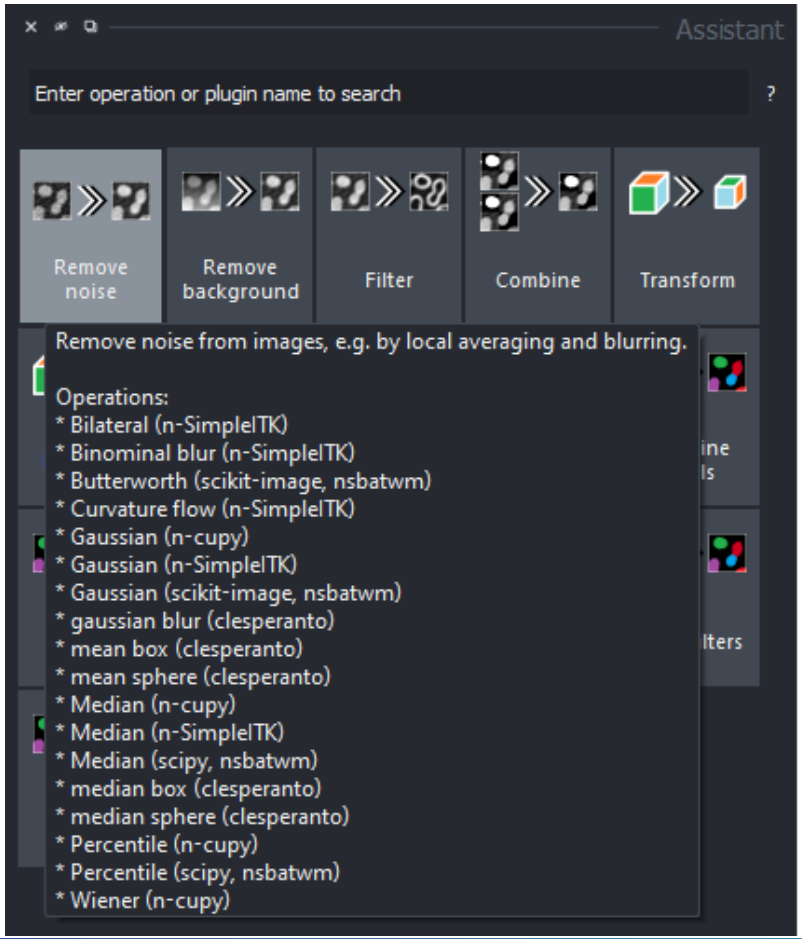
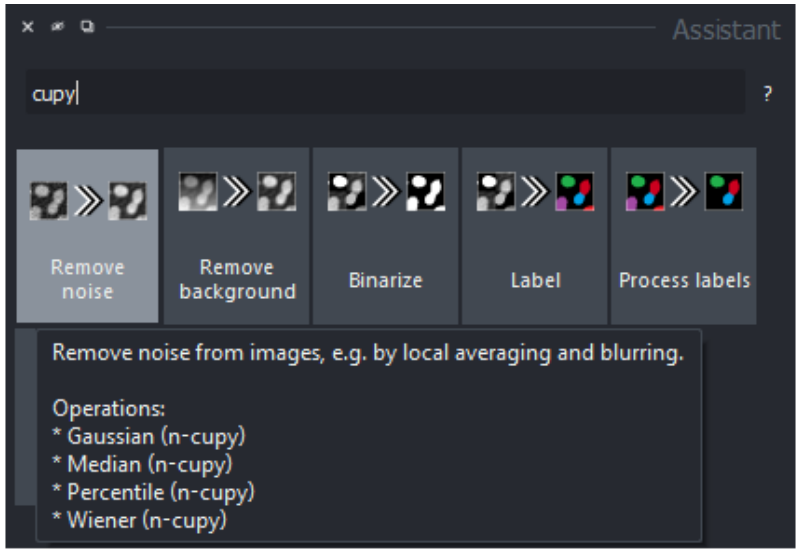
- To design cupy-based workflows using the Napari-assistant, enter “cupy” in the search field





Convenience for Napari users

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- Using the plugin from Python works as with other napari-assistant compatible plugins
- It aims avoiding memory transfer, if used the right way.

```
import napari_cupy_image_processing as ncupy
```

```
[2]: image = imread("../../data/blobs.tif")
```

If you pass a numpy array as input, …

```
[3]: blurred = ncupy.gaussian_filter(image, sigma=5)

     isinstance(blurred, np.ndarray)

[3]: True
```

the output will by numpy as well

```
[5]: cp_image = cp.asarray(image)

     isinstance(cp_image, np.ndarray)

[5]: False
```

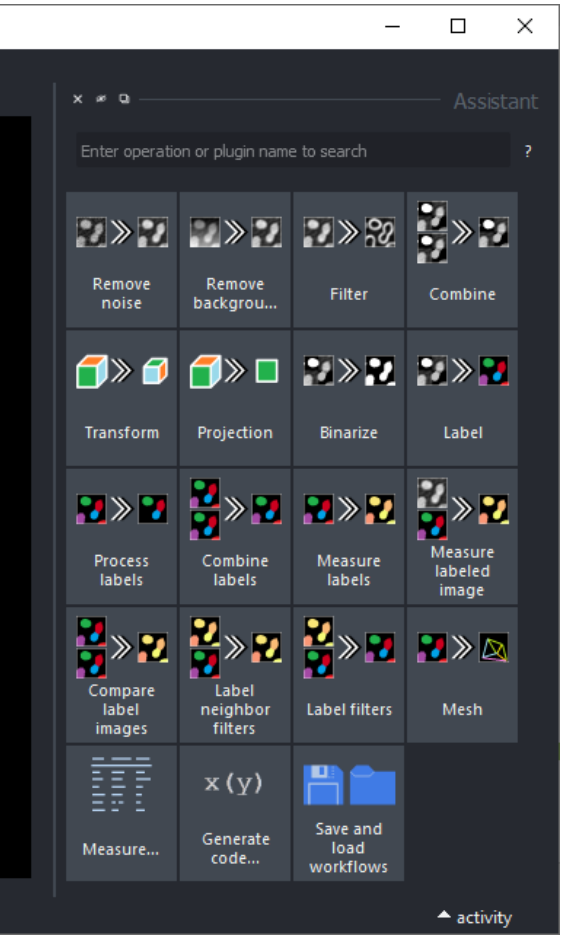
If you pass a cupy-array, …

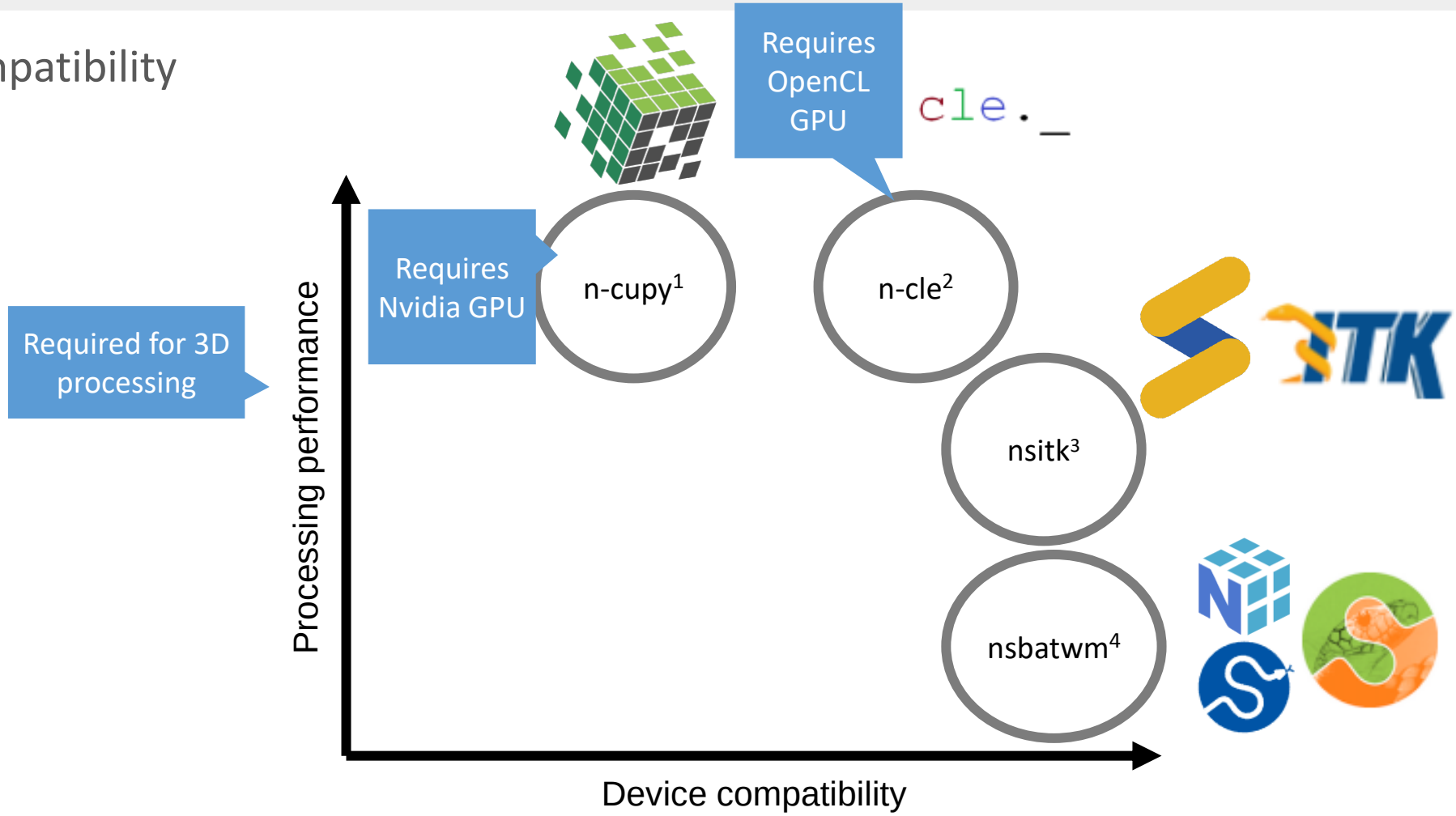
```
[6]: cp_blurred = ncupy.gaussian_filter(cp_image, sigma=5)

     isinstance(cp_image, np.ndarray)

[6]: False

[7]: type(cp_blurred)

[7]: cupy.ndarray
```

the output will by a cupy-array, too

Napari-Assistant compatible plugins

- Performance versus compatibility

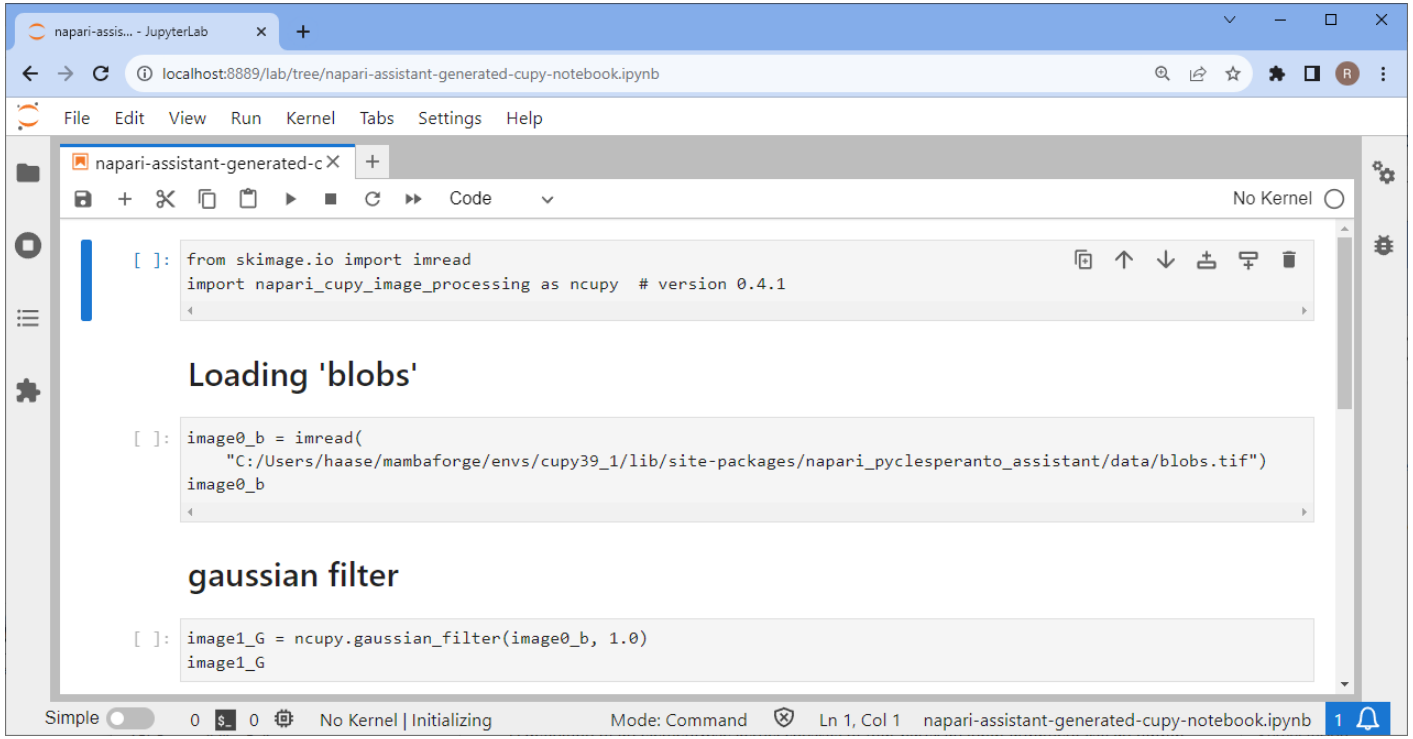




1 https://www.napari-hub.org/plugins/napari-cupy-image-processing
2 https://www.napari-hub.org/plugins/napari-pyclesperanto-assistant
3 https://www.napari-hub.org/plugins/napari-simpleitk-image-processing
4 https://www.napari-hub.org/plugins/napari-segment-blobs-and-things-with-membranes

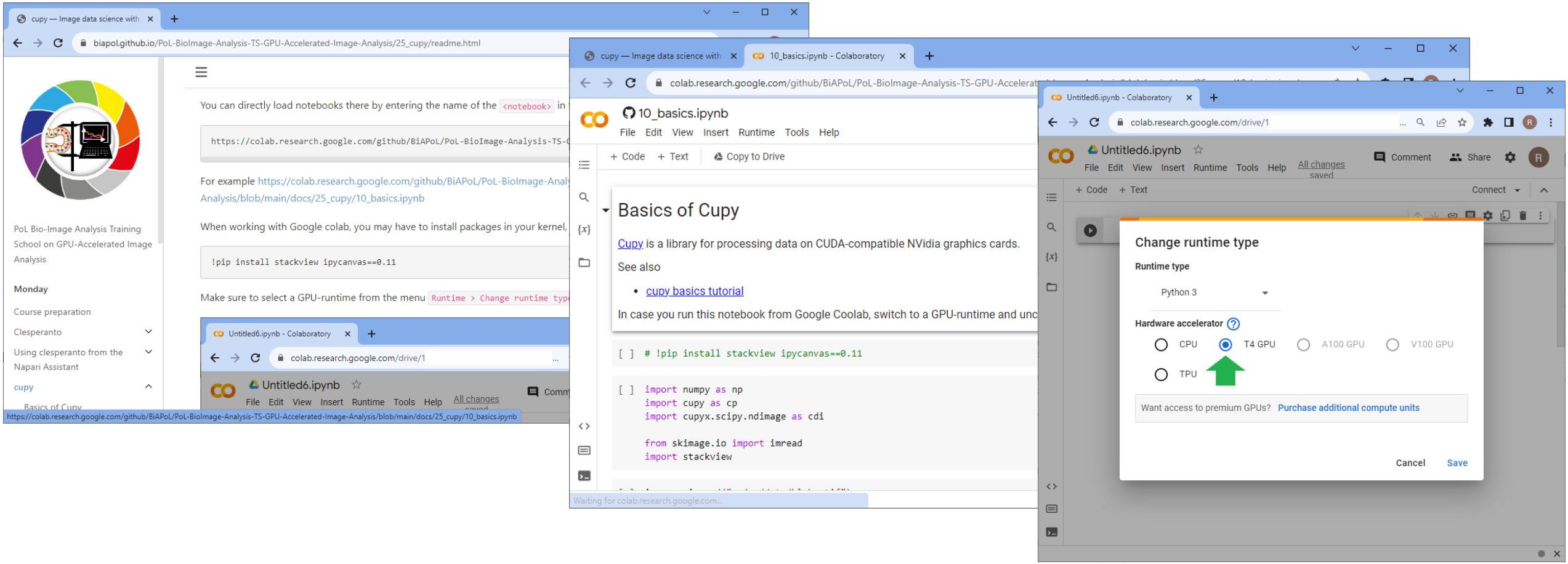
Exercises

- Design a workflow for segmenting blobs in napari using cupy operations only.
- Export a notebook.
- If cupy doesn't work on your laptop, there is a generated notebook available in the repository.



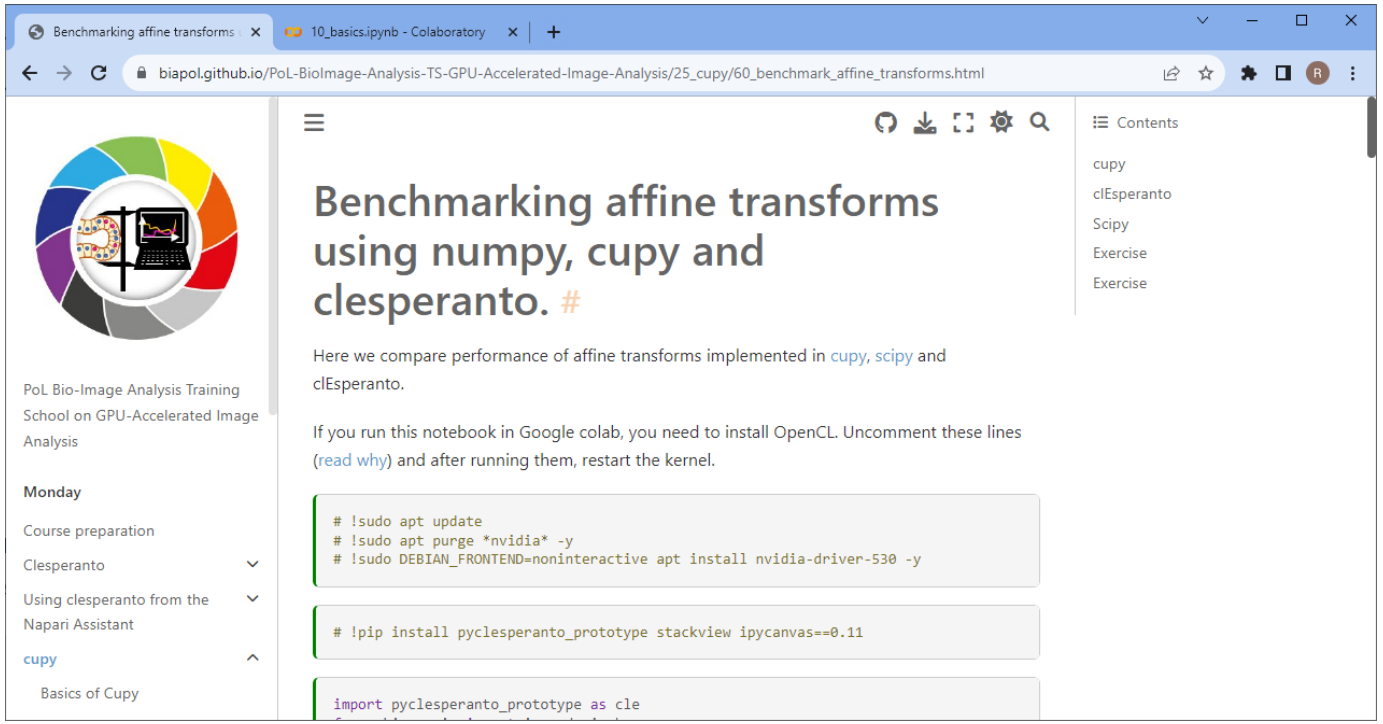
Exercises

- Run cupy-notebooks in google colab.



Exercises

- Benchmark cupy, clesperanto and numpy in comparison.
- How large do images have to be so that it makes sense to use a GPU?
- How different do operations behave differently?



https://biapol.github.io/PoL-BioImage-Analysis-TS-GPU-Accelerated-Image-Analysis/25_cupy/60_benchmark_affine_transforms.html

Acknowledgements

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Networks

BioDIP Biopolis Dresden Imaging Platform

CENTER FOR SYSTEMS BIOLOGY DRESDEN

NFDI4 BIOIMAGE

neubias network of european bioimage analysts

image.sc

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DFG public

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