Writing readable code

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Readable code

Recommendations for readable code

- Every command belongs on its own line
- Insert empty lines to separate important processing steps.
- Put comments to introduce sections
- Print out intermediate results
- Put spaces between operators and operands, because:

This is easier to read thanthat,orisnt'it?

- Keep code blocks it short.
- Consider writing code out instead of keeping it short.

```
[1]:  ang")
```

```
[2]: # initialize program
     a=5
     b=3
     c=8

     # compute result before we can evaluate it
     d=(a+b)/c
```

```
[3]: d
[3]: 1.0
```

```
[4]: d = (a + b) / c
     d
[4]: 1.0
```

```
[5]: print("Yin" if d==5 else "Yang")
     Yang
```

```
[6]: if d == 5:
         print("Yin")
     else:
         print("Yang")
     Yang
```

Naming conventions

- Write code so that others can read it. Your future self will thank you.
- Name variables and functions after English words.

```
A = w * h
print( A )
```

```
area = width * height
print( area )
```

```
nNucl = cntNcl(img)
```

```
number_of_nuclei = count_nuclei(image)

numberOfNuclei = countNuclei(image)
```

Snake-case

Camel-case

```
volume = travelled_distance / time
```

```
speed = travelled_distance / time
```

```
percentage = "Robert"
```

- Name variables using nouns
- Name functions as verb + noun

Don't repeat yourself (DRY)

- Use for-loops to prevent code duplication. It also makes code maintenance easier.

```
[8]: image = cle.imread("../../data/BBBC007_batch/17P1_POS0013_D_1UL.tif")
     labels = cle.voronoi_otsu_labeling(image, spot_sigma=3)
     number_of_nuclei = labels.max()
     number_of_nuclei
[8]: 44.0
```

```
[9]: image = cle.imread("../../data/BBBC007_batch/20P1_POS0005_D_1UL.tif")
     labels = cle.voronoi_otsu_labeling(image, spot_sigma=3)
     number_of_nuclei = labels.max()
     number_of_nuclei
[9]: 41.0
```

```
[10]: image = cle.imread("../../data/BBBC007_batch/20P1_POS0007_D_1UL.tif")
      labels = cle.voronoi_otsu_labeling(image, spot_sigma=3)
      number_of_nuclei = labels.max()
      number_of_nuclei
[10]: 73.0
```

```
[11]: folder = "../../data/BBBC007_batch/"
      files = ["17P1_POS0013_D_1UL.tif",
               "20P1_POS0005_D_1UL.tif",
               "20P1_POS0007_D_1UL.tif"]
```

```
[12]: for file in files:
          image = cle.imread(folder + file)
          labels = cle.voronoi_otsu_labeling(
                          image,
                          spot_sigma=3)
          number_of_nuclei = labels.max()
          print(file, number_of_nuclei)

17P1_POS0013_D_1UL.tif 44.0
20P1_POS0005_D_1UL.tif 41.0
20P1_POS0007_D_1UL.tif 73.0
```

Don’t repeat yourself (DRY)

- Use functions to prevent code duplication. It also makes code more flexible.

```
[8]: image = cle.imread("../../data/BBBC007_batch/17P1_POS0013_D_1UL.tif")
     labels = cle.voronoi_otsu_labeling(image, spot_sigma=3)
     number_of_nuclei = labels.max()
     number_of_nuclei

[8]: 44.0

[9]: image = cle.imread("../../data/BBBC007_batch/20P1_POS0005_D_1UL.tif")
     labels = cle.voronoi_otsu_labeling(image, spot_sigma=3)
     number_of_nuclei = labels.max()
     number_of_nuclei

[9]: 41.0

[10]: image = cle.imread("../../data/BBBC007_batch/20P1_POS0007_D_1UL.tif")
      labels = cle.voronoi_otsu_labeling(image, spot_sigma=3)
      number_of_nuclei = labels.max()
      number_of_nuclei

[10]: 73.0
```

Default parameter

```
[13]: def count_nuclei(image, spot_sigma=3):
          labels = cle.voronoi_otsu_labeling(
                          image,
                          spot_sigma=spot_sigma)
          number_of_nuclei = labels.max()

          return number_of_nuclei

[14]: count_nuclei(cle.imread(folder + files[0]))

[14]: 44.0

[15]: count_nuclei(cle.imread(folder + files[1]))

[15]: 41.0

[16]: count_nuclei(cle.imread(folder + files[2]))

[16]: 73.0

[18]: count_nuclei(cle.imread(folder + files[2]), spot_sigma=5)

[18]: 68.0
```

Prevent magic numbers

- Put all parameters of your workflow on top so that one can easily spot them.
- Give them reasonable names

```
[4]: # enter the image filename to be processed here
     file_to_process = "../../data/BBBC007_batch/17P1_POS0013_D_1UL.tif"

     # enter the expected radius of nuclei here, in pixel units
     approximate_nuclei_radius = 3
```

```
[3]: image = imread("../../data/BBBC007_batch/17P1_POS

     # noise removal
     blurred = gaussian(image, 7)

     # instance segmentation
     binary = blurred > threshold_otsu(blurred)
     labels = label(binary)

     # quantitative measurement
     labels.max()

[3]: 19
```

```
[5]: image = imread(file_to_process)

     # noise removal
     blurred = gaussian(image, approximate_nuclei_radius)

     # instance segmentation
     binary = blurred > threshold_otsu(blurred)
     labels = label(binary)

     # quantitative measurement
     labels.max()

[5]: 37
```

Divide and rule

- Prevent long, complicated macros ("spaghetti code")

[2]:
```python
image = imread("../../data/blobs.tif")
footprint = disk(15)
background_subtracted = white_tophat(image,
                                     footprint=footprint)
particle_radius = 5
denoised = gaussian(background_subtracted,
                    sigma=particle_radius)
binary = denoised > threshold_otsu(denoised)
labels = label(binary)
requested_measurements = ["label", "area", "mean_intensity"]
regionprops = regionprops_table(image,
                                labels,
                                properties=requested_measurements)
table = pd.DataFrame(regionprops)
mean_total_intensity = np.mean(table["area"] * table["mean_intensity"])
mean_total_intensity
```

- At least: Write sections of code with headlines

[3]:
```python
# configuration
file_to_analyze = "../../data/blobs.tif"
background_subtraction_radius = 15
particle_radius = 5
requested_measurements = ["area", "mean_intensity"]

# load data
image = imread(file_to_analyze)

# preprocess image
footprint = disk(background_subtraction_radius)
background_subtracted = white_tophat(image,
                                     footprint=footprint)
denoised = gaussian(background_subtracted,
                    sigma=particle_radius)

# segment image
binary = denoised > threshold_otsu(denoised)
labels = label(binary)

# extract features
regionprops = regionprops_table(image,
                                labels,
                                properties=requested_measurements)
table = pd.DataFrame(regionprops)

# descriptive statistics
mean_total_intensity = np.mean(table["area"] * table["mean_intensity"])
mean_total_intensity
```

Divide and rule

- Prevent long, complicated macros ("spaghetti code")

```
[2]: image = imread("../../data/blobs.tif")
footprint = disk(15)
background_subtracted = white_tophat(image,
                                     footprint=footprint)
particle_radius = 5
denoised = gaussian(background_subtracted,
                    sigma=particle_radius)
binary = denoised > threshold_otsu(denoised)
labels = label(binary)
requested_measurements = ["label", "area", "mean_intensity"]
regionprops = regionprops_table(image,
                                labels,
                                properties=requested_measurements)
table = pd.DataFrame(regionprops)
mean_total_intensity = np.mean(table["area"] * table["mean_intensity"])
mean_total_intensity
```

```
[4]: # reusable functions
def preprocess_image(image, background_subtraction_radius, particle_radius):
    """Apply background removal and denoising"""
    footprint = disk(background_subtraction_radius)
    background_subtracted = white_tophat(image, footprint=footprint)
    denoised = gaussian(background_subtracted, sigma=particle_radius)
    return denoised

def segment_image(image):
    """Apply thresholding and connected component analysis"""
    binary = image > threshold_otsu(image)
    labels = label(binary)
    return labels

def extract_features(image, labels, requested_measurements):
    """Measure specified properties"""
    regionprops = regionprops_table(image,
                                    labels,
                                    properties=requested_measurements)
    table = pd.DataFrame(regionprops)
    return table

def analyse_average_total_intensity(filename,
                                    background_subtraction_radius = 15,
                                    particle_radius = 5):
    """Load an image, segment objects and measure their mean total intensity."""
    image = imread(filename)
    denoised = preprocess_image(image,
                                background_subtraction_radius,
                                particle_radius)
    labels = segment_image(denoised)
    requested_measurements = ["area", "mean_intensity"]
    table = extract_features(image,
                             labels,
                             requested_measurements)

    # descriptive statistics
    mean_total_intensity = np.mean(table["area"] * table["mean_intensity"])

    return mean_total_intensity
```

- At least: Write sections of code with headlines
- Even better: Write custom functions

Reusing code from custom modules

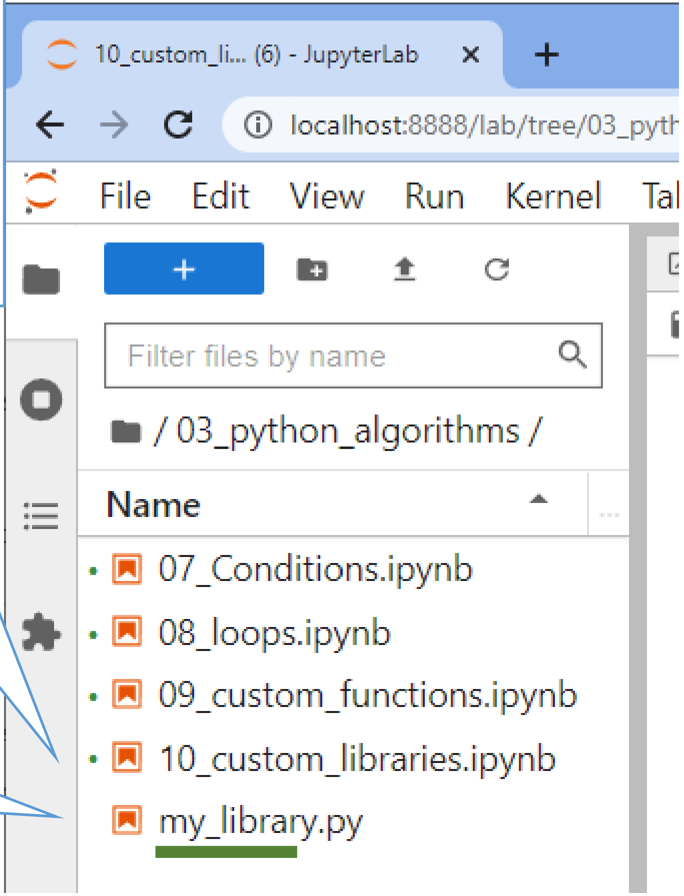
PoL Physics of Life TU Dresden

- For re-using functions between notebooks / projects, use libraries. -> Sustainability
- Simple python libraries are .py files containing multiple functions.
- The import statement allows you to import python files from the same folder.

```python
from my_library import square
```

```python
square(5)
```

```
25
```




```python
def wuzzle(number):
    '''
    The wuzzle function manipulates a number in a magic way and returns the result.
    '''

    import math
    return math.sqrt(number * 1.2)

def square(number):
    '''
    Squares a number by multiplying it with itself  and returns its result.
    '''

    return number * number
```

Divide and rule

- *Divide* complex issues into smaller, accessible issues like

```python
def analyse_average_total_intensity(filename,
                                    background_subtraction_radius = 15,
                                    particle_radius = 5):
    """Load an image, segment objects and measure their mean total intensity."""
    image = imread(filename)
    denoised = preprocess_image(image,
                                background_subtraction_radius,
                                particle_radius)
    labels = segment_image(denoised)
    requested_measurements = ["area", "mean_intensity"]
    table = extract_features(image,
                             labels,
                             requested_measurements)

    # descriptive statistics
    mean_total_intensity = np.mean(table["area"] * table["mean_intensity"])

    return mean_total_intensity
```

- It's easier to get an overview about small functions
- It forces programmers to organise their macros

Keep it short and simple(KISS)

PoL
Physics of Life
TU Dresden

- What does this program do?

```
image = imread("../../data/blobs.tif")

# define a list of functions and a corresponding list of arguments
functions = [gaussian_blur, threshold_otsu, label]
argument_lists = [[.5], [], []]

# go through functions and argument lists pair-wise
for function, argument_list in zip(functions, argument_lists):
    # execute function with given arguments
    image = function(image, *argument_list)

result1 = image
imshow(result1)
```

- The same like that?

```
image = imread("../../data/blobs.tif")

blurred = gaussian_blur(image, 5)
binary = threshold_otsu(blurred)
labels = label(binary)

result2 = labels

imshow(result2)
```

Yes No

- There are two ways design software:
  - make it so simple that there are obviously no issues or
  - make it so complicated that there are no obvious issues.

(based loosely on Tony Hoare, "The Emperor's Old Clothes," CACM Feb. 1981)

- Take home: Keep it *short and simple*!

http://zoo.cs.yale.edu/classes/cs422/2010/bib/hoare81emperor.pdf
https://en.wikipedia.org/wiki/KISS_principle

Exercise: modularization

Go through the code from yesterday and identify a workflow that worked well and contained these steps:

- Image preprocessing
- Image segmentation

Copy & paste code from the notebooks you worked with yesterday into a new custom module my_analysis.py. Write a new notebook that demonstrates how to use the functions of your my_analysis module.

```
def my_workflow(input_image, …):
    ...
    return label_image
```