UNIVERSITY OF GOTHENBURG

Python for bioimage analysis

Material:

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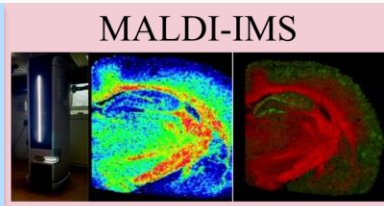
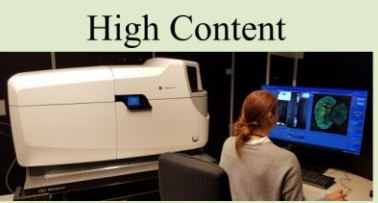
https://github.com/CamachoDejay/teaching-bioimage-analysis-python/tree/gotbin-nov-2022

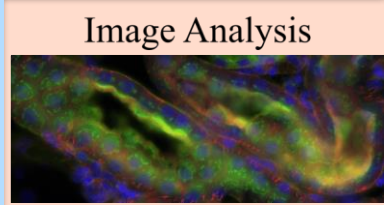
The Centre for Cellular Imaging

- The Centre for Cellular Imaging (CCI) is a national core facility that integrates both light and electron microscopy
- The CCI offers open-access state-of-the-art imaging equipment
- Researchers from universities or companies in Sweden and from abroad are equally welcome!
- We are part of the Euro-Bioimaging Swedish node

The Centre for Cellular Imaging







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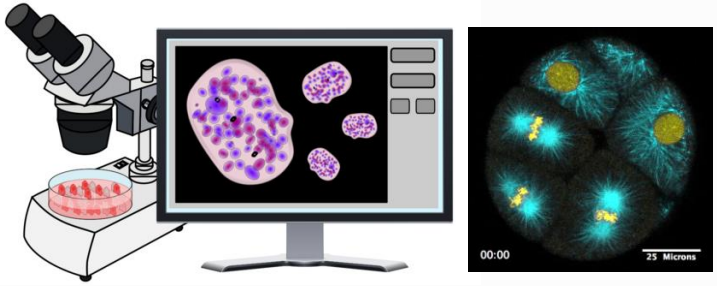
Introduction to quantitative imaging

Bioimage analysis and Python

Short demo

*Time lapse fluorescence imaging of dividing sea purple urchin's embryo. Full movie in von Dassow, J Cell Biol. (2009) 187, 831-845. Time in minutes : seconds

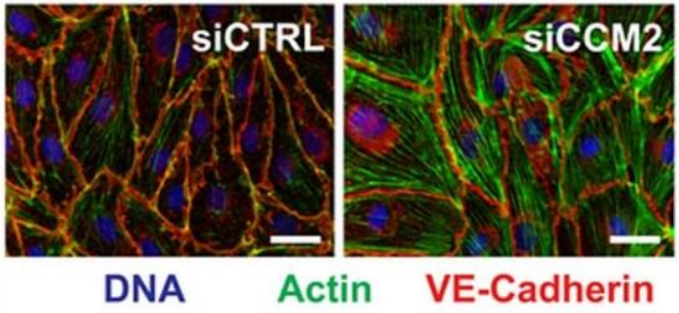
Image-based Quantitative Biology



*urchin's embryo development.

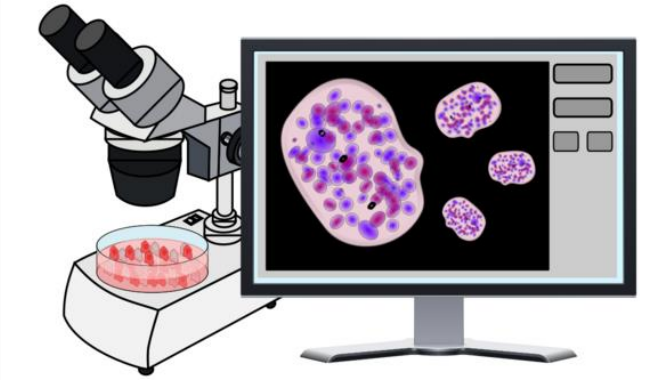
Image-based quantitative biology uses the rich information present in biological images to creates a list of descriptors that can be analysed to discover relevant patters.

Therefore, many samples must be imaged to achieve statistically meaningful results.

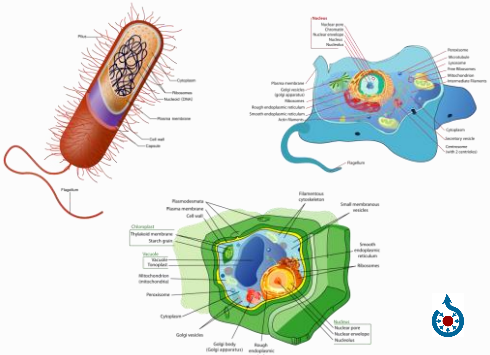


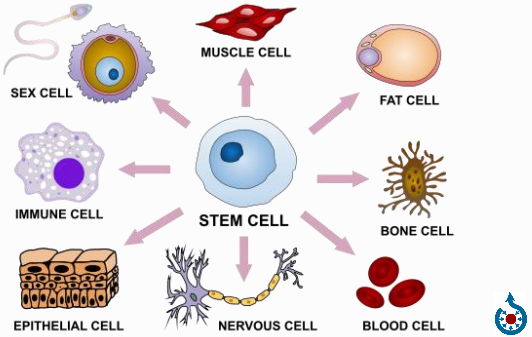
Circulation. 2015;131:289–299
siCTRL → "healthy" cells || siCCM2 → "diseased" cells
Immunofluorescence images of endothelial cells treated with siCTRL or siCCM2 stained for DNA (blue), actin (green), and VE-cadherin (red).

Image-based Quantitative Biology | The challenge



Biological system as inherently complex.
As a consequence, obtaining sufficiently large datasets during manual operation can become very time-consuming, especially when the phenotypes of interest are rare or occur only during specific biological stages.





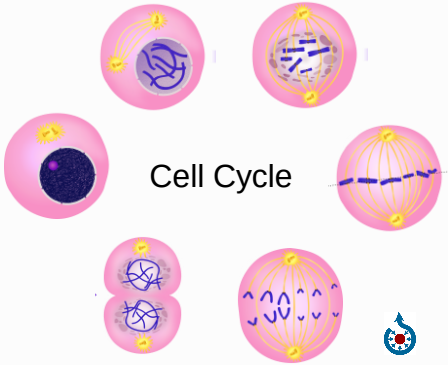
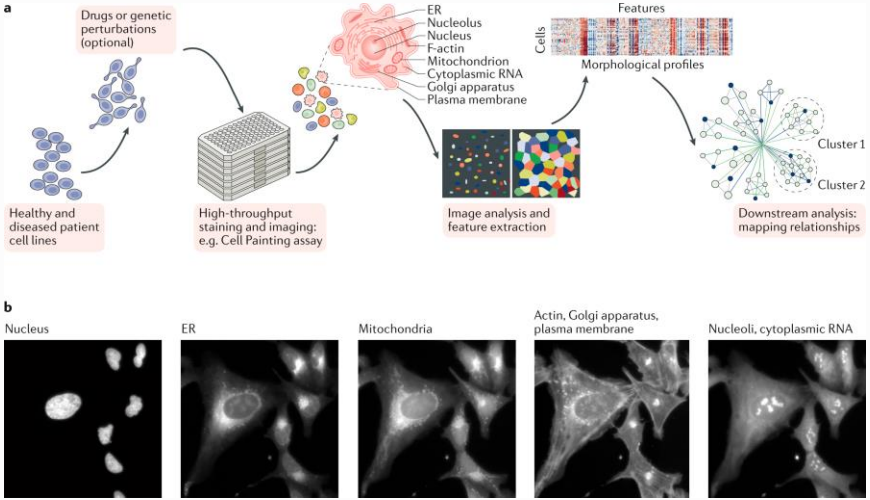


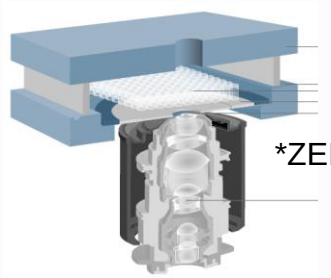
Image attribution disclaimer: all figures marked by come from https://commons.wikimedia.org

Automated microscopy | E.g. HCS Microscopy

Cells are seeded in a multi-well plate. These are exposed to different conditions. All wells are imaged and features extracted.

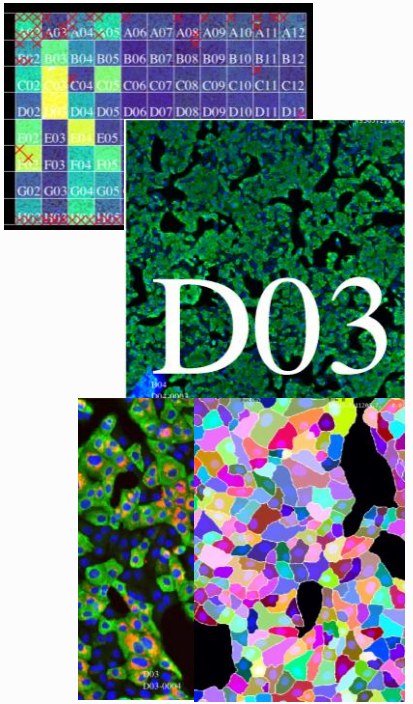


[Nature Reviews Drug Discovery, 20, 145–159 (2021)]



*ZEISS

Computer controlled microscope



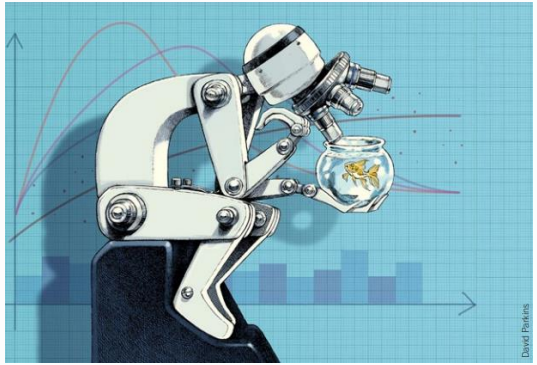
https://github.com/embl-cba/plateviewer

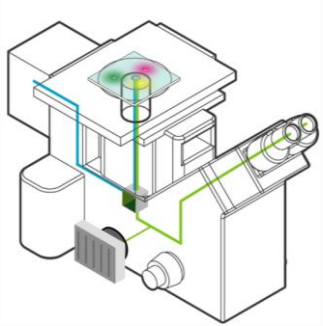
* https://github.com/micro-manager/pycro-manager

Smart Microscopy | Feedback Microscopy

Over the last decade, much effort has been made to connect bioimage analysis (used to, e.g., detect specific cells in microscopy images) with fully motorised and computer-controlled microscopes (via proprietary or open-source software packages) to generate automated and adaptive imaging workflows, referred to as ***smart microscopy***.

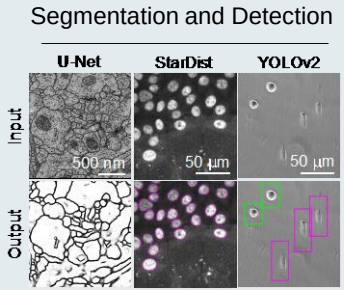
Nature Biotechnology, 33, 815–818 (2015)

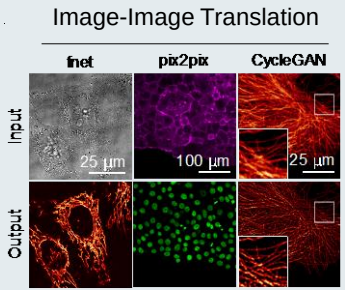


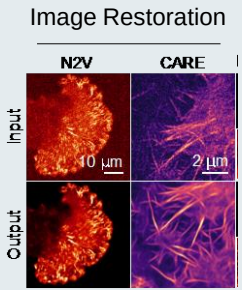


* Pycro Manager

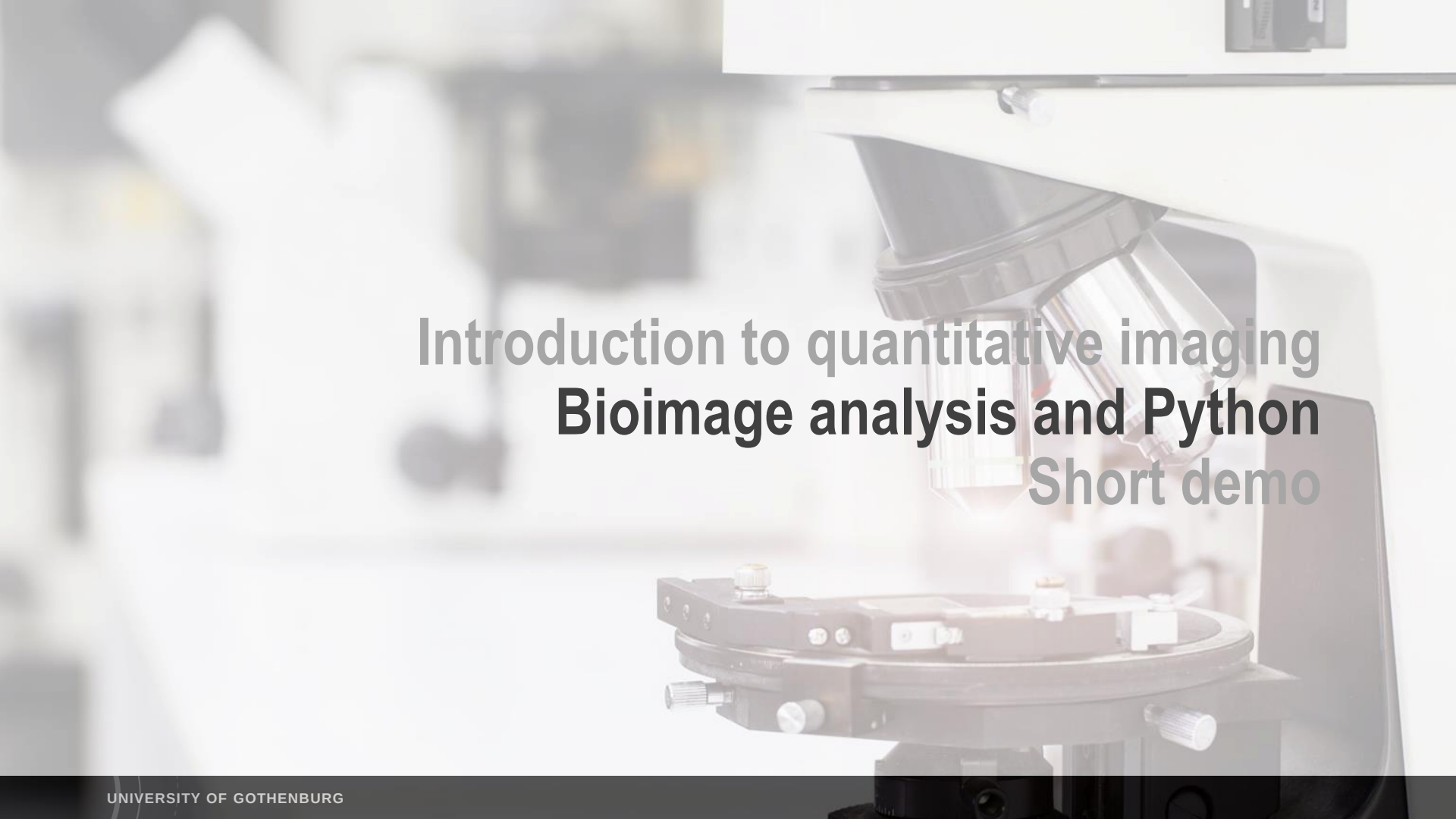
µManager







von Chamier L et al Nat Communs 2021



Introduction to quantitative imaging
Bioimage analysis and Python
Short demo

Bioimage analysis

Could be defined as “the process of identifying spatio-temporal distribution of biological components in images, and measure their characteristics to study their underlying mechanisms in an unbiased way.”

Miura & Tosi, 2016, Introduction, “Bioimage Data Analysis”

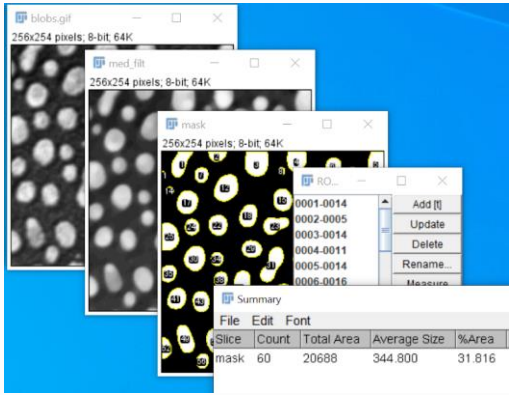


Image loading
- Data conversion
- Metadata
- Proprietary file formats

Pre-processing
- Filtering
- Stitching
- Corrections

Segmentation
- Morphological operations
- Post processing

Quantification
- Connected component analysis
- Object filtering
- Num. Output

Bioimage analysis vs Image analysis (computer vision)

“Image analysis is a process of discovering, identifying, and understanding patterns that are relevant to the performance of an image-based task. One of the principal goals of image analysis by computer is to endow a machine with the capability to approximate, in some sense, a similar capability in human beings”

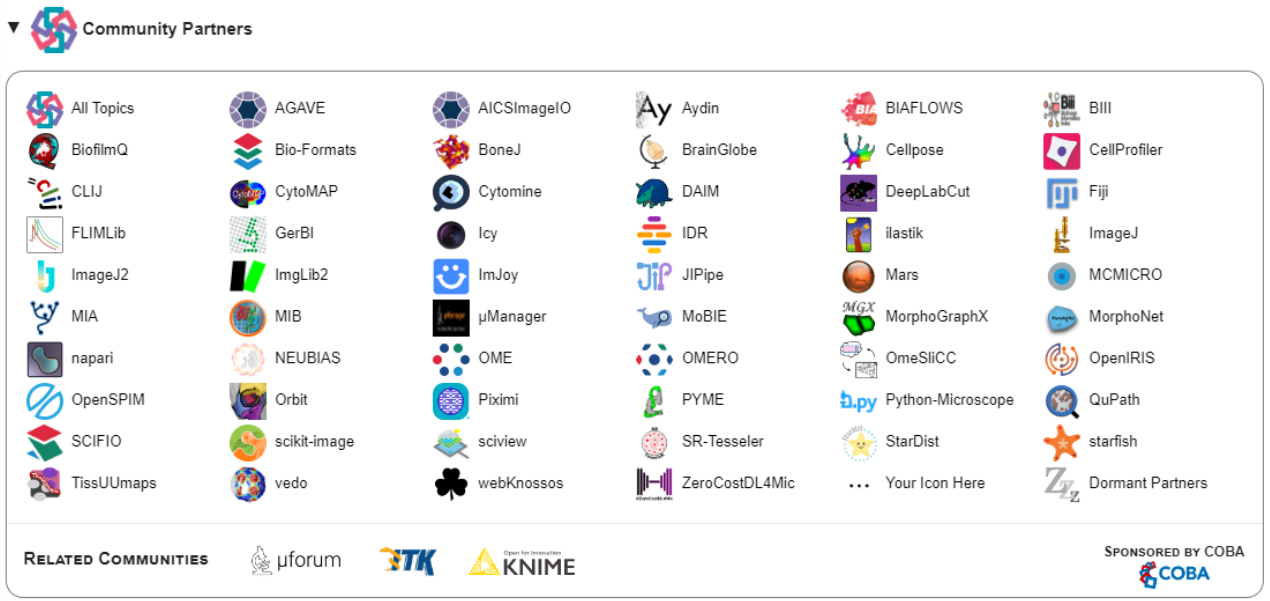
Gonzalez & Woods, “Digital Image Processing”, 2008

In Bioimage analysis we do not emphasize human recognition. The focus is objectivity of quantitative measurements, rather than agreement with human recognition.

Adapted from Kota Miura: https://github.com/miura/reproducible_bioimage_analysis

Bioimage analysis landscape

image.sc https://forum.image.sc/



Some examples of programming languages:

Java
ImageJ – macro
FIJI
Micromanager

Python
Scikit-image
*ML + data mining

MATLAB
Many packages
Material science and engineering

Why Python

The usuals: Easy to learn*, versatile, packages, thriving community…

For reproducibility and training: Jupyter notebooks (example later today)

The “new”: Machine learning, Napari, Chan Zuckerberg Initiative (CZI) ,…

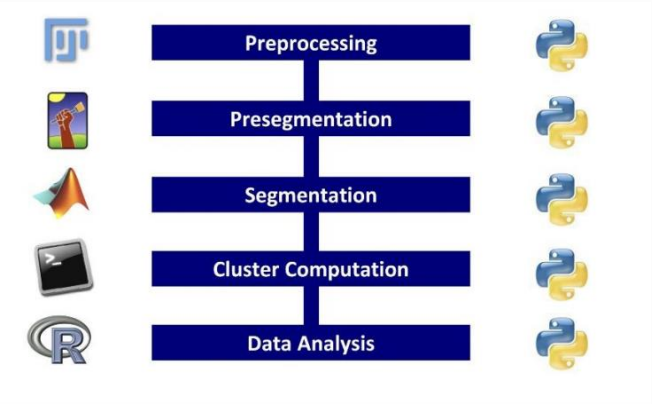


Image Jonas Hartmann (MIT licensed)
https://github.com/WhoIsJack/python-bioimage-analysis-tutorial

The “One Ring effect”

Python for bioimage analysis

The good

- Sharing and reproducibility
- Collaboration
- Openness

The challenges

- Teaching to beginners
- Lack of general knowledge
- Lack of knowhow in research groups

The opportunities

- Access to other communities
- Machine learning
- Hardware control
- Smart-microscopy

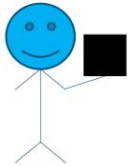
Openness of software / projects

PoL Physics of Life TU Dresden

Communication is key!

Choose your project's level wisely, and communicate it clearly

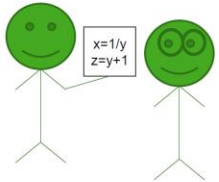
Closed source



- Open to collaborations
- "Black box"
- Compiled code (e.g. C/C++)
- Good for protecting intellectual properties ($$$)

Hardware device drivers

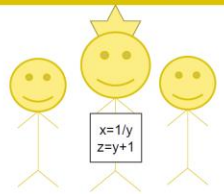
Open source



- Code available to read
- Not necessarily executable code
- No maintenance / support efforts

Custom image analysis scripts

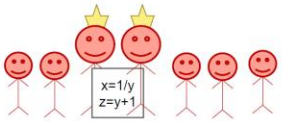
Benevolent dictatorship



- Open to contributions
- Single maintainer, often overwhelmed
- Efficient decision making
- Bus factor ≈1

TrackMate, SNT, MorpholibJ, CLIJ

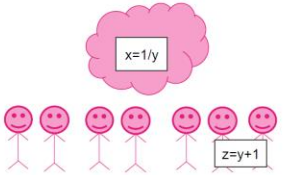
Community driven



- Open to contributions
- Partially democratic
- Board of maintainers (core developers)
- Long-winded decision making

scikit-image, scipy, OpenCL

Openly extensible



- Openly extensible; without maintainers involved
- Partially community driven

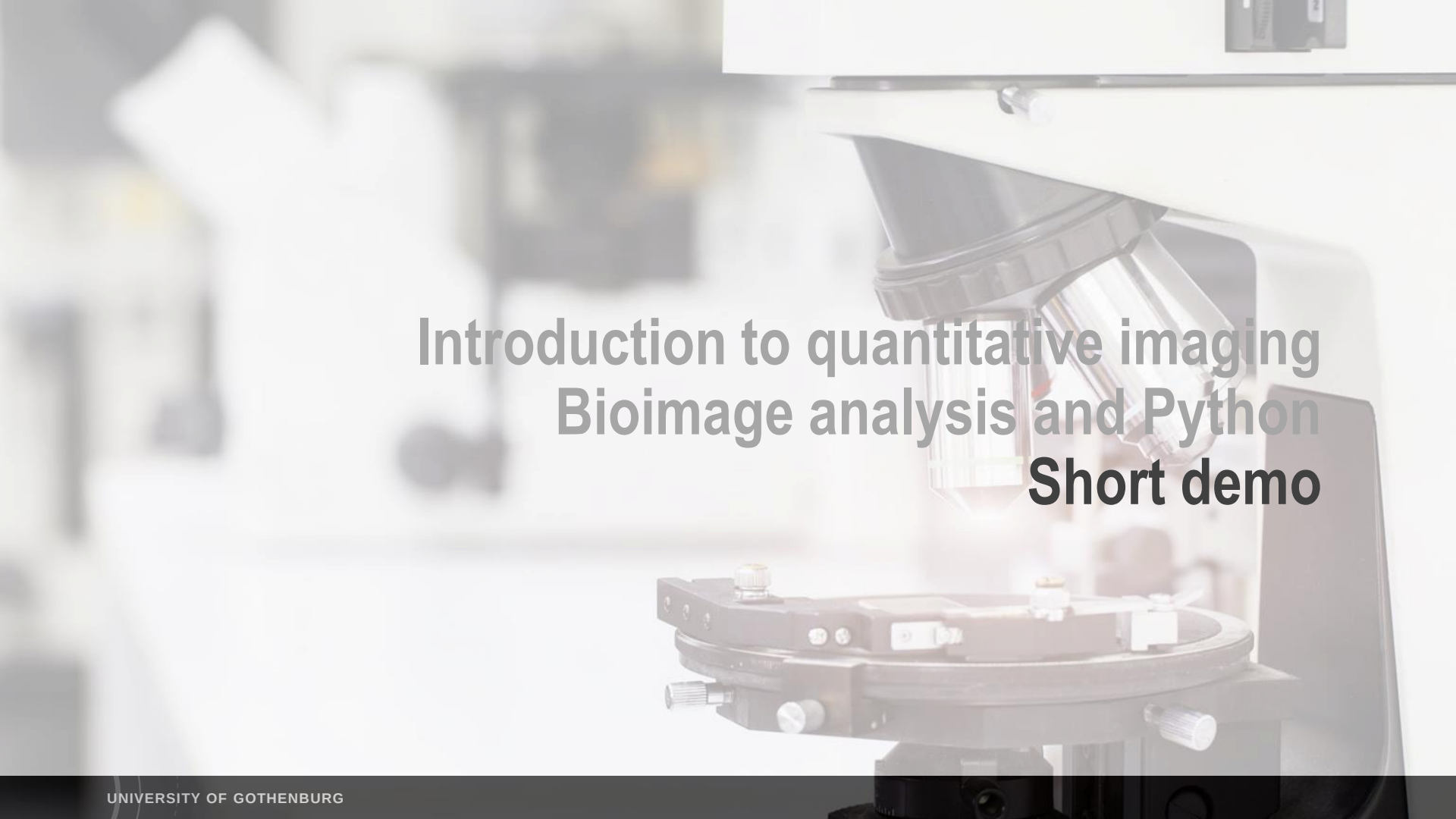
ImageJ, Python, numpy

@haesleinhuepf
@PoLDresden

Read more: https://www.coiled.io/blog/stages-of-openness

TECHNISCHE UNIVERSITÄT DRESDEN DRESDEN concept 24

Slide by Robert Haase Hitchhiking through a diverse Bio-image Analysis Software Universe. *F1000Research* 2022, **11**:746 (slides) (https://doi.org/10.7490/f1000research.1119026.1)



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Short demo

Short demo

We will use Python for bioimage analysis. In this context we will be using Napari as an multi-dimensional image viewer, skimage for image processing operations, aicspylibczi for advanced loading example (metadata + proprietary file format).

Napari - https://napari.org/stable/

skimage - https://scikit-image.org/

aicspylibczi - https://github.com/AllenCellModeling/aicspylibczi

Material:

https://github.com/CamachoDejay/teaching-bioimage-analysis-python/tree/gotbin-nov-2022

List of resources

Napari hub, discover, install and share Napari plugins: https://www.napari-hub.org/

NEUBIAS: http://eubias.org/NEUBIAS/

Image.sc Forum https://forum.image.sc/

Bio-Image analysis wiki http://wiki.cmci.info/start

Introduction to Bioimage Analysis By Pete Bankhead jupyter-book
https://bioimagebook.github.io/README.html

Neubias F1000 gateway: https://f1000research.com/gateways/neubias

Books:

Bioimage Data Analysis, Editor: Kota Miura

https://analyticalscience.wiley.com/do/10.1002/was.00050003

Bioimage Data Analysis Workflows, Editors: Kota Miura and Nataša Sladoje

https://www.springer.com/gp/book/9783030223854

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https://www.gu.se/en/core-facilities/centre-for-cellular-imaging


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Julia Fernandez-Rodriguez
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We are recruiting!