Detection and classification of intracellular filamentous structures

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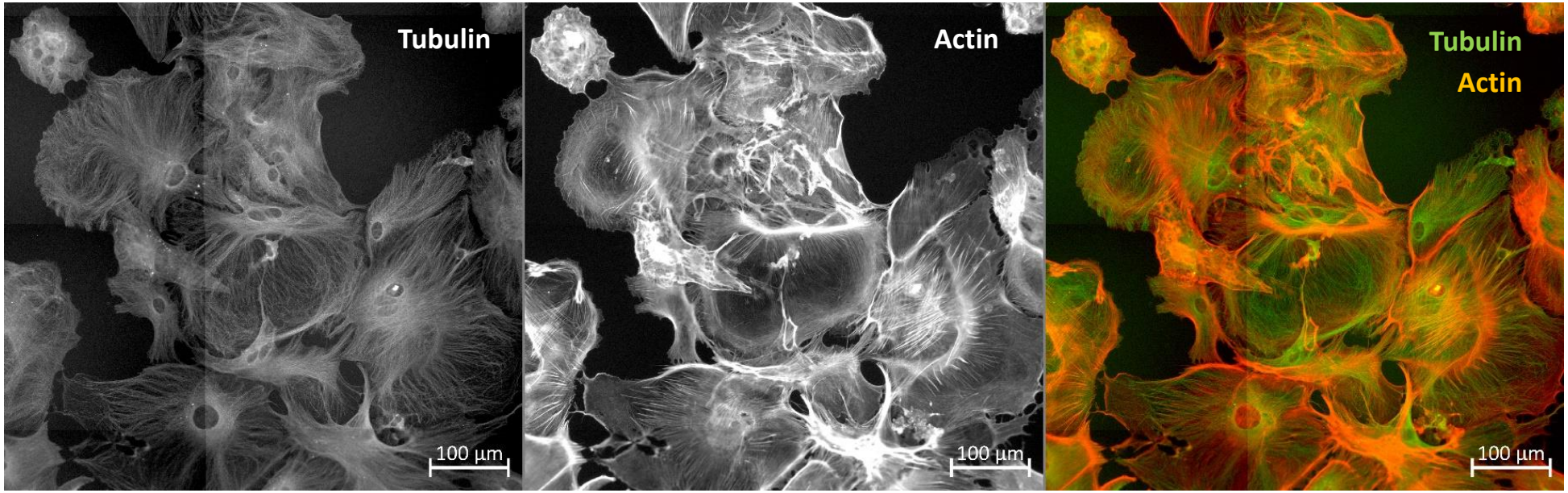
Introduction



- Detect and characterize components of filamentous networks of the cytoskeleton (actin & tubulin)
  - Filament characteristics: length, width, curvature, branching points, orientation within the cell
- Recognize changes and quantify properties between cells treated in different environmental conditions:
  - Environmental stimuli: exposed to microgravity or physical stress
- Filament structures are important for structural integrity, intracellular transport, sensing of environmental conditions and signal transduction

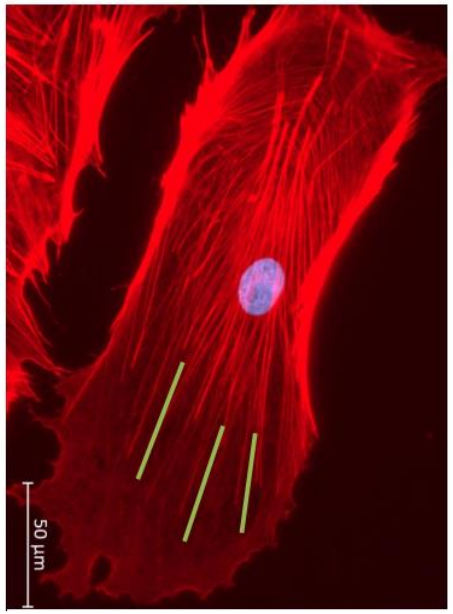
Introduction

- Currently filaments are analyzed manually which causes an extremly high workload

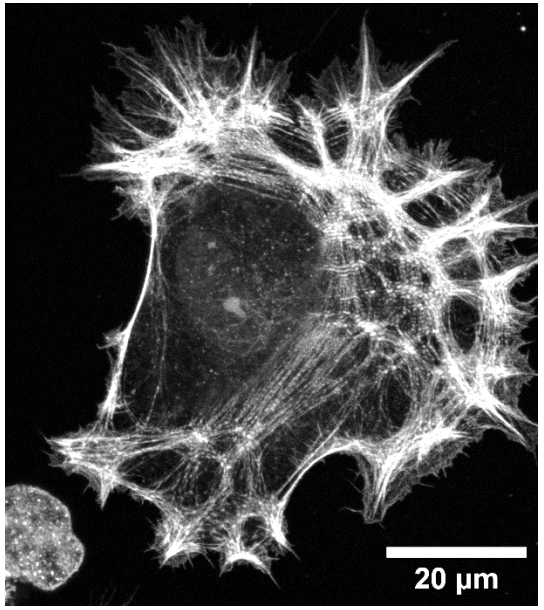
  → automated analysis would be needed (for most biological research areas)

Actin

Epifluorescense image

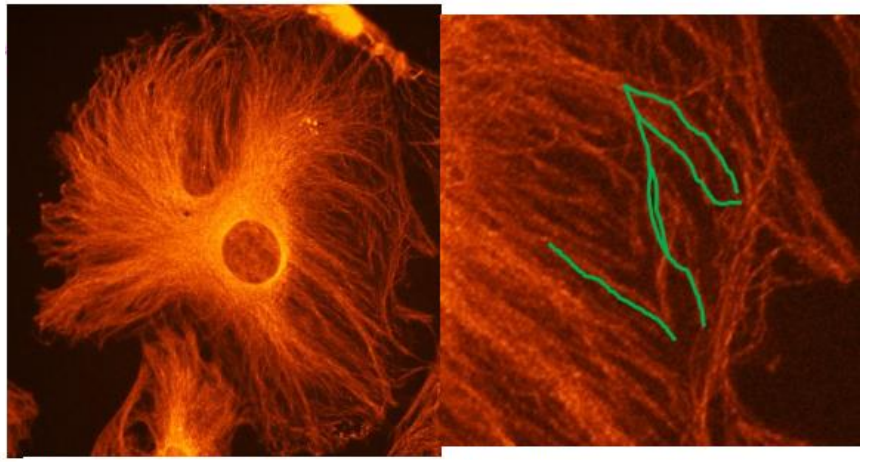


STED image

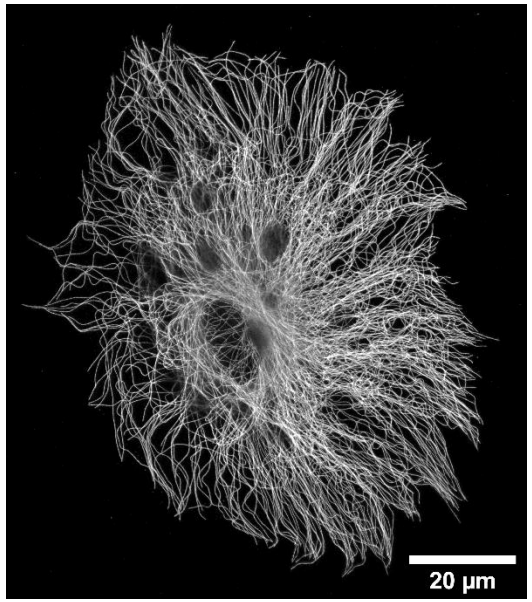


Tubulin

Epifluorescense image

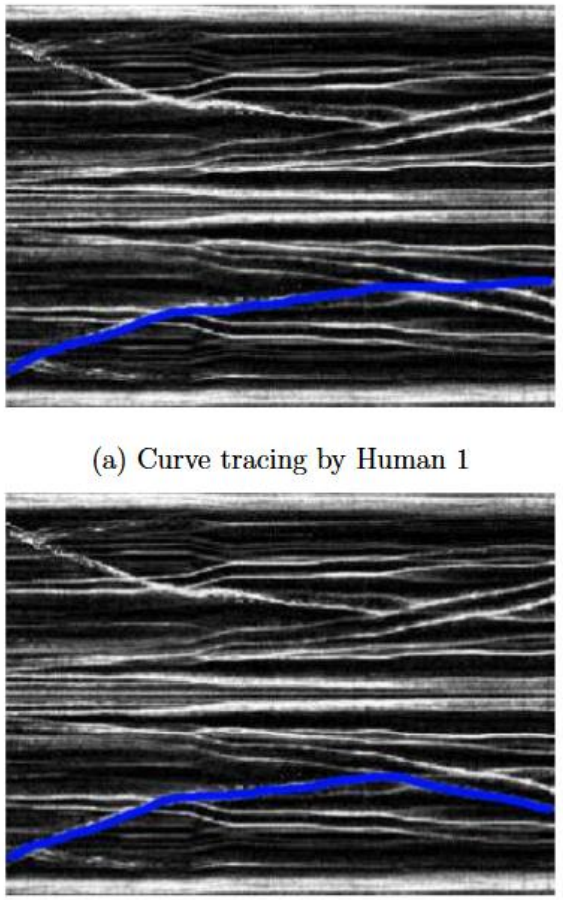


STED image



Curve Tracing for Tubulin

- Overlaps often ambiguous
- Still open problem in the literature



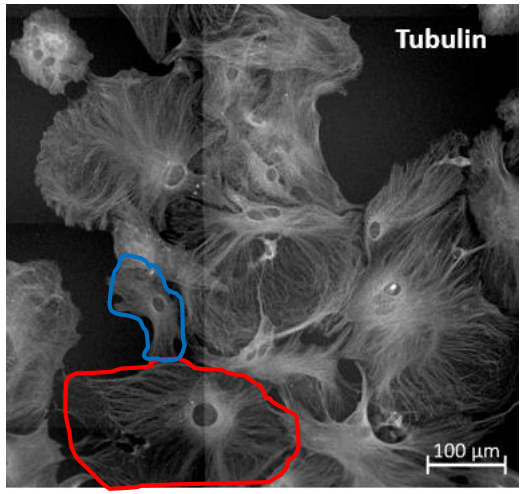
(a) Curve tracing by Human 1

(b) Curve tracing by Human 2

Figure 2.11: Desired result is not well defined

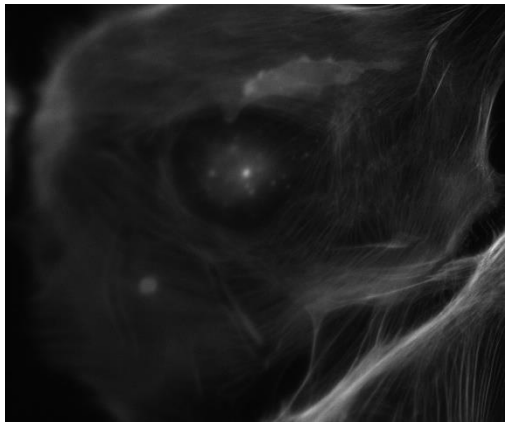
Raghupathy, K. (2004). Curve tracing and curve detection in images (Master Thesis, Cornell University).

Image analysis

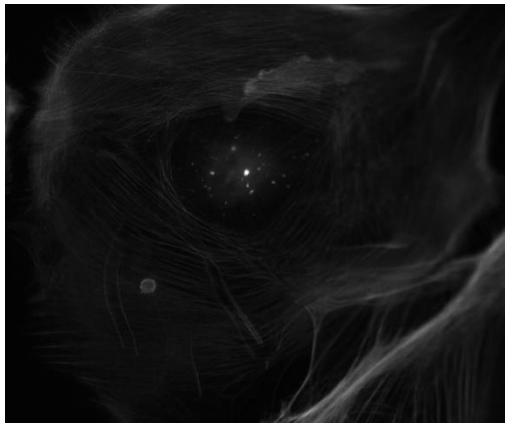


Cells are normally growing closely together in a 2D cell layer
→ To extract single cells a **segmentation** is needed

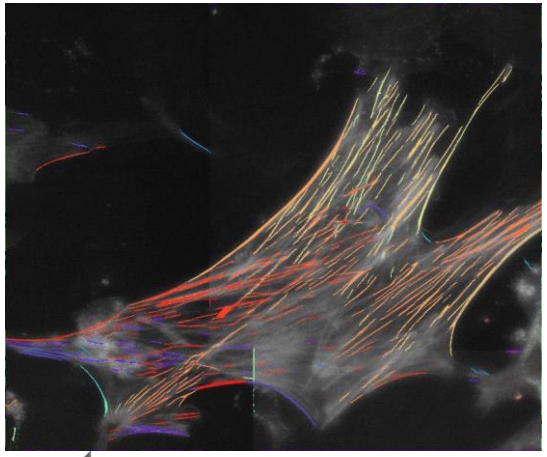
Segmentation



Deblurring



Filament Analysis

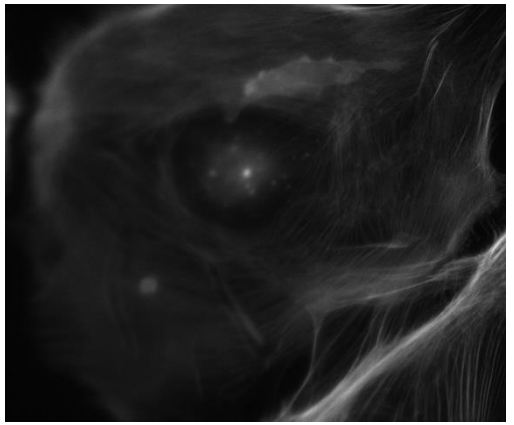


Microscopic images can contain blurry parts due to:
- diffraction barrier
- astigmatism
- defects
- human error

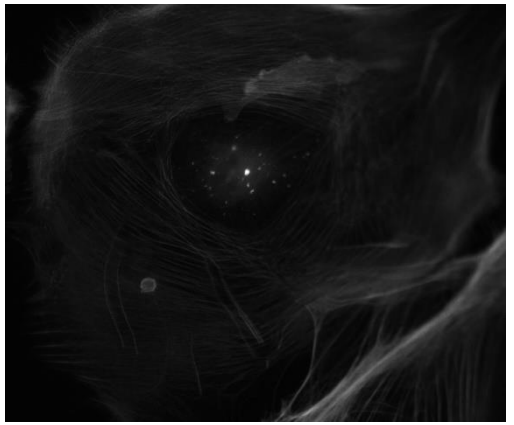
→ Difficult to trace filaments, thus a **deblurring** is needed

Deblurring

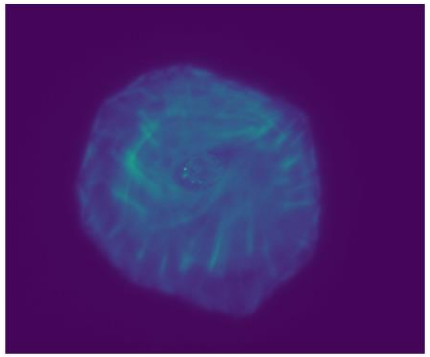
- Use a CycleGAN to translate blurry images into sharp images
- Using https://github.com/junyanz/pytorch-CycleGAN-and-pix2pix implementation [1]
- Results based on 103 paired images with blurry and sharp version
  - Has been generated via z-stacking



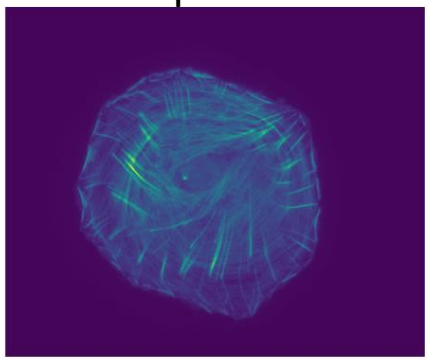
Deblurring



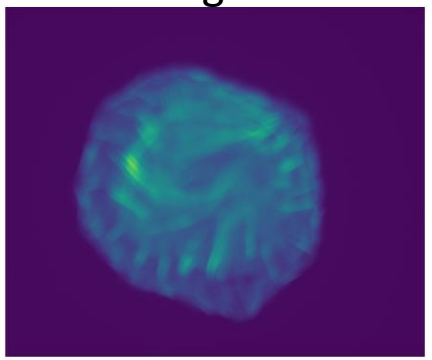
Low z



Optimal z



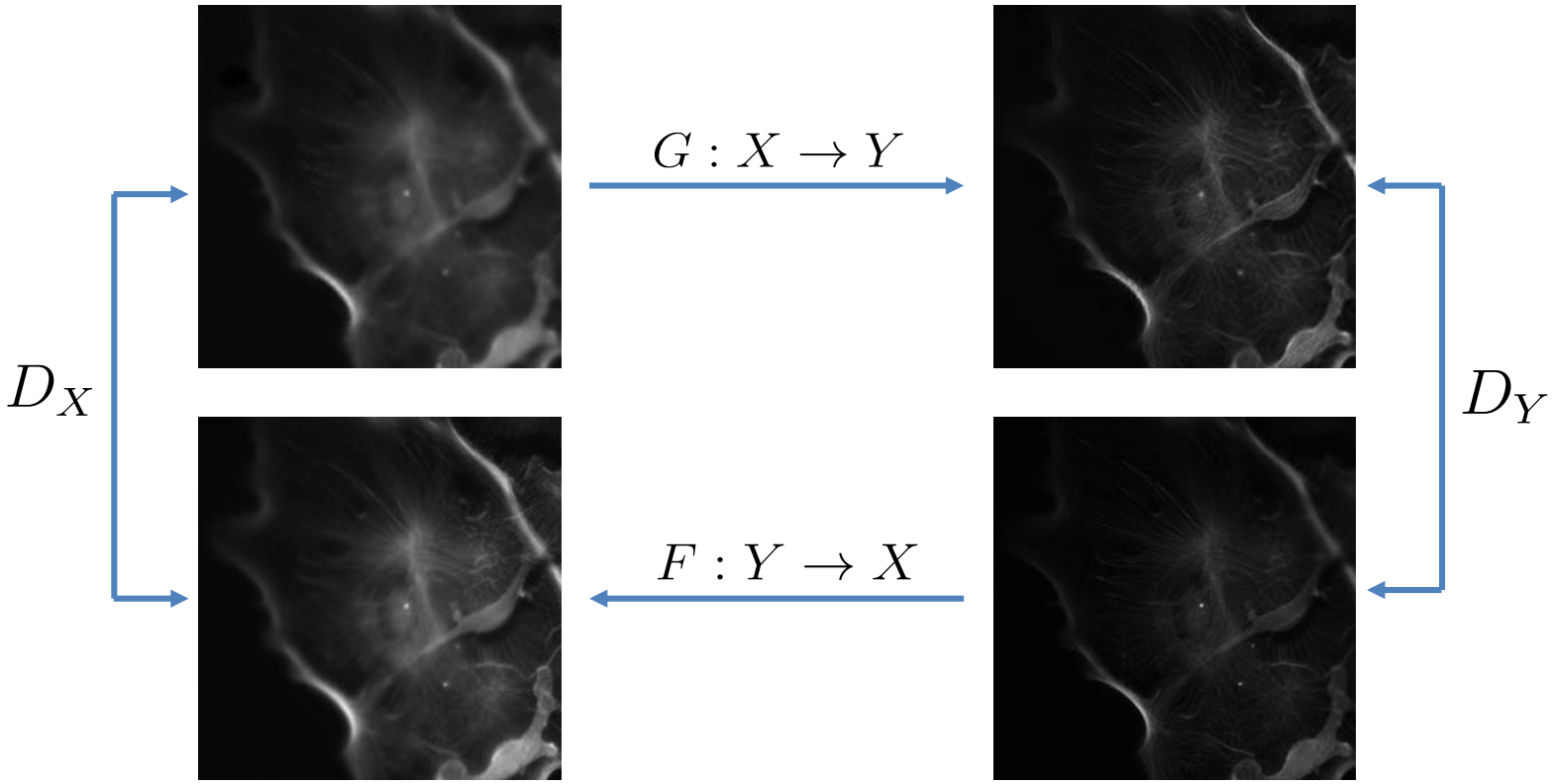
High z



[1] Unpaired Image-to-Image Translation using Cycle-Consistent Adversarial Networks. Jun-Yan Zhu*, Taesung Park*, Phillip Isola, Alexei A. Efros. In ICCV 2017. (* equal contributions)

CycleGAN Schema including Results

- Training data consists of blurry images (domain Y) and paired sharp images (domain X)
- Based on domain X/Y, G/F generates fake images in domain Y/X
- D_X/D_Y discriminates if images is from domain X/Y



Adversarial loss

$$\mathbb{E}_{y \sim p_{\text{data}}(y)}[\log D_Y(y)] + \mathbb{E}_{x \sim p_{\text{data}}(x)}[\log(1 - D_Y(G(x)))]$$

Cycle consistency loss

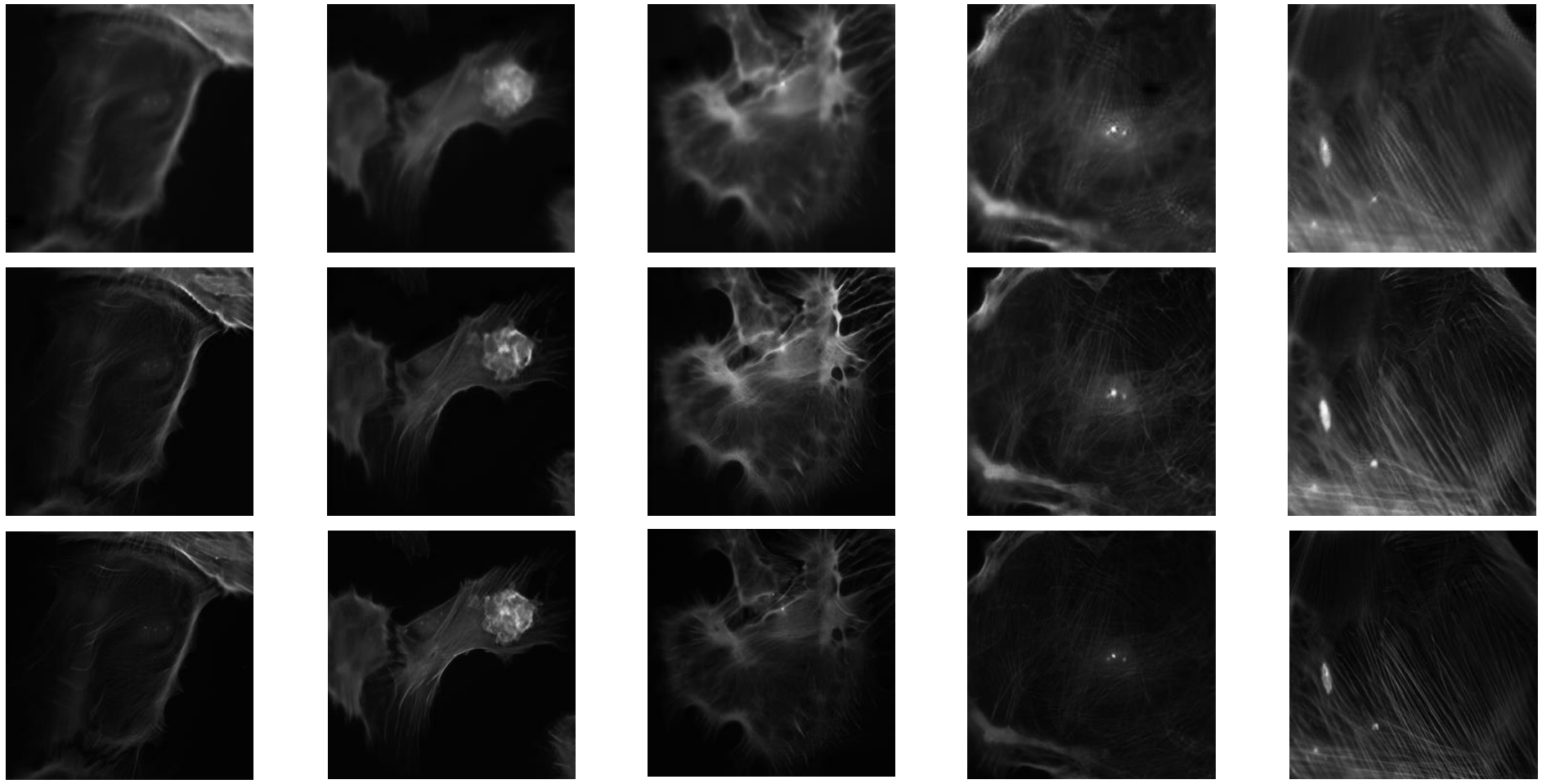
$$\mathbb{E}_{x \sim p_{\text{data}}(x)}[\|F(G(x)) - x\|_1] + \mathbb{E}_{y \sim p_{\text{data}}(y)}[\|G(F(y)) - y\|_1]$$

More Results

Blurry

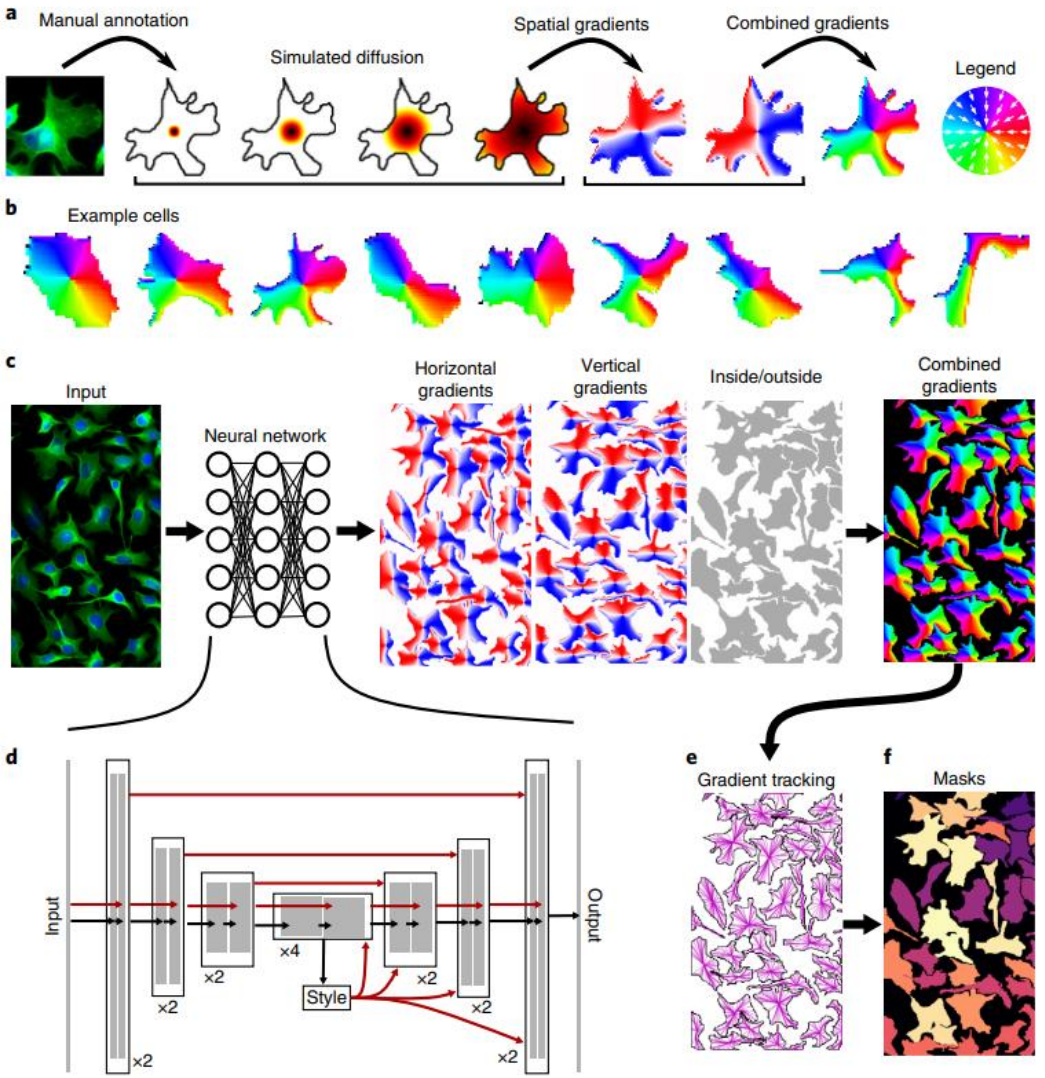
Generated

Sharp



Cellpose

- A generalist algorithm for cellular segmentation
- U-Net Backbone
- HITL-Training possible
- Pre-trained models available for finetuning

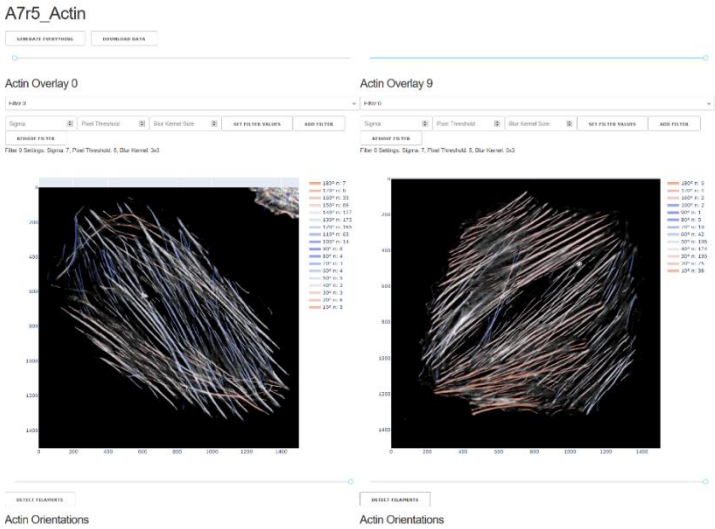


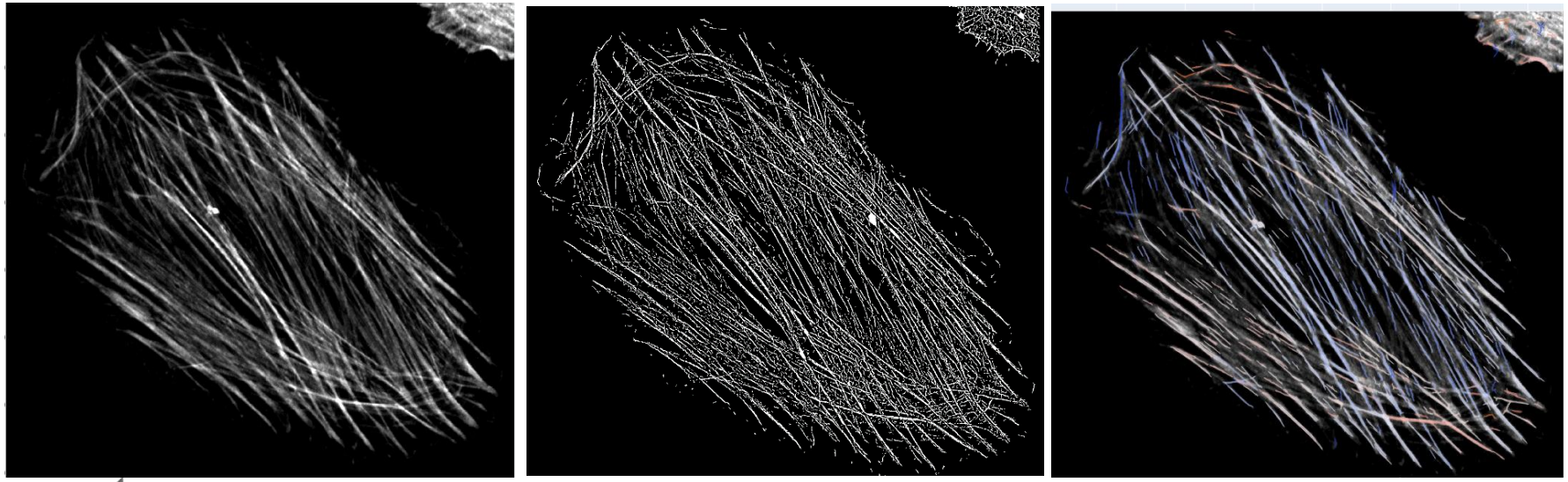
Stringer, C., Wang, T., Michaelos, M. et al. Cellpose: a generalist algorithm for cellular segmentation. Nat Methods 18, 100–106 (2021). https://doi.org/10.1038/s41592-020-01018-x

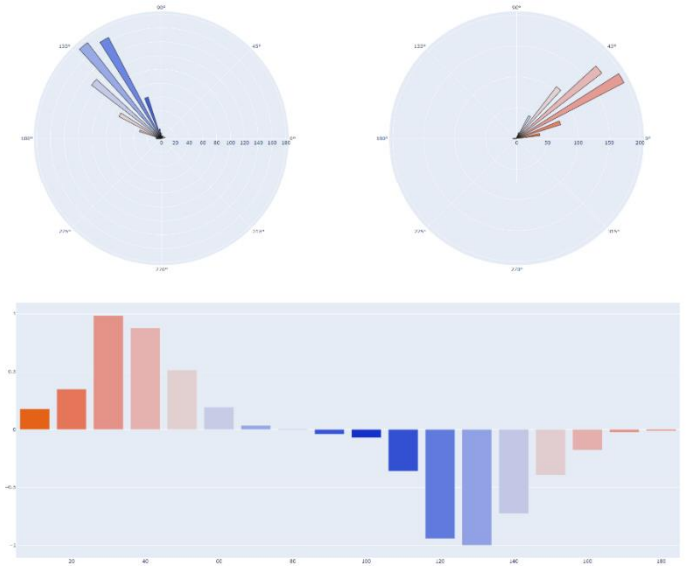
http://www.cellpose.org/

Orientation of actin filaments inside the cytoskeleton of eukaryotic cells

- Methodology:
  - Blur image with low-pass filter (remove artefacts)
  - Detect ridges via eigenvalues of the hessian matrix of the images
  - Detect contours on ridge image [1]
  - Apply principal component analysis for each contour
  - Create interactive dashboard to adjust filter parameters and to plot and download statistics







[1]Suzuki, S. (1985). Topological structural analysis of digitized binary images by border following. Computer vision, graphics, and image processing, 30(1), 32-46.