02456 - Project 22: Multiview Image Segmentation
Group 30

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1 Motivation

Understanding the mechanical forces that biological cells exert on their surroundings is fundamental for various applications in cell biology, tissue engineering, and mechanobiology [1]. Traction force microscopy (TFM) quantifies the forces biological cells exert on their surroundings by measuring the displacement of the substrate, in this case nanopillars, on which cells are cultured [1]. Traditionally, fluorescence microscopy is used to label cells, facilitating the detection of cell boundaries and corresponding nanopillar interactions [1]. While effective, this approach has significant limitations: the addition of fluorescence markers can alter cell behavior, complicate the experimental process, and may be infeasible for certain biological applications due to toxicity, cell type constraints or limited access to imaging equipment [2, 3, 4, 5]. Brightfield (BF) microscopy provides a compelling alternative as it uses standard optical setups without the need for fluorescent dyes [6]. However, current methodologies for cell detection in BF images are challenged by noise and lack of contrast, making robust segmentation difficult [7] even without the added challenge of broken pillars and debris.

2 Background

The goal of this project is to develop a CNN-based deep learning model that is able to segment cells based on brightfield microscopy images. This model should be robust to noise and deliver fast segmentations. Based on a short literature review including [8], [9], [10] it seems that more advanced architectures such as an attention-based Unet as in [8] yield better performance for cell segmentation in brightfield microscopy data. We will compare the performance of several CNN-based models ranging from relatively simple models to more advanced models such as an attention-based Unet [11]. Ther performance of the models will be compared based on Dice, Intersection-over-Union, accuracy, sensitivity and specificity to allow detailed conclusions and diagnosis of potential issues.

3 Milestones

Week	**Milestone**
1.- 10.11	Inspect Dataset, Define Dataloader, Image Analysis, Literature Review
11.- 17.11	Construct CNN model, Evaluate test runs, Define Loss Functions, Data Augmentation, Explore Pre-trained Models
18.- 24.11	Finalise Model Architecture and Model Regularisation
25.- 1.12	Train Final Model and Evaluate the Results
2.- 9.12	Documentation

Table 1: Milestones for the project.

References

[1] T. Iskratsch, H. Wolfenson, and M. P. Sheetz, "Appreciating force and shape — the rise of mechanotransduction in cell biology," *Nature Reviews Molecular Cell Biology*, vol. 15, pp. 825–833, 12 2014.

[2] R. Dixit and R. Cyr, "Cell damage and reactive oxygen species production induced by fluorescence microscopy: effect on mitosis and guidelines for non-invasive fluorescence microscopy," *The Plant Journal*, vol. 36, pp. 280–290, 10 2003.

[3] L. S. D. Clerck, C. H. Bridts, A. M. Mertens, M. M. Moens, and W. J. Stevens, "Use of fluorescent dyes in the determination of adherence of human leucocytes to endothelial cells and the effect of fluorochromes on cellular function," *Journal of Immunological Methods*, vol. 172, pp. 115–124, 6 1994.

[4] A. Ettinger and T. Wittmann, *Fluorescence live cell imaging*, pp. 77–94. 2014.

[5] K. Toman, *Toman's Tuberculosis: case detection, treatment, and monitoring: questions and answers*. World Health Organization, 2004.

[6] J. Selinummi, P. Ruusuvuori, I. Podolsky, A. Ozinsky, E. Gold, O. Yli-Harja, A. Aderem, and I. Shmulevich, "Bright field microscopy as an alternative to whole cell fluorescence in automated analysis of macrophage images," *PLoS ONE*, vol. 4, p. e7497, 10 2009.

[7] R. Ali, M. Gooding, M. Christlieb, and M. Brady, "Advanced phase-based segmentation of multiple cells from brightfield microscopy images," in *2008 5th IEEE International Symposium on Biomedical Imaging: From Nano to Macro*, pp. 181–184, IEEE, 5 2008.

[8] A. Ghaznavi, R. Rychtáriková, M. Saberioon, and D. Štys, "Cell segmentation from telecentric bright-field transmitted light microscopy images using a residual attention u-net: A case study on hela line," *Computers in Biology and Medicine*, vol. 147, p. 105805, 2022.

[9] M. A. Ali, K. Hollo, T. Laasfeld, J. Torp, M.-J. Tahk, A. Rinken, K. Palo, L. Parts, and D. Fishman, "Artseg—artifact segmentation and removal in brightfield cell microscopy images without manual pixel-level annotations," *Scientific Reports*, vol. 12, no. 1, p. 11404, 2022.

[10] E. Ferreira and G. Silveira, "Classification and counting of cells in brightfield microscopy images: an application of convolutional neural networks," *Scientific Reports*, vol. 14, no. 1, p. 9031, 2024.

[11] O. Ronneberger, P. Fischer, and T. Brox, "U-net: Convolutional networks for biomedical image segmentation," in *Medical image computing and computer-assisted intervention–MICCAI 2015: 18th international conference, Munich, Germany, October 5-9, 2015, proceedings, part III 18*, pp. 234–241, Springer, 2015.