MSc Student project proposal: Development of a 3D cell segmentation model

Introduction

In the study of cancer migration, three-dimensional (3D) models have become indispensable tools for mimicking the complex tumour microenvironment more realistically than traditional 2D methods. These cell models allow for the study of cell behaviour, including migration, proliferation, and interaction with the extracellular matrix [1]. However, the complexity of 3D cell culture presents significant challenges for data analysis, particularly when it comes to monitoring and quantifying dynamic cellular processes like migration [2]. This is where advanced image analysis plays a critical role.

Objective

The main objective of this student project is to develop and implement an image segmentation algorithm for accurately identifying and segmenting individual tumour cells in 3D cell cultures embedded in a hydrogel matrix (see figure 1). The segmentation process will be the critical first step in analysing cell migration within a microfluidic system under controlled shear flow conditions.

Your role in this project

This master student project offers an opportunity to contribute to the development of innovative tools for cancer research. Your goal will be the development of a MATLAB-based segmentation pipeline that can accurately identify individual tumour cells within 3D spheroid cultures, based on real-time imaging data. To capture the data, a series of 2D images are captured at different focal planes throughout the depth of the sample. This stack of images (z-stack) will be the starting point of the segmentation process. In this project, you will work on image pre-processing, algorithm development, and validation.

This project represents an advancement in the field of cancer research. Your work will provide the foundation for a larger framework aimed at understanding how tumour cells migrate in 3D environments, offering new insights into tumour behaviour and potential therapeutic solutions.

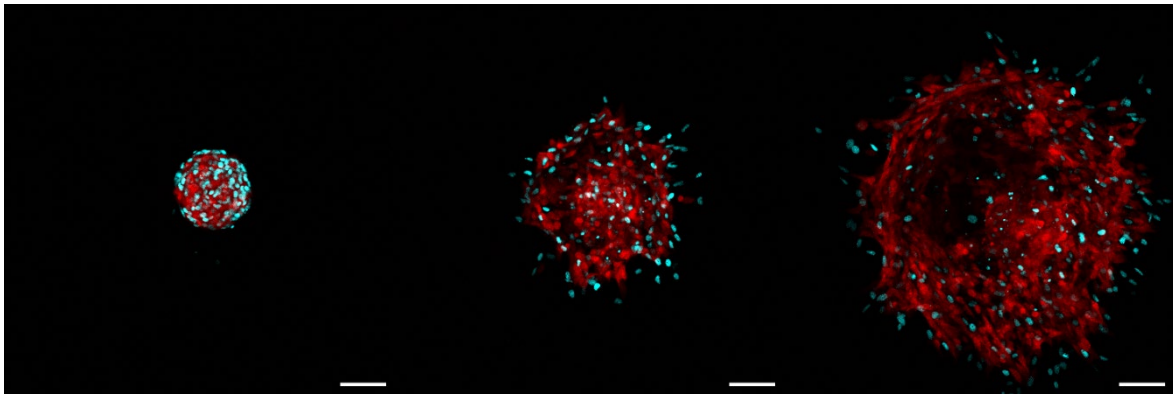

Figure 1. Images of cancer cells spreading. The cancer cells (red) and fibroblasts (blue), suspended in a fibrin hydrogel. The images were obtained via confocal fluorescence microscopy, and were taken as a z-stack and represented here in a max intensity projection. At t=0, the cells clustered together (A), after which they migrated outwards, imaged here at t=20h (B) and t=40h (C). Scalebar is 100 µm.

For inspiration, see the following links

- Volumetric Semantic Instance Segmentation of the Plasma Membrane of HeLa Cells
- A general algorithm for consensus 3D cell segmentation from 2D segmented stacks
- Interstitial flow potentiates TGF-β/Smad-signaling activity in lung cancer spheroids in a 3D-microfluidic chip†

Required experience

- Coding (Matlab/Python)

Duration of the project

- 4-6 months

Contact information

- a.d.bordoloi@tudelft.nl
- s.smink@tudelft.nl

References

[1] C. Jubelin *et al.*, "Three-dimensional in vitro culture models in oncology research," *Cell Biosci*, vol. 12, no. 1, Dec. 2022, doi: 10.1186/S13578-022-00887-3.

[2] Y. H. V. Ma, K. Middleton, L. You, and Y. Sun, "A review of microfluidic approaches for investigating cancer extravasation during metastasis," *Microsystems & Nanoengineering 2018 4:1*, vol. 4, no. 1, pp. 1–13, Apr. 2018, doi: 10.1038/micronano.2017.104.