Data-assimilation for models of biological tissues

MSc Thesis with dr.ir. Lisanne Rens and prof.dr.ir Arnold Heemink

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Motivation of study

Detailed models of tumour growth are currently being developed with the ultimate aim of application in the clinic [2]. In an ideal scenario, patient images and data are used to develop a virtual twin of the tumor. Simulations of the virtual twin can help determine the optimal treatment that the cancer patient should receive. During the course of the treatment, the tumour changes in shape and the tumour cells change their behavior. Thus, the treatment should be continuously adapted so that the treatment is still optimal. An idea is to iteratively employ the most up-to-date patient data to update the model parameters of the virtual twin to recalibrate the treatment [3].

Project description

In this project, you will explore the application of data assimilation techniques to cell-based models of tissues. Cell based models are a type of agent-based models that describe each cell as an individual actor, that has distinct behavior and interacts with other cells. We will identify a suitable case-study simulation, for instance, simple sorting of two cell types, or a simple tumour growth simulation. You will adapt the Ensemble Kalman Filter to be able to estimate the model parameters using (simulated) tissue data.

Mathematical techniques

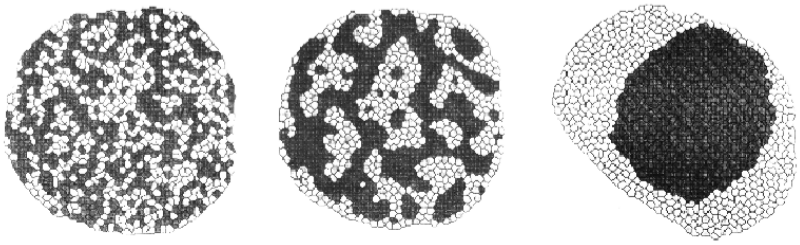
Besides Ensemble Kalman filtering, you will become familiar with a specific type of cell-based model called the cellular Potts model. You will use the open-source platform Morpheus (`https://morpheus.gitlab.io/` developed at TU Dresden, uses XML input files and C++). Other type of (open-source) cell-based modeling platforms may also be used, if there is a strong preference. You will construct quantification methods (in Python/Matlab) to identify simulated tissue properties (such as tumour size, or its compactness) which are also measurable in real-life.

References

[1] Mark Alber, Maria Kiskowski, James Glazier, and Yi Jiang. On cellular automaton approaches to modeling biological cells. *IMA V Math*, 134, 01 2003.

[2] Ibrahim M Chamseddine and Katarzyna A Rejniak. Hybrid modeling frameworks of tumor development and treatment. *Wiley Interdisciplinary Reviews: Systems Biology and Medicine*, 12(1):e1461, 2020.

[3] Eric J Kostelich, Yang Kuang, Joshua M McDaniel, Nina Z Moore, Nikolay L Martirosyan, and Mark C Preul. Accurate state estimation from uncertain data and models: an application of data assimilation to mathematical models of human brain tumors. *Biology direct*, 6(1):64, 2011.



(a) (b) (c)

Figure 1: Sorting of two cell types in the Cellular Potts Model. Image from [1]