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Phase Field Methods for Biomedical Growth Processes
Phasenfeldmethoden für biomedizinische Wachstumsprozesse

Simulating the behavior of building structures under different load cases is only one of many application areas of numerical methods. Another area is the simulation of biomedical growth processes, e.g., the growth of a malign tumor [1]. The aim is to develop patient-specific simulation models to help surgeons with treatment. These types of problems come with their own unique set of numerical challenges. Biomedical growth processes lead to moving boundary problems. Tracking these boundaries in each time step is numerically challenging. An alternative approach is to use so-called phase field methods. The evolution of the boundary becomes integrated into the solution of the equation. To guarantee the conservation of the phase-field leads to a particular case of phase field methods, the so-called Cahn-Hilliard equation. This equation exhibits fourth-order derivatives, and cannot be easily solved with standard Finite-Element methods. An alternative phase field type is the Allen-Cahn equation [2], which has no higher-order derivatives but also no conservation properties.

In the scope of this thesis, the theory of phase field methods and biomedical growth processes should be reviewed. A comparison between the two main types of phase fields, Cahn-Hilliard and Allen-Cahn, should be drawn and the advantages and disadvantages compared. An Allen-Cahn type phase field should be implemented in the context of the biomedical tissue growth in either Matlab or FEniCS. The results should be compared to the solution of the Cahn-Hilliard equation.

Required knowledge:

- Solid understanding of Finite Element Methods
- Basic programming skills (Matlab or Python)
- Motivated to familiarize with biomedical problems

Literature:

[1] CRISTINI, VITTORIO, & LOWENGRUB, JOHN (2010): Multiscale modeling of cancer: an integrated experimental and mathematical modeling approach. Cambridge University Press.

[2] ALLEN, SAMUEL M, & CAHN, JOHN W (1979): A microscopic theory for antiphase boundary motion and its application to antiphase domain coarsening. Acta metallurgica, 27(6), 1085-1095.