Phase-field modelling of crack propagation in brittle media using the Finite Cell Method

★★★★☆	Programming Skills (JAVA)	Start:	immediately
★★★★☆	Finite Element Method	Duration:	6 months
★★★☆☆	Development	Language:	English
★★★★★	Research		

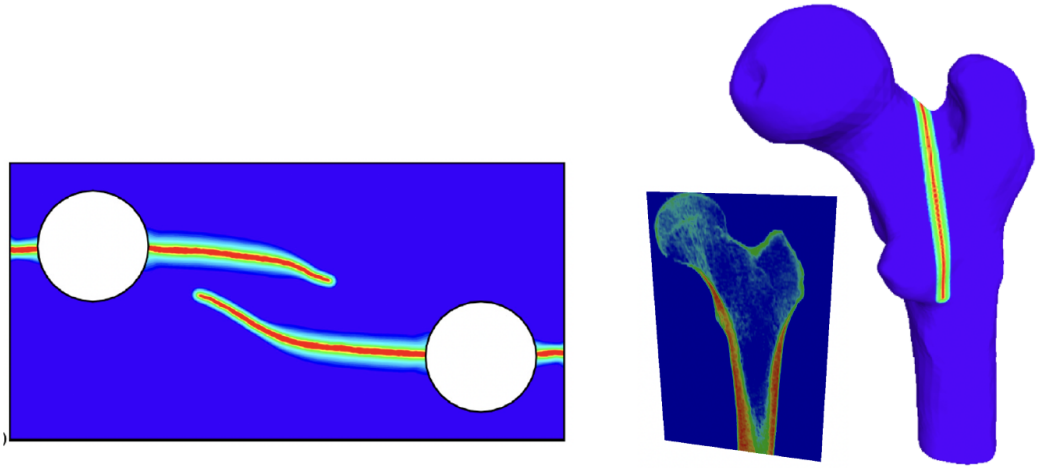

Bild 1: Modelling crack propagation using phase field analysis. Left: crack propagation in a plane stress state [2];, right: crack propagation in a human femur based on CT data [1].

Motivation

This project aims to expand an existing implementation of the finite cell method for phase-field analysis of crack growth in brittle media, such as cast iron, ceramics or concrete. The basic idea behind the phase-field approach is to describe discontinuous cracks using a continuous scalar field c, the so-called phase-field. This field assumes the value $c = 1$ in undamaged material and decreases continuously to $c = 0$ in the crack area. The phase-field acts as a coupling variable, which in particular locally attenuates the tensile energy components, thereby specifically reducing the load-bearing capacity of the material in the crack area.

The phase-field concept is closely related to the fictitious domain approach of the finite cell method. Both methods allow complex geometries and interfaces to be described independently of the underlying mesh. The diffusive approximation of the crack using a length scale parameter l_0 eliminates the need to explicitly map cracks as discontinuities in the mesh. Instead, crack initiation and crack propagation result directly from the solution of an additional differential equation. The chosen approach has proven to be robust for capturing complex crack mechanisms in two- and three-dimensional problems and is suitable for both quasi-static and dynamic load cases.

[1] V. Varduhn, M.C. Hsu, M. Ruess, D. Schillinger. The tetrahedral finite cell method: Higher-order immersogeometric analysis on adaptive non-boundary-fitted meshes, *Int'l Journal for Numerical Methods in Engineering, 107(12): 1054-1079* (2016)

[2] Aldakheel, F., Hudobivnik, B., Hussein, A., Wriggers, P. Phase-field modeling of brittle fracture using an efficient virtual element scheme, *Computer Methods in Applied Mechanics and Engineering, 341:443-466*,(2018)

The following extensions to the framework are required for simulation using phase fields:

- Solution of the coupled system: You implement a solver for two coupled equations: the classical momentum balance (displacement field, implementation already exists) and the evolution equation for the phase-field.
- Energetic splitting: Since cracks usually only occur under tension, you must split the strain energy into a tensile and a compressive component so that the phase field only reduces the tensile stiffness.
- Length scale l_0: You investigate how fine the FCM background mesh must be in order to sufficiently resolve the diffusive crack zone (controlled by l_0). As an alternative to global mesh refinement, a locally adaptive refinement strategy can be used, which is associated with a significant increase in efficiency.
- Verification of numerical results using selected benchmark problems. Possible extension: crack propagation simulations in thin (Kirchhoff) plates.
- Careful documentation of your developments and results in LaTeX.

Wir bieten

- Regular meetings and continuous scientific supervision throughout the entire project period.
- Introduction to current developments and research topics in scientific computing in engineering.
- Transparent and clearly defined evaluation criteria.
- Practical software development in engineering based on scientific findings.

Kontakt

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