Project Work – Material Point Method

This group project aims to deepen your understanding of MPM theory and numerical concepts by extending the educational Python code provided in the exercise sessions. You are expected to implement new features and then carry out suitable verification and validation tests to assess correctness and robustness of your work. The outcomes should be summarized in a poster for presentation at the end of the course, with collaboration encouraged as long as each group member maintains a general understanding of the overall project and results.

Task 1 – Boundary particles: geometric definition and data structure

Extend the provided MPM Python code with a concept of boundary particles for imposition of non-conforming boundary conditions as presented in the lecture slides.

- Introduce a suitable data structure (e.g. a new class) to represent boundary particles, including position, normal direction and an appropriate “weight” (integration factor).
- Implement a way to define simple boundary geometries (e.g. line segments) and to generate boundary particles along these geometries.
- Ensure that boundary particles can interact consistently with material points via nodal connectivity.

Task 2 – Weak imposition of non-conforming boundary conditions using penalty augmentation

Use the boundary particles to impose non-conforming Dirichlet boundary conditions in a weak sense, following the penalty augmentation concept from the lecture.

- Implement Dirichlet boundary conditions via a penalty approach by adding/ assembling the corresponding penalty terms to the global stiffness matrix and residual vector for the selected degrees of freedom.
- Provide access to reaction forces resulting from the penalty terms so that boundary reactions can be evaluated and interpreted.

Task 3 – Verification and validation of the implementations

Devise and perform meaningful tests to verify and validate your new implementations.

- Develop at least three test scenarios (e.g. cantilever beam clamped at a non-conforming location inside the background grid, MPM body falling on a fixed boundary represented by boundary particles, comparison of reactions with an equivalent FEM setup)
- For each test, define initial and boundary conditions such that the expected behaviour (displacement, stresses, reaction forces) can be estimated from theory or simple reference solutions.
- Compare numerical results with these expectations and assess accuracy, plausibility and sensitivity with respect to the penalty parameters and boundary-particle discretization in your documentation and poster.