LowLevelFEM – API logical structure (working draft)

Core

Fundamental data structures and concepts used everywhere.

- Problem
- Material
- BoundaryCondition (base type)
- InitialCondition
- ScalarField
- TensorField
- TimeStepper / TimeGrid
- Mesh / entity access helpers
- Nodes ↔ Elements mapping
  - nodesToElements
  - elementsToNodes

Preprocessing

Preparation of the FEM problem before assembly and solution.

Mesh handling

- loadMesh
- setCurrentMesh
- entity queries (physical groups, entities)

Boundary conditions

- BoundaryCondition
- DirichletBC
- NeumannBC
- RobinBC

- FollowerLoadBC
- applyBoundaryConditions

Initial conditions

- InitialCondition
- setInitialField

Loads and sources

- BodyForce
- SurfaceLoad
- VolumeSource

Operators

Weak-form building blocks, independent of specific physics.

Scalar field operators

(typically Poisson-type problems)

- poissonMatrix
- poissonMatrixVector
- laplaceMatrix
- sourceVector
- diffusionOperator

Vector field operators

- gradDivMatrix
- curlCurlMatrix
- divergenceOperator
- gradientOperator

Mass and time-related operators

- massMatrix

- dampingMatrix

Mechanics

Solid mechanics formulations.

Linear mechanics

Small deformation theory.

- stiffnessMatrix
- internalForceVector (linear)
- planeStressMatrix
- planeStrainMatrix
- axisymmetricMatrix
- linearElasticMaterial

Nonlinear mechanics

Large deformation, energy-based formulations.

- deformationGradient
- greenLagrangeStrain
- firstPiolaKirchhoff
- secondPiolaKirchhoff
- internalForceVector (nonlinear)
- materialTangentMatrix
- geometricTangentMatrix
- followerLoadVector
- followerLoadTangent

Structural dynamics

Mechanical systems with inertia.

- massMatrix (mechanical)
- dynamicResidual
- dynamicTangent

- NewmarkIntegrator
- HHTIntegrator

Heat transfer

Thermal problems.

Steady-state heat conduction

- heatStiffnessMatrix
- heatFluxVector
- steadyHeatSolver

Transient heat conduction

- heatCapacityMatrix
- transientHeatResidual
- transientHeatTangent
- timeStepHeatSolver

Dynamics

General time integration framework (physics-independent).

- TimeIntegrator
- Newmark
- HHT
- generalizedAlpha
- timeResidual
- timeTangent
- advanceTimeStep

Postprocessing

Evaluation and interpretation of results.

Field evaluation

- evaluateFieldAtNodes
- evaluateFieldAtGaussPoints
- interpolateField

Derived quantities

- strainField
- stressField
- energyDensity
- heatFlux

Export and visualization

- exportVTK
- exportCSV
- exportField

Utilities

Internal helpers and debugging tools.

- debugMatrix
- debugVector
- checkConsistency
- estimateLengthOfIJV
- performance helpers
- logging utilities