MFRONT: AN OPEN-SOURCE CODE GENERATOR FOR COMPLEX CONSTITUTIVE LAWS

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Constitutive equations describe how the internal state variables of a material evolve with changing external conditions or due to gradients of thermodynamic variables. Those state variables can describe many microstructural aspects of the material (grain size, dislocation density, hardening state, etc.) or be phenomenological in nature (equivalent plastic strain). The knowledge of those internal state variables allows the computation of local thermodynamic forces which affect the material equilibrium at the structural scale.

`MFront` is an open-source code generator for complex constitutive laws which aims at ease of use, numerical efficiency and portability (See [5, 3]). `MFront` has been developed under very stringent quality requirements in the context of nuclear fuel element simulation under the `PLEIADES` platform (see [6]), which is co-developed by CEA, EDF and Framatome.

`MFront` provides several domain specific languages (DSL) build on top of the `C++` language and associated with specific integration schemes that allows to readily implement the constitutive equations in source code close to their mathematical expressions. Numerical details are hidden by default allowing the user to focus on the physics. The underlying mathematical library, called 'TFEL/Math', provides optimised tensor objects and makes heavily use of template metaprogramming to generate optimised code.

Those DSLs are translated into `C++` sources adapted to the targeted solver. Interfaces are provides for `Cast3M`, `Code_Aster`, `Europlexus`, `Cyrano`, `Abaqus/Implicit`, `Abaqus/Explicit`, `Ansys`, `CalculiX`, `AMITEX_FFTP`, etc. Experimental interfaces are available for `DIANA FEA`, `Comsol` and `LS-DYNA`.

A so-called `generic` interface has recently been introduced and is meant to be used through the `MFront-GenericInterfaceSupport` project (MGIS) (See [4]). This project provides tools (functions, classes) for solvers' developers and bindings for `C`, `C++`, `python`, `Julia`, `fortran2003`. Several open-source or commercial solvers already uses `MGIS`, such as: `OpenGeoSys`, `Mefisto`, `XPer`, `Kratos Multiphysics`, etc...

Examples showing how `MFront` constitutive laws through `MGIS` can be used in the `FEniCS` platform to build complex mechanical simulations (See [1, 2]) will be presented.

References

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