Imperial College London | Firedrake

Firedrake

Automated simulation right from the equations

Scientists and engineers express simulation challenges in concise, readable, mathematics. Traditionally, this was just the first step in a long and arduous software engineering effort to produce correct, efficient and parallel simulations. With Firedrake, a scientist or engineer can type a differential equation in weak form and have a highly efficient parallel finite element simulation generated and executed automatically.

Key features

- Support for a limitless range of differential equations
- A wide range of finite element spaces, including structure-preserving H(div) and H(curl) element families
- Specialised support for high aspect ratio domains for critical simulation fields such as ocean and atmosphere flows
- Automated support for MPI and hybrid MPI/OpenMP parallelism. A subset of Firedrake functionality is available for GPU
- Sophisticated inner loop optimisations and automated exploitation of the vector features of latest generation CPUs
- High level access to the complete suite of world class linear and non-linear solvers provided by the PETSc package
- High level, maths based, interactive programming environment which maximises the productivity of the scientist or engineer and minimises debugging

A mathematical problem statement

Find $u \in \mathrm{P4}(\Omega)$ such that:

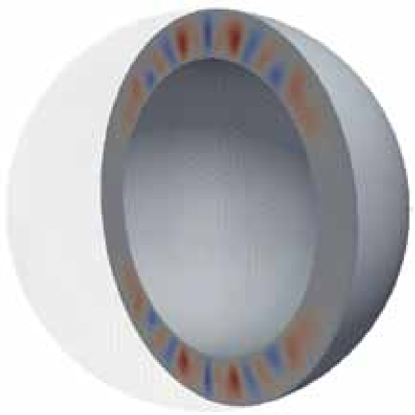
$$\int_\Omega uv + \nabla u \cdot \nabla v - (1 + 8\pi^2)\cos(2\pi x)\cos(2\pi y)\,\mathrm{d}x = 0$$

can be expressed as a few lines of typed mathematics

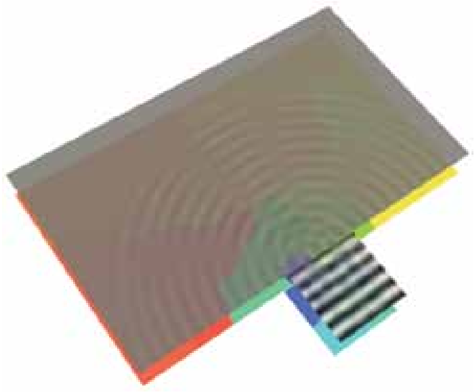
```
from firedrake import *
Omega = Mesh("meshfile.msh")
P4 = FunctionSpace(Omega, "CG", 4)
v = TestFunction(P4)
u = Function(P4)
f = Function(P4)
f.interpolate(Expression("(1+8*pi*pi)*cos(x[0]*pi*2)*cos(x[1]*pi*2)"))
solve(u*v + (dot(grad(u), grad(v)) - f*v)*dx == 0, u)
```

and the solve call instructs Firedrake to automatically generate the simulation code and execute it.

Applications



▲ Pressure waves propagating in an idealised atmosphere simulation.



▲ Interference patterns from a Firedrake simulation of the Young's double slit experiment (foreground), and the MPI decomposition of the problem (background).

Vision: defeating multidisciplinary complexity by separating concerns

Advancing simulation science requires complex scenarios to be simulated using advanced numerics on sophisticated parallel hardware. The code generation approach in Firedrake enables computer scientists to advance the compiler and parallelisation technology, independent of the numerics, while numericists can develop sophisticated discretisations independent of their implementation. The result will be that scientists and engineers can deploy high performance implementations of these numerics to complex simulation problems efficiently and effectively. Firedrake is the glue that enables experts to advance their own field, while directly deploying the outcome across disciplines.

Licence

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www.prism.ac.uk