HPC for industrial use

EDF’s software policy for structural mechanics

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Mechanics: characterization of scalability

- **Domains of massive scalability (>500 procs):**
  - CFD
  - Explicit structural mechanics
  - Implicit structural mechanics for 3D models in linear elasticity

- **Moderate scalability (50-100 procs):**
  - Implicit structural mechanics
  - Models mixing 3D and structural elements
  - Non linear behaviour
  - Contact
  - Multi-point constraints and rigid body elements

**Code_Aster purpose**
Scalability of Code_Aster: common use

- Parallelism for all users
  - Switching a key-word (*SOLVEUR*) + choosing the number of procs
  - *distribution of FEM elemental contributions*
  - *Parallel resolution of linear systems*
  - Iso-fonctionality with the sequential usage

- **MUMPS v4.9.2**
  - Numerous features
    - *Real, complex, simple or double precision*
    - *Analysis, factorization, solving*
    - *Out-of-core*
    - *Null pivot detections*

- Parallelism is becoming into common use
  - 40% of EDF’s computations in mechanics are //
Scalability of Code_Aster

- Example: a model of a pressure vessel
  - 0.86 M dof with 11000 MPC
  - 71 M non-zero terms in the matrix, cond(K)~10^9
  - Speed-up of 10 on 32 procs
    - 40 minutes CPU reduced to 4 minutes

![Graph showing scalability](image)
Scalability of Code_Aster

- Other solutions for experimented users
  - FETI-1
    - DD solver with rigid body modes detection and lumped preconditioning
  - PETSc
    - Library: iterative solvers and parallel preconditionners

- Not a popular success (yet)
  - More difficult for the average user
  - Non compatible with all the (numerous) code features
  - Lack of robustness

- But good performances
  - polycristal: 3.3 M dof
    - MUMPS 1proc: 11h
    - PETSC 1proc: 55 min
      - 4 proc: 13 min
Improving software performances: 1\textsuperscript{st} need

- When even small models are costly: highly non-linear, complex phenomena
  - Behaviour laws, coupling different physics, contact, models with rich mechanical content
  - Long and fine transients (seismic simulation, plane crash): drastic multiplication factor
  - Challenge: from academic models and sketches to usable simulation for industry

Simulation of seismic load

- Hujeux law: shear behaviour of clays and sands
  - 22 parameters for the law

50,000 DOF

- 98% of CPU spent in behaviour resolution
Improving software performances : 2nd need

- When you cannot idealize (too much) the structure : big FEM models
  - The valuable information is at a fine local scale (e.g. tracking crack growth)
  - The problem is implacably multiscale. Substructuring is impossible or too simplifying : global loads, local interest, feedback from local to global
  - Challenge : brute performance on big meshes, parallel solvers, confinement of non-linear models in the zone of interest.
Improving software performances: 2\textsuperscript{nd} need

- When you cannot idealize (too much) the structure: big FEM models

Elastoplasticity with creep and swelling induced by irradiation
From 4 meters to 20 millimeters
Unilateral contact on each of 200 screws

- 6.7 M DOF without contact: OK
- 6.7 M DOF with 50000 contact nodes: challenge
- 0.8 M DOF with 15000 contact nodes: OK