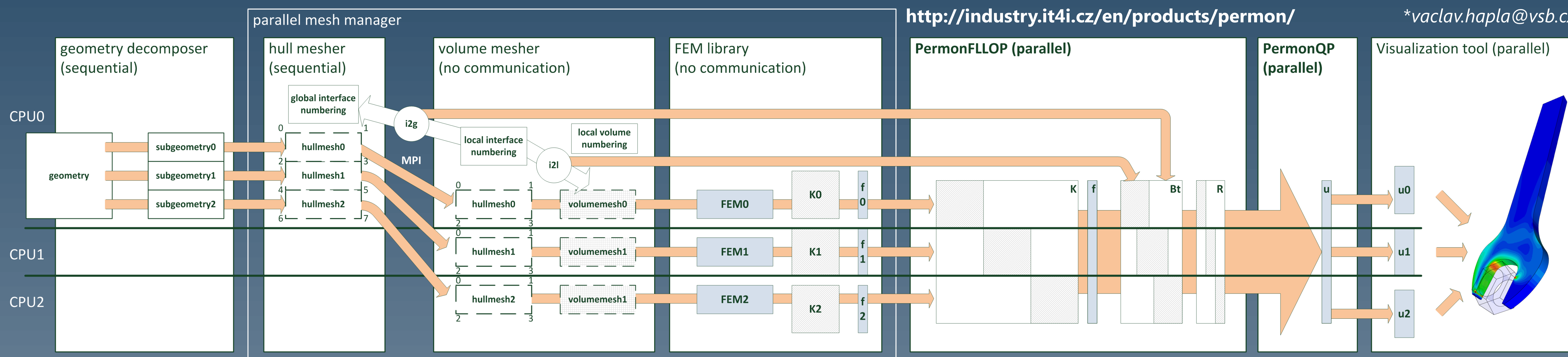


PERMON

Parallel, Efficient, Robust, Modular, Object-oriented, Numerical simulations

- discretization methods
- linear system solvers
- application-specific modules
- domain decomposition methods
- quadratic programming solvers
- PETSc extension

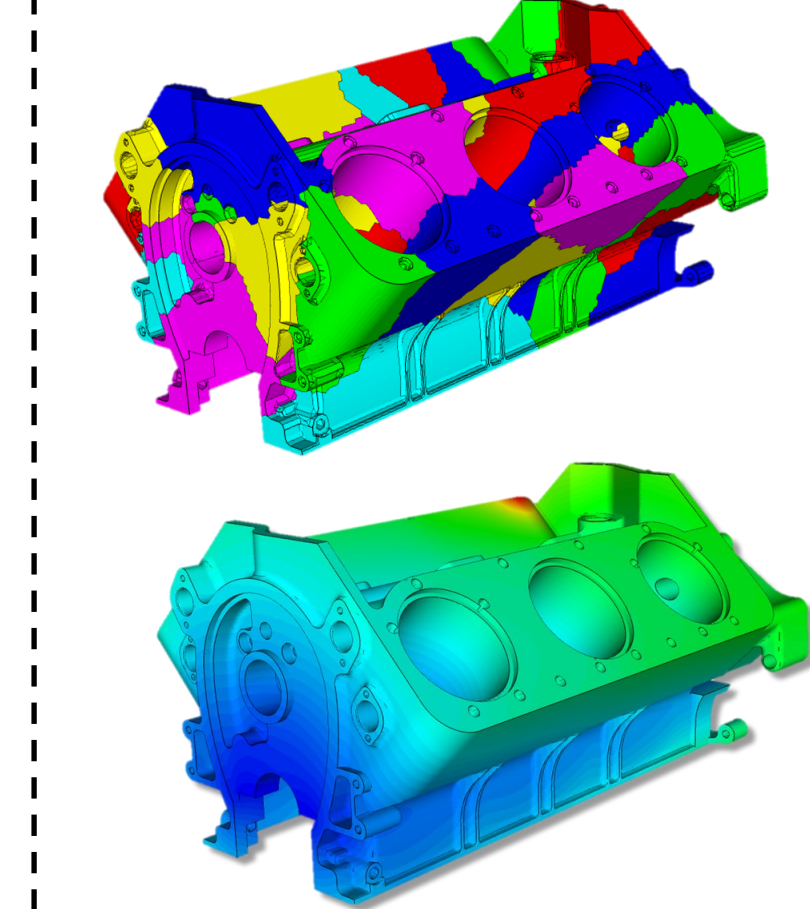


PermonFLLOP

- extends PermonQP with domain decomposition methods of the FETI type
- problems without / with contacts
- scalability up to tens of thousands of CPU cores, billions of unknowns
- assembly of FETI-specific objects

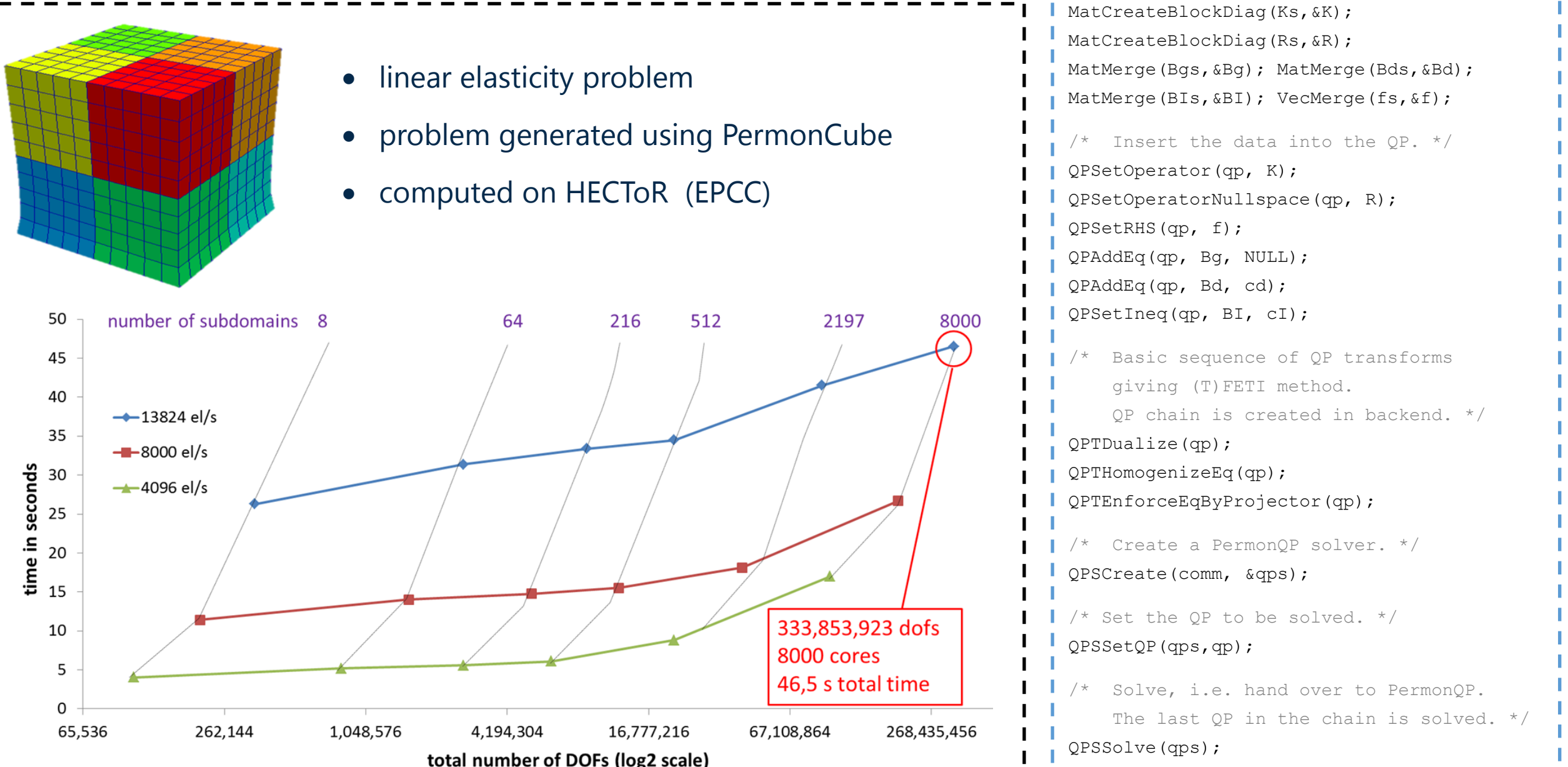
- realistic linear elasticity problem
- displacement computed
- boundary conditions prescribed in one cylinder
- quadratic tetrahedral elements with midnodes
- METIS mesh decomposition
- benchmark prepared by Tomáš Brzobohatý (IT4Innovations)

# DOF	98,214,558
# constraints (dual dim.)	13,395,882
# partitions = # cpus	5,012
# CG iter.	181
computer	HECTOR CURIE Hermit
total setup time	28 s 64 s 30 s
total solution time	233 s 283 s 283 s



- realistic elasticity problem with contact
- displacement computed
- gluing and non-penetration constraints
- METIS mesh decomposition
- benchmark prepared by Tomáš Brzobohatý (IT4Innovations)
- bigger problems currently limited by the FEM implementation, work in progress

# DOF	193,227
# constraints (dual dim.)	24380
# partitions = # cpus	39
# outer SMALSE iter.	12
# inner MPRGP iter.	588
computer	Salomon
total setup time	0.5 s
total solution time	24.4 s

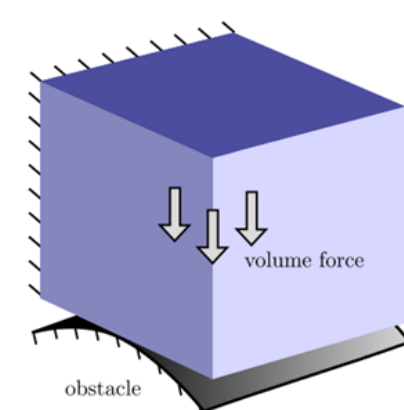


PermonIneq

- part of PermonQP
- algorithms for solution of inequality constrained QP problems

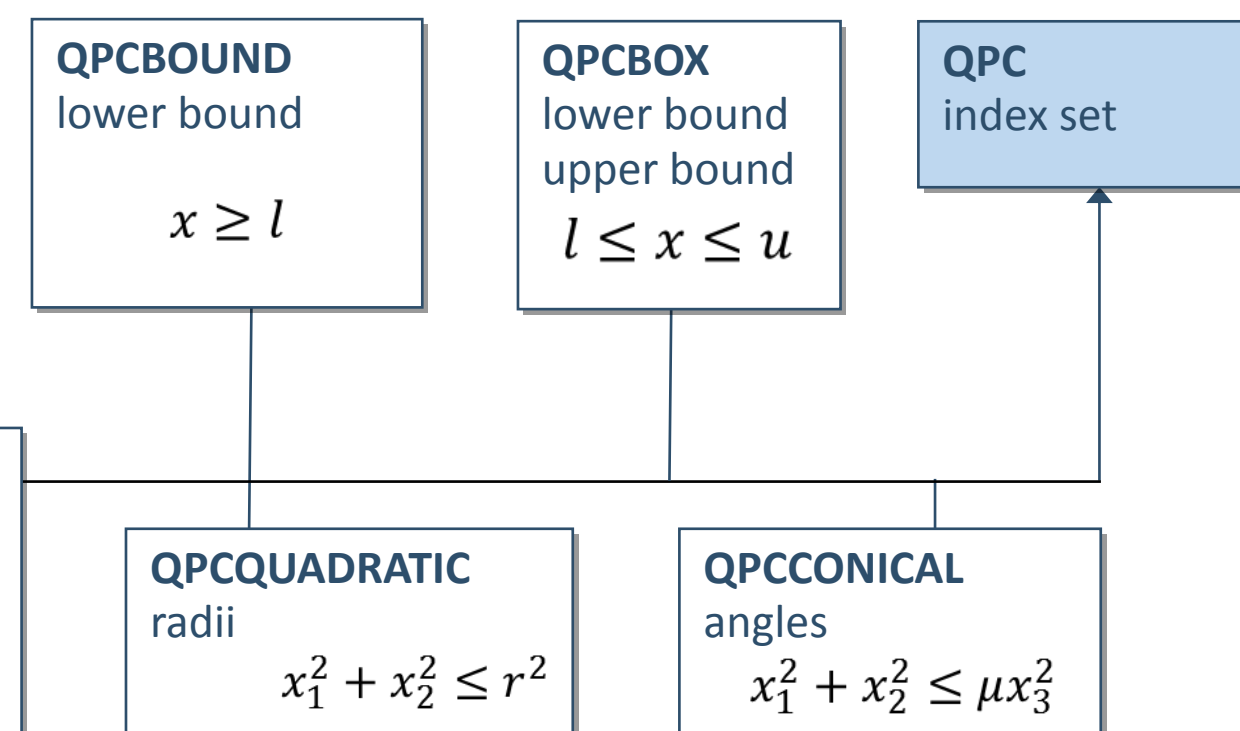
Algorithms

- MPRGP (Modified Proportioning w/ Reduced Grad. Projection)
- SPG-QP (Spectral Projected Gradient method for QP problems)
- PBBf (Projected Barzilai-Borwein method with fallback)
- APGD (Accelerated Projected Gradient Descent method)



QPC class

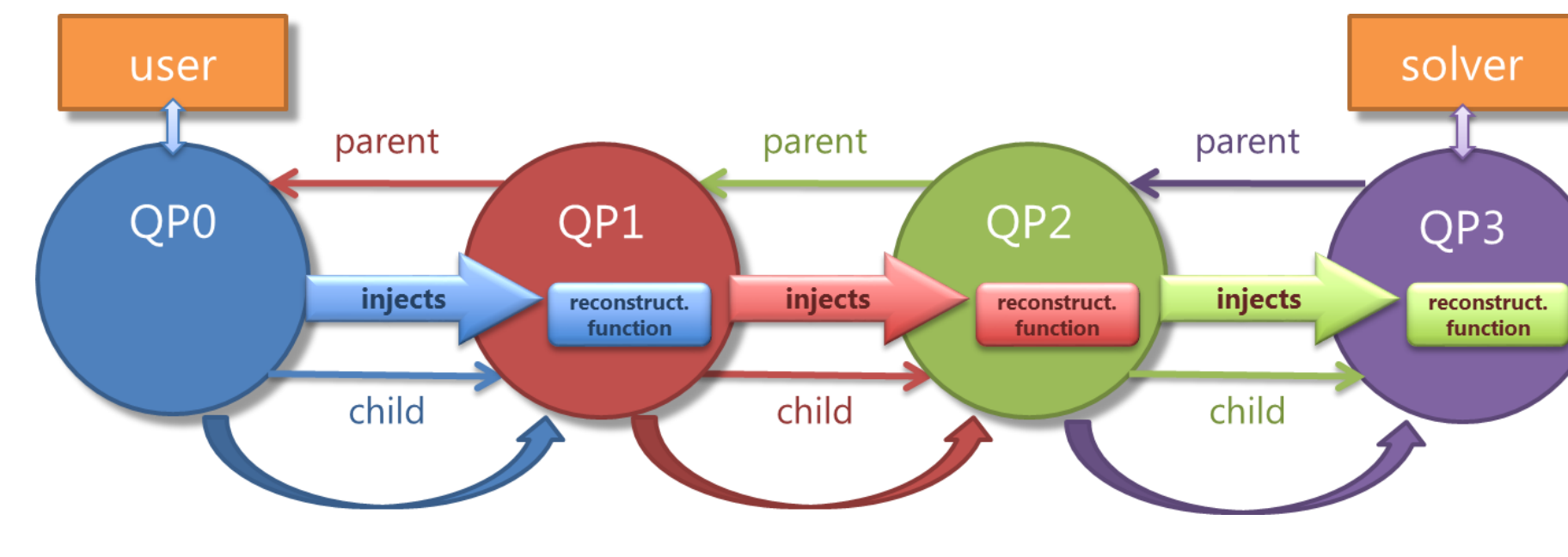
- manipulation with bound, box, quadratic, elliptic, and conical separable constraints
- each QPC type has its own implementation of
 - constraint function (feasibility)
 - projection of a point into feasible set, projected gradient
 - outer normal in boundary point



PermonQP

- framework and concrete solvers quadratic programming (QP)
- QP problems, transforms, solvers
- easy-to-use / HPC-oriented
- workflow

- QP problem specification
- QP transforms
- automatic/manual choice of an appropriate solver



```

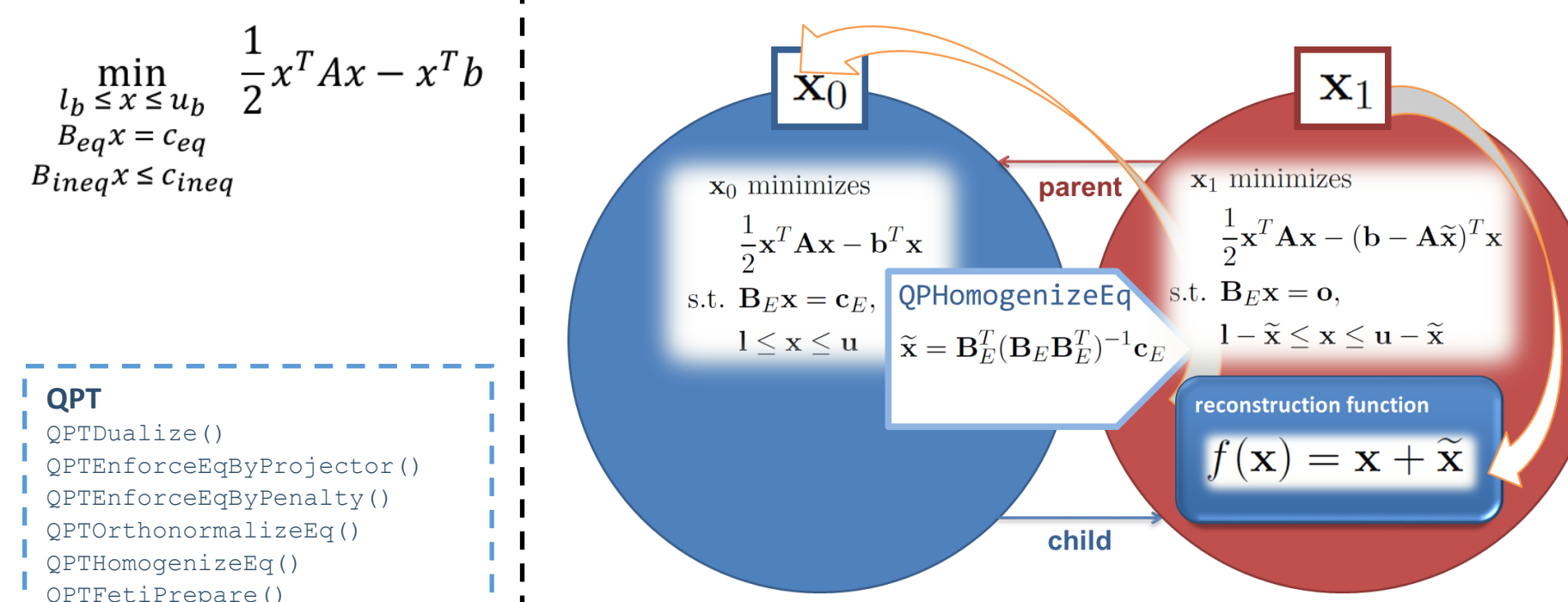
QP parent, child: /* QP chain objects */
Vec x; /* solution */
Mat A; /* Hessian matrix */
Vec b; /* right-hand side */
Vec lambda; /* equality Lagrange multipliers */
QP constraint; /* inequality constraints */

QP topQP, solQP; /* QP chain objects */
PetscReal rtol, atol, divtol; /* alg. tolerances */
PetscReal norm; PetscInt it; /* current state */
QPMonitor monitor;

/* Basic sequence of QP transforms giving (T)FETI method.
  QP chain is created in backend. */
QPDualize(qp);
QPHomogenizeEq(qp);
QPEnforceEqByProjector(qp);
/* Create a PermonQP solver. */
QPSCreate(comm, qp);
/* Set the QP to be solved. */
QPSetQP(qps, qp);
/* Solve, i.e. hand over to PermonQP.
  The last QP in the chain is solved. */
QPSolve(qps);
    
```

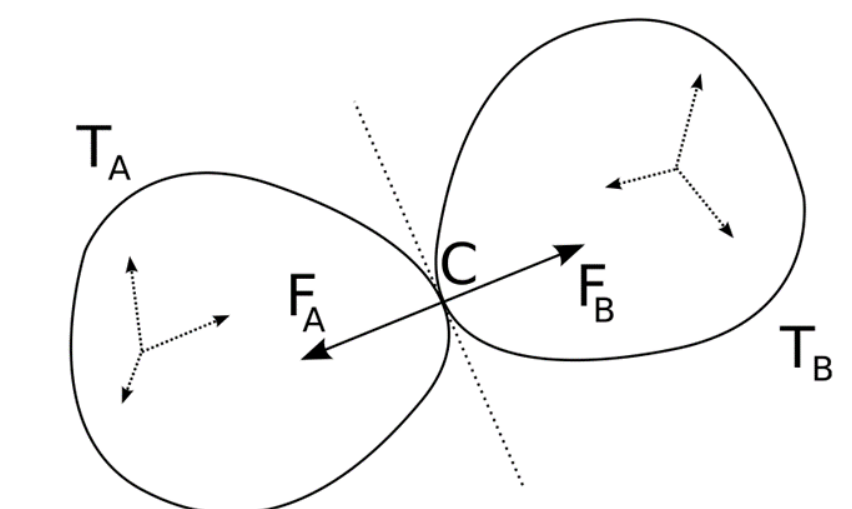
Homogenization of equality constraints

- an example of QP transformation for problem



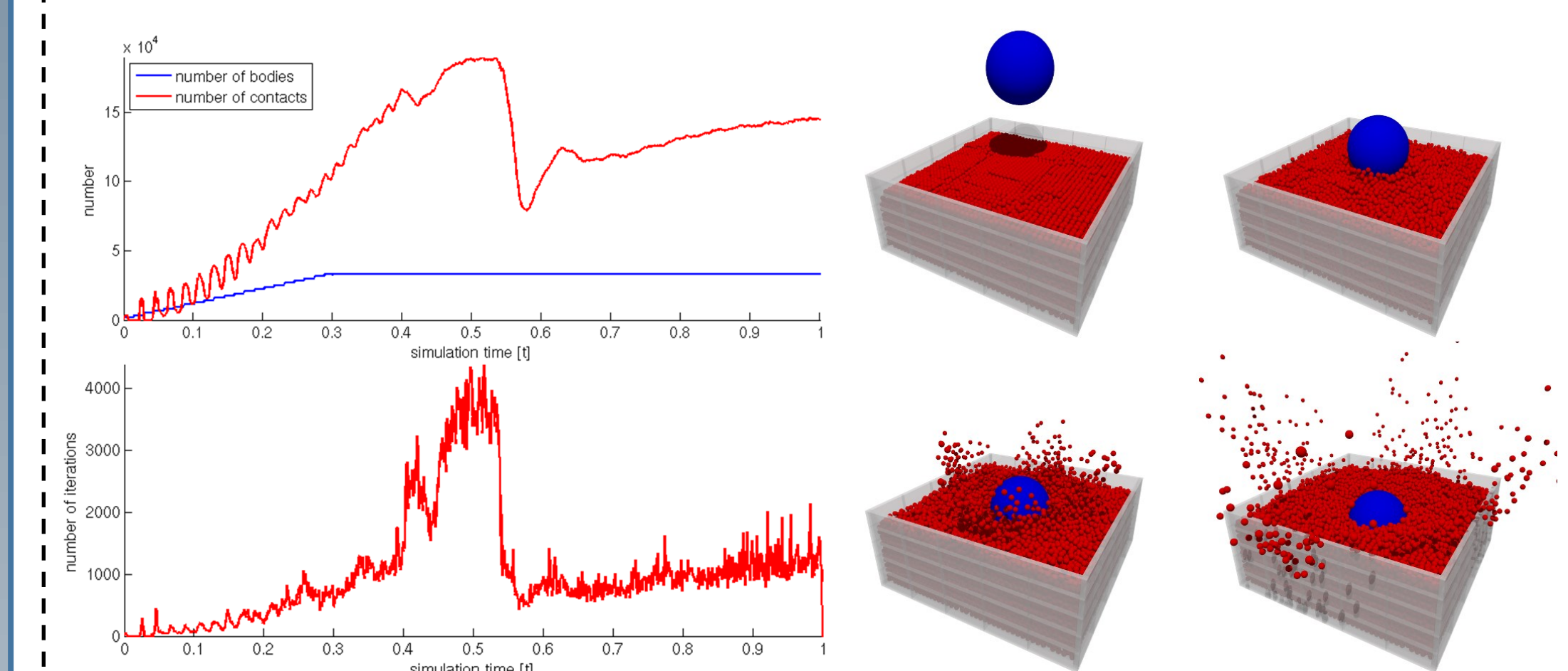
PermonMultiBody

- module for multi-body problems
- Newton laws discretized by Euler method
- can be reformulated to QP with SPS matrix and bound constraints / separable conical constraints (non-friction / friction)



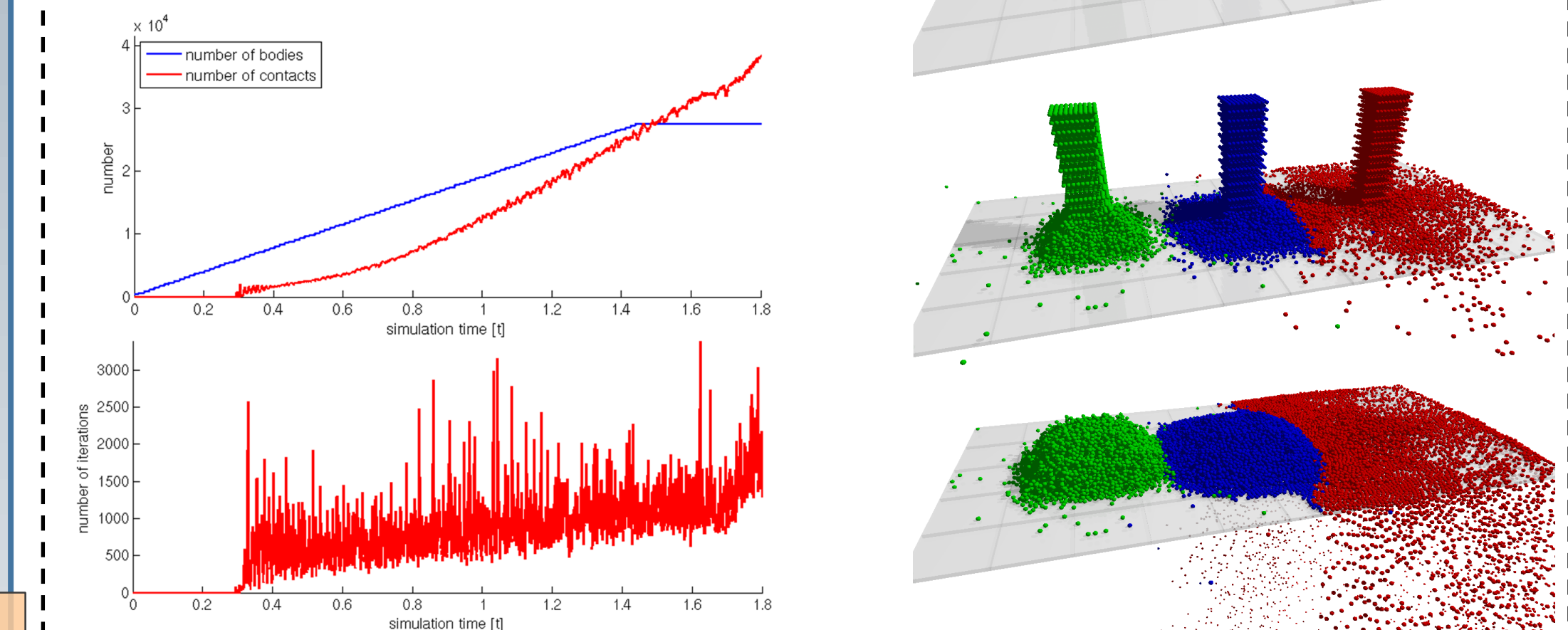
Non-friction problem

- 32,810 spherical particles and 5 box obstacles, up to $1.8 \cdot 10^5$ contacts



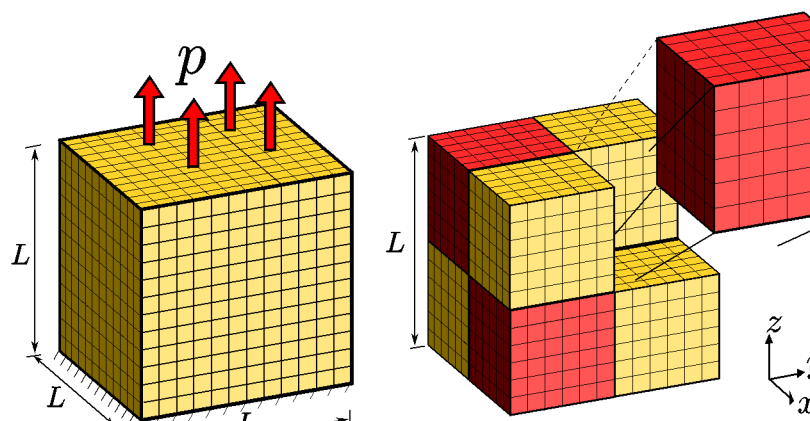
Problem with Coulomb friction

- 24,435 spherical particles and 1 box obstacle
- with various coefficients of friction, up to $4 \cdot 10^4$ contacts



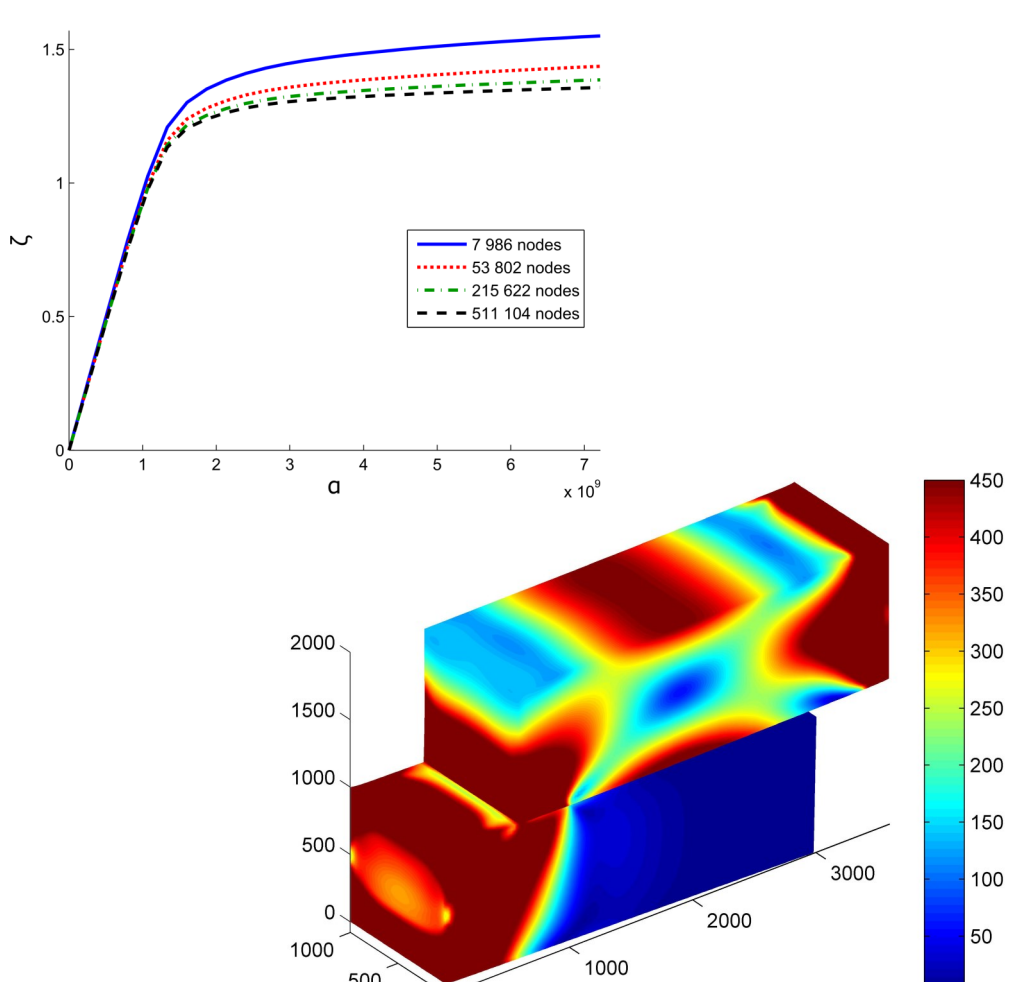
PermonCube

- benchmark generation - mesh with billion of unknowns in parallel over the cubical domain
- FEM assembly
- deformable body, contacts

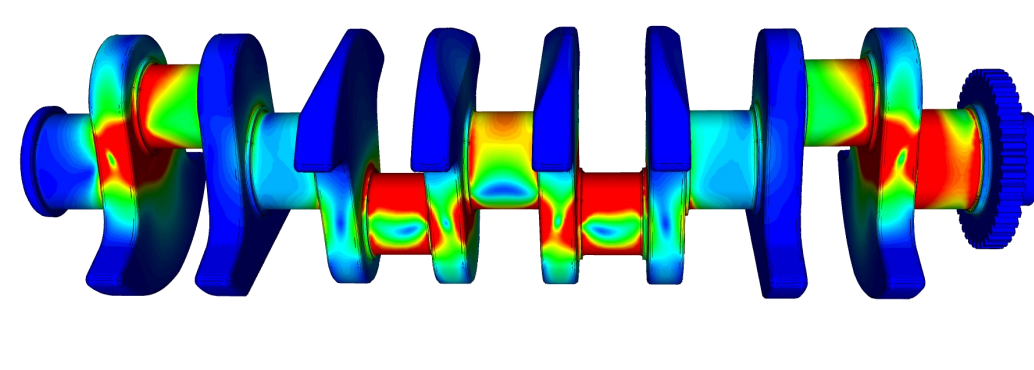


PermonPlasticity

- module for elasto-plastic problems
- implicit Euler method for time discretization, FEM for the space discretization
- perfect plasticity with contact
- problem dimension depends on number of nodes
- von Mises stress and loading path depicted in figures



- the problem is decomposed into 512 subdomains using METIS
- 12,644,721 DOFs; 1,385,037 dual variables
- 512 cores on HECTOR, von Mises plastic criterion with kinematic hardening depicted in figure



PermonImage

- module for image processing problems
- uses libraries such as Boost, OpenCV, VTK
- uses other Permon packages to solve inner problems

Elastic image registration

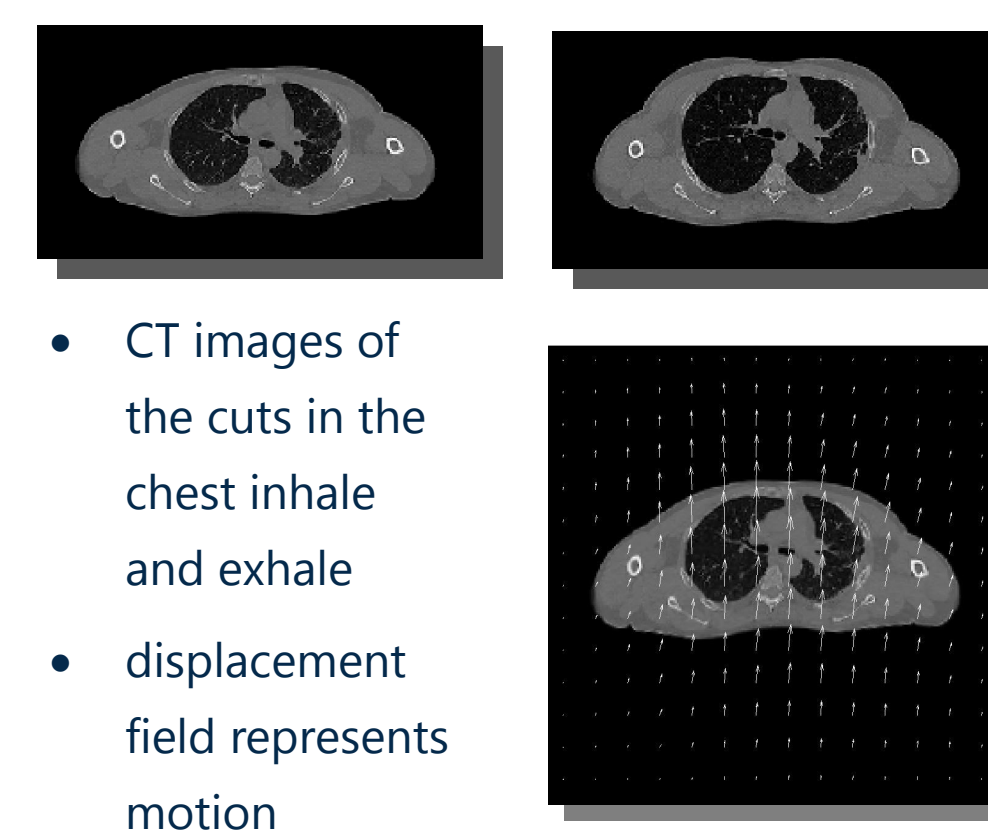


Image reconstruction

- image reconstruction by QP



Piecewise smooth image segmentation

- sufficiently large object in piecewise smooth image
- uses simplification of Mumford Shah functional with free boundary conditions
- our approach is based on the modification of spectral clustering method

