LMGC90 primer

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2013

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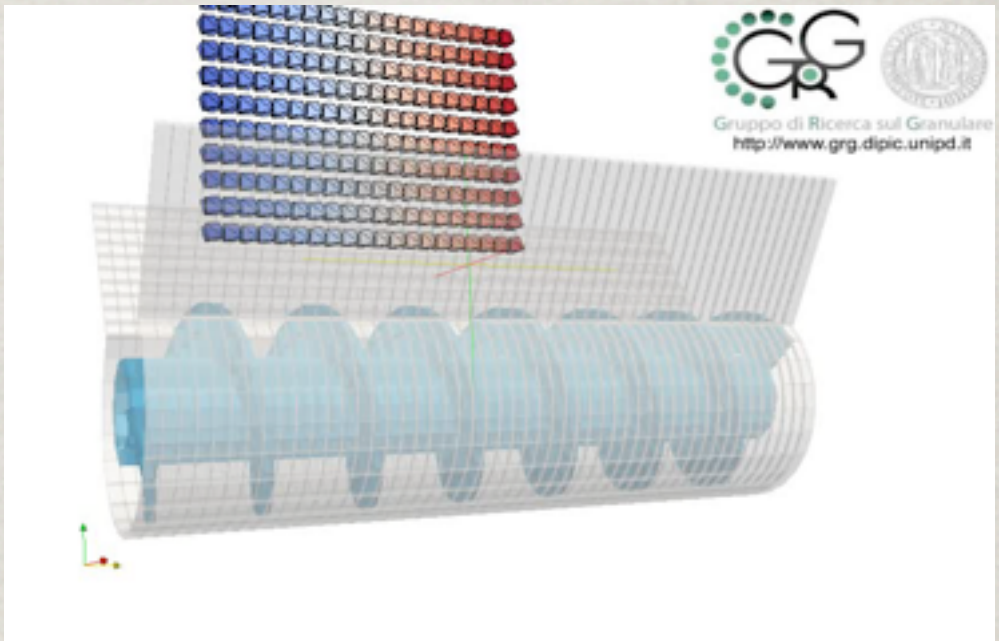
  - object shapes (disk/sphere, polygon/polyhedra, etc)
  - interaction laws (contact, friction, cohesion, etc)
  - multiple-physics and couplings (thermal, fluid, porous)
- An analysis framework with various strategies (md, cd, etc.)

What for ?

What for ?

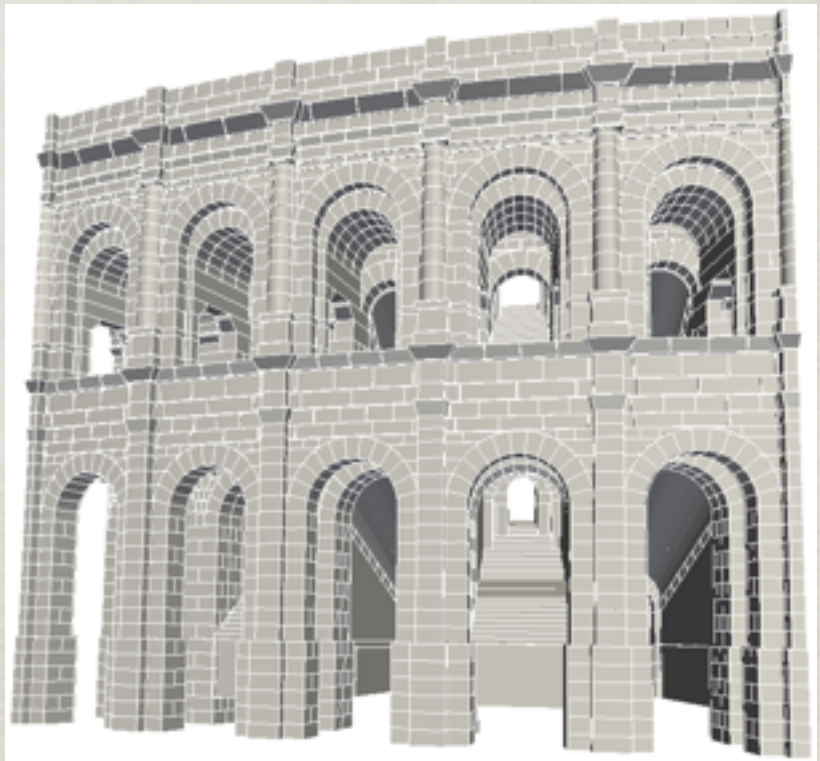
Granular Materials



What for ?

Granular Materials

Masonry



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Granular Materials

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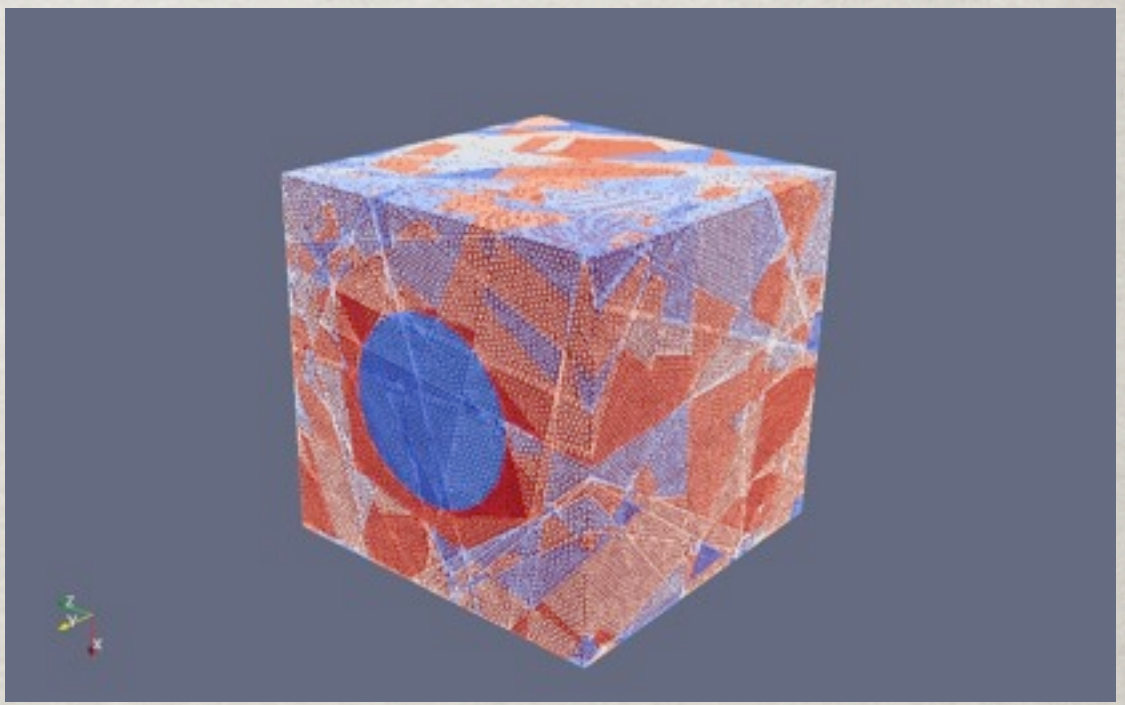
Fractured RockMass



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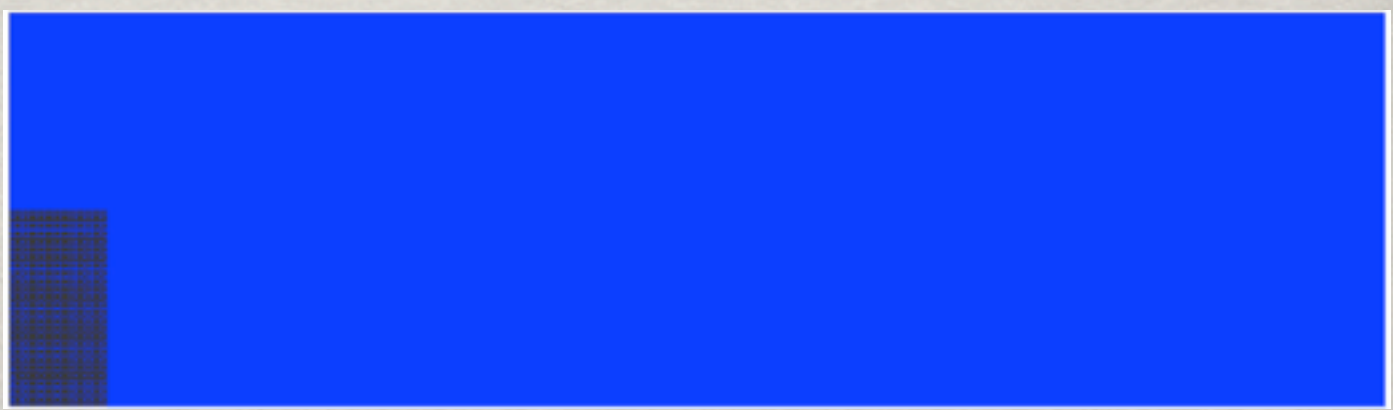
Multiple physics



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Multiple physics

etc ...

Modeling framework

Decoupling of the various parts of the model.

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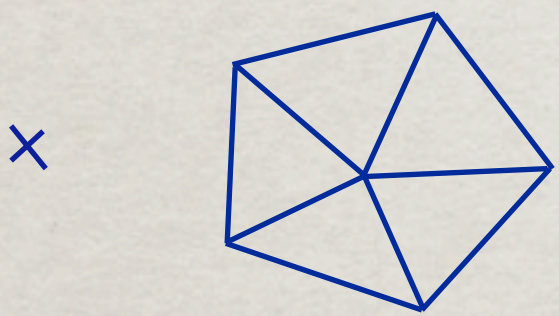
Bulk model (m,I or FE model)



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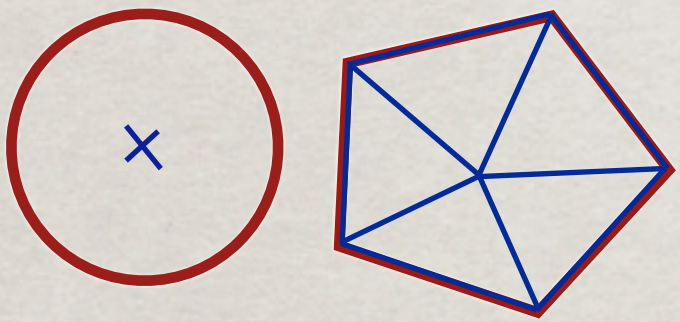

Bulk model (m,I or FE model)

Contactor

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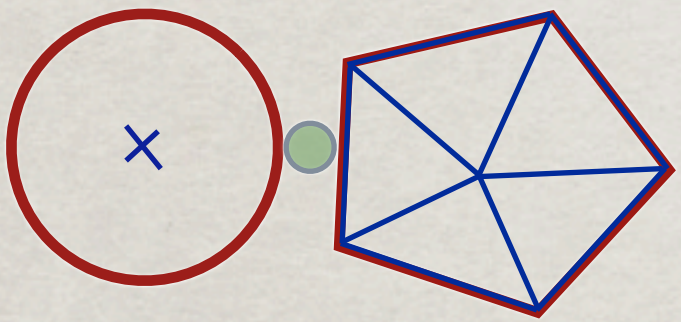

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Interaction

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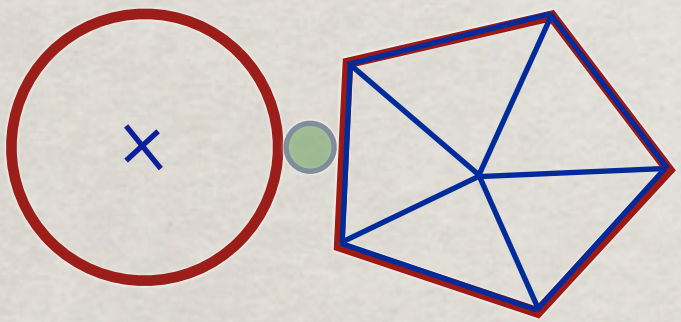

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Interaction

A contactor maps interaction variables to bulk models variables

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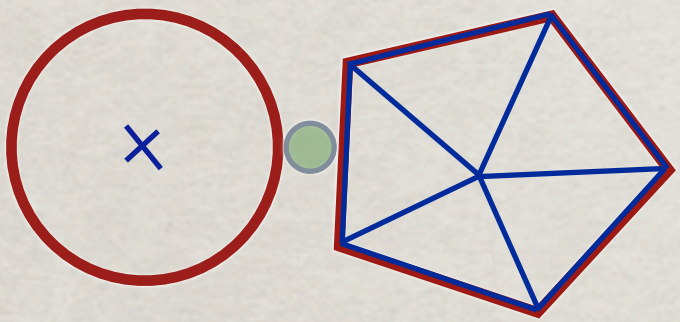

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Contact detection between 2 contactors generates interactions:
=> contact locus, local frame, gap, H(q), etc

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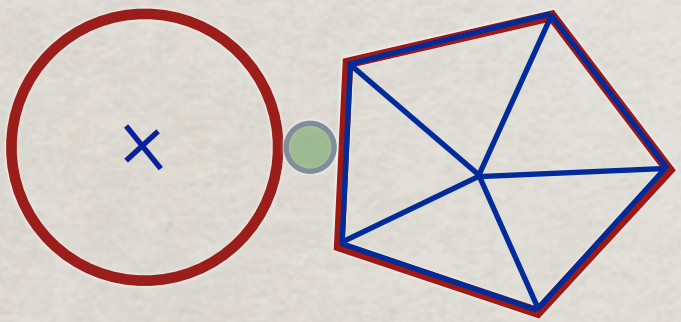

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Contact detection between 2 contactors generates interactions:
=> contact locus, local frame, gap, H(q), etc

A complex shape may be defined as a compound of contactors

BULK BEHAVIOR

- rigid (q,R), and quasi-rigid (q,R + shape dofs)

- deformable: FEM model,
  - rigid | small def. | corotational | large def.
  - linear or non linear material (uses MatLib)

  other possibilities: meshless, lattice, etc

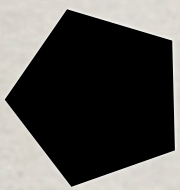
- using external FEM software is possible:
  PELICANS, Code_Aster.

- Couplings with other physics are possible:
  thermal effects, fluid-particles mixture, etc

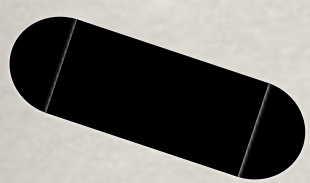
2D SHAPES OF CONTACTORS

disk (DISKx), pneumatic disk (DISPx),
disk on a mesh edge (DISKl)

hollow disk (xKSID), pneumatic hollow disk (xPSID)

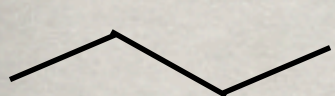


convex polygon (POLYG)



wall (JONCx)

point (PT2Dx),
point on a mesh edge (CLxxx, PT2Dl)



poly-line (ALpxx)

3D SHAPES OF CONTACTORS

Sphere (SPHER)

Pill (CYLND)

Polyhedron (POLYR|POLYF|POLYD)

×

Point (PT3Dx), Point on a mesh surface (CSxx3,CSxx4)

patch on a mesh (ASpx3, ASpx4)

Plane (PLANx)

Cylinder (CYLND), Hollow cylinder (DNLYC)

Contact detection

- broad detection: computes neighborhood
  => SBB + cells, AABB

- narrow detection: eliminates simple case
  => sat, shadow overlap

- fine detection
  => direct, common plane, intersection, minimum distance

Generates interaction: 1 for rounded convex shapes,
3 or 4 otherwise

2D Contact detection

Antagonist \ Candidate	Disk	HollowDisk	Polygon	Wall	Point	Poly-line
Disk	X					
HollowDisk	X		X			
Polygon	X		X			
Wall	X		X			
Point					X	
Poly-line	X		X			X

3D Contact detection

Antagonist \ Candidate	Sphere	Pill/Cylinder	HollowCylinder	Polyhedron	Wall	Point	Poly-surface
Sphere	X						
Pill/Cylinder	X	X					
HollowCylinder	X			X			
Polyhedron				X			X
Wall	X	X		X			X
Point						X	
Poly-surface	X						X

Contact detection

- 2D:
  DKDKx, DKJCx,DKKDx, DKDPx,DKPDx,DKPLx,
  PLPLx, PLJCx,
  DKALp,DPALp,PLALp,
  CLALp,CLJCx,DKDKL,
  PTPT2,P2P2L

- 3D:
  SPSPx,SPPLx,SPCDx,SPDCx,
  CDCDx,CDPLx,
  PRPRx,PRPLx,PRASp,
  CSPRx, CSASp,
  PTPT3

Interaction laws

Numerous possibilities:

- Frictional contact: static/dynamic friction, gap or velocity unilateral condition, deformable contact, etc
- Frictional cohesive law: Mohr-Coulomb, capillarity, damage, etc
- bilateral conditions: kinematic relation, elastic or visco-elastic wire and rod, etc

Written if possible, through changes of variables, as Signorini-Coulomb law

Interaction laws

Rigid/Rigid: IQS_CLB, IQS_DS_CLB, IQS_WET_DS_CLB, ...
RST_CLB, RST_DS_CLB, ...

Defo/Defo
Rigid/Defo: GAP_SGR_CLB, GAP_SGR_DS_CLB, ...
VEL_SGR_CLB ....

Contact dynamics

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Non-smooth dynamics framework

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Implicit time integration (theta method)

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Contact solver: NLGS, PCGP (// or not) + Siconos/Numerics

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Remark on CD method:

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$$U \xleftarrow{\quad law(U,I) = true \quad} I$$

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Remark on CD method:

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$$U \xleftarrow{\quad law(U,I) = true \quad} I$$

- Bulk model

$$v \longleftrightarrow i$$

$$M(v_f - v_i) = \int_{t_i}^{t_f} f_{ext}(t)dt + i$$

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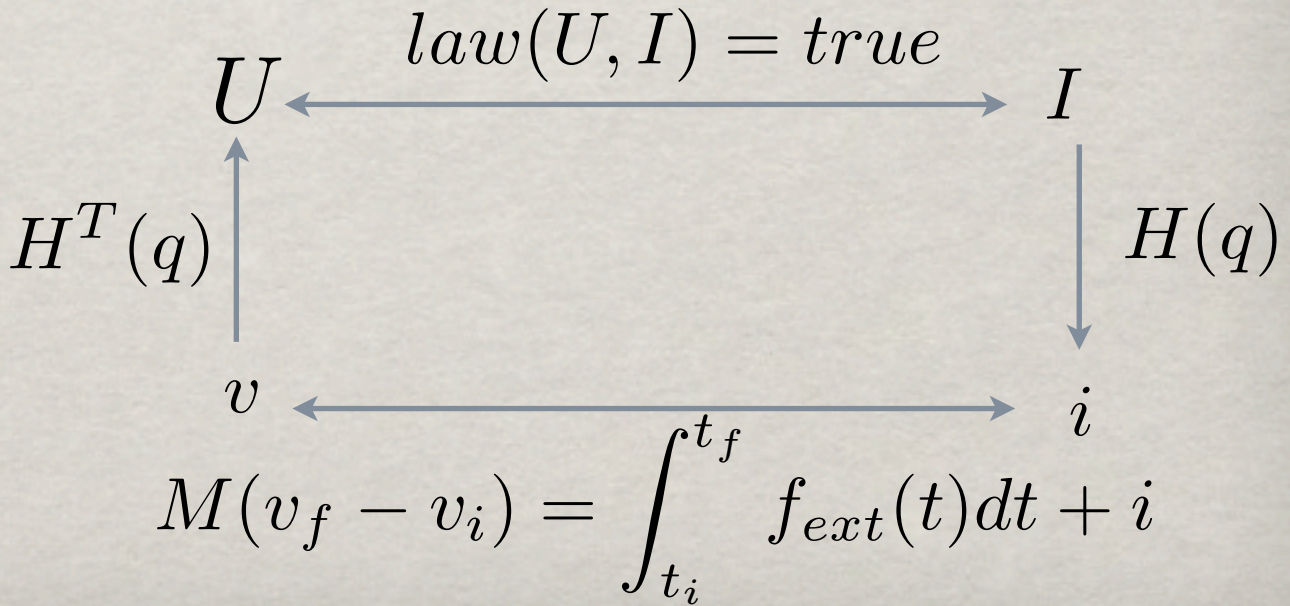

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Computational effort:
contact forces evaluation

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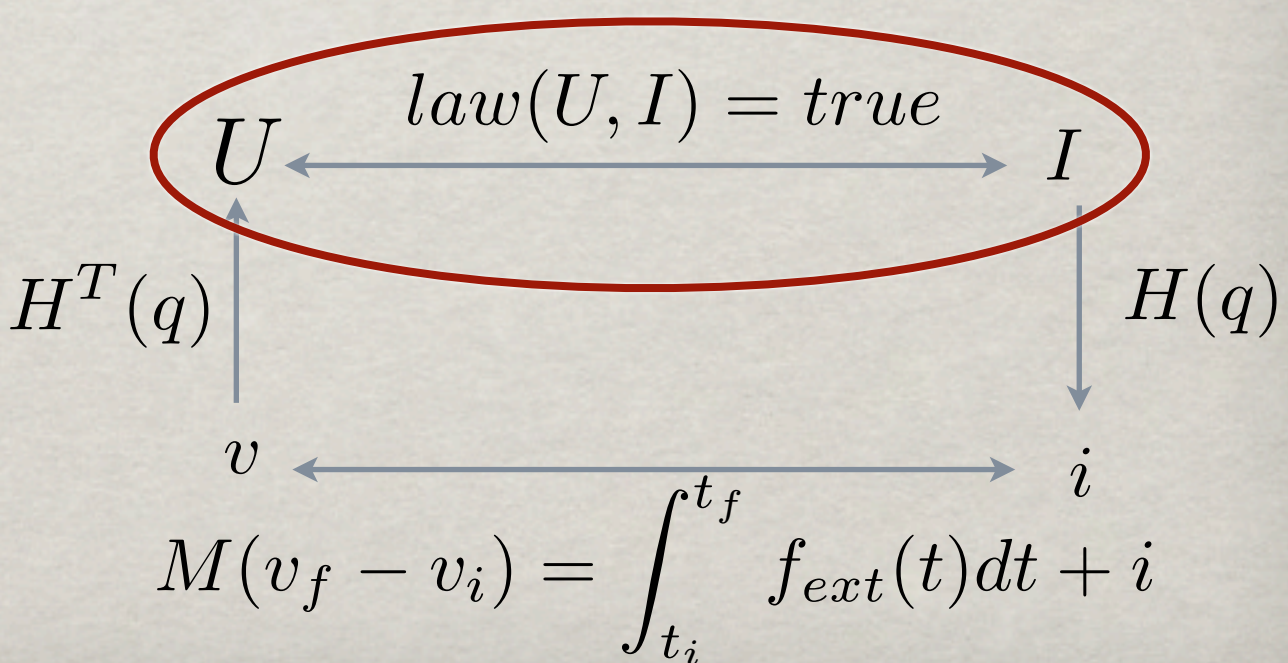

Molecular Dynamics

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Smooth dynamics framework

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For example MD method:

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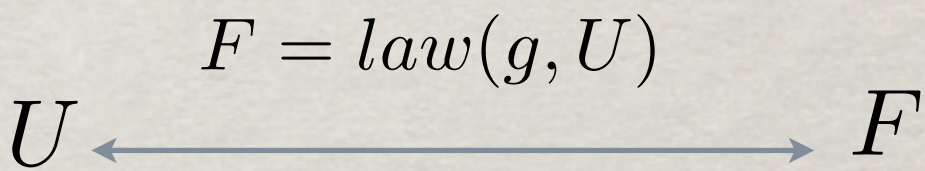

Molecular Dynamics

Smooth dynamics framework

Explicit time integration (theta method)

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For example MD method:

- Interaction

$$F = law(g, U)$$

$$U \longleftrightarrow F$$

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$$M\dot{v}_f = F_{ext}(t_i) + f$$

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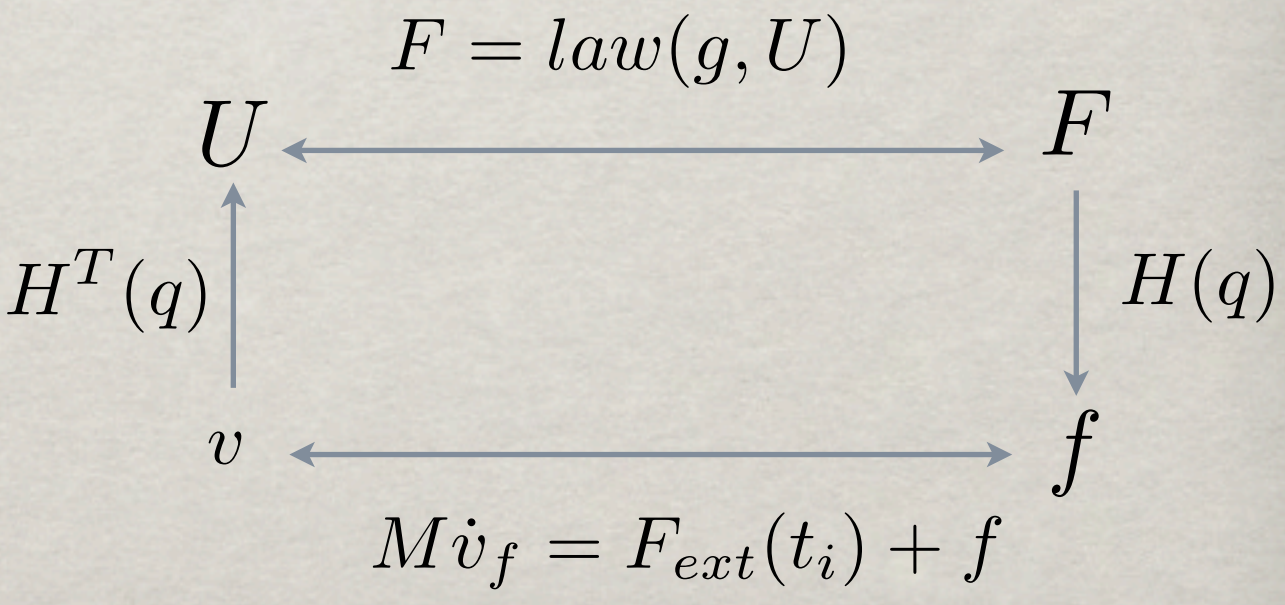

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For example MD method:

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Computational effort:
contact detection

$$F = law(g, U)$$

$$\begin{array}{ccc} U & \longleftrightarrow & F \\ \uparrow H^T(q) & & \downarrow H(q) \\ v & \longleftrightarrow & f \end{array}$$

$$M\dot{v}_f = F_{ext}(t_i) + f$$

CURRENT WORK

- recast of the global software architecture
- hpc (openMP, MPI+DDM)
- bulk models (behaviour, discretization switching)
- multi-physics
- continuous-discrete transition

USING LMGC90

Pre-requisites

- ✓ Unix system
- ✓ Up-to-date Fortran9x compiler (ifort, pgf90, gfortran, g95)
- ✓ C++ compiler
- ✓ Python (devel) + numpy
- ✓ Swig
- ✓ Cmake
- ✓ paraview for visualization
- ✓ subversion

Installing

✓Download rev_2013_install.sh from :

https://subver.lmgc.univ-montp2.fr/trac_LMGC90v2/attachment/wiki/download/rev_2013_install.sh

✓run the script and be patient:
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Running an example

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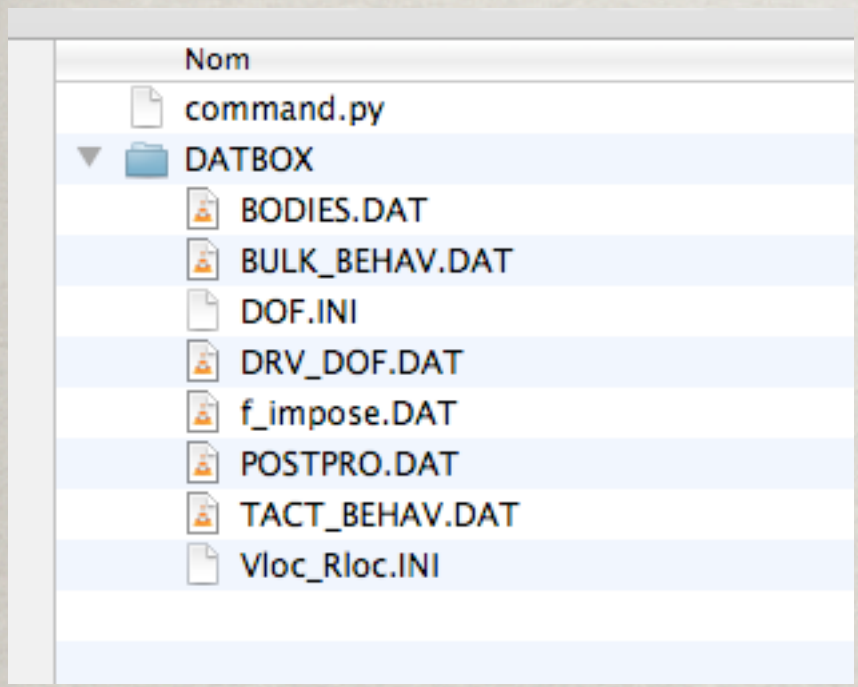
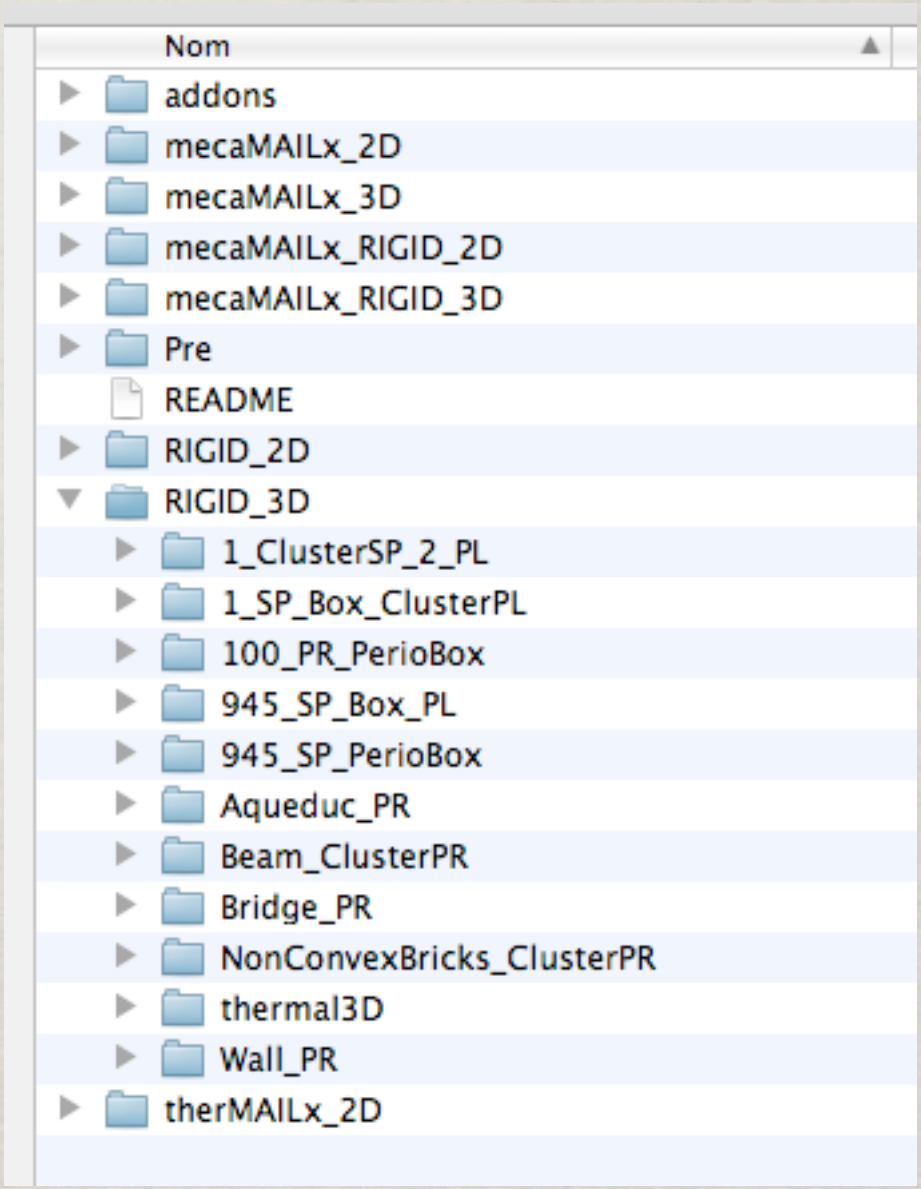
python command.py





Content of command.py explained in docs and manuals

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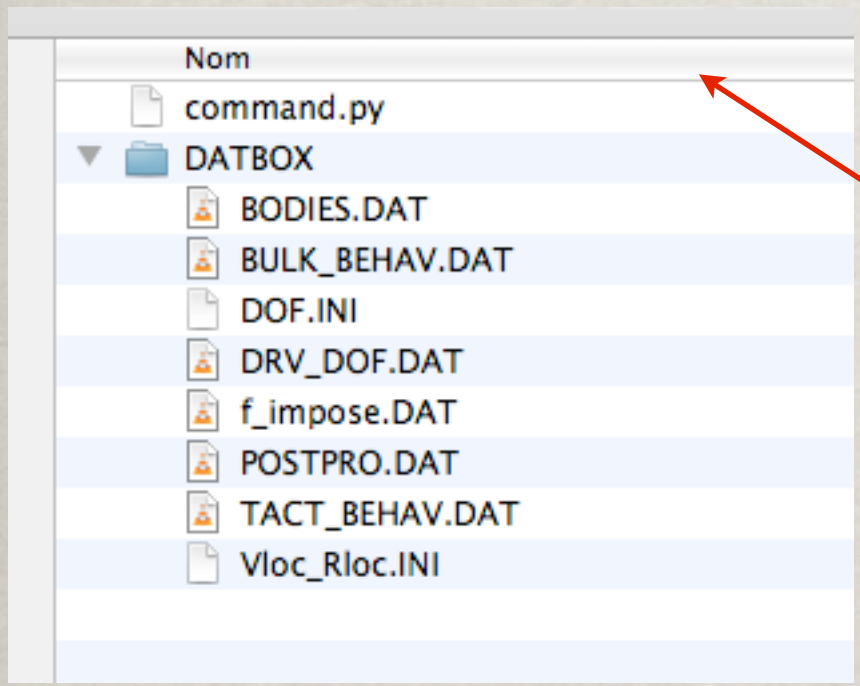

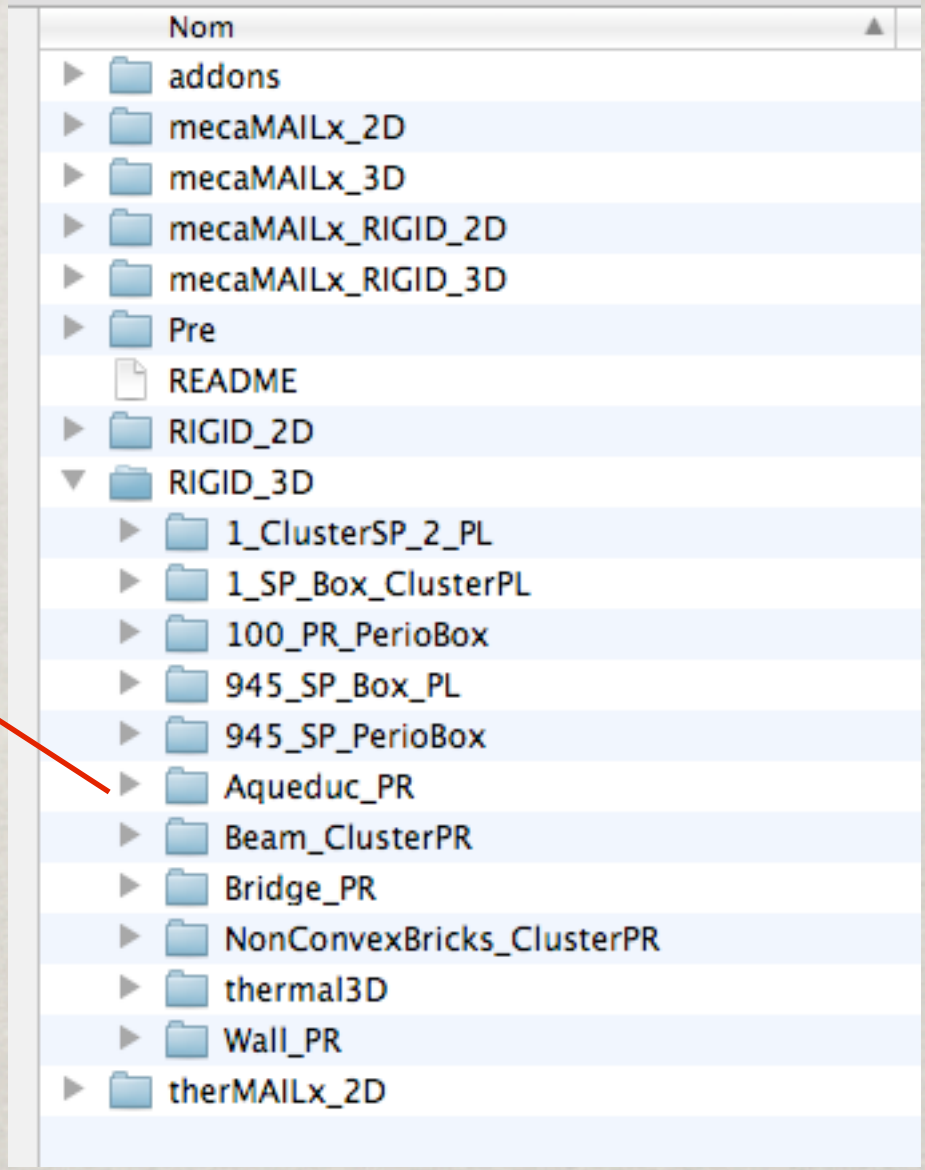

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Running an example

Displaying results

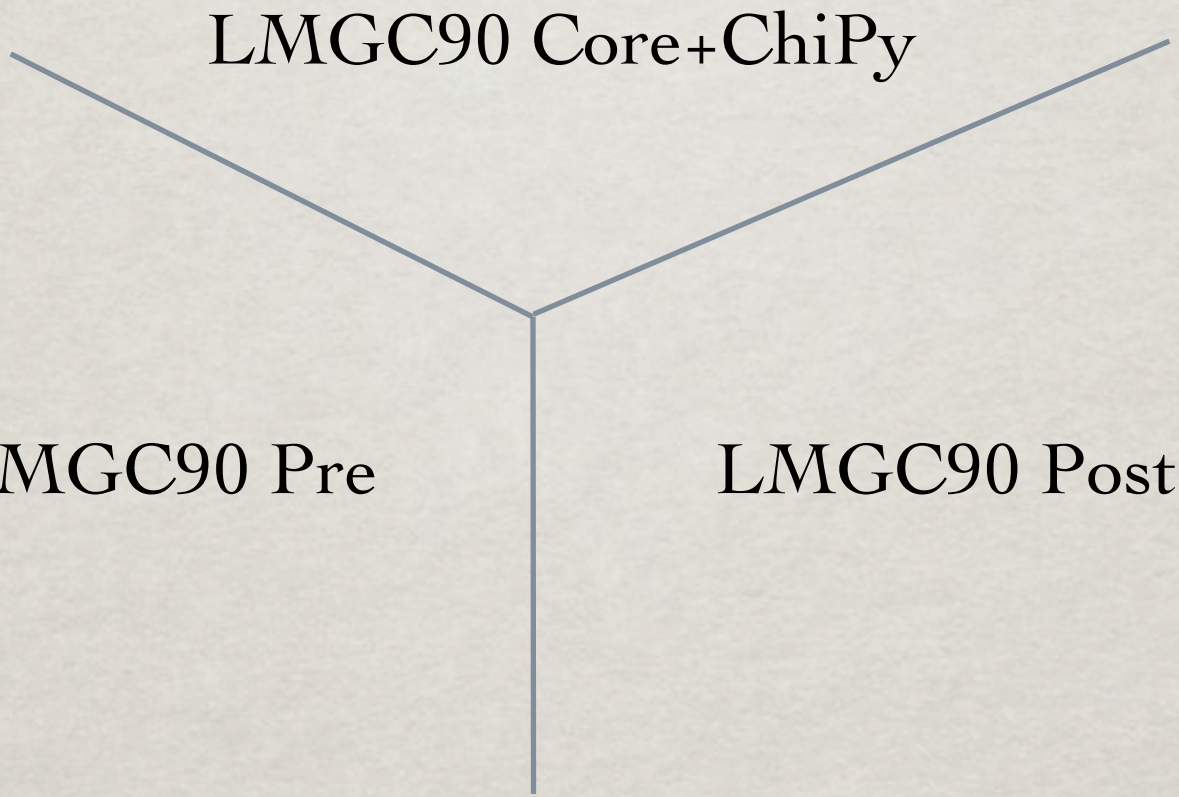
2D: Paraview

inters.pvd
tacts.pvd
mecafe.pvd

3D: Paraview

DISPLAY/rbdy3....vtu
DISPLAY/mailx....vtu
DISPLAY/tact....vtu
DISPLAY/inter....vtu

What else ?



Documentation

https://subver.lmgc.univ-montp2.fr/trac_LMGC90v2_dev/wiki/docs

Conclusion

- LMGC90 is a free Open Source software,
  (belongs to CNRS-UM2)

  https://subver.lmgc.univ-montp2.fr/trac_LMGC90v2
  https://subver.lmgc.univ-montp2.fr/trac_LMGC90v2_dev

- LMGC90 is a collaborative research code:
  perpetual evolution, not so well documented,
  lack of funds to develop user friendly interface.

Co-workers:

- Michel Jean
- Mathieu Renouf, Alexandre Martin, Rémy Mozul, Frédéric Perales
- Dominique Ambard, Cyril Bordreuil
- Gilles Saussine, Brahim Chetouane, Emilien Azema, Robert Perales, Ali Rafiee, Damien Iceta, Paul Taforel, Marine Bagneris, Vincent Visseq, Walid Saber-Sherif
- Jean Jacques Moreau, Farhang Radjai, Pierre Alart, Vincent Acary, Yann Monerie