Development of a LevelSet approach to model complex biphasic media

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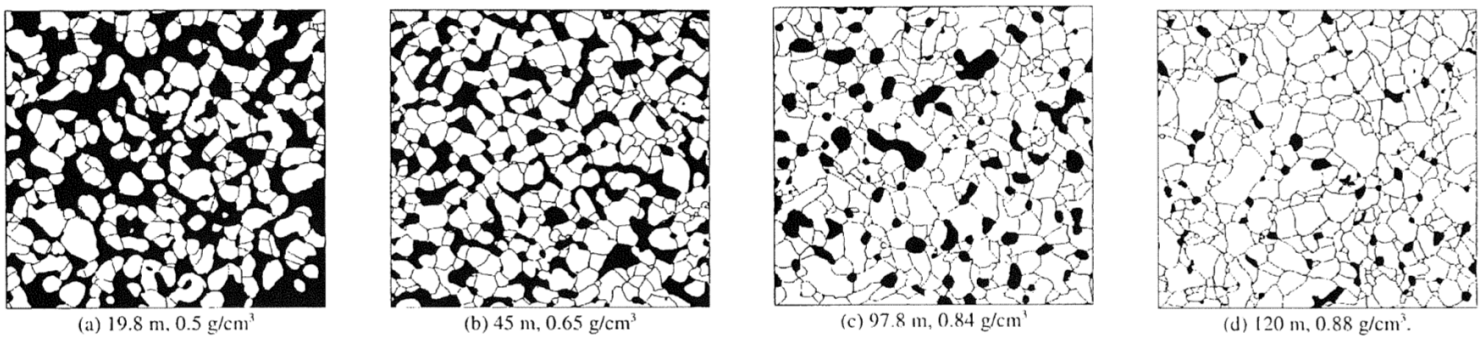
Deformation of firn

In cold polar region, snow accumulate with time.
-> Old snow get compressed and densify.
-> Pores shrink and eventually trap gases.



Firn densification from Arnaud et al, 2000

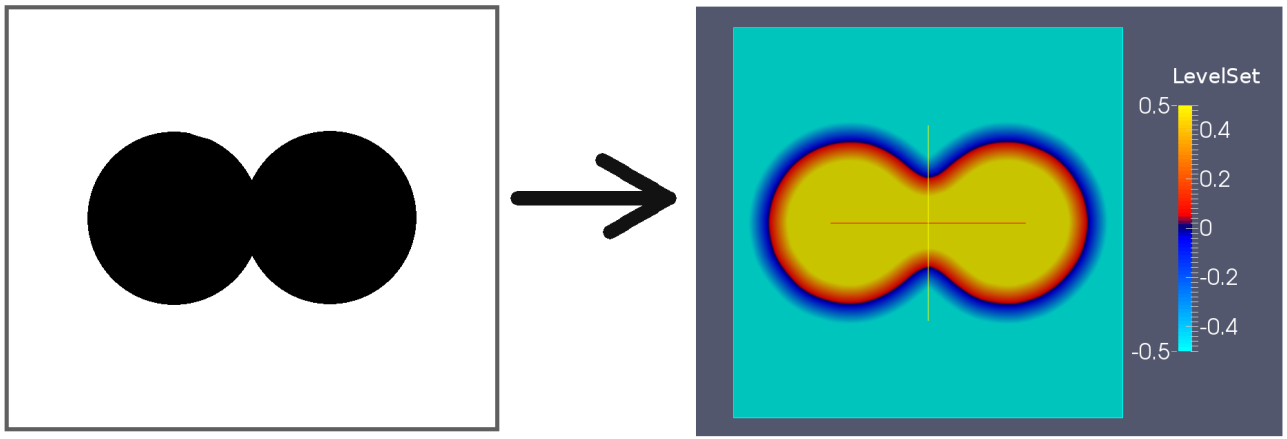
Goal of the model

Current firn densification model are bulk with few physics inside.

Development of a new model representing firn densification.
It should:
- Explicitly represent the porous medium (ice + pore)
- Handle topological changes and large deformation

LevelSet framework

Biphasic medium is represented has an heterogeneous monophasic medium, thanks to the LS function.



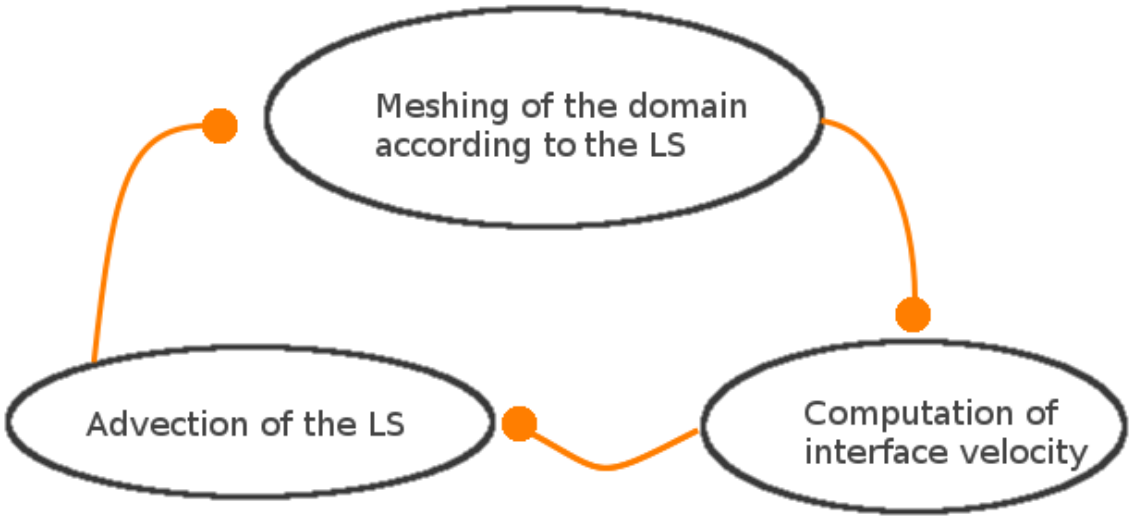
Moving interfaces are handle by advecting the LS.

LevelSet framework

Advantages of the LS:
- Topology is naturally handled
- Interfaces do not have to be on element boundaries !

Drawbacks of the LS:
- Requires extra steps
- Need a pure advection step
- Does not naturally conserve volume
- Need fine meshing around the interfaces

General approach of the model



All the physics is in the computation of the interfaces speed.
General framework for biphasic media, beyond snow/firn.

Available tools in Elmer/Ice

- Physical solvers are ready to go (Navier-Stokes, etc)

- Dedicated Elmer LevelSet Solvers:
  LevelSetDistance, LevelSetSolver, LevelSetCurvature

- Mesh Adaptation Solver: Small deformation of meshes

Shortcomings of Elmer

Two mains problems currently with Elmer:

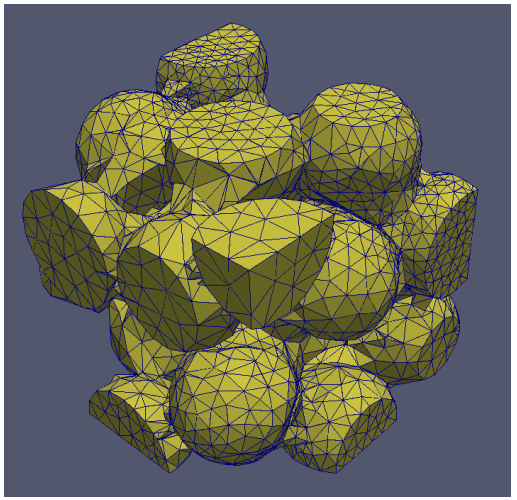
- Mesh Adaptation Solver does not seems naturally suited for LS
- LevelSetDistance is brute force and only in 2D.

MMG remesh lib and other tools

MMG is a free and open-source meshing library with a Fortan API.

With a LS function can generate a mesh:

- Refined around interface
- Conform, i.e. nodes meshing the interface are on the interface.
- Using only the LS as input !



MMG remesh lib and other tools

Solver doing the interface between MMG and Elmer is almost done.

- Convert Elmer mesh to the MMG format
- Run the meshing function
- Convert the new MMG mesh to the Elmer format

MMG can do more than LS remeshing (ask Fabien)

MMG remesh lib and other tools

MMG developers also propose:

- Advect: An advection tool (method of characteristics)
- MshDist: A redistancing tool (3D)

They easily integrate with MMG, so I'm using them at the moment.

Typical Simulation

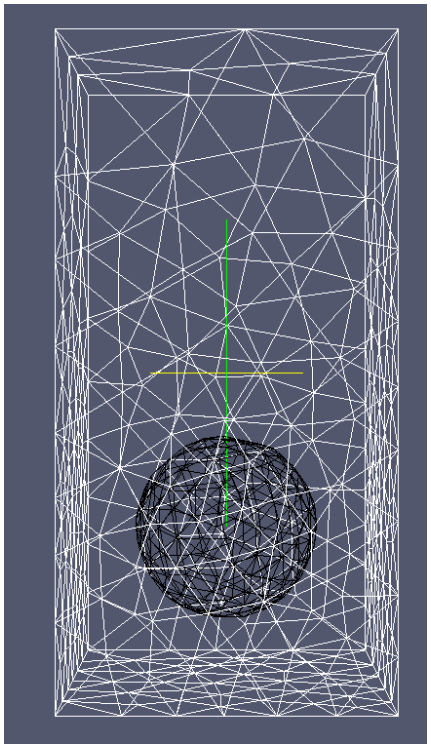
Simulation loop:

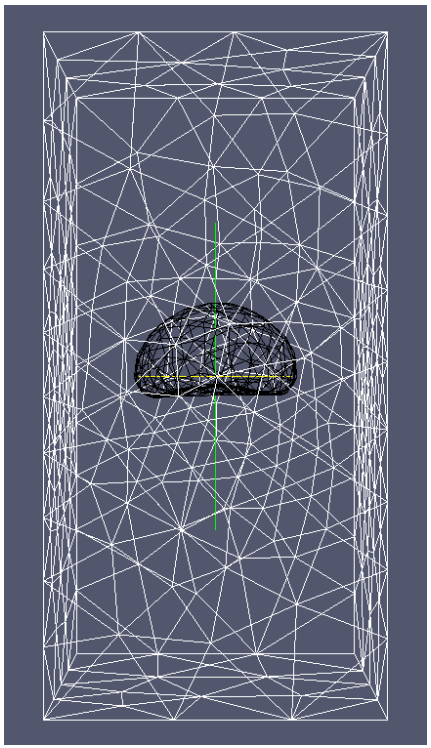
- Compute interface speed with whatever solver you want
- Advection of the LS with Advect
- Remesh based on the new LS with MMG
- Redistance the LS function with MshDist

All embedded in Elmer Solvers.

Typical Simulation

For instance with the physics of a rising bubble in water !





Prospectives

Major problem to solve right now is volume conservation.

Possible leads:

- Very fine mesh around the interface
- Very fine mesh around the interface's arrival
- Conservation with "decompression" step (Olsson et al, 2007)

Once solved Elmer should be suited for large deformations simulations in 3D using LS.

Thank You !