Latest news of Basilisk

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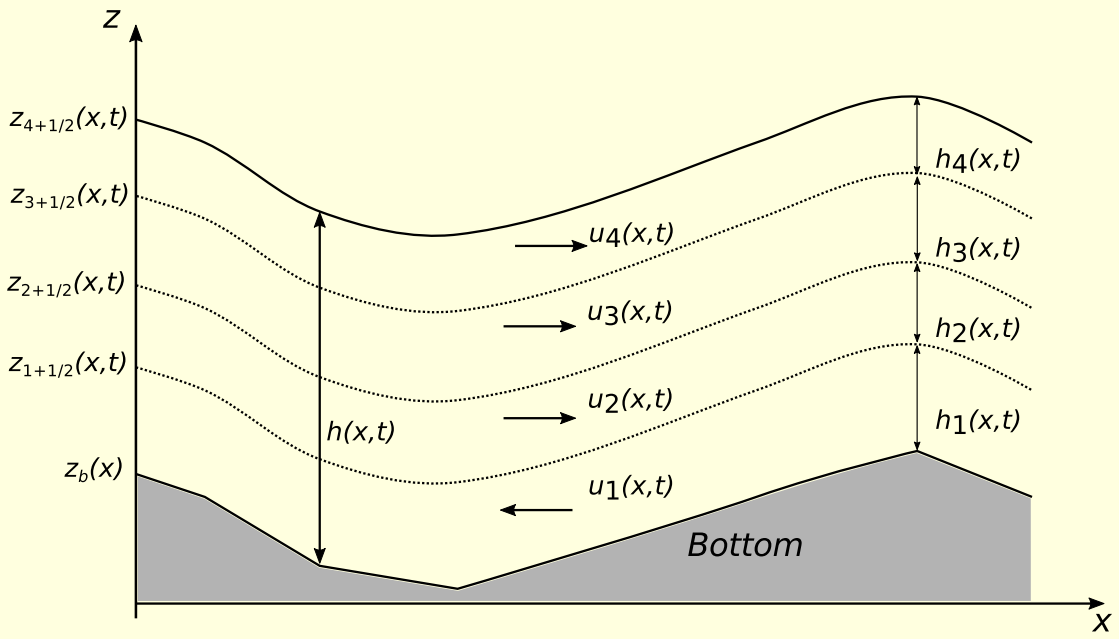
Outline

- Newish features (already there)
- To appear soon (already in sandboxes)
- Work in progress
- Plans
- Main issues / priorities
- Statistics

Newish features (2016-2017)

- Multilayer Saint-Venant solver (Francesco De Vita et al.)



Implemented as a simple extension of the single layer Saint-Venant model

`basilisk.fr/src/multilayer.h`

- Semi-implicit Saint-Venant solver (Kirstetter & Popinet)

  Relaxes the gravity wave speed CFL restriction $\Rightarrow$ low Froude number regimes can be captured much more efficiently

  Naturally well-balanced

  Extension of the all-Mach solver

  `basilisk.fr/src/saint-venant-implicit.h`

- VOF-scheme can transport associated tracers

$$\begin{aligned} \partial_t f_i + \mathbf{u}_f \cdot \nabla f_i &= 0 \\ \partial_t t_{i,j} + \nabla \cdot (\mathbf{u}_f t_{i,j}) &= 0 \\ t_{i,j} &= c_j f_i \end{aligned}$$

  `basilisk.fr/src/vof.h`

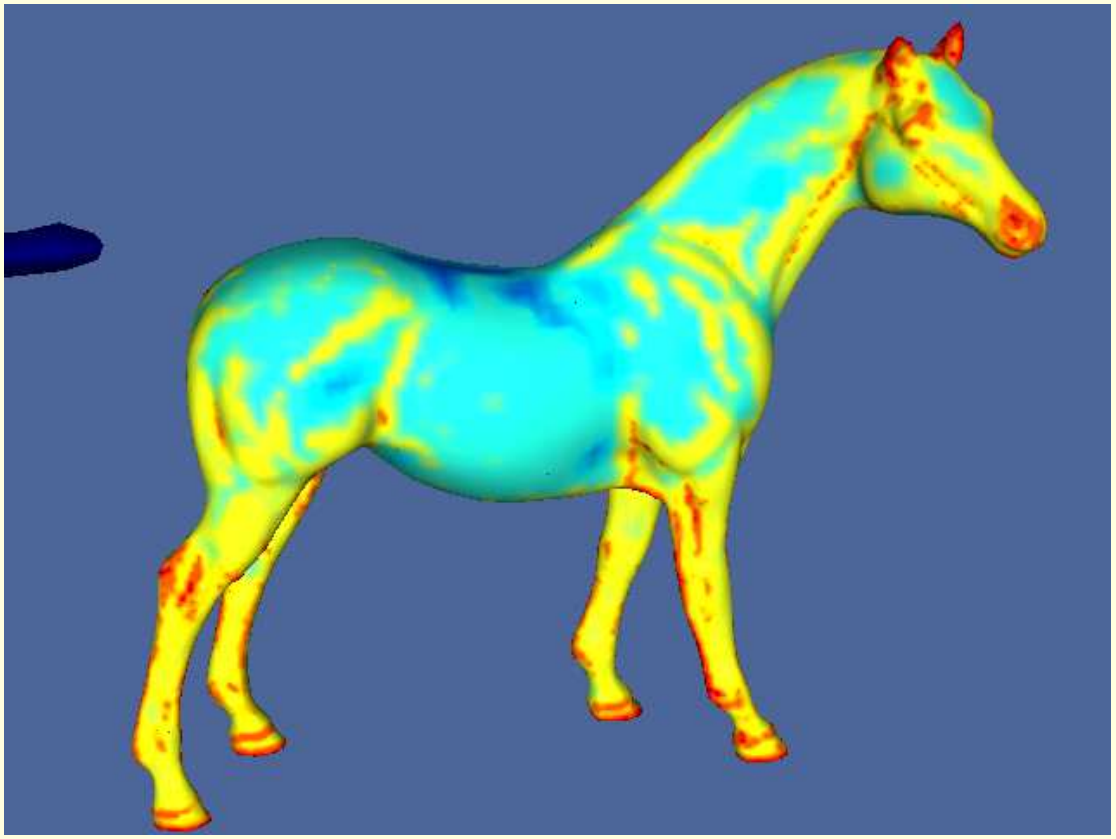
- Momentum-conserving two-phase flow scheme

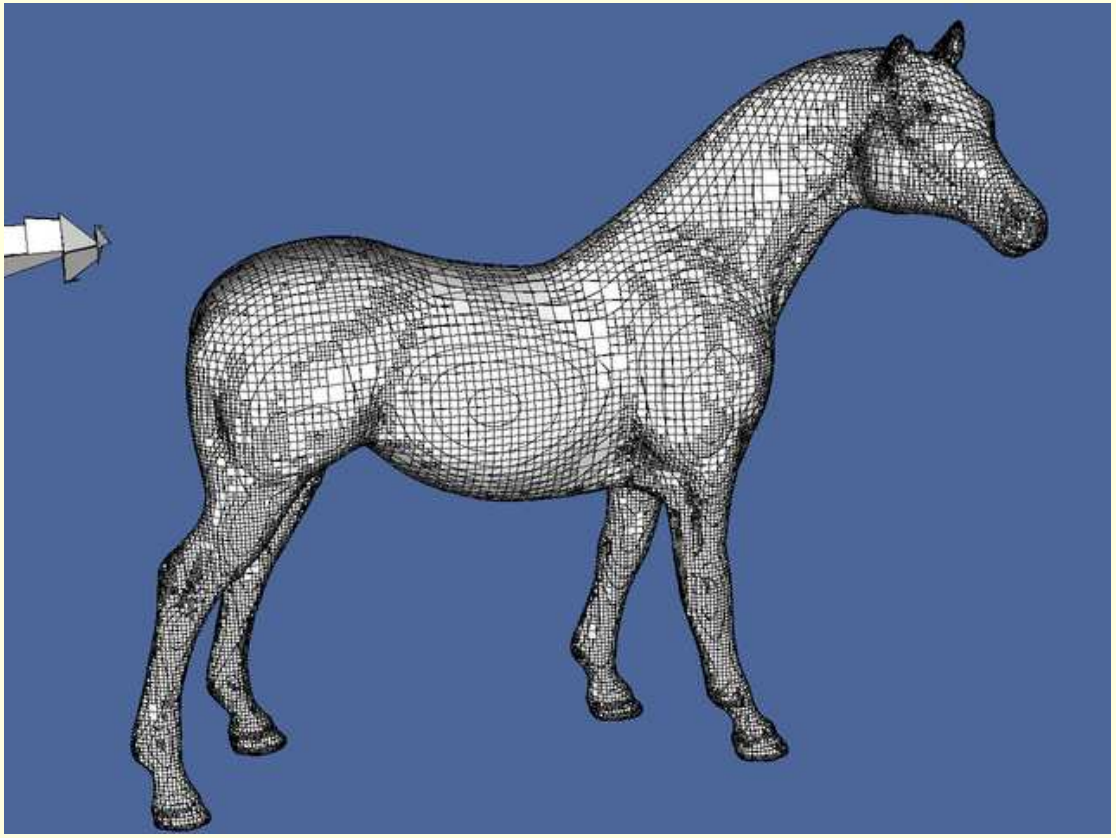
  Not conserving (yet) in the adaptive case

  `basilisk.fr/src/momentum.h`

- Construction of distance functions (i.e. levelsets) from STL files

  STL is a standard for (surface) CAD models (i.e. in industry)





Much more robust than GfsSolid in Gerris (i.e. tolerates self-intersecting surfaces, inconsistent orientations etc.)

Adaptive refinement

`basilisk.fr/src/examples/distance.c`

- Tagging of connected neighborhoods

  A simple parallel algorithm

  Used for drop distribution statistics etc.

  `basilisk.fr/src/tag.h`

- Dump/restore/restart works in parallel for multigrid or quadtree MPI

  Can also restart using different number of processors

  Uses the Z-curve linear encoding on disk to automatically load-balance at read time, on a variable number of MPI processes

- Good MPI performances on a range of large parallel systems: Infiniband clusters, Silicon Graphics shared-memory machines, IBM BlueGene

- The Basilisk web site has been split in two: src/ and the rest. This allows access using the command-line to everybody for the non src/ part.

To appear soon (already in sandboxes)

- Reduced gravity: body force $\rightarrow$ surface force

$$\begin{aligned} -\boldsymbol{\nabla} p + \rho \boldsymbol{g} &= -\boldsymbol{\nabla} p' - [\rho] \boldsymbol{g} \cdot \boldsymbol{x} \boldsymbol{n} \delta_s \\ p' &= p - \rho \boldsymbol{g} \cdot \boldsymbol{x} \end{aligned}$$

  see Annual Review of Fluid Mechanics, 2018.

  well-balanced with adaptivity

  simplifies open boundary conditions for gravity waves

- A new momentum-conserving two-phase flow scheme

  A simple extension of `navier-stokes/centered.h` rather than a derivation from the `all-mach.h` solver

- Basilisk view (`bview`) i.e. a (better!) GfsView for Basilisk
  - an (OpenGL) library to display geometric objects derived from Basilisk fields: VOF surfaces, isosurfaces, isolines, vector fields etc.

```
#include "view.h"
...
clear();
draw_vof (f);
cells();
squares (p, linear = true);
output_view (stdout);
```

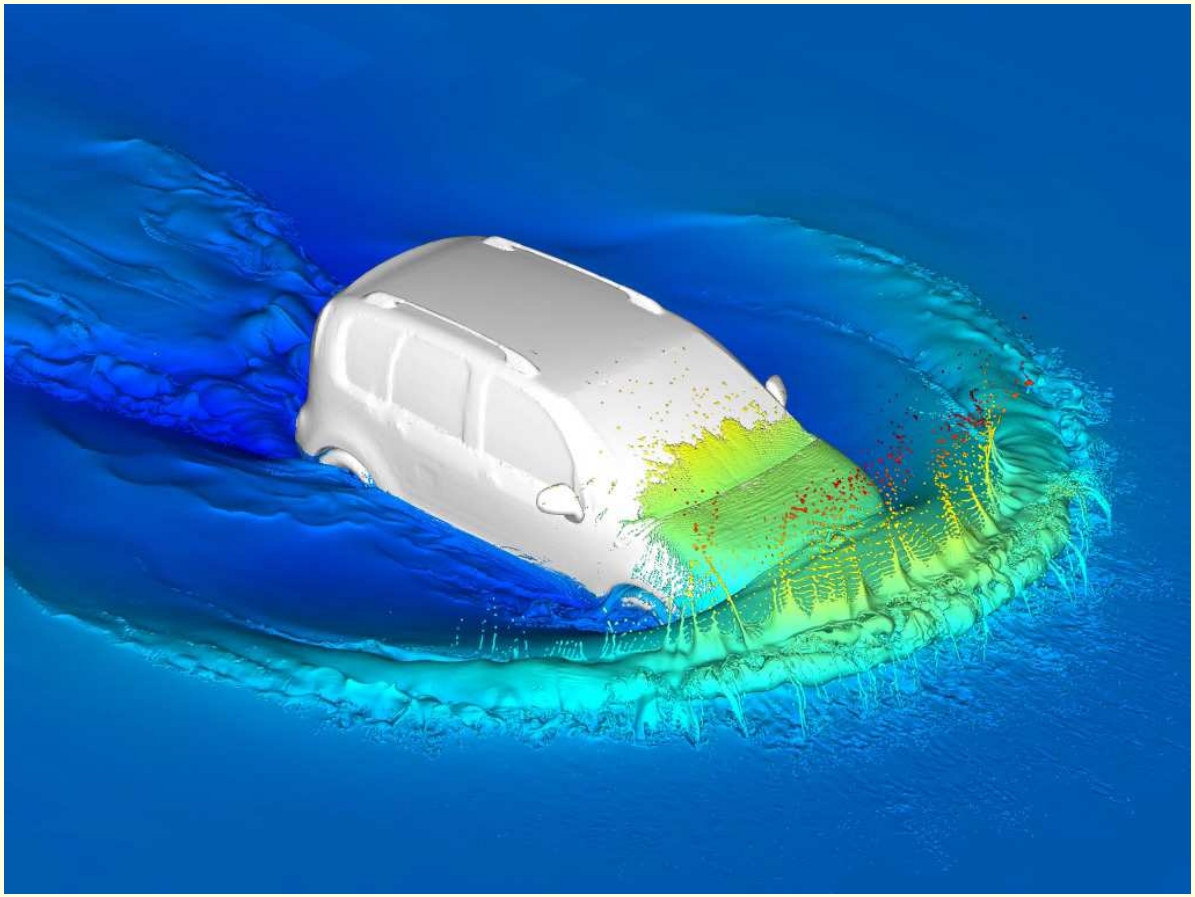
- MPI-parallel, only depends on OpenGL: either the hardware-accelerated version or OSMesa
- an interactive client/server program (similar to paraview):

  the MPI-parallel server can run on large clusters

  the client(s) send commands through unix pipes

  the commands are just library function calls (as above)
- A simple (245 lines), portable (python + tkinter) client: allows rotation, translation, zoom etc. with the mouse but no buttons, menus etc.
- bview reads "dump" file format: there will be changes in this format

- Example: new momentum-conserving scheme + STL files + simple embedded boundaries + reduced gravity + MPI + dump/restart + adaptivity + bview



12 levels, 16 million grid points (vs $2^{36} = 68 \times 10^9$), 24 hours $\sim$ 600 cores

A new version of the preprocessor (qcc)

- Almost ready since December 2016!
- Automatic boundary conditions

  Current:

```
foreach() {
  a[] = ...
  b[] = ...
}
// apply BCs to make sure stencils are consistent
boundary ({a,b});
...
foreach()
  // note that here we access the stencil for b
  // but not for a
  a[] += (b[1] - b[-1])/(2.*Delta);
```

New: BCs are automatically enforced only when necessary

```
foreach() {
  a[] = ...
  b[] = ...
} // a and b are marked as "dirty" (by qcc)
...
// qcc detects that the stencil of b is dirty
// and applies BCs
// nothing is required for a[]
foreach()
  a[] += (b[1] - b[-1])/(2.*Delta);
```

- Simplifies significantly the user interface
- The preprocessor will do a better job of tracking read/write dependencies than the user $\longrightarrow$ consistency and optimisation (particularly important for MPI)
- The preprocessor will also check illegal stencil access patterns: indices out of stencil range, illegal writes etc.

- Allows for other more complex optimisations, for example automatic overlapping communications/computations with MPI

  User-code:

```
foreach()
  a[] += (b[1] - b[-1])/(2.*Delta);
```

  Behind-the-scenes:

```
// apply non-MPI BCs (domain/refinement boundaries)
boundary_non_mpi ({b});
// start asynchronous MPI communication
boundary_mpi_start ({b});
// loop over process-local cells whose stencils do
not contain MPI ghost cells
foreach_local_stencil()
  a[] += (b[1] - b[-1])/(2.*Delta);
// wait for completion of MPI communication
```

```
boundary_mpi_wait ({b});
// update process-local cells whose stencils contain
MPI ghost cells
foreach_remote_stencil()
  a[] += (b[1] - b[-1])/(2.*Delta);
```

- Looks simple but this is not so simple to implement in practice!

  This is also limited by the "rustic" nature of qcc (which should be re-implemented using a yacc grammar).

To appear soon (following presentations)

- Higher-order schemes for hyperbolic and elliptic systems (Rajarshi)
- Multiphase compressible solvers (Daniel)
- Phase-change (Quentin)
- Viscoelastic fluids, hyperelastic solids (Jose-Maria)
- Rheologies for granular materials, Bingham fluids (Pierre-Yves)

Work in progress

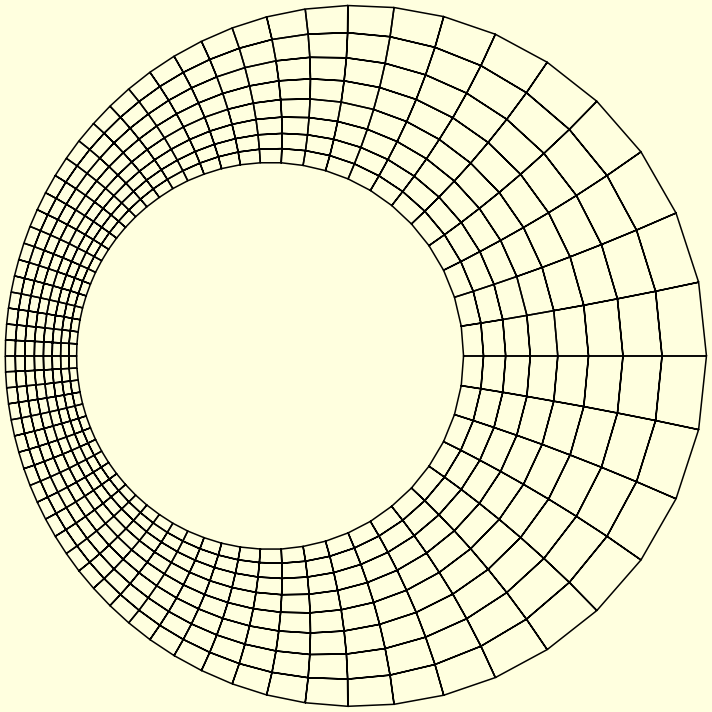
- Embedded solid boundaries: several approaches
  - Cut cells "à la Gerris"
  - `mask()` rework/redesign: solve MPI/dump incompatibilities, possibility of coupling different solvers on the same domain
  - Solid particules: 2nd-order schemes of Anthony Wachs (Can Celsuk, UBC post-doc)
- Augmented Lagrangian formulation for yield-stress fluids (A. Wachs)
- Conservative integral formulation for variable surface tension

  Levelset paper submitted to JCP (Abu-Al-Saoud, Popinet, Tchelepi)

  Marangoni flows etc.

  3D? VOF + Height Functions?

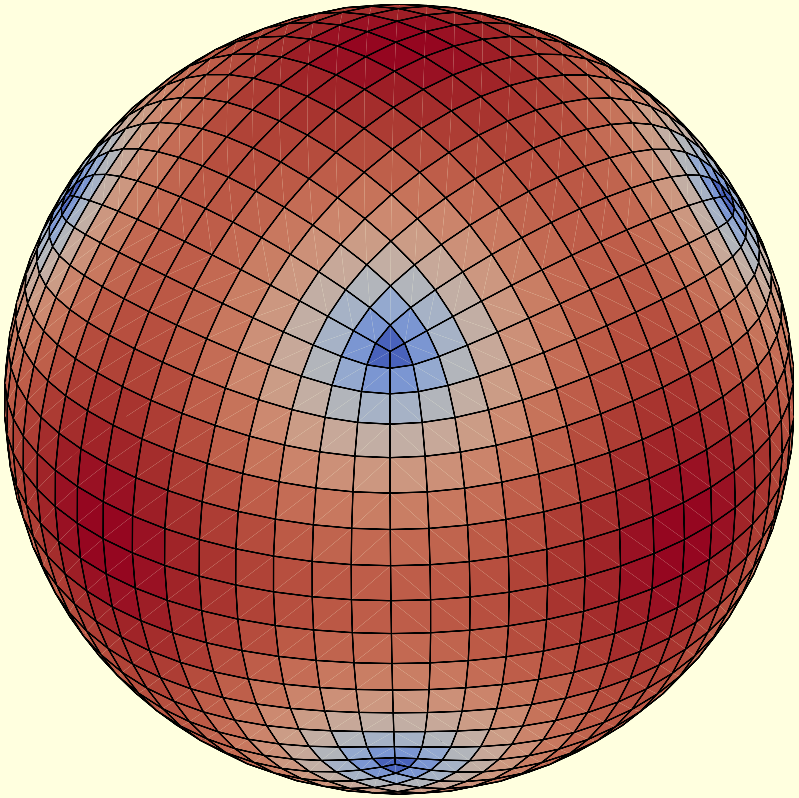
- Metric: goal: reach similar point as in Gerris i.e. Navier–Stokes (single phase) using e.g. bipolar coordinates



`http://gerris.dalembert.upmc.fr/gerris/tests/tests/wannier.html#bipolar`

Future plans

- Periodic boundary conditions and more general topologies e.g. cubed sphere (for geophysical fluid dynamics)



"Multi-boxes" but more flexible than Gerris (2:1 box connections)

- Multi-layer non-hydrostatic "generalised Saint-Venant" model:

  Saint-Venant $\longrightarrow$ multilayer Saint-Venant $\longrightarrow$ free-surface Navier–Stokes
- Conservative Serre–Green–Naghdi model (Clamond et al. 2016)
- Contact angles (using the integral formulation)
- Generalised fluid/solid solver using e.g. the "reference map" method of Kamrin & Nave (2009)

Main issues / priorities

1. Periodic boundaries and other topologies
2. "Masking" / Cut cell solids and other embedded boundary representations
3. Metric
4. Documentation / workshops / summer schools
    a) update existing docs
    b) new "developer" tutorial
5. Further development of bview (other visualisation options?)
6. Various improvements to the wiki/servers

Some statistics

197 members in basilisk-fr google group

Published papers or PhD manuscripts: `basilisk.fr/Bibliography`

2017

J. Eggers et al., “Spatial structure of shock formation", *Journal of Fluid Mechanics*

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Emily Lane et al., “Effects of Inundation by the 14th November, 2016 Kaikoura Tsunami on Banks Peninsula, Canterbury, New Zealand", *Pure and Applied Geophysics*

G. Legros et al., “Direct numerical simulation of an atomizing biodiesel jet: Impact of fuel properties on atomization characteristics"

Roberto Marivela-Colmenarejo, “Numerical Perspective on Tsunami Hazards and Their Mitigation by Coastal Vegetation"

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S. Popinet, “A quadtree-adaptive multigrid solver for the Serre–Green–Naghdi equations", *Journal of Computational Physics*

Lines of code