# Aerodynamical applications of *Gerris*

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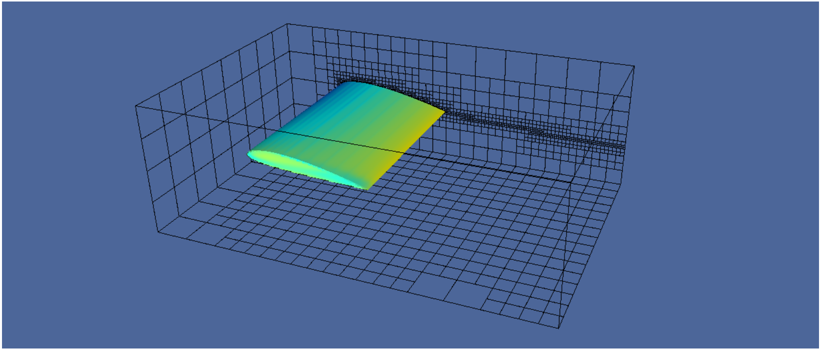
# Introduction

Mampitiyarachchi, S. (2006).
'3D flow visualization of a micro air vehicle with winglets'.
BE thesis,
Dept Aerospace, Mechanical, & Mechatronic Engg,
The University of Sydney
`http://gfs.sf.net/papers/mampiti2006.pdf`

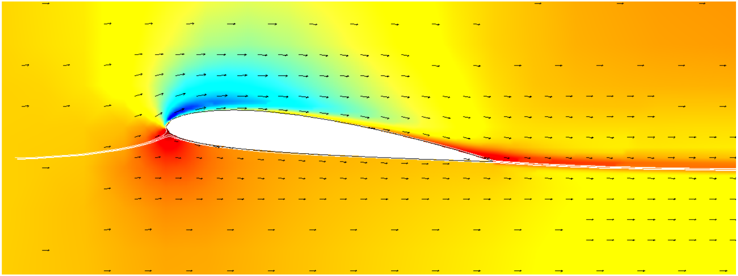
# The Gerris wind-tunnel



The basic framework of Gerris—an arbitrary obstacle immersed in a flow through a rectangular box—coincides neatly with that of aerodynamics.

# Aerodynamics in two dimensions

Much of classical aerodynamics takes place in the plane.

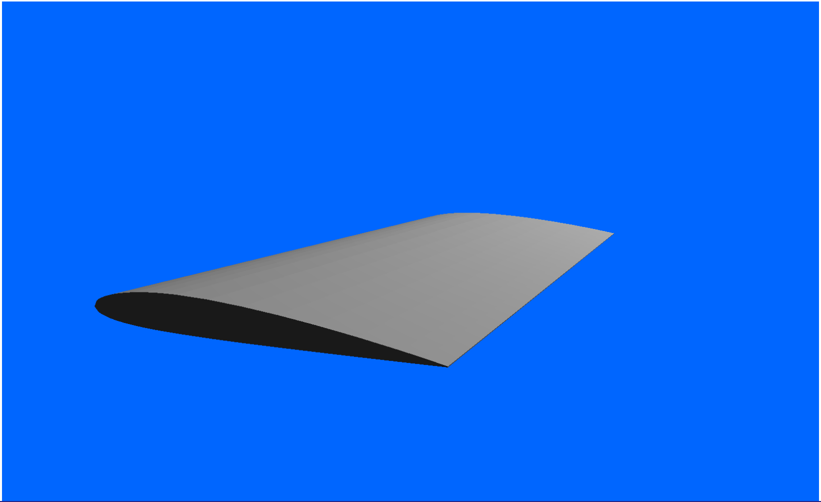


The generation of lift is essentially two-dimensional.

# UIUC Airfoil Coordinate Database

```
$ wget http://www.ae.illinois.edu/m-selig/ads/coord/naca241
$ cat naca2412.dat
NACA 2412
1.0000     0.0013
0.9500     0.0114
0.9000     0.0208
...
1.0000     -0.0013
$ shapes <(tail -n +2 naca2412.dat) > naca2412.gts
```

# gts2pov: rapid visualization of GTS aerofoils



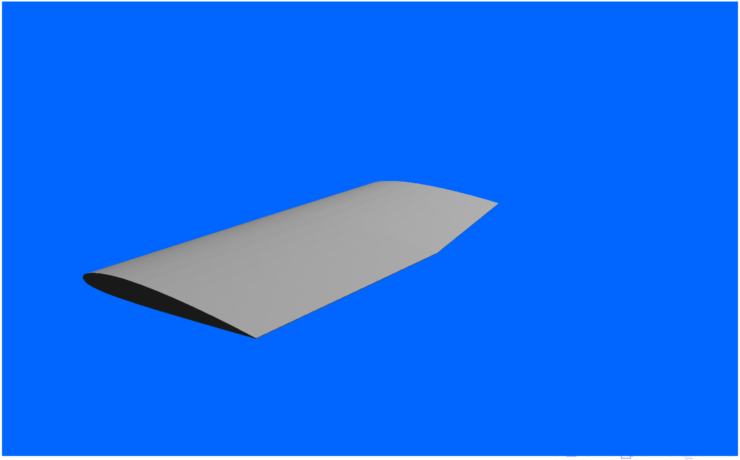
# Aerodynamics in three dimensions

There are some three-dimensional effects in aerodynamics which are too important to ignore, *viz.*:

- wingtip vortices and
- induced drag.

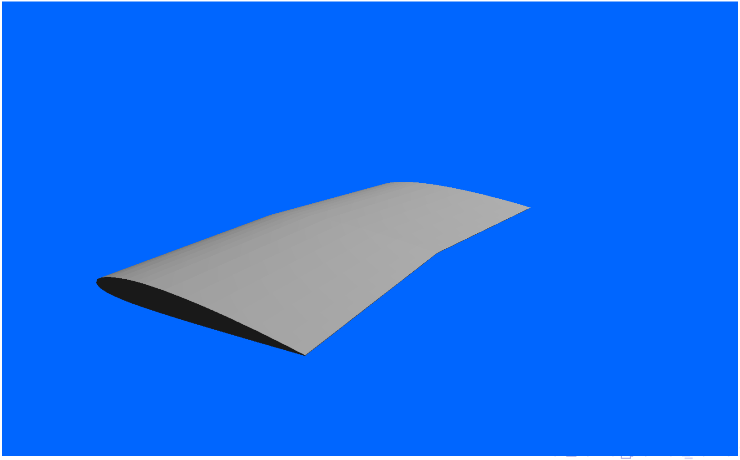
# wingshapes

## taper



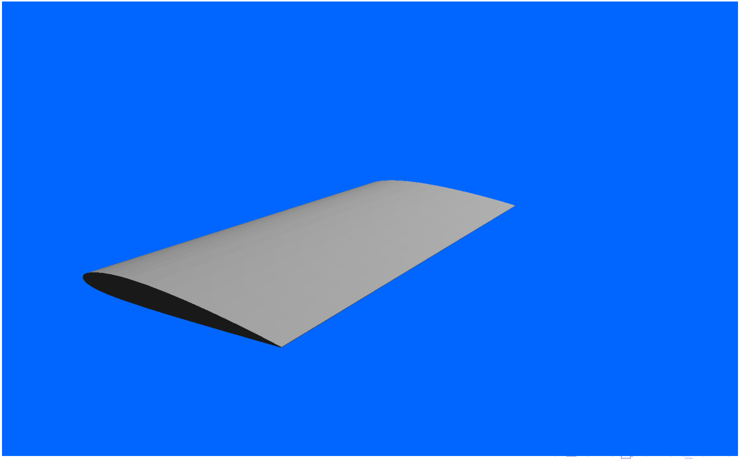
# wingshapes

## sweep



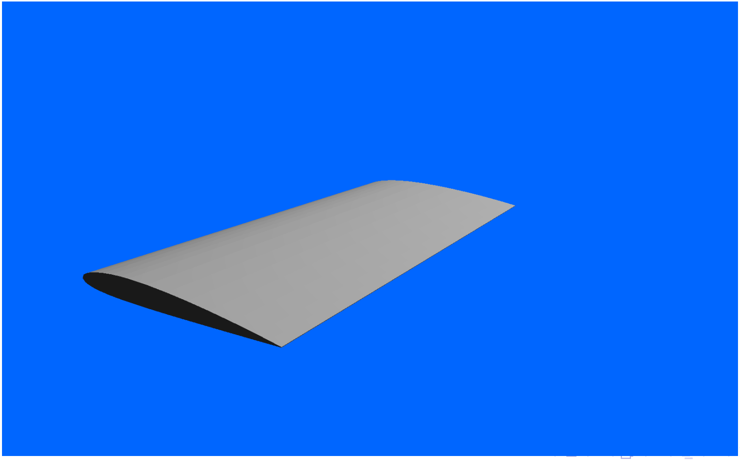
# wingshapes

## dihedral



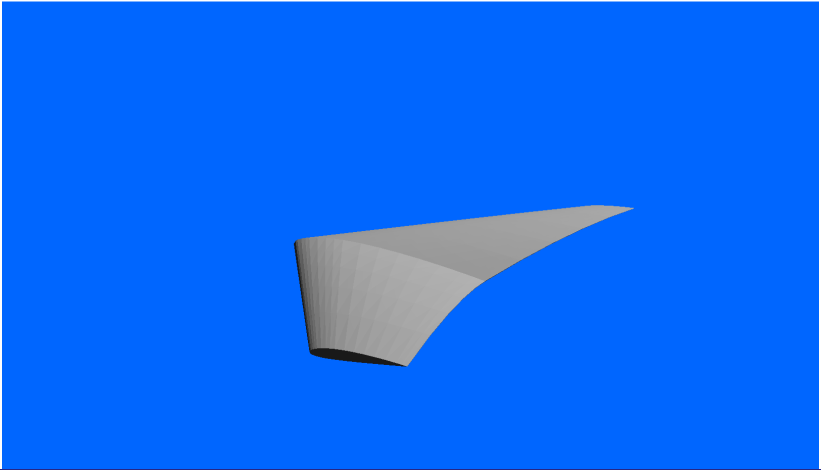
# wingshapes

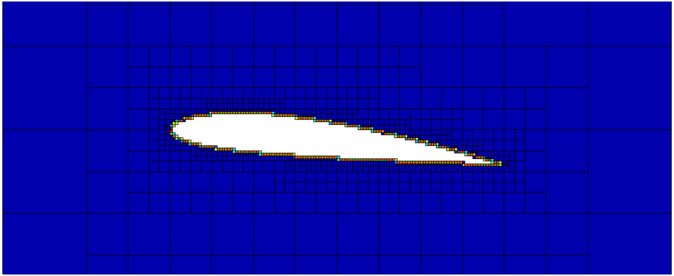
## twist



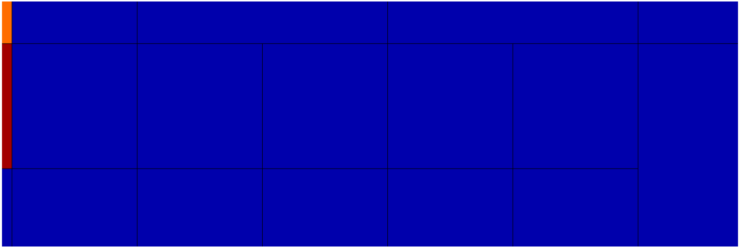
# wingshapes

## taper, sweep, dihedral, & twist





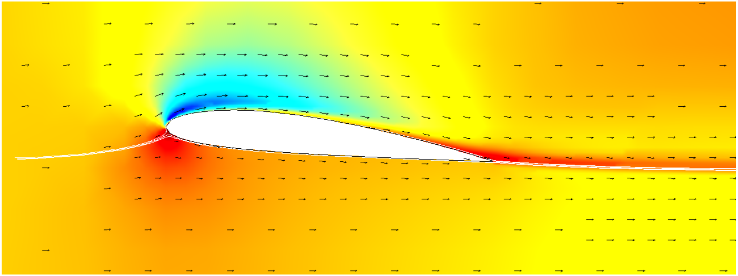
'It is also important to note that a major restriction of the quad/octree structure is that it imposes a locally spatially isotropic refinement. This can be an issue in highly non-isotropic flows (i.e. boundary layers, large scale atmospheric flows etc. . . ).'
(Popinet 2003, *J. comput. Phys.*)



‘This solid boundary description assumes that the geometries represented do not possess features with spatial scales smaller than the mesh size. In particular, sharp angles or thin bodies cannot be represented correctly. This can be an issue for some applications’ (Popinet 2003, *J. comput. Phys.*)

# Pressure difference

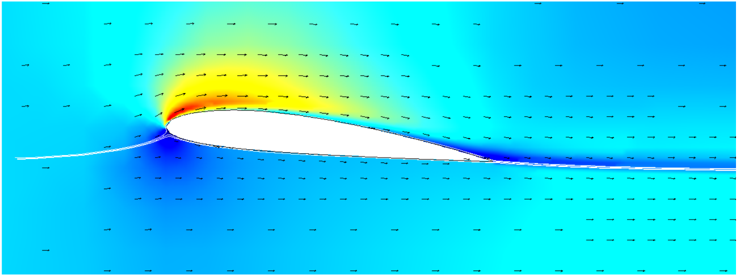
The pressure above must be less. . .



. . . than that below.

# Bernoulli's equation

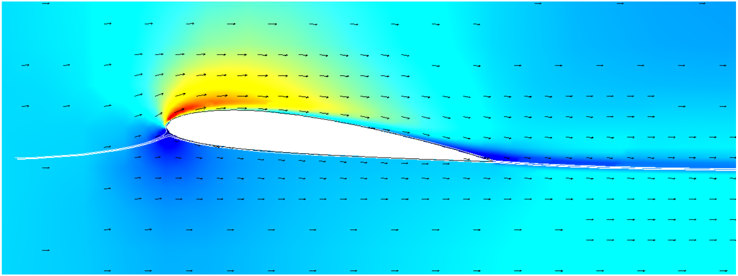
$p + \frac{\rho q^2}{2} = \text{const.}$



therefore, velocity above must exceed that below.

# Circulation

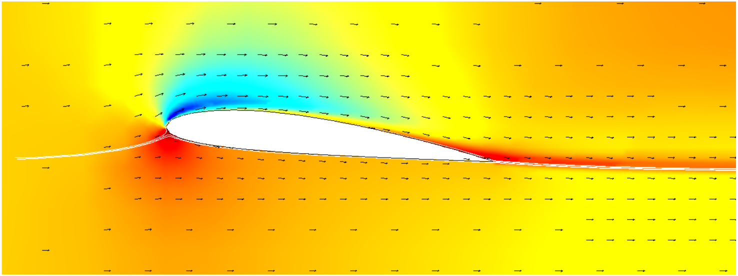
$$\Gamma \equiv -\oint_S \mathbf{q} \cdot \hat{\boldsymbol{\tau}} \, \mathrm{d}S$$



Need a net positive *circulation*.

# Stagnation points

Typically there are two main separatrices.

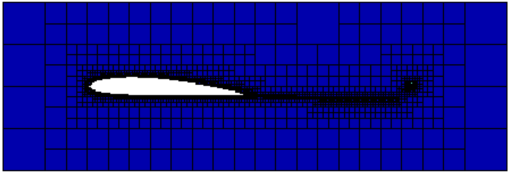


The question is where they are.

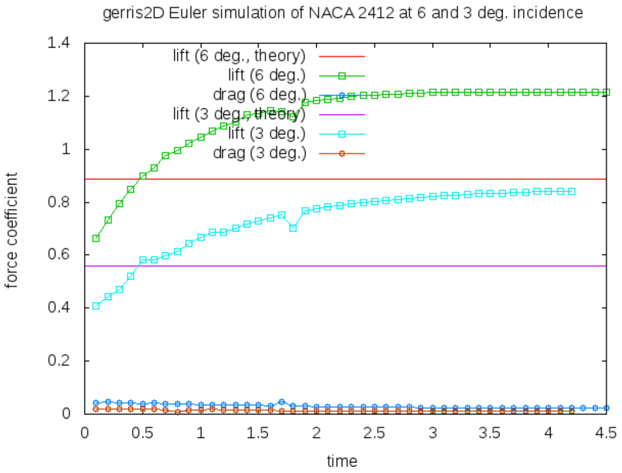
# The starting vortex

Circulation around any fluid-loop is preserved.
Because the upper and lower airflows rejoin at the rearward separatrix, the contour which is the aerofoil at any instant is broken if advected backwards in time.
Advecting forwards in time, any contour initially containing the aerofoil must also contain some of the wake. This fluid issuing through the trailing edge contains a concentrated vortex, equal and opposite to the circulation generated around the aerofoil.

# Visualizing the starting vortex in gerris2D



# Calculating lift and drag in two dimensions

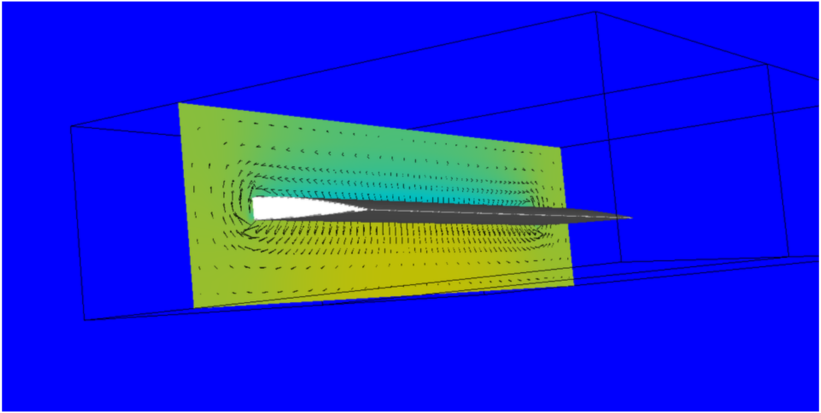


# Another approach: GfsPoisson

- Instead of solving the Euler equations,
- P.-Y. Lagrée has demonstrated another inviscid method
- assuming it has irrotational circulation
- calculate $\phi$ from Neumann problem (displacement effect)
- calculate $\psi$ from Dirichlet problem (circulation)
- each in `gerris2d` with `GfsPoisson`
- combine with Kutta–Joukowsky condition.
- Very fast, very accurate!

# Pressure difference and wingtips

Lift implies higher pressure below than above.



This drives air around wingtips.

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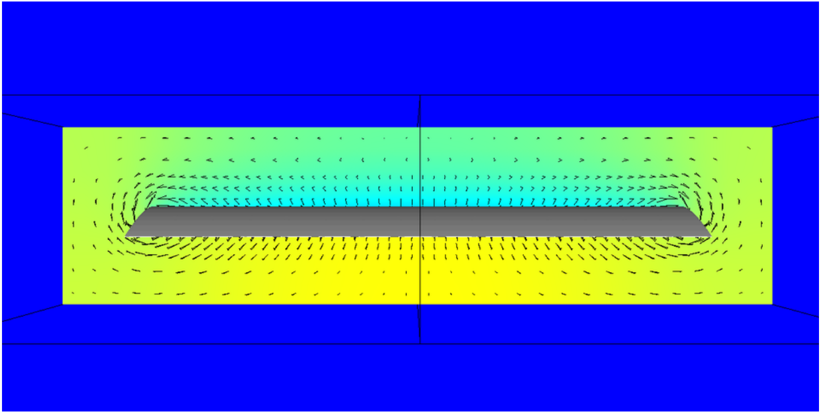
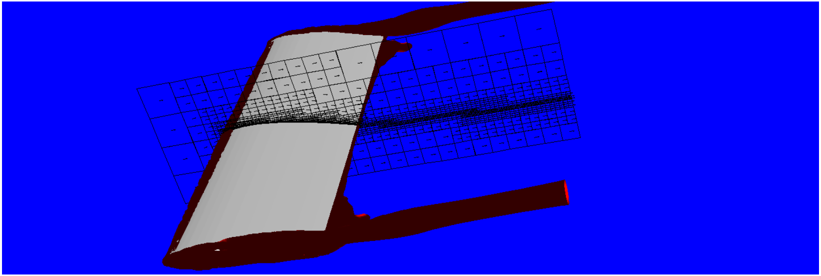


This drives air around wingtips.

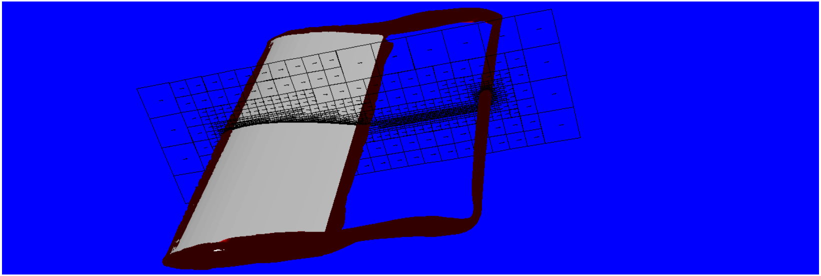
# The starting vortex in three dimensions

Vortex lines cannot end in the fluid.

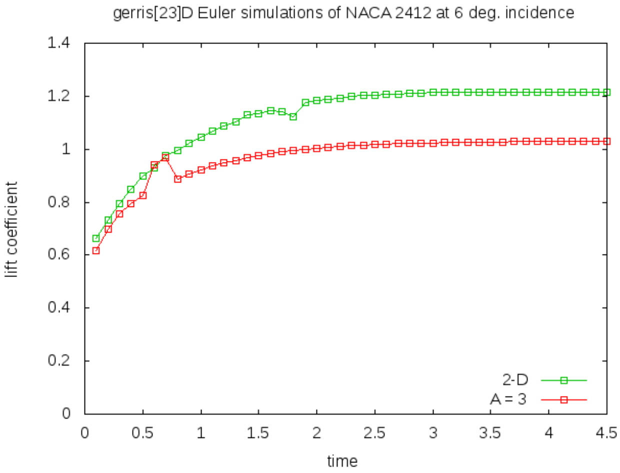


The starting vortex must originate from the wingtips.

# Visualizing the wingtip vortices in gerris3D



# Calculating loss of lift in three dimensions



- Successes:
  - really easily demonstrated & visualized:
    - starting vortex
    - trailing vortex-sheet roll-up
    - wingtip vortices
  - `wingshapes` for taper, sweep, dihedral, & twist
- Open questions:
  - Can we get quantitative lift & drag? Try:
    - increasing wind-tunnel size
    - nondefault pressure-projection parameters
  - How does the Euler solver get the Kutta–Joukoskwy condition right? One often reads that the flow is inviscidly indeterminate and only determined by viscosity. . .
  - What next? Viscosity, or boundary layer & wake?