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# A REYNOLDS-AVERAGED NAVIER-STOKES SOLVER WITH TRANSITION PREDICTION CAPABILITY

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The prohibitive cost of simulating all the scales of turbulence (DNS) or even part of them (LES) has made the cheaper RANS equations the de-facto approach in industry. As expected, there is a price to pay for this in that turbulence has to be modeled rather than directly computed. While there exists a variety of turbulence models to represent the Reynolds stresses, none of them can reliably account for the onset of turbulence. On the other hand, 50 years of work on the stability analysis of boundary layers has produced a significant amount of semi-empirical transition prediction methods suitable for engineering applications, most notably, the $e^N$ method.

In this talk we will describe a high order RANS solver with transition prediction, based on the $e^N$ method. In this solver, the mesh is generated implicitly with the solution and is specifically adapted for the viscous layer in an automatic way. This avoids issues like identifying the edge of the boundary layer or the need for high quality boundary layer profiles, that have often hindered the application of the $e^N$ method in the RANS context.

The solver itself is composed of three modules: a Hybridized DG discretization of the RANS equations in Arbitrary Lagrangian-Eulerian (ALE) form, a nonlinear elasticity solver to generate the mesh and a surface PDE solver for the evolution of the boundary layer thickness indicator as well as the amplification factor for transition. All these modules are coupled in a monolithic and solved using an implicit nonlinear iteration. These robust methodology allows us to compute a variety of transitional flows ( e.g.: laminar separation bubbles, shock-boundary layer interaction ) that we will discuss in the talk.

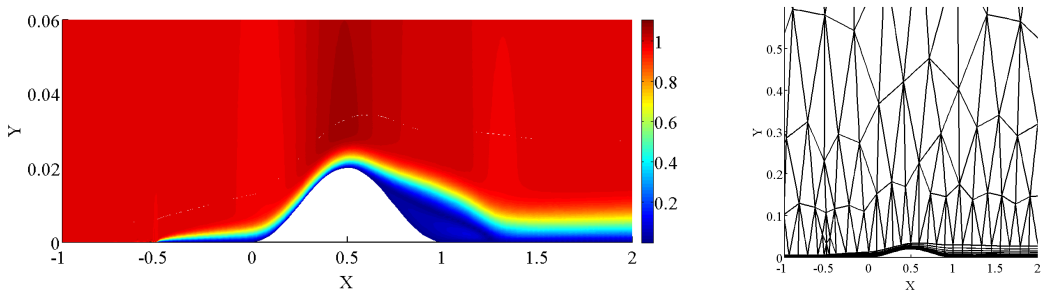


Figure 1: Laminar separation bubble around a 2% sine squared bump at $Re = 3e5$ computed using polynomials of order $p = 4$. Left, velocity magnitude $||\mathbf{v}||$, right, hybrid mesh. Axis are not to scale for visualization purposes.

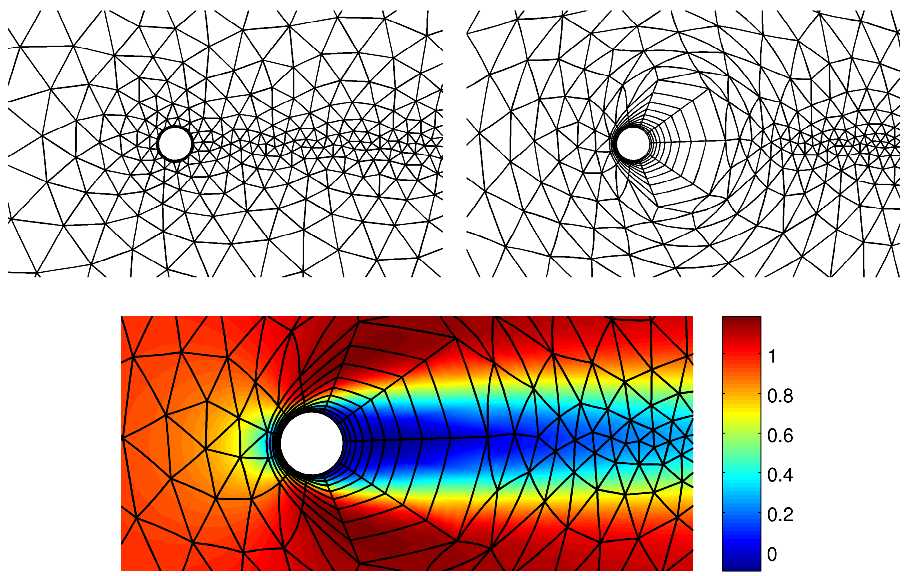


Figure 2: Laminar flow around a cylinder at $Re = 40$ computed using polynomials of order $p = 3$. Top-left, intial mesh, top-right, final mesh, bottom, horizontal velocity field $u_x$.

## REFERENCES

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