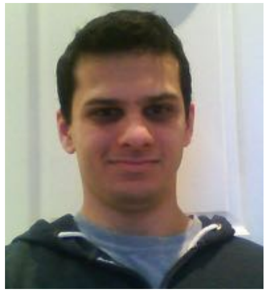
Nektar++ Workshop 2016
Imperial College London

Chris Cantwell

David Moxey

Gianmarco Mengaldo



Douglas Serson

Our anniversary

```
commit 989db9bf2373cb1f536c5ff2c63fbf8520a64f78
Author: Mike Kirby <kirby@sci.utah.edu>
Date:   Thu May 4 18:43:20 2006 +0000

    Initial version.


    git-svn-id: https://gforge.sci.utah.edu/svn/nektar/trunk@2 305cdda6-5ce1-45b
3-a98d-dfc68c8b3305
```

Our Icon evolution

Nektar++

NEKTAR++
SPECTRAL/HP ELEMENT FRAMEWORK

Workshop Outline

- Overview of Nektar++
- Nektar++ Development Strategy
- Future Directions
- User Applications: *4pm-6pm*
- *….. dinner !*

Workshop Outline

- Application updates
- New and upcoming features
  - r & p adaption
  - Coordinate transformations
  - NekMesh
- Tutorial sessions

Nektar++: Spectral/hp element toolkit

Imperial College, University of Utah

www.nektar.info

- Incompressible/compressible Solvers
- Wide range of discretisations: CG/DG, Fourier, modal/nodal with 1, 2 and 3D, embedded manifolds
- Arbitrary-order curvilinear mesh elements for complex domains
- MPI parallelism and scalable to many thousands of cores
- Modern modular C++ object-oriented design with an extensive testing framework
- Cross-platform (Linux, OSX, Windows)
- MIT Licence

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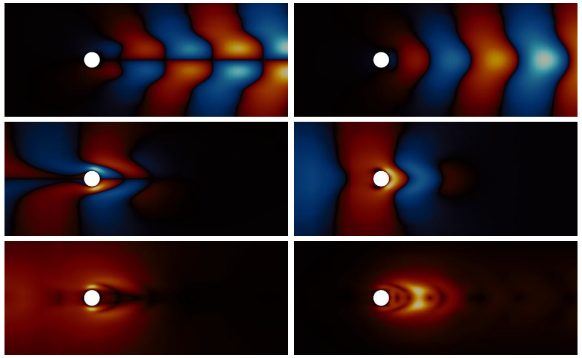
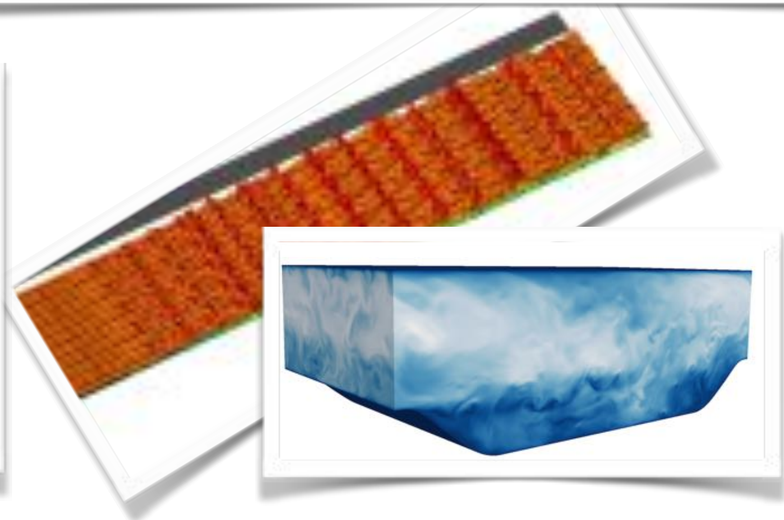
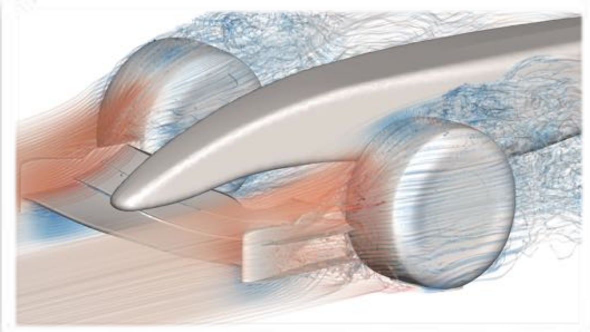
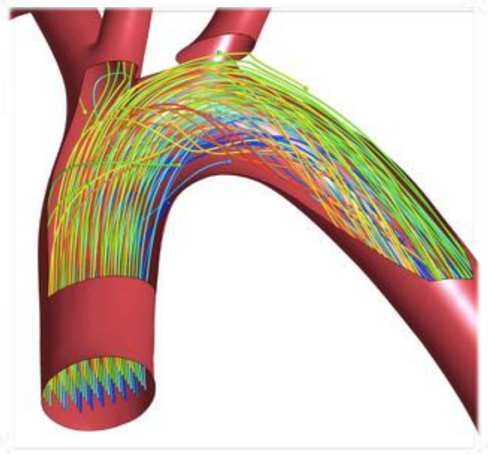
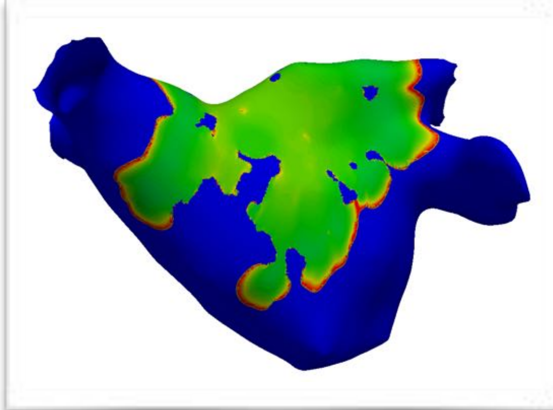
Nektar++ Applications

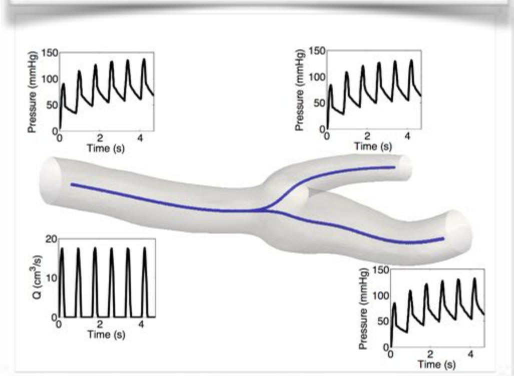


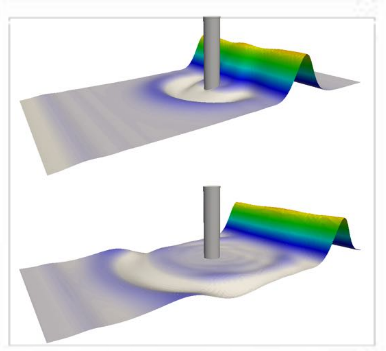


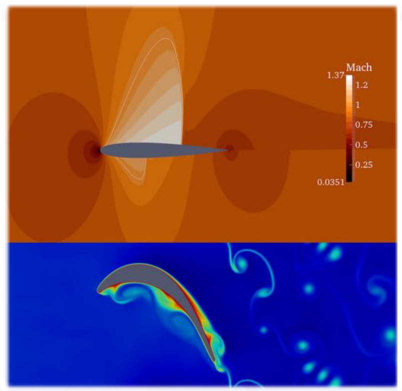


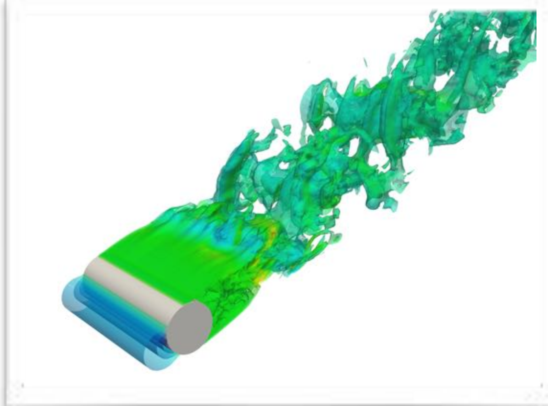












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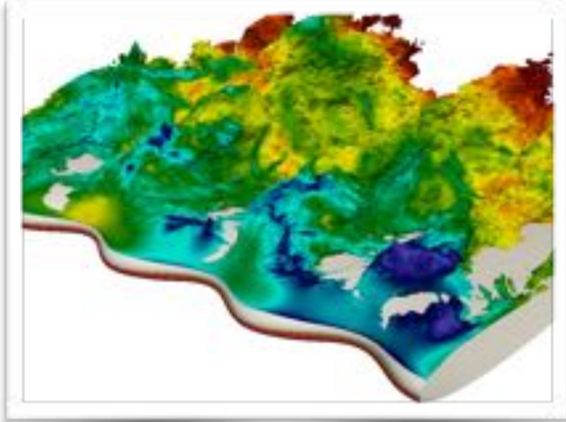
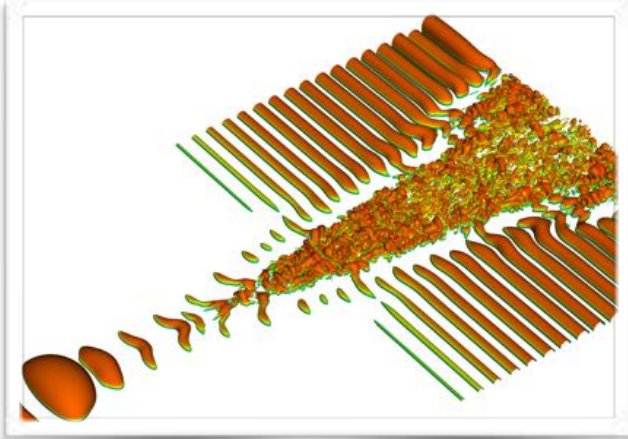
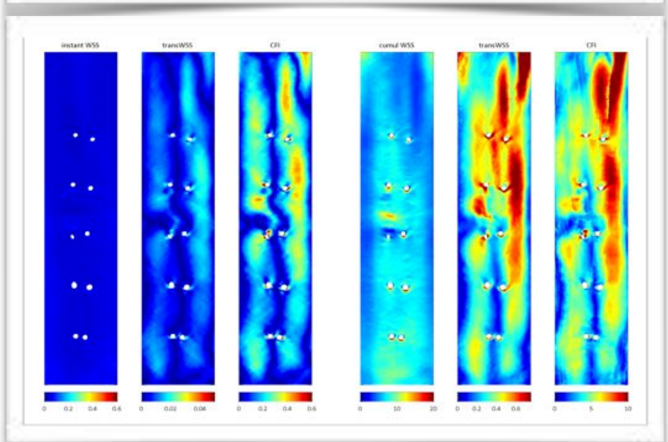
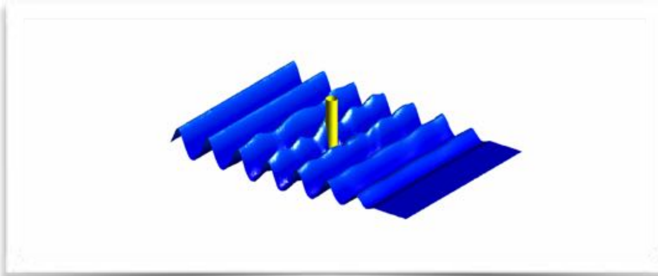
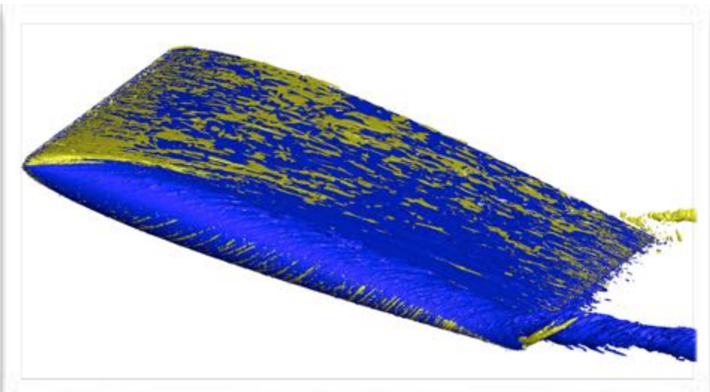
Nektar++ Applications

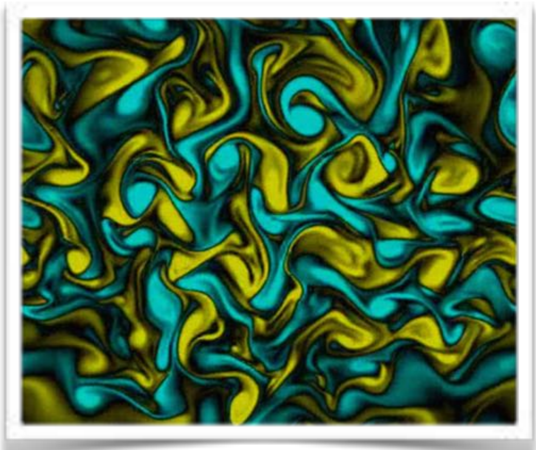


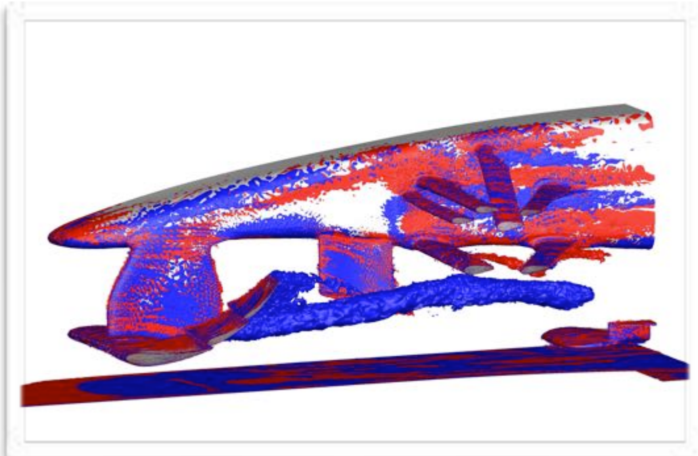








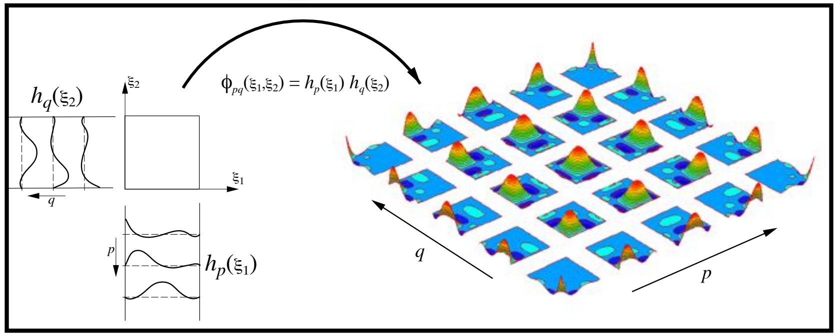


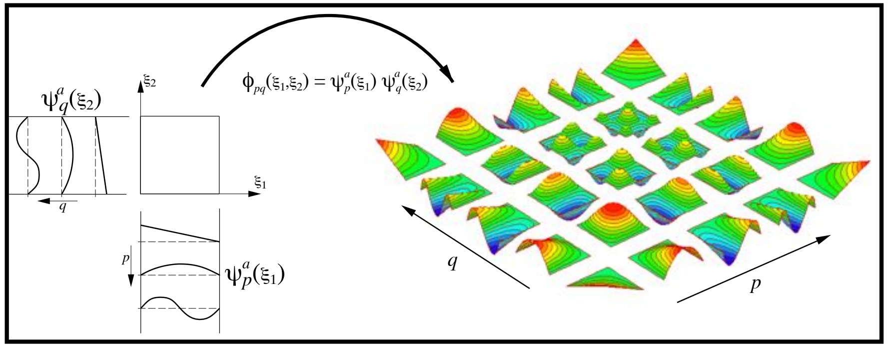


Nektar++ Scope

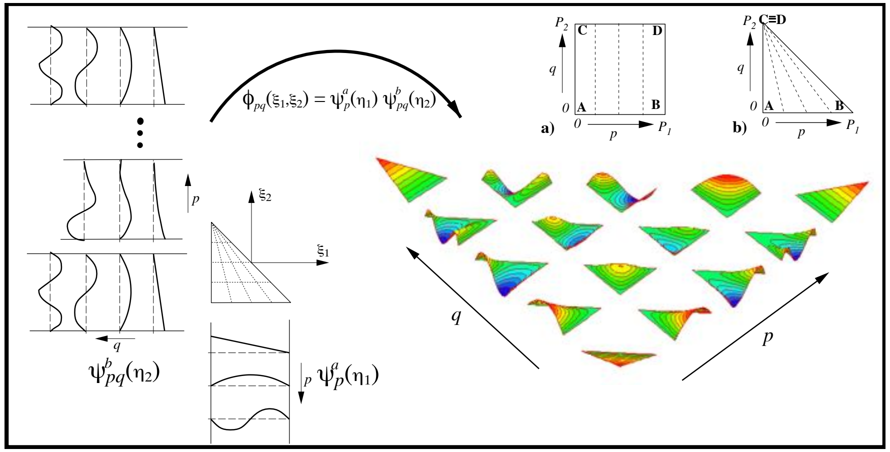
- Scalar basis fields (explicitly coupled)
  - Time dependent non-linear solvers
  - Implies scalar boundary conditions

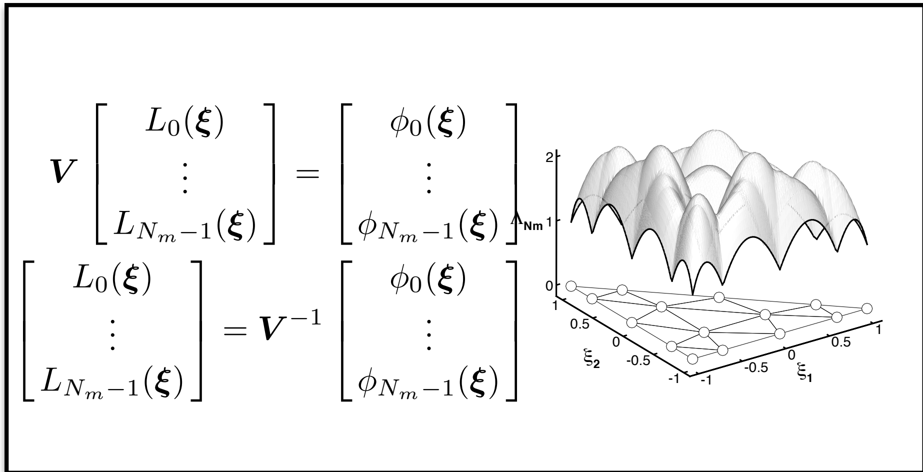
Nektar++ Scope



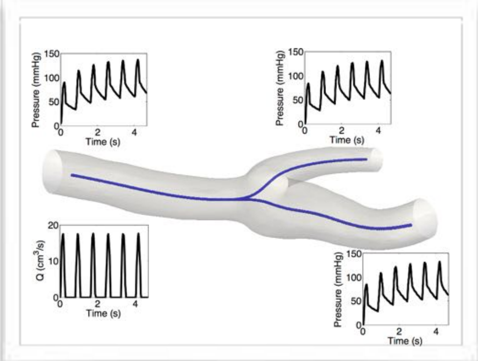


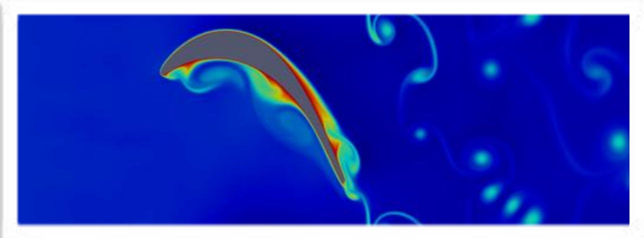
- Tensor nodal & modal product definition
- Nodal unstructured through mapping

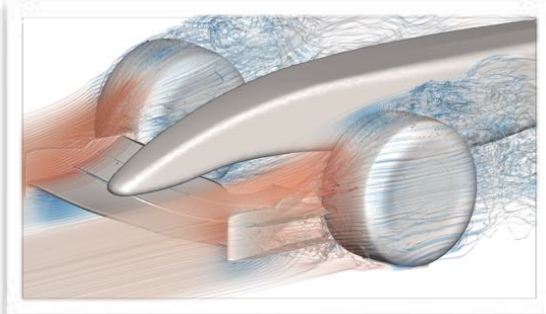




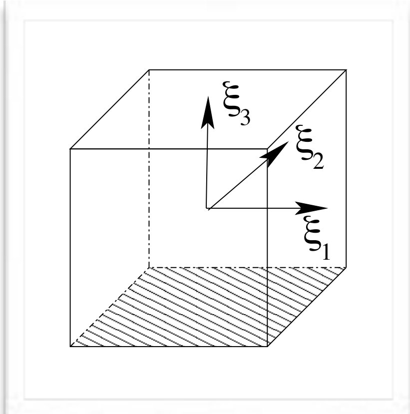
Nektar++ Scope

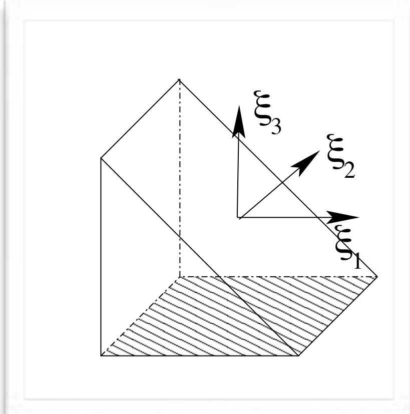


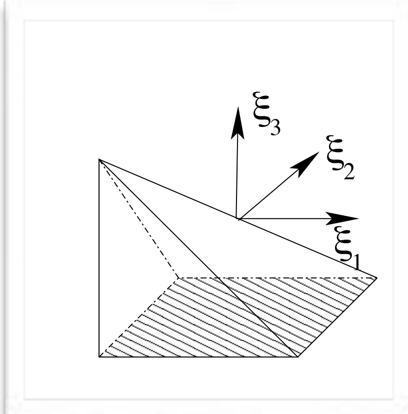


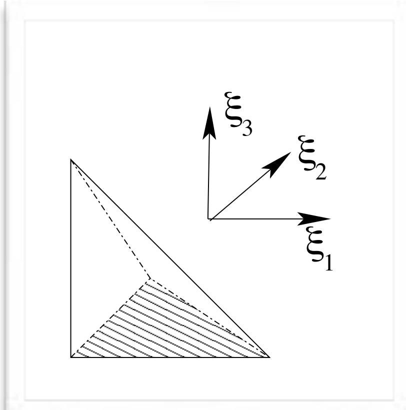


- Segment (1D), plane (2D) and volume domains (3D) & manifolds
- Hybrid Domains

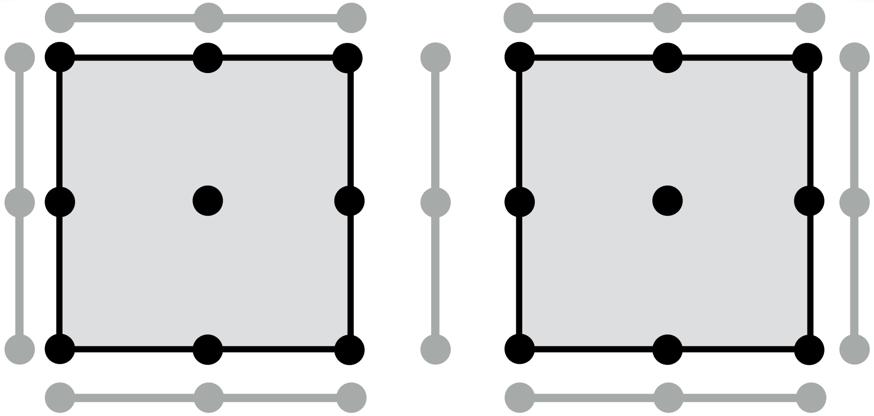




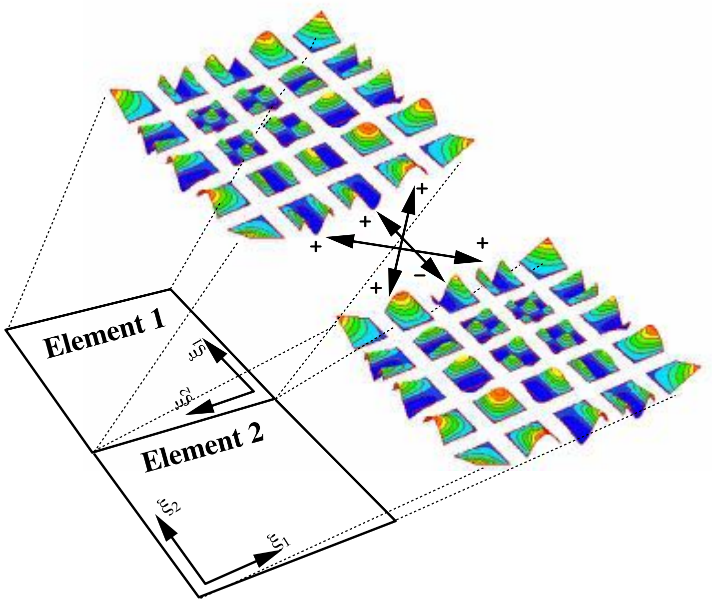


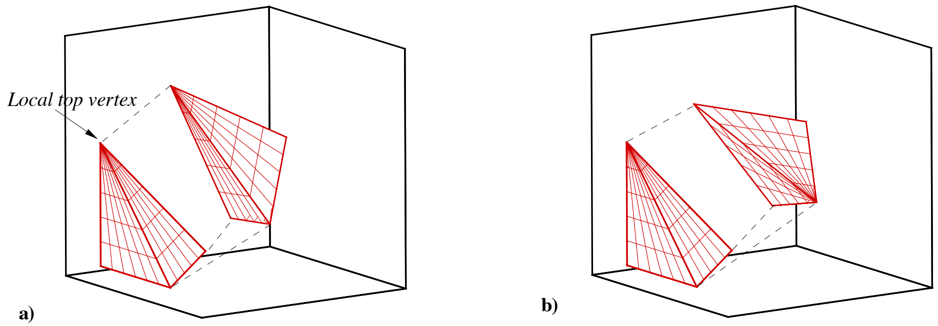


Nektar++ Scope

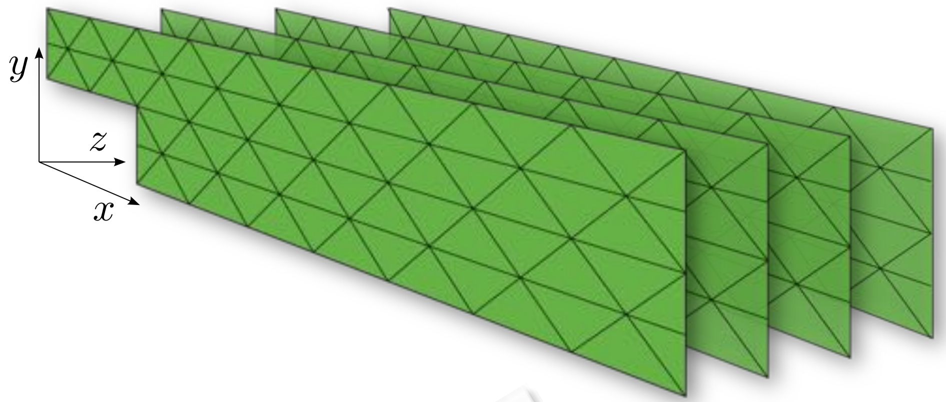


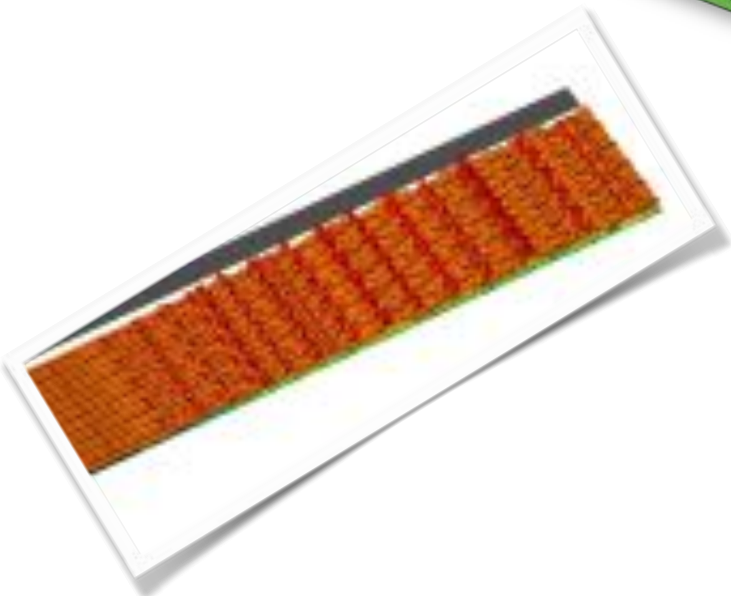
- Continuous and Discontinuous approx.
  - DG & Flux Reconstruction

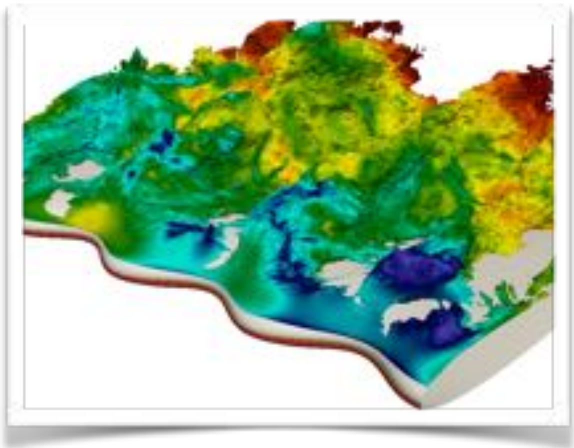


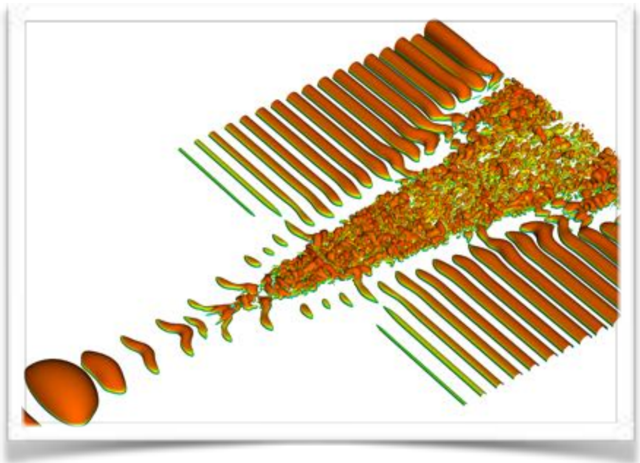


Nektar++ Scope



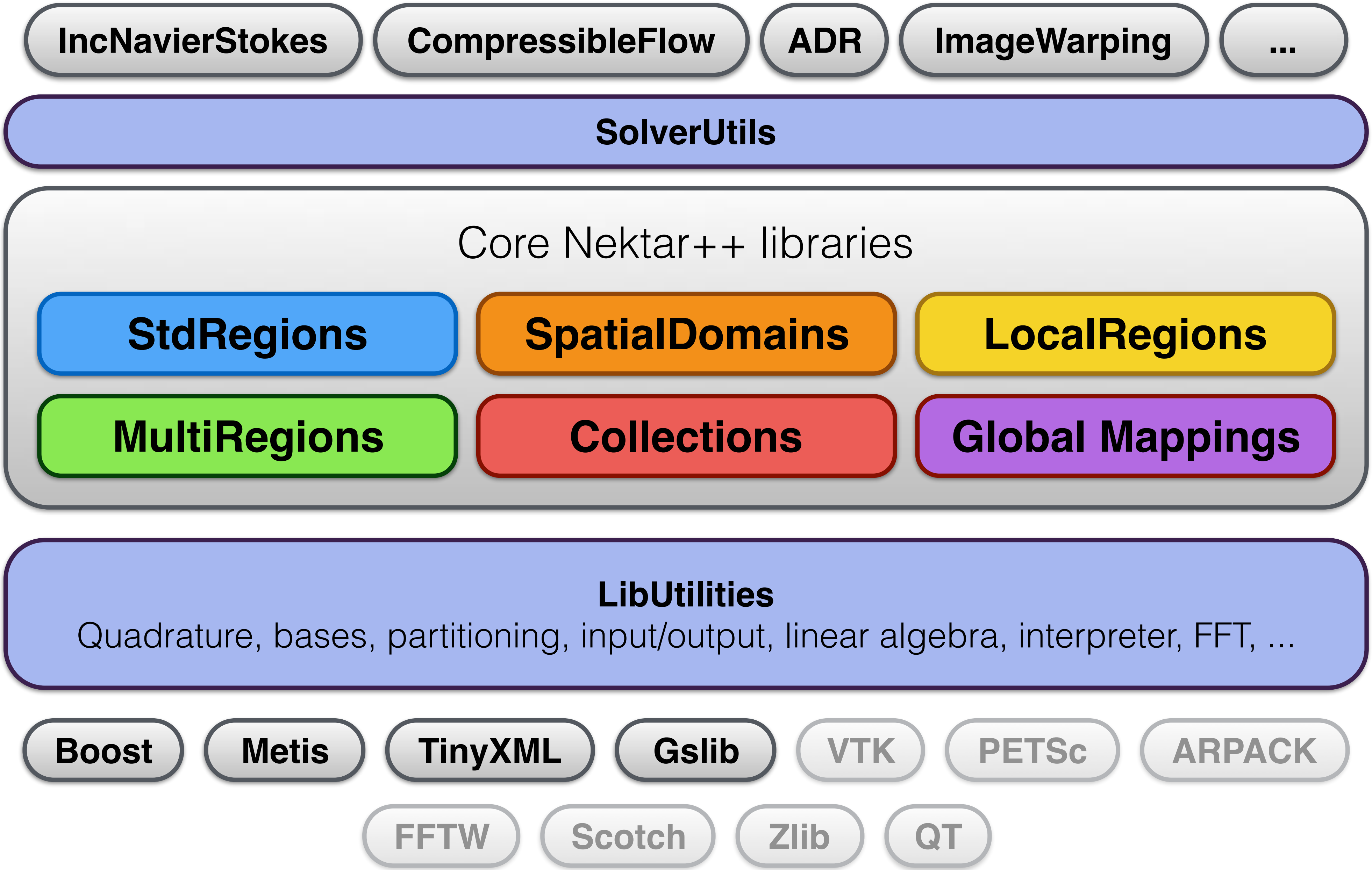




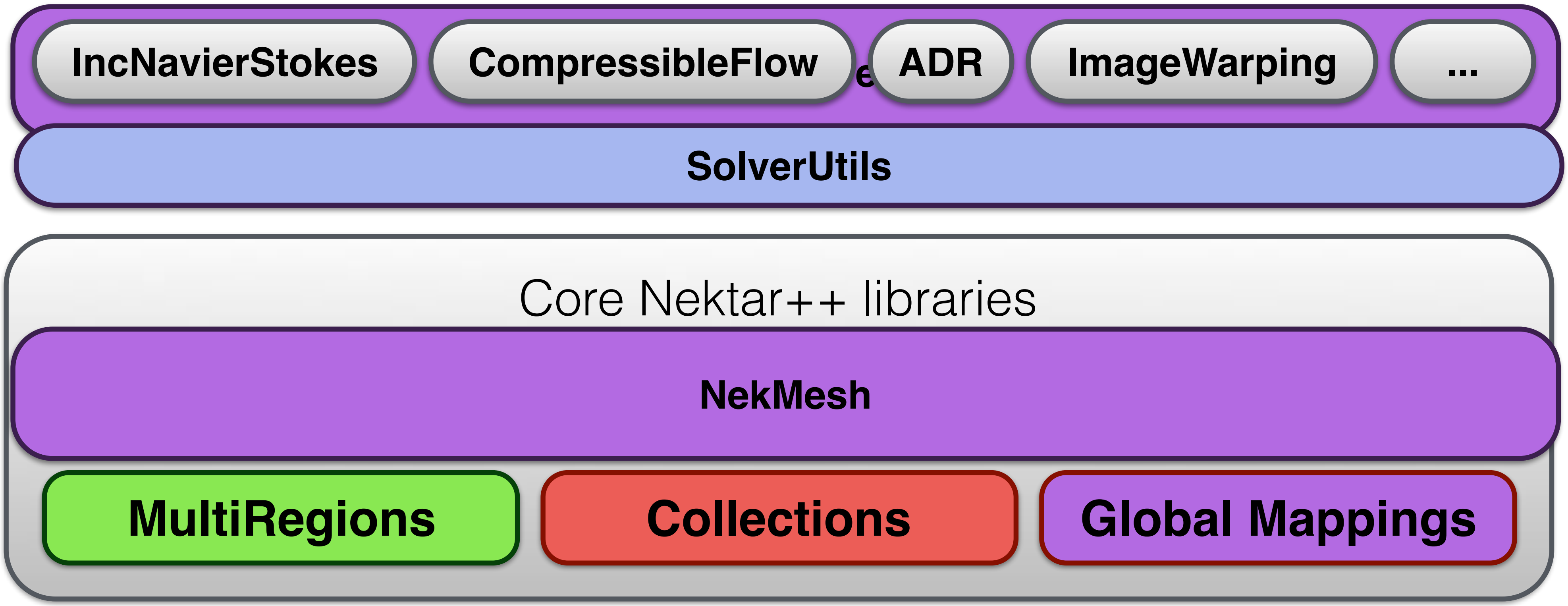


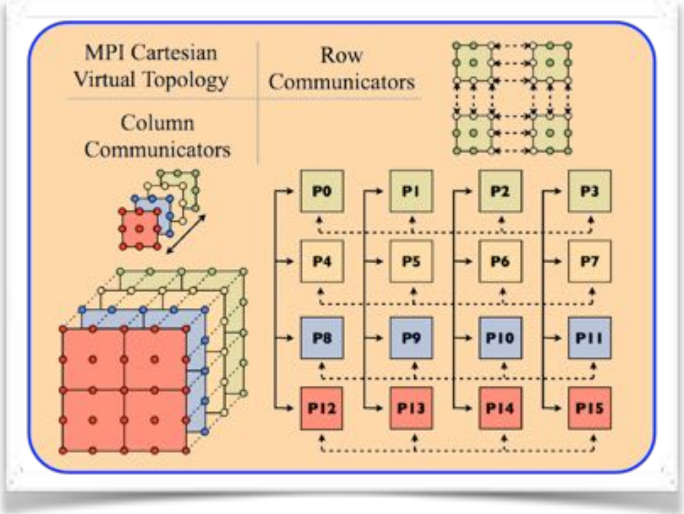
- Homogeneous expansions

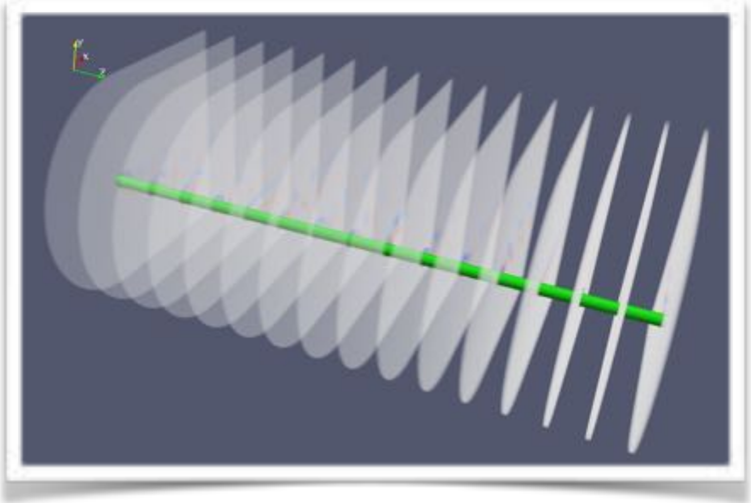
Framework design



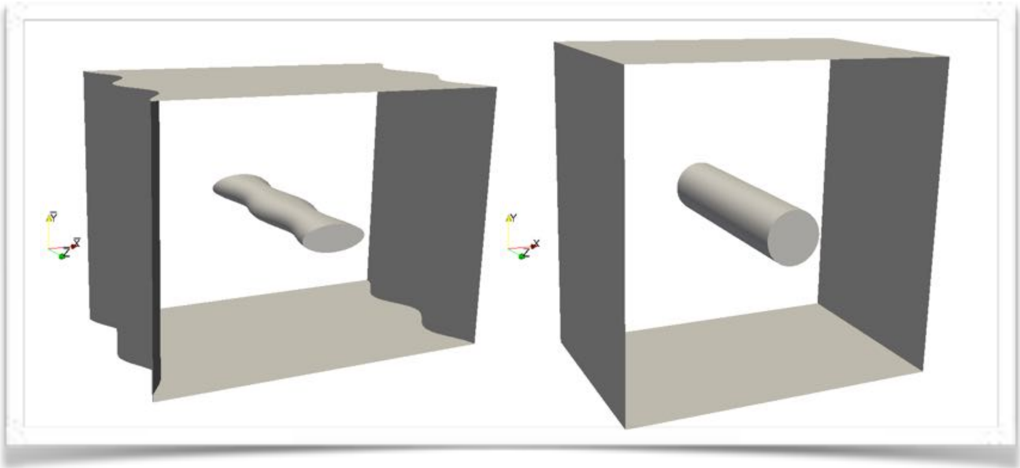
Framework design







Recent Developments



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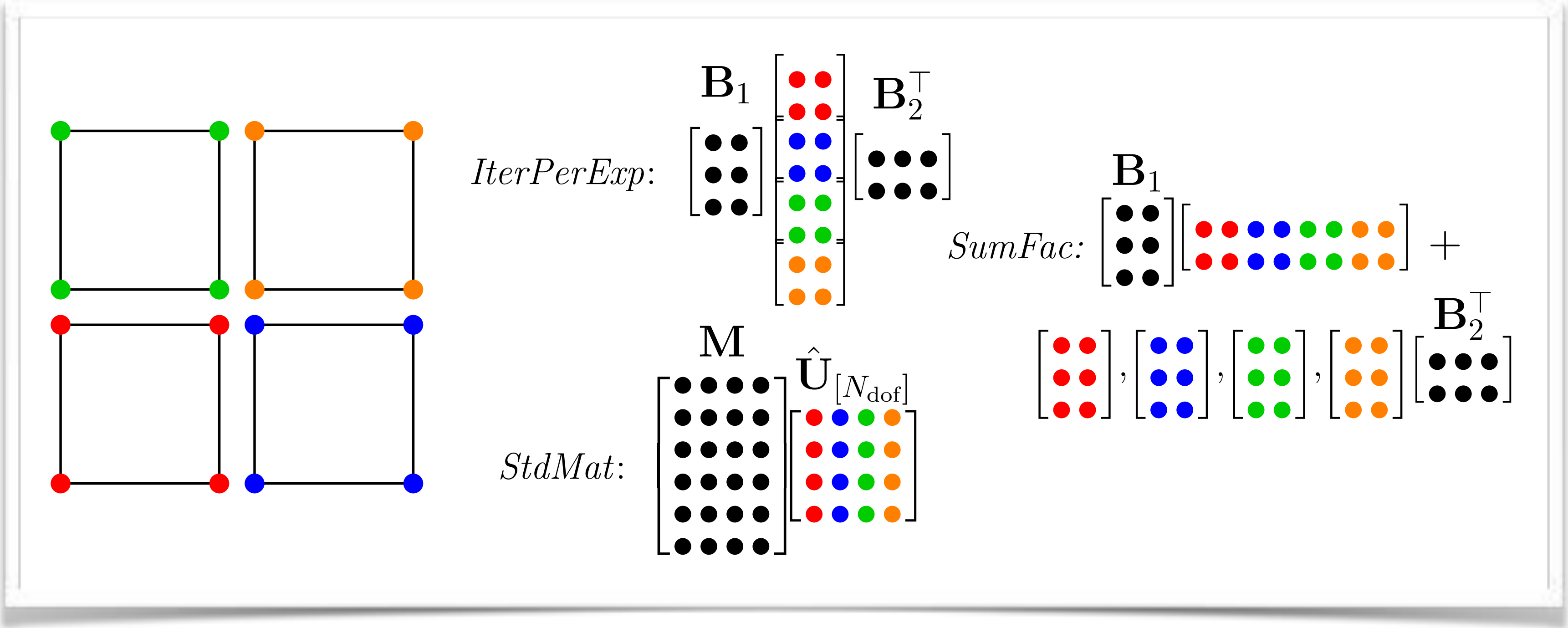
Collections

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Other Developments

Compressed I/O


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```


> **Note**
>
> The description below explains how the `GEOMETRY` section is laid out in uncompressed ascii format. From Jan 2016 the distribution uses the compressed format for each of the above sections. To convert a compressed xml file into ascii format use
>
> `NekMesh file.msh newfile.xml:xml:uncompress`

HDF 5

`--io-format Hdf5`

Threading

```
m_threadManager->QueueJob(
    new AdvectionWeakDGJob(
        this, nConvectiveFields, fields, inarray, numflux));
```

```
AdvectionWeakDGJob(
    AdvectionWeakDG* const                                  pEC,
    const int                                               nConvectiveFields,
    const Array<OneD, MultiRegions::ExpListSharedPtr> &fields,
    const Array<OneD, Array<OneD, NekDouble> >        &inarray,
          Array<OneD, Array<OneD, NekDouble> >        &numflux)
    : pEC(pEC), nConvectiveFields(nConvectiveFields), fields(fields),
      inarray(inarray), numflux(numflux)
{
}

void Run()
{
    pEC->GetTraceSpace(nConvectiveFields, fields, inarray, numflux);
}
```

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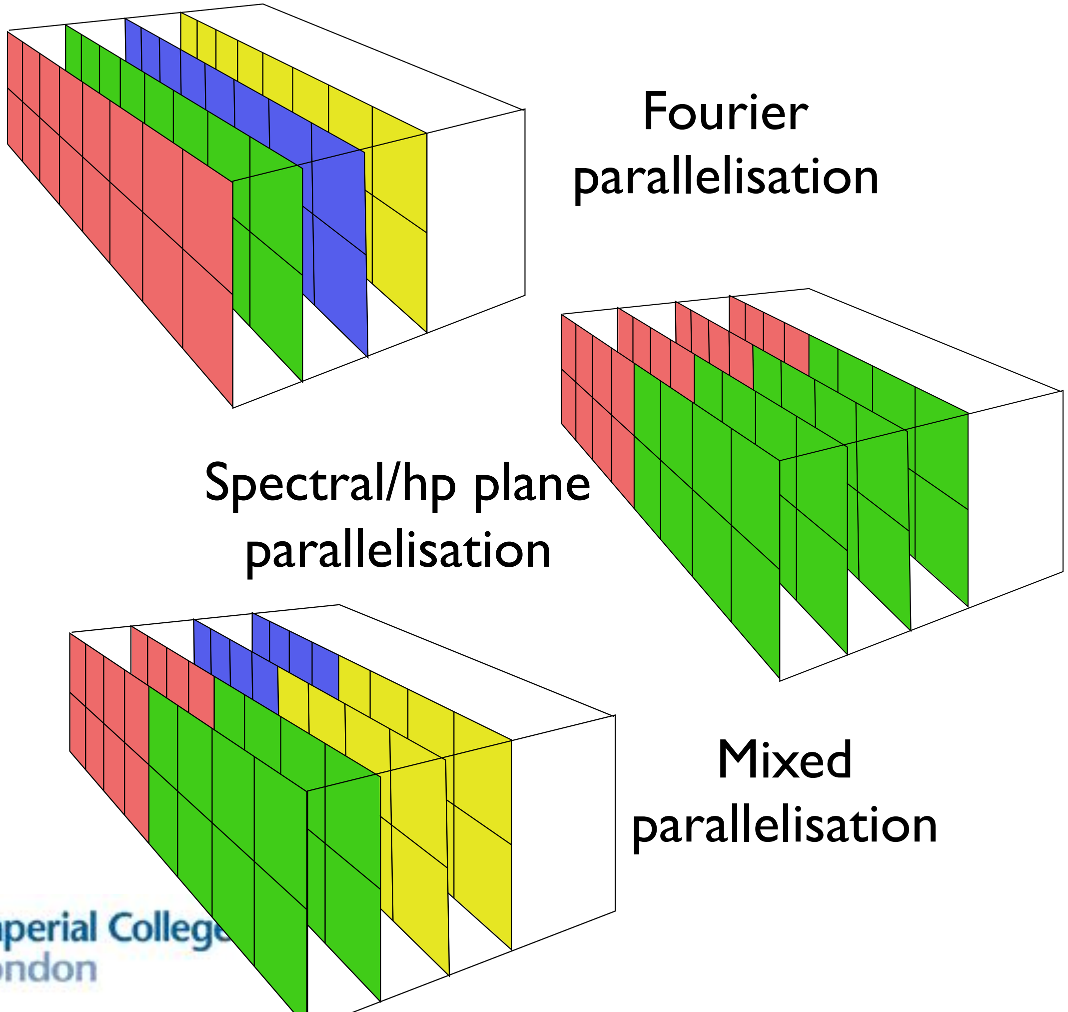
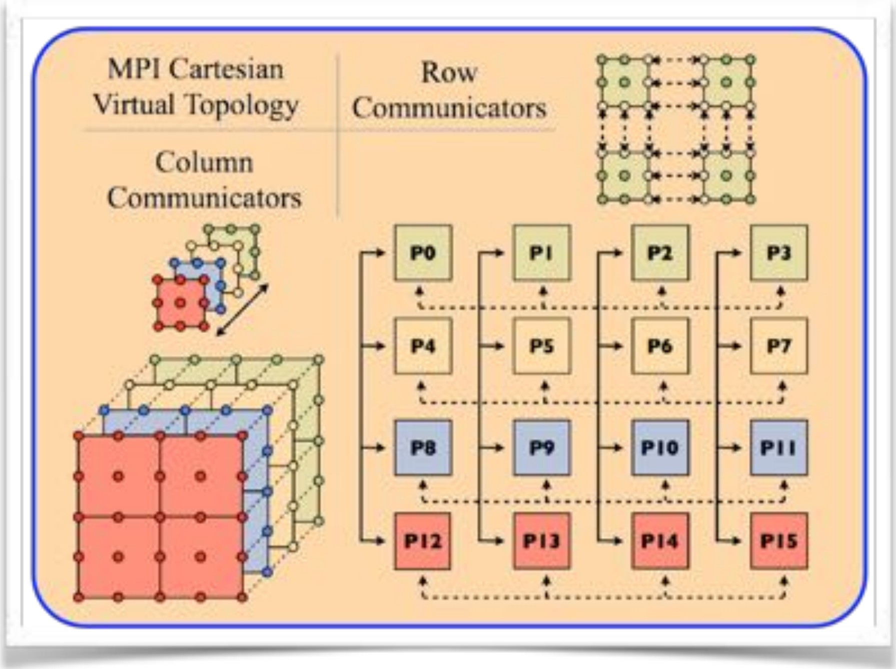
Recent Papers

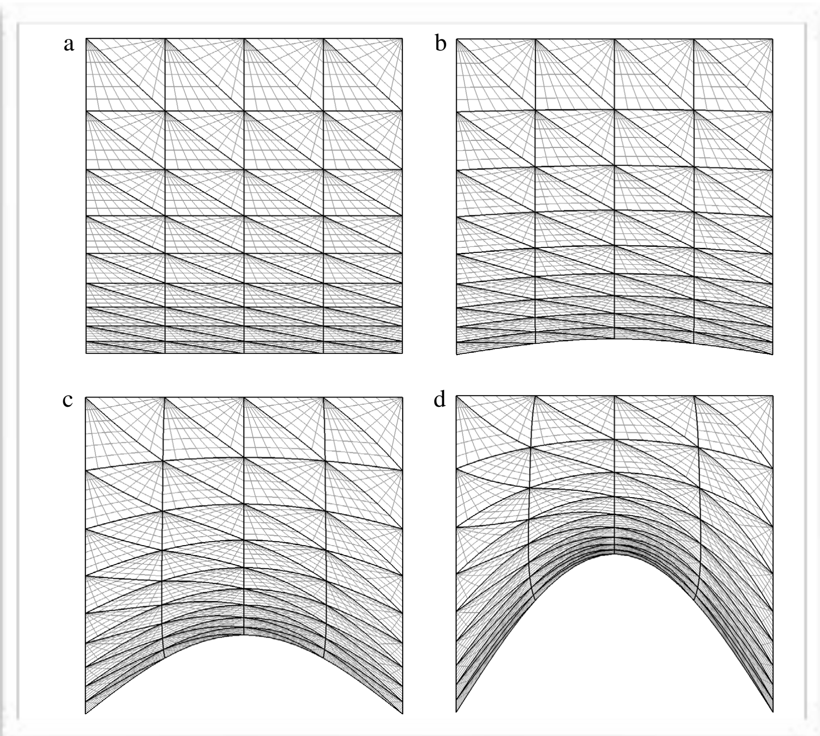
- A. Bolis, C. Cantwell, D. Moxey, D. Serson, and S. Sherwin, “An adaptable parallel algorithm for the direct numerical simulation of incompressible turbulent flows using a fourier spectral/hp element method and mpi virtual topologies,” Computer physics communications, 2016.

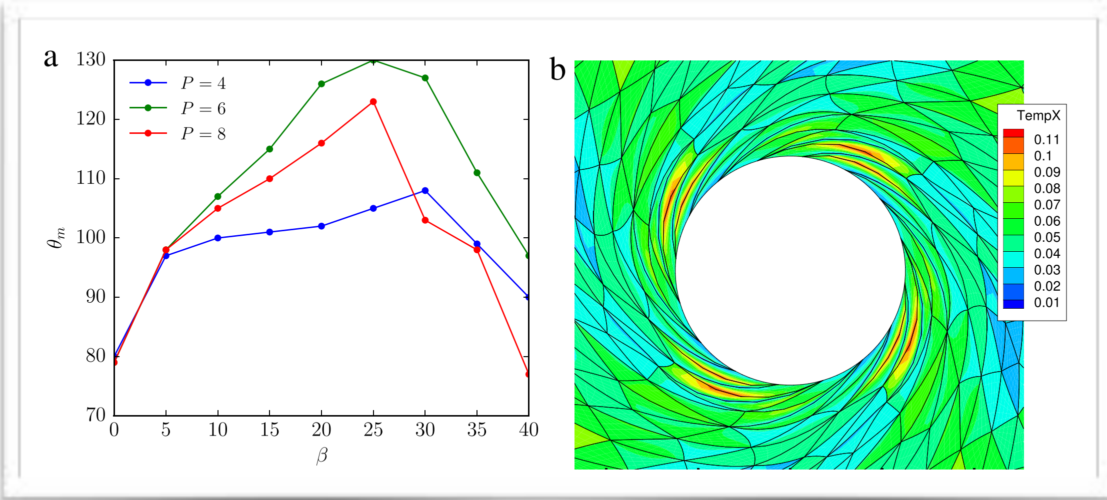




Recent Papers

- Moxey D, Ekelschot D, Keskin U, Sherwin SJ, Peiro J, 2016, High-order curvilinear meshing using a thermo-elastic analogy, COMPUTER-AIDED DESIGN, 2,130-139





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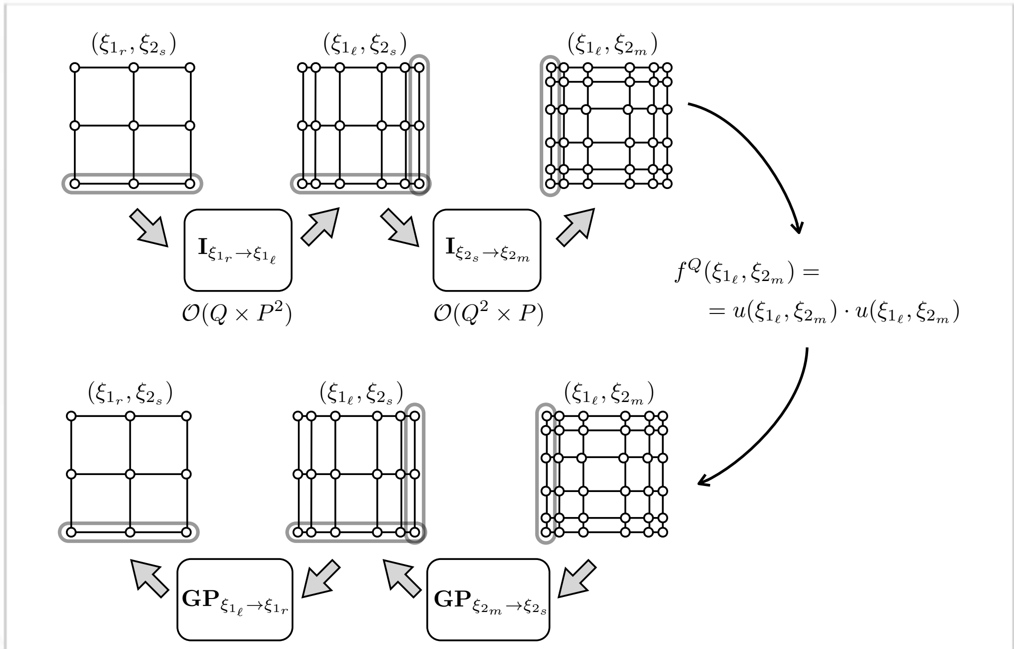
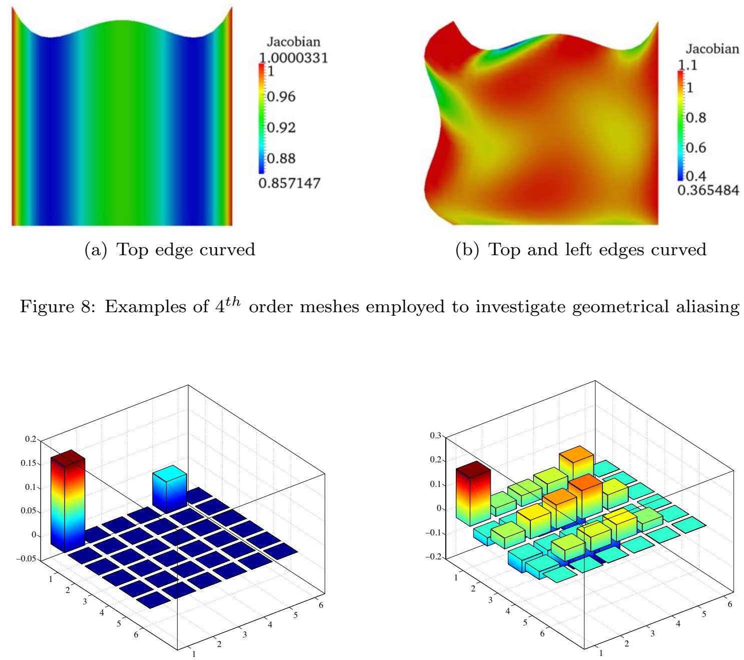
Recent Papers

- Mengaldo, G., De Grazia, D, Moxey, D., Vincent, P.E., Sherwin, S.J. "Aliasigin techniques for high-order spectral element methods on regular and irregular grids", J. Computational Physics, 2015





(a) Top edge curved (b) Top and left edges curved

Figure 8: Examples of 4^{th} order meshes employed to investigate geometrical aliasing

(a) Top edge curved (b) Top and left edges curved

Recent Papers

- Mengaldo G, De Grazia D, Vincent PE, Sherwin SJ, 2016, On the Connections Between Discontinuous Galerkin and Flux Reconstruction Schemes: Extension to Curvilinear Meshes, Journal of Scientific Computing, 67,1272-1292

Table 1 Connections between different types of DG and FR schemes derived in this work for elements with a spatially varying Jacobian

	DG_{SEM}-GLL		DG_{SEM}		$DG_{(Q>P)}$	
	Lumped mass matrix		Exact mass matrix		Exact mass matrix	
Flux type	Linear	Nonlinear	Linear	Nonlinear	Linear	Nonlinear
FR_{HU}	✓*	✓*	✗	✗	✗	✗
FR_{DG}	✗	✗	✓	✓	✗	✗
$FR_{DG(Q>P)}$	✗	✗	✗	✗	✓	✓

✓ indicates that the schemes are equivalent, whereas ✗ indicates differences between the schemes
* The equivalence holds true for Gauss–Lobatto–Legendre points only

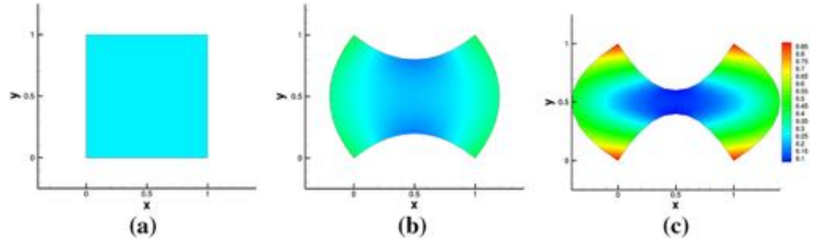


Fig. 1 Mesh A. Single-element mesh configuration

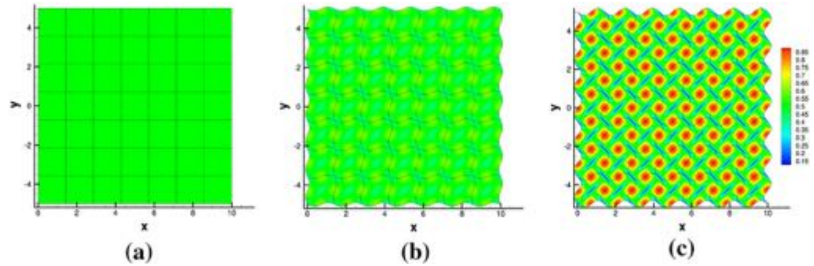
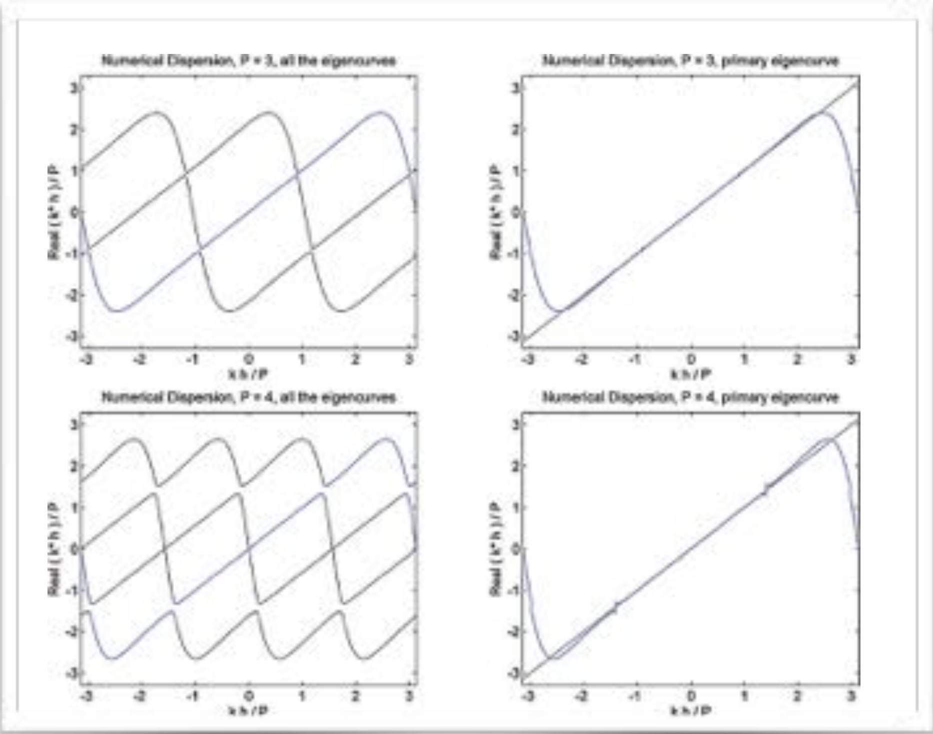
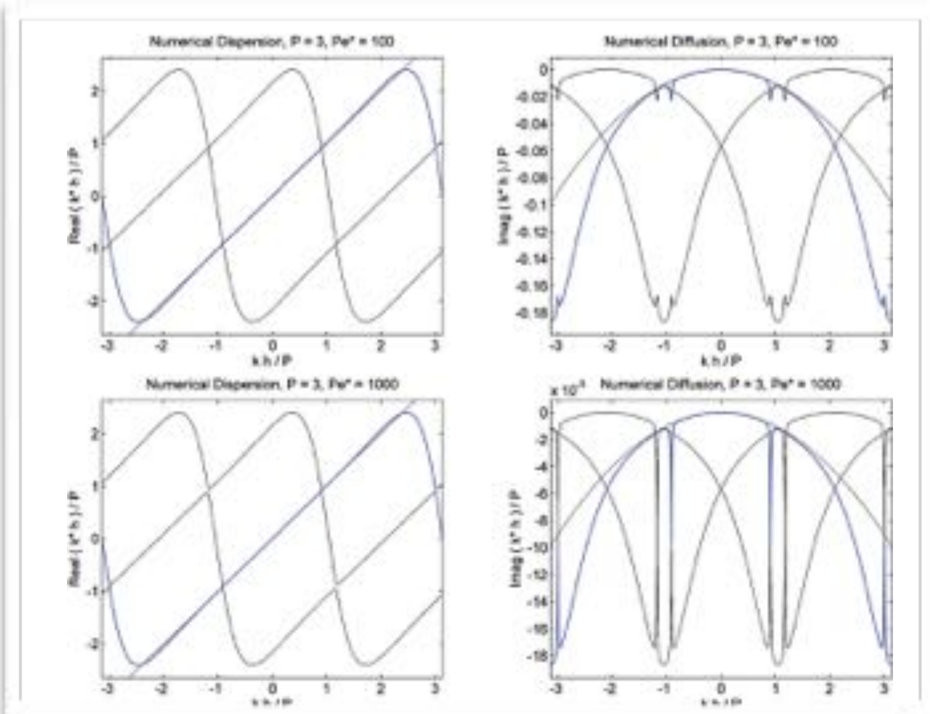


Fig. 2 Mesh B. Multi-element mesh configuration

Recent Papers

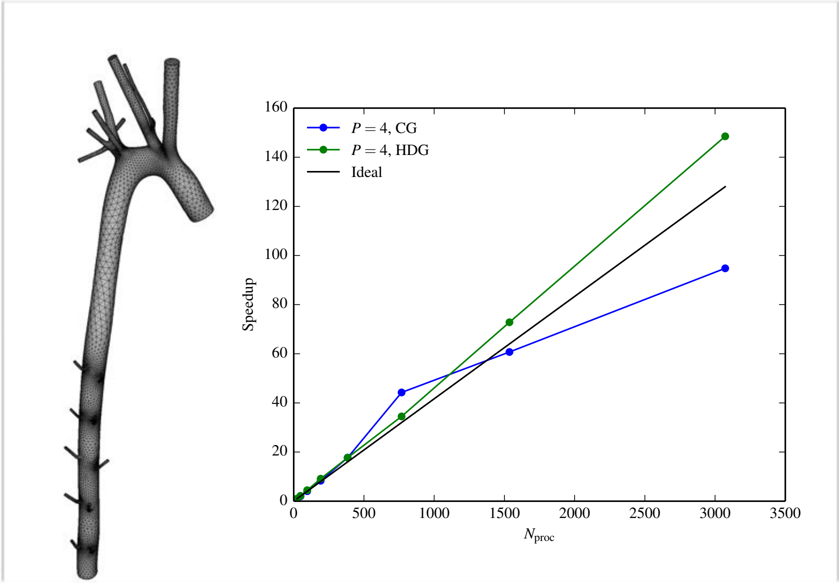
- R. C. Moura, S. J. Sherwin, and J. Peiró, “Eigensolution analysis of spectral/hp continuous galerkin approximations to advection-diffusion problems: insights into spectral vanishing viscosity,” Journal of computational physics, vol. 307, pp. 401-422, 2016.

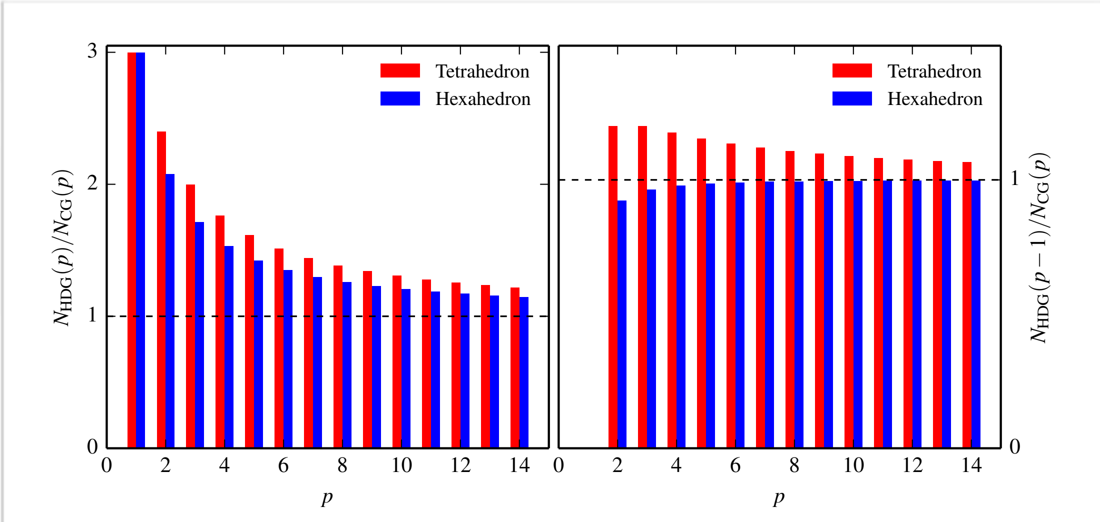




Recent Papers

- Yakovlev S, Moxey D, Kirby RM, Sherwin SJ, 2016, To CG or to HDG: A Comparative Study in 3D, J. Scientific Computing, 67,192-220,





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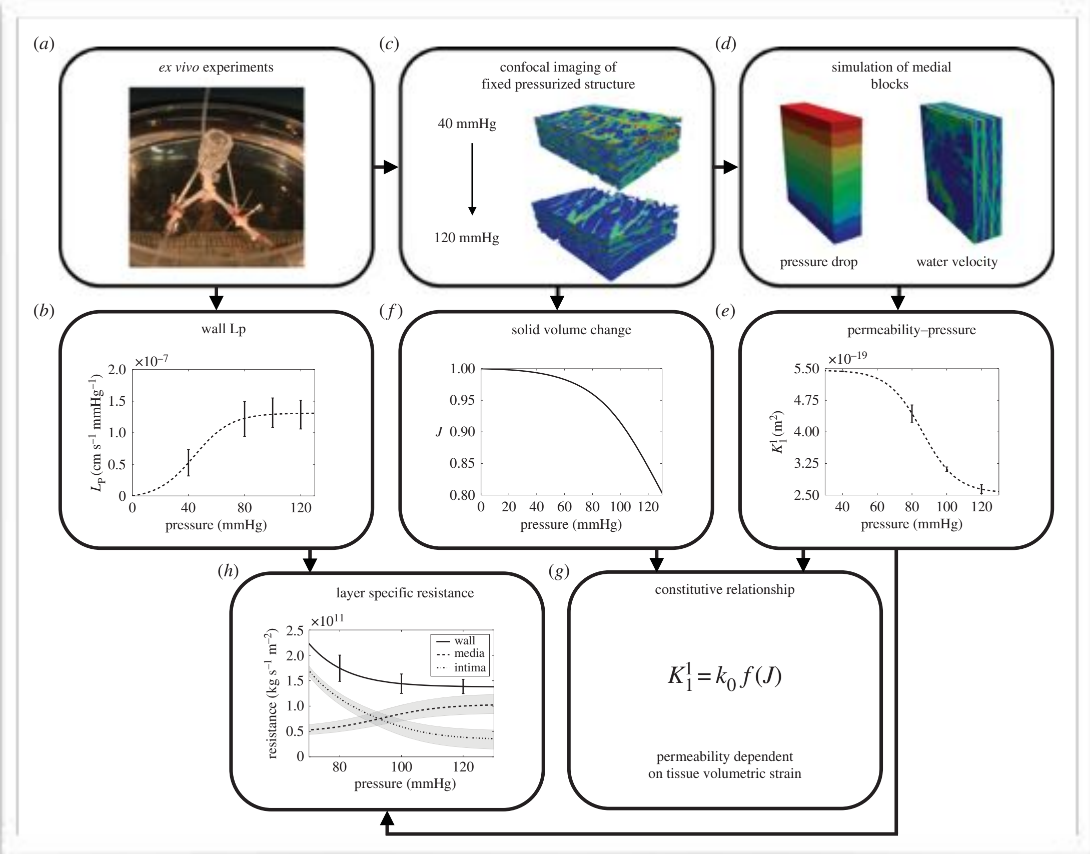
Recent Papers

- Chooi KY, Comerford A, Sherwin SJ, Weinberg PD, "Intimal and medial contributions to the hydraulic resistance of the arterial wall at different pressures: a combined computational and experimental study", Journal of the Royal Society Interface, 2016



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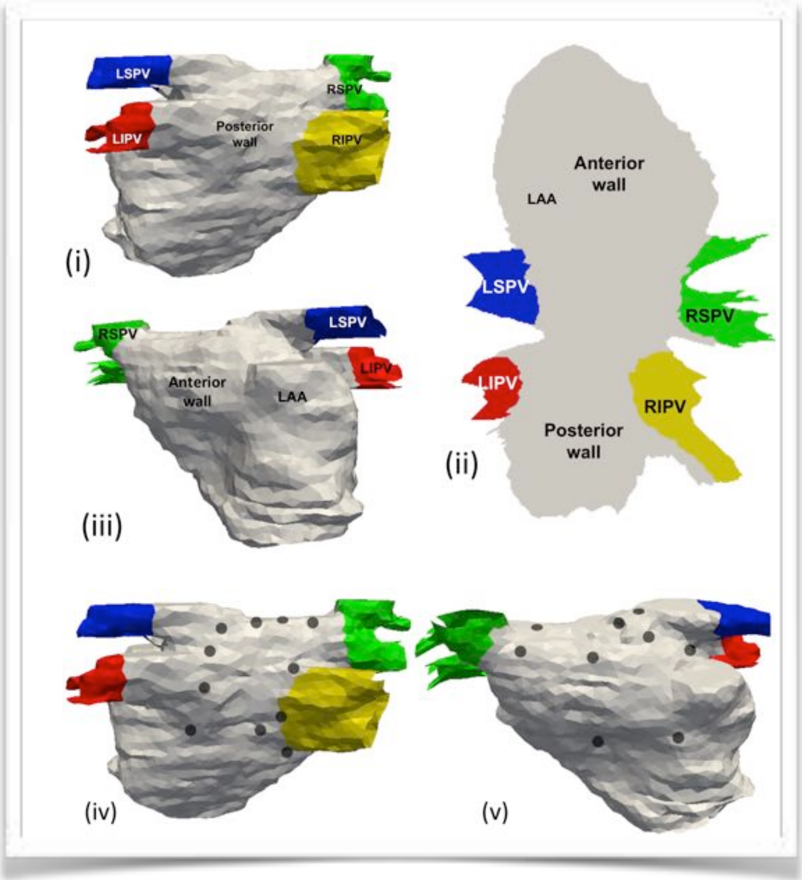

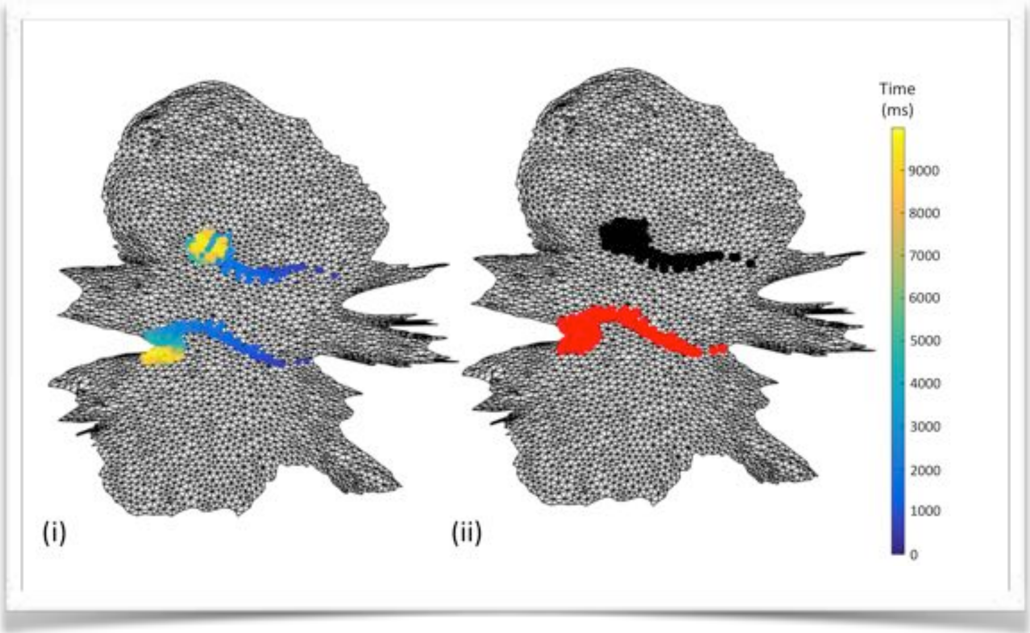

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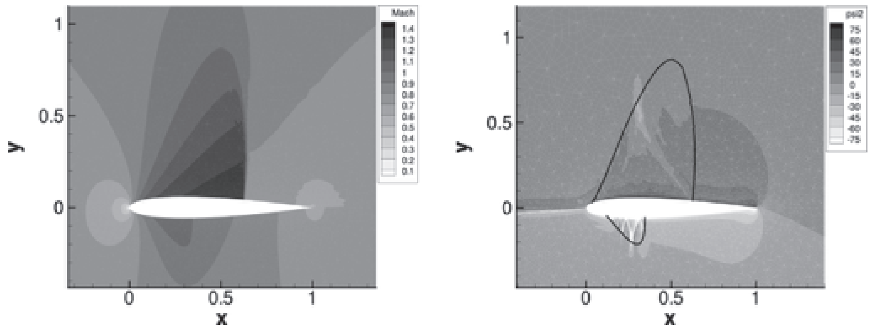
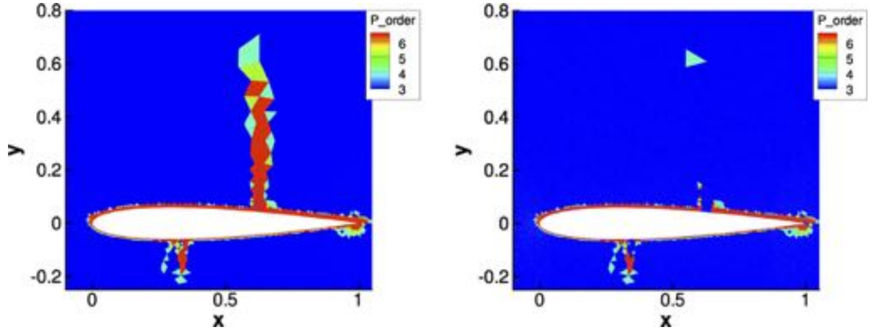


(a) Mach number **(b)** Adjoint variable for ψ_2.

Fig. 8. The solutions to the governing (8a) and adjoint (8b) equations for transonic inviscid flow past a NACA 0012 ($Ma = 0.8,\ \alpha = 1.25^\circ$).



(a) Unrestricted polynomial order. **(b)** Polynomial order restricted to $P = 3$ at shocks.

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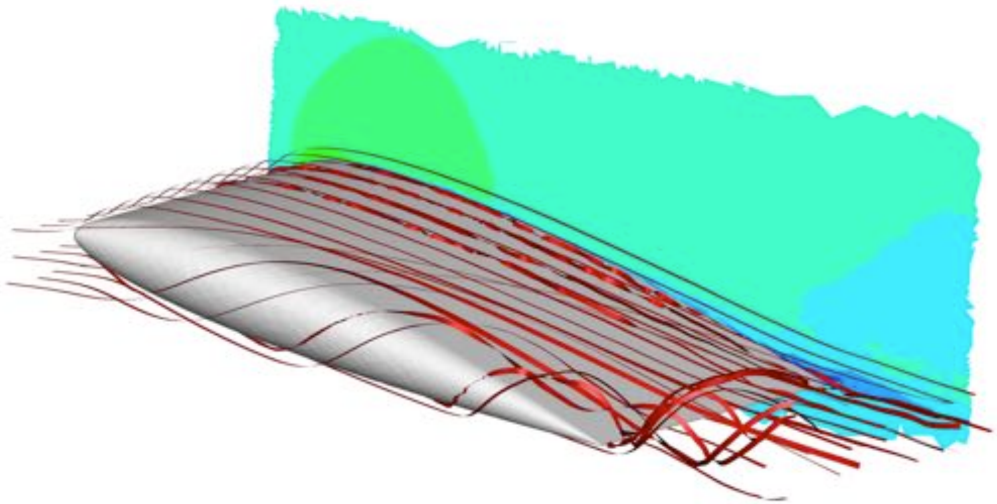
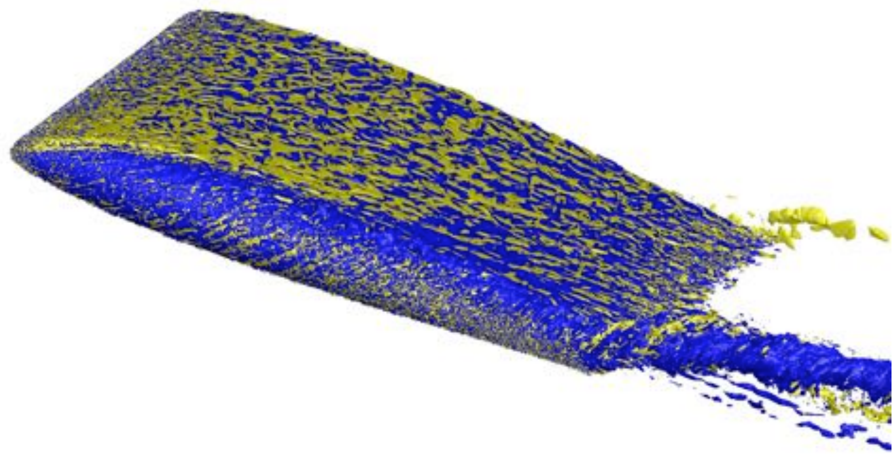
- Lombard J-EW, Moxey D, Sherwin SJ, Hoessler JFA, Dhandapani S, Taylor MJ, 2016, Implicit Large-Eddy Simulation of a Wingtip Vortex, AIAA JOURNAL, 54, 506-518, 2016





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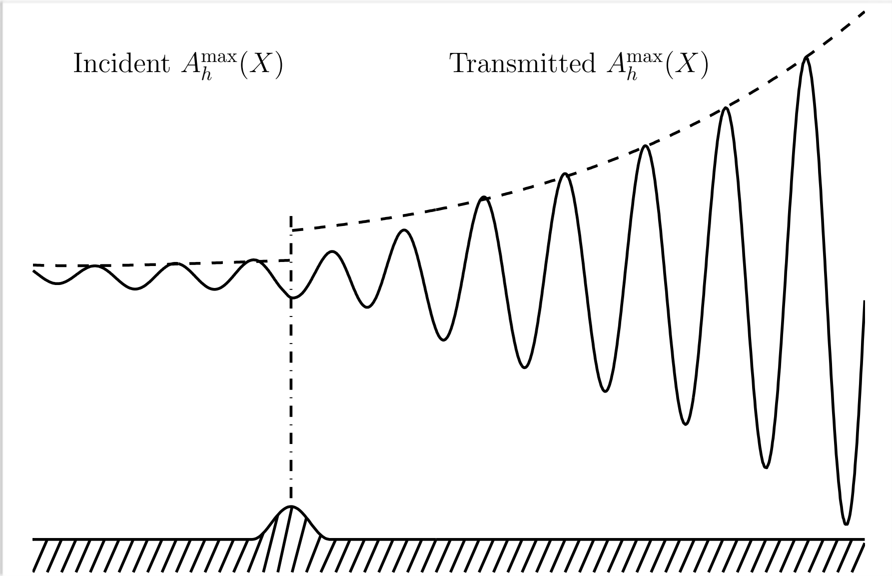

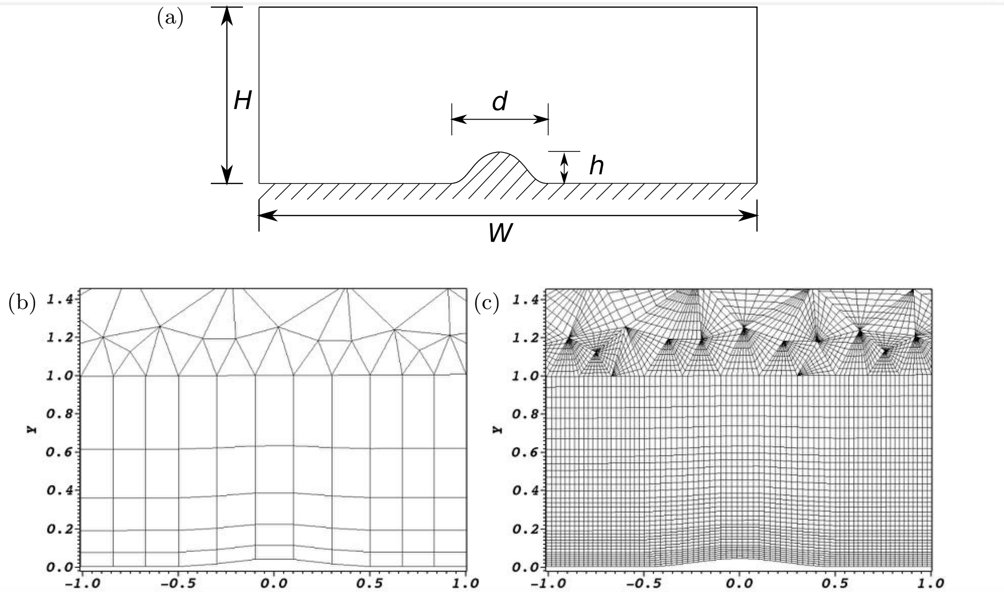

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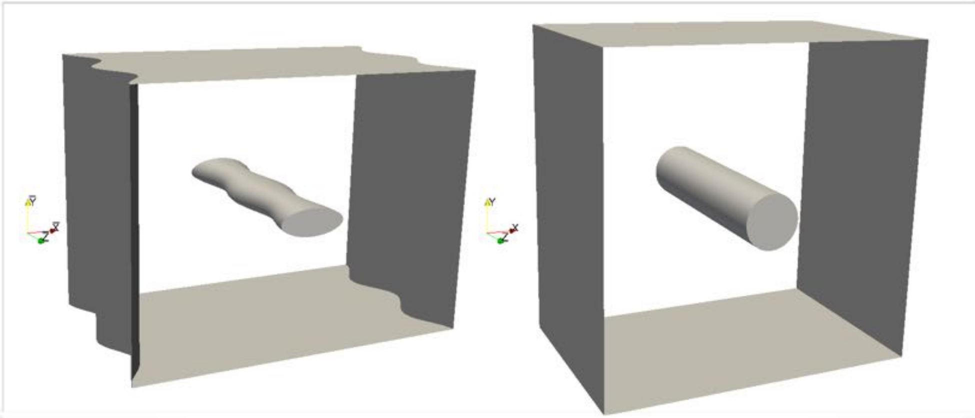

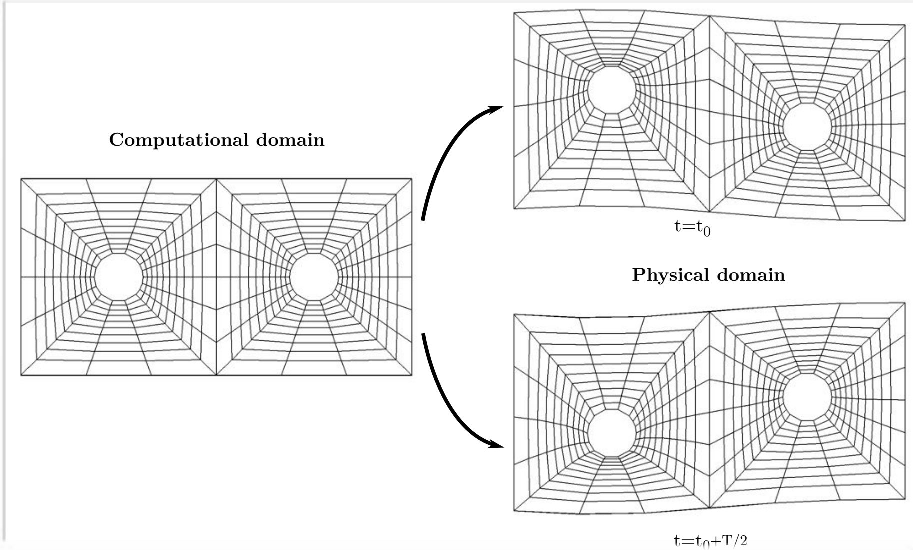

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Adaptive Polynomial Order

The basic steps of the adaptive procedure are:

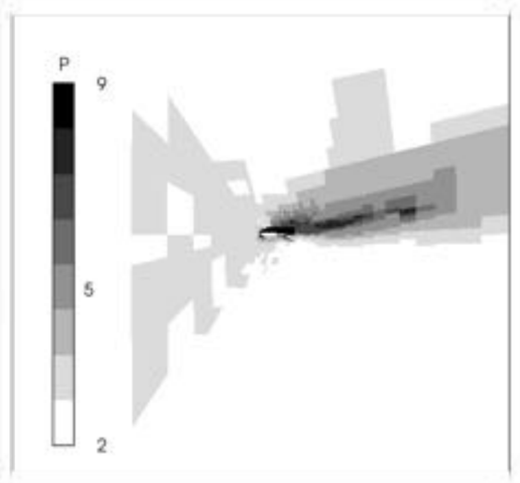
1) Advance the equation for steps
2) Estimate the spatial resolution error in each element by

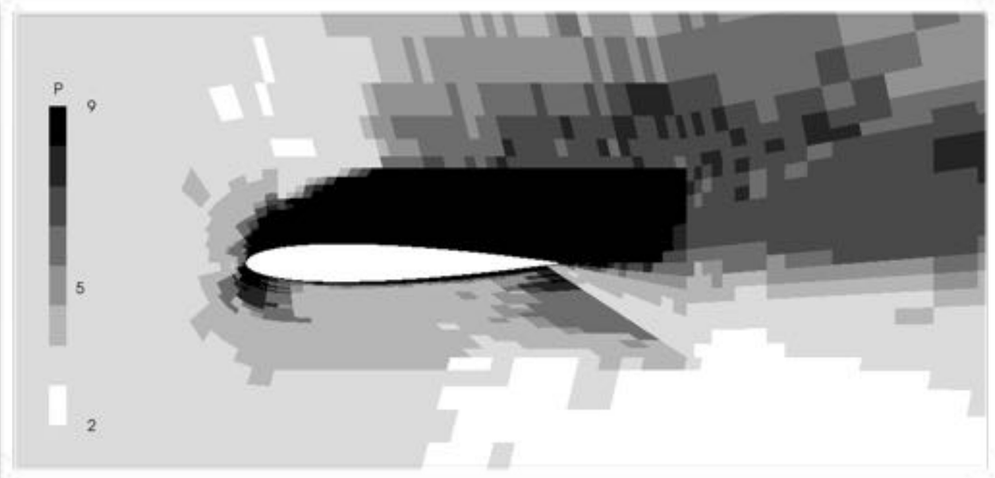
$$S_e = \frac{||u_P - u_{P-1}||^2_{2,e}}{||u_P||^2_{2,e}}$$

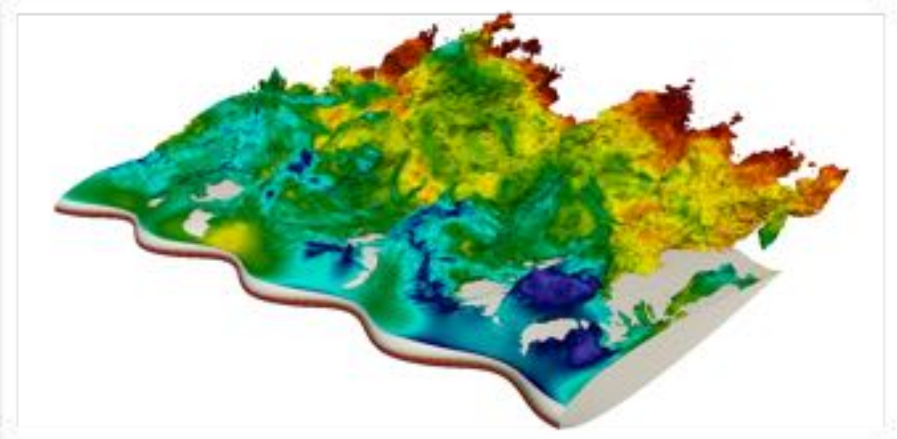
3) Modify the polynomial order in each element using the following rule
    - If S_e > ε_u and P<P_max, increase P by 1
    - If S_e < ε_l and P>P_min, decrease P by 1
    - Maintain P if none of the above is true
4) Project the solution to the new polynomial space
5) Repeat the procedure for n_{runs}

Adaptive Polynomial Order

- Example: Naca0012 with Re=50,000 and alpha=15 (P_{min} = 2, P_{max} = 9)







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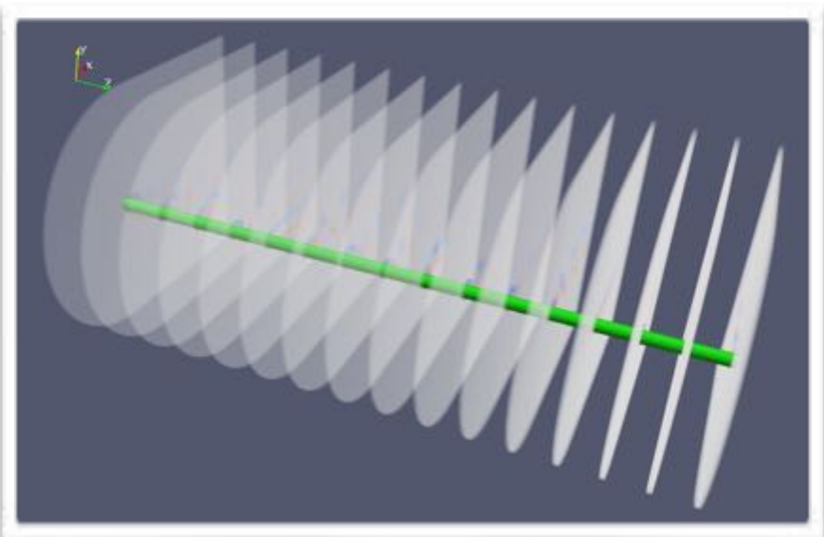
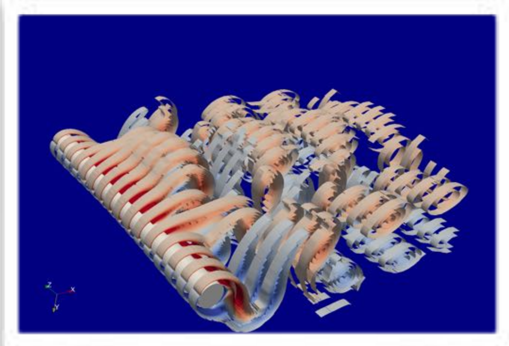
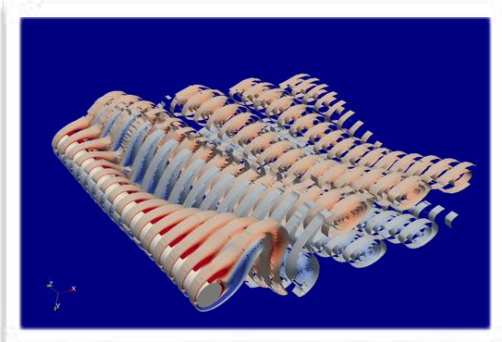
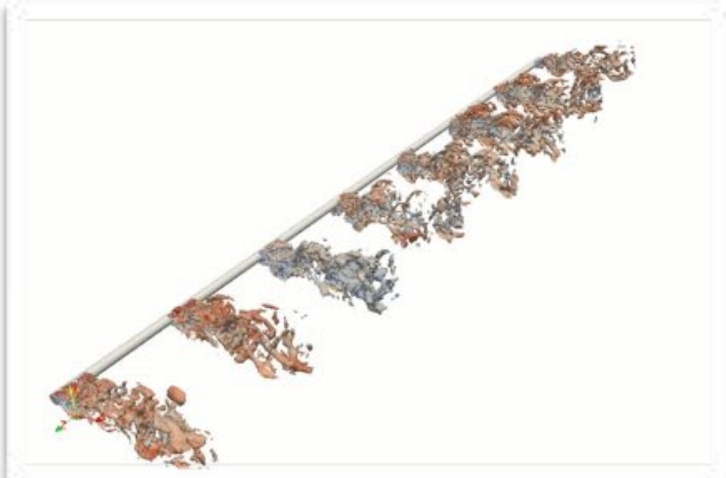
- Y. Bao, R. Palacios, M. Graham, S. Sherwin, “Generalized thick strip modelling for vortex-induced vibration of long flexible cylinders ” Journal of computational physics, accepted, 2016.









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Send us your papers!

Workshop Outline

- Overview of Nektar++
- Nektar++ Development Strategy
- Future Directions
- User Applications: *4pm-6pm*
- *Group Photo*
- *….. dinner !*