Intro - Computational Fluid Dynamics (CFD) using Graphics Processing Units

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What is CFD?

- Computational Fluid Dynamics: solve governing equations of fluid motion *numerically*
  - Conservation of Mass (Continuity Equation)
  - Conservation of Momentum (Newton's 2nd Law)
  - Conservation of Energy (1st Law of Thermodynamics)
- Coupled set of nonlinear Partial Differential Equations (PDEs)
- Solution time can be *very long* → makes GPUs very attractive

Governing Equations

Conservation of Mass

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \mathbf{u} = 0$$

Conservation of Momentum

$$\rho \frac{D\mathbf{u}}{Dt} = -\nabla p + \nabla \cdot \bar{\bar{\tau}}$$

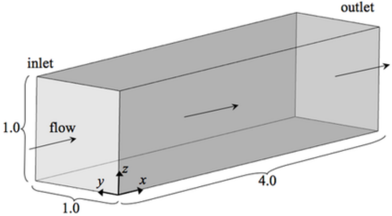
Conservation of Energy

$$\rho C_p \frac{DT}{Dt} = \beta T \frac{Dp}{Dt} + \nabla \cdot (k \nabla T) + \Phi$$

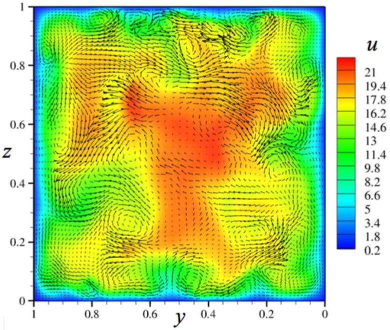
viscous stress tensor: $\bar{\bar{\tau}} = \mu \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) + \delta_{ij} \lambda (\nabla \cdot \mathbf{u})$

substantial derivative: $\frac{D(\;)}{Dt} = \frac{\partial(\;)}{\partial t} + \mathbf{u} \cdot \nabla(\;)$

Turbulent Flow in 3D square duct



(a) Computational domain



(b) cross-flow plane at $x = 2.0$