Computational Heat & Fluid Flow (ME 605)

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Assignment 5 – Navier-Stokes equations

By employing finite volume method, discretize the Navier-Stokes equations to solve flow within the lid-driven cavity at a Reynolds number of 100 with uniform meshing. Write a computer program to solve discretized equations. Use central difference method for discretization of convective terms. You may employ any method of your choice (SIMPLE, SIMPLER, or fractional-step method) to get the steady state solution. Solve the resulting equations using Gauss-Seidel method. Compare your results with those presented in Ghia et. al. (1982). Submit a report containing the details of discretization and the results. The geometry and boundary conditions are shown in figure 1. As presented in figure 2, $u-$ along YY and $v-$ along XX should be presented in your report. Lines XX and YY are illustrated in figure 1. Reference values are given in Tables 1 and 2 of the reference paper. Use 64×64 grid to discretize the domain.

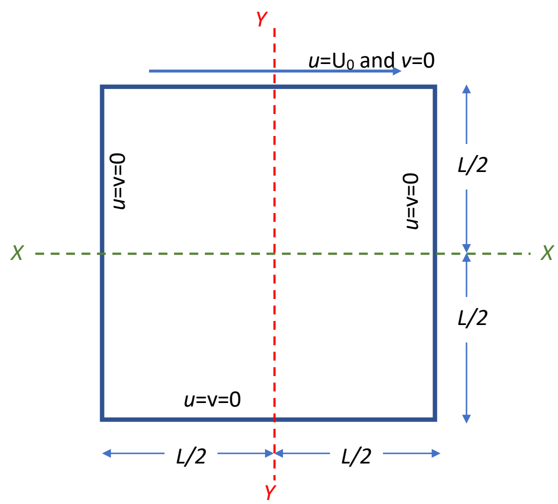
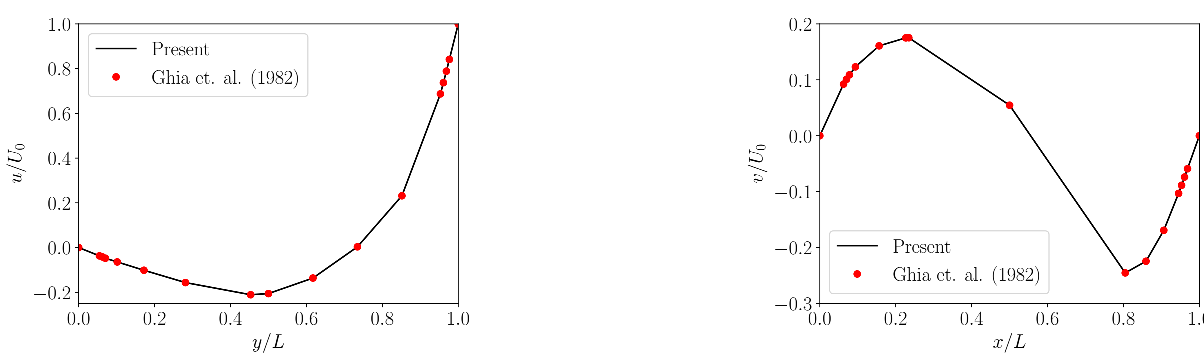


Figure 1: Geometry and boundary conditions for lid driven cavity.



(a) $u-$ along YY

(b) $v-$ along XX

Figure 2: Results: Velocity at mid-channel and comparison with Ghia et. al. (1982)

These are optional tasks but fetch you additional points:

- Use first order upwind for convective terms, and demonstrate the effect of artificial diffusion.
- Demonstrate that at a sufficiently large Pe number central differencing scheme results in unphysical oscillations, while upwind scheme provides a smooth solution.
- Implement SOR to solve the linear system of equations, and demonstrate the computational speedup for Reynolds number $= 100$ for relaxation factor $\omega \in [1, 2]$ with increment of 0.1.
- Compare results for Reynolds number of 1000 and above.
- Use non-uniform grids (finer mesh near the walls, and coarser near the cavity centre).
- Plot streamlines within the cavity

Reference

U Ghia, KN Ghia, and CT Shin, High-Re Solutions for Incompressible Flow Using the Navier-Stokes Equations and a Multigrid method, *Journal of Computational Physics*:48, 387–411, (1982).