Progress Report

Syed Ahmad Raza
D10503816

2018.11.07

1 Testing parallelization of 3D code with OpenMP

The three-dimensional solver for Navier-Stokes equations has been parallelized using OpenMP. Currently, only the pressure loop has been paralellized for validation and because the pressure loop is critical to the performance of the whole code due to its numerous iterations in time steps.

2 Results and validation of three-dimensional solver

The 3D solver was used to model a lid-driven cubic cavity flow for the case of Re = 100 with a $41 \times 41 \times 41$ grid size. Simulation results from the parallelized code have been compared with the output from non-parallelized code and the published results of Ku et al. [1] for three-dimensional cubic cavity flow and Ghia et al. [2] for two-dimensional square cavity flow. The figures below represent the comparison of x-direction velocity u on the vertical centerline and y-direction velocity v on the horizontal centerline of the cubic cavity at the mid-plane in z-direction.

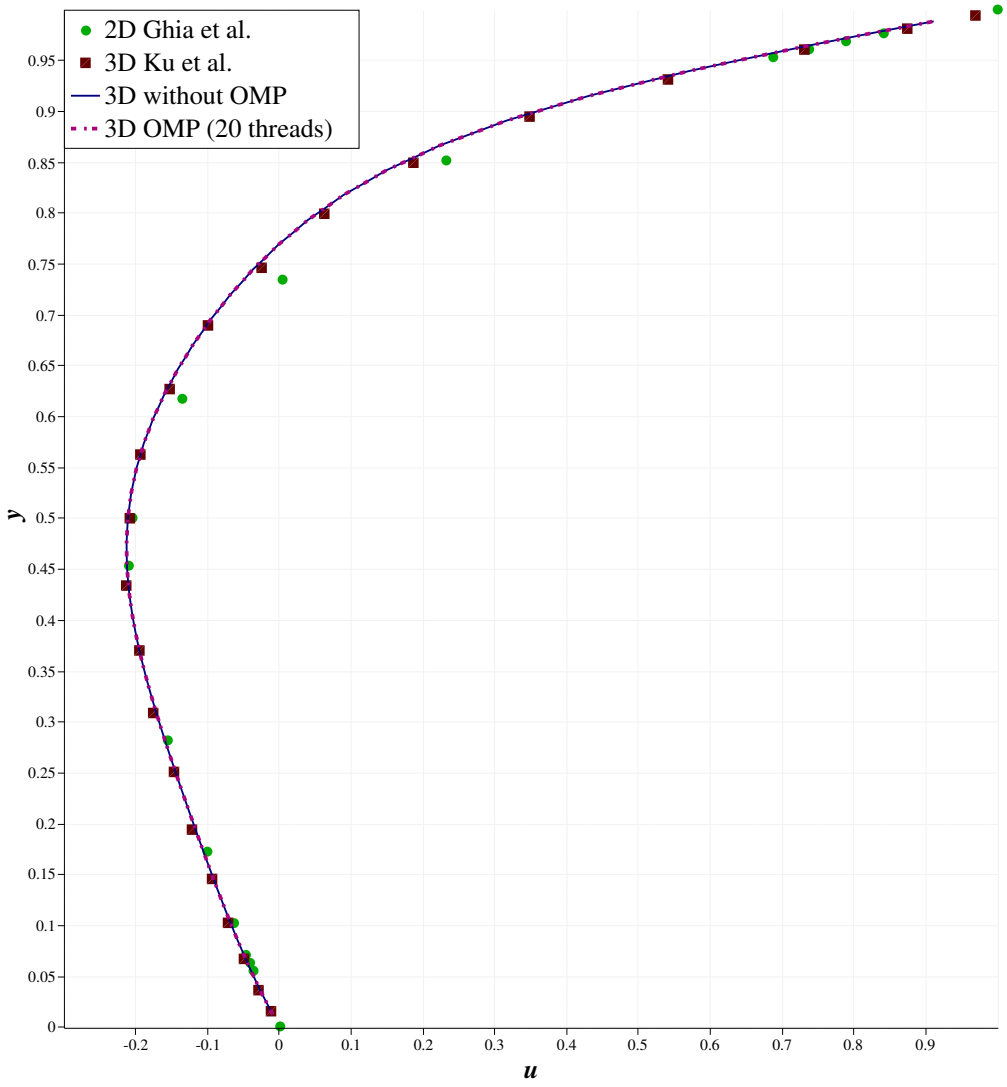

Figure 1: u-velocity profiles on the vertical centerline in cubic cavity (at the center of z-axis) for the various cases.

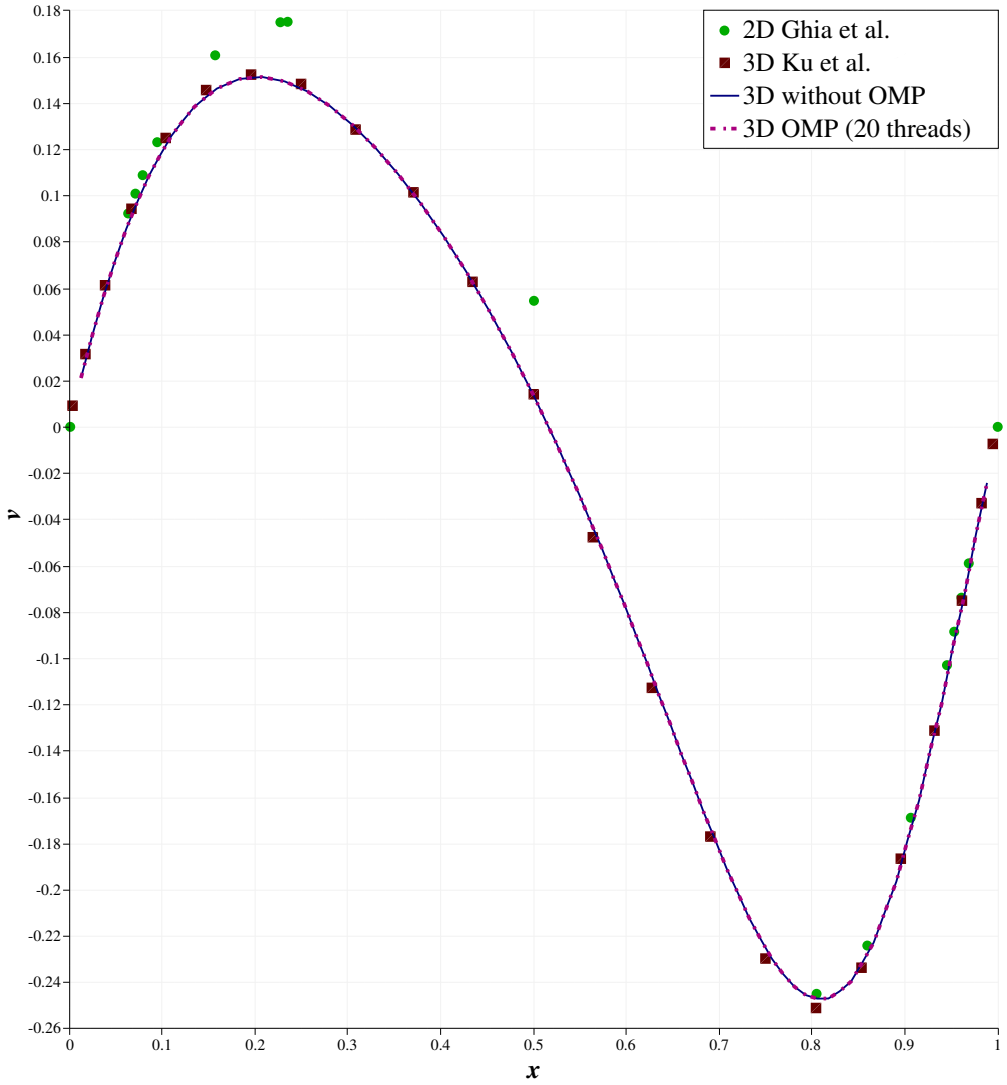

Figure 2: v-velocity profiles on the horizontal centerline in cubic cavity (at the center of z-axis) for the various cases.

The results of the parallelized code are also in very good agreement with the three-dimensional results of Ku et al [1] and match the non-parallelized version's results exactly. The differences with two-dimensional flow are apparent due to the effect of three-dimensional boundary conditions.

Number of threads	Simulation time (minutes)	Reduction in time (%)
1 (old code)	376	-
1 (revised code)	333	-
4	103	69.1
5	87	79.9
10	55	83.5
12	50	85.0
18	45	86.5
20	40	88.0

Table 1: Comparison of simulation times for different number of threads after parallelization with OpenMP, for a grid size of $41 \times 41 \times 41 (= 68,921)$.

References

[1] Hwar C. Ku, Richard S. Hirsh, and Thomas D. Taylor. A pseudospectral method for solution of the three-dimensional incompressible navier-stokes equations. *J. Comput. Phys.*, 70(2):439–462, June 1987.

[2] U Ghia, K.N Ghia, and C.T Shin. High-re solutions for incompressible flow using the navier-stokes equations and a multigrid method. *Journal of Computational Physics*, 48(3):387 – 411, 1982.