

# HPCA for Multidisciplinary Applications of Complex Fluid Flow

T. K. Sheel

Department of Mathematics

Shahjalal University of Science & Technology, Sylhet 3114, Bangladesh

E-mail: [tksheel@sust.edu](mailto:tksheel@sust.edu); [nabon\\_2000@yahoo.com](mailto:nabon_2000@yahoo.com)

## **Background & Aims:**

One of the greatest challenges in simulating complex fluid flows, which arise in many real-life engineering and bioengineering situations, continues to be the demand to straddle many scales. New research in computational methods is still sorely needed to build schemes that are intelligent, can resolve the multi-scales of problem, and adapt. Moreover, we need computing programs that are hardware-aware. Most complex fluid flows are **vortex** dominated and often highly complicated as represented by free jets and flows around a flapping body. The **aim** of the proposed research is, therefore, to develop a high performance-computing algorithm (HPCA) with an advanced acceleration technique for the 3D vortex calculation, using the vortex method without loss of any numerical accuracy. The vortex method has not been recognized yet as a mainstream method for Computational Fluid Dynamics (CFD), and it demands an enormous calculation cost because the Fast Poisson Solver is usually used as a mainstream method. With the help of the proposed new techniques, we will be able to study moderate to high-Reynolds-number turbulent flows around complex geometries. This proposed method holds a great promise to allow for computations of highly complex, unsteady flows. Besides, for solving multi-scale problems, we **aim** to build a hybrid method, namely, a means of combining continuum and particle approaches in our HPCA scheme.

## **Programme & Methodology:**

The main difficulty in vortex methods, as originally formulated, is that the cost of evaluation of the velocity field induced by flow vortices. It is at the order of  $O(N \times N)$  for  $N$  vortices. This expense grows rapidly in 3D flow where a large number of elements are computed simultaneously. The advent of fast algorithms, e.g. fast multipole method (FMM), made it possible to achieve a scaling of as small as  $O(N)$ , and with the help of the rapid development in computational hardware (e.g. special-purpose computer, MDGRAPE), a calculation involving millions of vortex elements became possible. The combination of these two innovations led to a new paradigm, i.e. solving flows of moderate Reynolds numbers and fully resolving these flows [1, 2]. In the present research, the new HPCA will be able to handle high-Reynolds-number flows and potentially overcome the limitations we had in our previous studies. This algorithm in conjunction with mesh-less approach will be capable of solving high-Reynolds-number turbulent flows in complex geometry.

The proposed algorithm will be applied in highly complex flows such as homogeneous shear flow, fully developed channel flow with moving boundary problems, aerodynamic flapping, heart valves and truly grid-free LES of transitional and turbulent incompressible vortex dominated flow; and the results will be assessed against with experimental data available in literature. In conclusion, the proposed scheme will make a huge contribution to the simulations that have been previously difficult to perform with existing methods.

## **References:**

1. R. Yokota, **T. K. Sheel**, S. Obi, Calculation of isotropic turbulence using pure lagrangian vortex method, Journal of Computational Physics, 226:1589-1606, 2007.
2. **T. K. Sheel**, K. Yasuoka, S. Obi, Fast vortex method calculation using a special-purpose computer, Computers and Fluids, 36:1319-1326, 2007.