A high order vortex method for unsteady incompressible flows

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Vortex methods are numerical schemes for approximating solutions to the Navier-Stokes equations using a linear combination of moving basis functions to approximate the vorticity field of a fluid. Typically, the basis function velocity is determined through a Biot-Savart integral applied at the basis function centroid. Since vortex methods are naturally adaptive, they are advantageous in flows dominated by localized regions of vorticity such as jets, wakes and boundary layers. While they have been successful in numerous engineering applications, the complexity of understanding grid-free methods make their analysis a uniquely mathematical endeavor. One recent outcome of rigorous analysis is an new naturally adaptive high order method with basis functions that deform as they move according to flow properties. This new class of methods is very unusual because the basis functions do not move with the physical flow velocity at the basis function centroid as is usually specified in vortex methods. One of the leading edge research problems associated with high accuracy methods of this type is how to re-project extremely deformed elements onto a configuration of regular elements to prevent catastrophic growth of interpolation errors. Recent progress in this area brings together ideas from radial basis function interpolation, pre-conditioners, image processing, and partial differential equations. These new techniques are implemented in BlobFlow, a free open source project.