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Development of incompressible viscous flow solver with guaranteed accuracy

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Not only computational fluid dynamics, a continuous systems represented by structure analysis and electromagnetic field analysis is computed by that partial differential equation describing the system's behavior solve with finite defference method and finite volume method, finite element method. A common feature of these methods is discretizing to discontinuous finite region from essentially continuous field.

Solution obtained by these methods is approximate solution which contained error, because the original continuous space was approximated by the discontinuous space. Therefore, in these methods, the use of more finer mesh and more highly accurate scheme is recommended for higher accracy. But, it is rare to analyze the accuracy of approximation solution obtained by such method. In many cases, only the result is believed blindly without analysis reliability of approximate solution, and used.

Because, this is the past, It seems that it has been thought that the amount of the calculation for verification of approximated solution is larger than that of the aimed calculation. In recent years, however, it is becoming clear because of the development of study of verification for computation result called numerical method with guaranteed accuracy or numerical verification method. Therefore, a quantitiative discussion to accuracy of numerical simulation results will be becoming possible. These numerical methods with guaranteed accuracy technique exist on simultaneous linear equations and interpolation and fanctional calculus, numerical differential, numerical integrate, but these is technique for rounding error in numerical calculation. But, in the simulation of systems descripted differential equation that represented by fluid dynamics simulation governed Navier-Stokes equation, dominant error is discretization error which provided by discritizing to discontinuous finite region essentially continuous field. It is thought that methods of treating discretizing error and rounding error indicated solution space of differential equation suggested by Nakao is most effective.

In this study, to reliability improving of a fluid dynamics simulation used as prerequisite tool in various fields of science or engineering, I attempted to enable quantitative discussion of accuray by that “numerical methods with guaranteed accuracy” applied to incompressible viscous flow equation. To apply “Nakao methods” for equation governing incompressible viscous flow, I solve tha Navier-Stokes equation by fractional splitting methods(flow velocity correction methods) which is one of the various methods of simulation by finite element methods for Navier-Stokes equation.

In naturally, at the analysis of the incompressible and viscous flow simulation, the unknown function which should be solve is two-dimensional or three-dimensional flow velocity and pressure. It is thought that the accuracy of pressure field is predominant in entire accuracy, because calculation methods of flow velocity was transformed to the explicit equation calculate from pressure by lumping differentiated shape function term on the formalize of fractional splitting methods.

Therefor, as verification test case of fluid dynamics simulation, I try to verification of error range for pressure field. In two-points boundary condition problem of ordinally differential equation of one-dimension solved by Glarkin style finite element method, verification of evaluated error range conteined exact solution was succeeded. Continuously, to numerical verification with guaranteed accuracy for pressure poisson equation used by Nakao's methods, I correct time forwarding loop of fractional splitting method in verification algorithm, and succeed verification of evaluated error range.

It is extremely few that application example of numerical verification with guaranteed accuracy for fluid dynamics simulation, it is glad useful even if this research is a little.