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# LEVEL SET-BASED TOPOLOGY OPTIMIZATION METHOD FOR VISCOUS FLOW USING LATTICE BOLTZMANN METHOD

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## Abstract

In the field of numerical fluid dynamics, the lattice Boltzmann method (LBM) has attracted much recent attention, as a new numerical approach for solving fluid problems [1]. The LBM is based on the Boltzmann equation used in gas molecular dynamics, which represents flow properties by using the velocity distribution function of gas molecules. Thus, macroscopic variables such as the flow velocity and pressure can be represented by the moments of the velocity distribution functions. These macroscopic variables are theoretically corroborated as having identical solutions with those derived through the Navier-Stokes equation. Furthermore, since the LBM is formulated as a liner and explicit scheme, its algorithm can be constructed simply and thus the LBM is especially suitable for methods employing parallel computation. Given recent developments in computer technology, the LBM can also be considered useful in parallel computation approaches for solving complex fluid problems in which calculation costs are typically enormous.

Topology optimization methods that incorporate the LBM in optimization problems have been presented [2, 3], and they showed that optimization problems can be formulated using the LBM instead of the traditional approach based on the Navier-Stokes equation. However, the methodology in this past research includes a large-scale asymmetrical matrix in the sensitivity analysis that is based on the adjoint variable method. As a result, the calculation costs required for the matrix calculations are especially troublesome, and tend to cause numerical oscillation during the optimization procedure.

To overcome these problems, we propose a topology optimization method that avoids matrix calculation altogether. Here, the optimization problem using the LBM is formulated as a continuous formula, i.e., the Boltzmann equation. Therefore, the adjoint equation can also be constructed as a continuous formula, using the same framework as that of the Boltzmann equation, and then expressed in a discrete form. Since this discrete adjoint equation can be solved explicitly along with the LBM, our proposed method enables implementation of parallel computation for the equilibrium problem as well as the adjoint problem.

In this study, we confirm the applicability and utility of the above methodology by comparing its optimized solutions with those obtained using a traditional implementation of the Navier-Stokes equation, for a flow friction minimization problem in an internal flow channel. In addition, we use a level set-based topology optimization method [4] in order to obtain effective optimized solutions that have clear structural boundaries.

## References

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