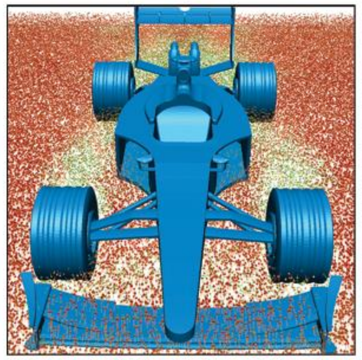
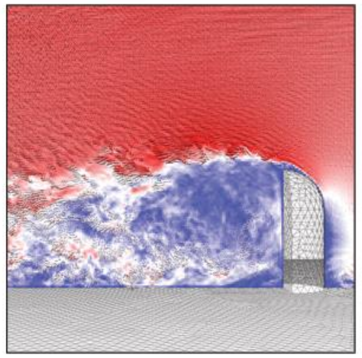
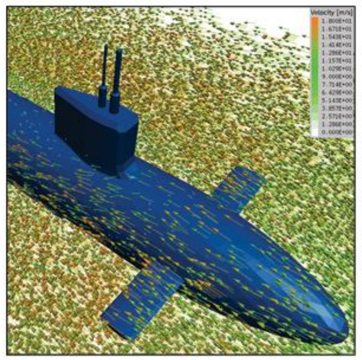
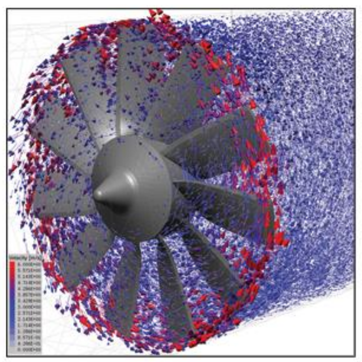
samadii™/lbm

Metariver Technology









Governing Equations

In physics, specifically non-equilibrium statistical mechanics, the Boltzmann equation or Boltzmann transport equation (BTE) describes the statistical behavior of a thermodynamic system not in thermodynamic equilibrium.
It was devised by Ludwig Boltzmann in 1872. The classic example is a fluid with temperature gradients in space causing heat to flow from hotter regions to colder ones, by the random (and biased) transport of particles.
In the modern literature the term Boltzmann equation is often used in a more general sense and refers to any kinetic equation that describes the change of a macroscopic quantity in a thermodynamic system, such as energy, charge or particle number.

$$\partial_t f_i + \hat{e}_i \cdot \nabla f_i = \Omega_i$$

f_i is the probability distribution of the fluid particle in velocity field; and the momentum exchange process caused by the collision between the fluid particles A and B can be expressed as follows:

$$\Omega_i = \iint g I(g,\Omega)\left[f(\mathbf{p}'_A,t) f(\mathbf{p}'_B,t) - f(\mathbf{p}_A,t) f(\mathbf{p}_B,t)\right] d\Omega d^3\mathbf{p}_A$$

In order to interpret this problem, partial, non-linear, and integro-differential equation needs to be solved as above; and Bhatnagar-Gross-Krook (BGK) collision operator, one of the mitigating factors of algebraic equations, is replaced as follows:

$$f_i(x + e_i\Delta t, t + \Delta t) - f_i(x,t) = -(1/\tau)\left[f_i(x,t) - f_i^{eq}(x,t)\right] + \Delta t \vec{F}_i$$

$$f_i^{eq} = \omega_i \rho \left(1 + \frac{3\vec{e}_i \vec{u}}{c^2} + \frac{9(\vec{e}_i \vec{u})^2}{2c^4} - \frac{3(\vec{u})^2}{2c^2}\right)$$

τ is the dimensionless time required for the momentum transfer process caused by the collision between the fluid particles; and f^{eq} is the macro function of the velocity and density with Maxwell Boltzmann distribution showing the equilibrium of fluids. The progress process from non-equilibrium state to equilibrium is expressed explicitly, with along the time flow during a given relaxation time.
The basic analysis process in LBM consists of process of streaming and collision: in streaming stage, it means that particles on a lattice point move across the other neighboring lattice points; and in collision stage, it means to calculate interaction between neighboring lattice points. At the particles' inlet and outlet, fluid particles are regenerated to be matched at the boundary conditions and streamed back into the flow field; and at the surface of the wall, the momentum of the fluid particle are determined by considering the relative velocity between the wall and particles.
The basic equations to process the boundary of the flow are used as follows:

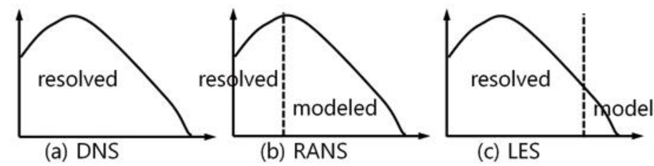
$$\hat{f}_{i^*}(x,t+1) = f_i(x,t) - 6 w_i \rho e_i \vec{u}_w$$

Followings are the basic boundary conditions supported by samadii/lbm:

Inlet/Outet boundary condition
- Velocity boundary
- Pressure boundary
- Massflux boundary
- Flowrate boundary
- Far out boundary
- Cyclic boundary
- Wall boundary condition
- No slip wall
- Sliding wall
- Slip wall
- Symmetry boundary
- Moving boundary

Main Features

samadii/lbm uses the LES (large eddy simulation) for analysis of turbulence.
Of course there exist Direct Numerical Simulation (DNS), LES, Reynolds-averaged Navier-Stokes (RANS) among the conventional numerical simulation of turbulent flow, which are designed to recognize the details of turbulent flow fields.
RANS model, which is most widely used in engineering science, is a kind of modeling methods that calculate ensemble averaged turbulent flow through Navier-Stokes equations and Reynolds average; but there are some problems in numerical reliabilities as well as in the over-estimation or under-estimation of turbulent flow motions. Otherwise, LES model aims to calculate turbulent flow directly and to model ultrafine eddies below the Taylor microscale of turbulent flow; therefore it requires lower computational cost rather than DNS, as well as acquires more accurate calculation results rather than RANS. In the use of LES model analysis, it is required to use small enough cells in local, in order to increase the analytical resolution higher enough to the isotropic areas; samadii/lbm can increase its analytical reliabilities as well as decrease the memory usage and its analysis time, with employing the AMR (adaptive mesh refinement) in LES analysis.



samadii/lbm supports the analysis of immersed body. For the simulation of flow around an arbitrarily moving body, an immersed boundary method is developed in a non-inertial reference frame that is fixed to the body. In the immersed boundary method, the structure is represented on a Lagrangian coordinate by creating virtual boundary to reflect flow field as Lagrangian particles are positioned along with surface at regular intervals.

$$\vec{F}_{f,I} = \sum_L f(x_L)\delta(x_f - x_L)$$

Lagrangian particles, which represent the surface of immersed body, are going to move along the object and therefore the drag forces inside the fluid can be calculated; the sum of those drag forces equals to the drag forces acting on objects. By redistributing these drag forces like above equation, it can be interpreted as object existing in the actual flow field.

In the chemical engineering or environmental field, the conventional approach which depends 1-way coupling way has limitations, while investigating any changes in flow phenomenon or in the system induced by the solute included in the solvent. It happens because the interaction between solvent and solute is getting to be dominant in the flow. To fulfill with these analytical necessities, in case of the insoluble large particles in the solvent samadii/lbm and samadii/dem are coupled to simulate that case, 2-way coupling between the particles.
Otherwise, if a solute is dissolved in the solute or is expressed as ultrafine particles like a spray, 2-way coupling is available to execute co-simulation with samadii/sciv which depends on statistical inference; also this allows you to predict the concentration changes or solvent contamination inside the solute diffusion of particles in the atmosphere.
Also with coupled analysis with samadii/em, EHD and MHD analysis which fluid itself receives electromagnetic forces is available.