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Large-eddy simulation of turbulent flow around a car body using lattice Boltzmann method on the TSUBAME supercomputer

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Car aerodynamic study is one of the most exciting topics in CFD (Computational Fluid Dynamics). In order to understand the detail of the turbulent flow around a car body, it is necessary to carry out large-scale CFD simulations. We have developed a CFD code based on LBM (Lattice Boltzmann Method) for GPU supercomputers with high cost performance and high electrical efficiency. Since LBM is based on local memory access with a simple algorithm, it is suitable for large-scale calculations including objects with complex shapes. However the original LBM cannot describe turbulent flows at high Reynolds number, a LES (Large-Eddy Simulation) model has to be introduced to solve the LBM equation [1]. Although the dynamic Smagorinsky model [2] is often used recently, it requires an average operation for a wide area to determine the model constant with huge overhead for large-scale computations. We apply the coherent-structure Smagorinsky model [3] without any spatial averages and the model parameter can be locally determined.

The code for GPU computing is written in CUDA, and the GPU kernel function is well tuned to achieve high performance on both Fermi-core and Kepler-core GPUs. By introducing the overlapping technique between the GPU-to-GPU communication and the GPU kernel computation, we obtained fairly good performances in both the strong and the weak scalabilities. Our simulations on the TSUBAME 2.5 supercomputer at Tokyo Institute of Technology achieved 288 TFLOPS using 960 GPUs in single precision.

We examine a large-scale turbulent flow simulation around a car body. The model was set in the wind tunnel at a speed of 60 km/h and we used 288 GPUs for the computation with $3{,}072 \times 1{,}536 \times 768$ mesh. By executing this large-scale computation, the detailed turbulent flows around a car body are revealed with much higher accuracy than before.

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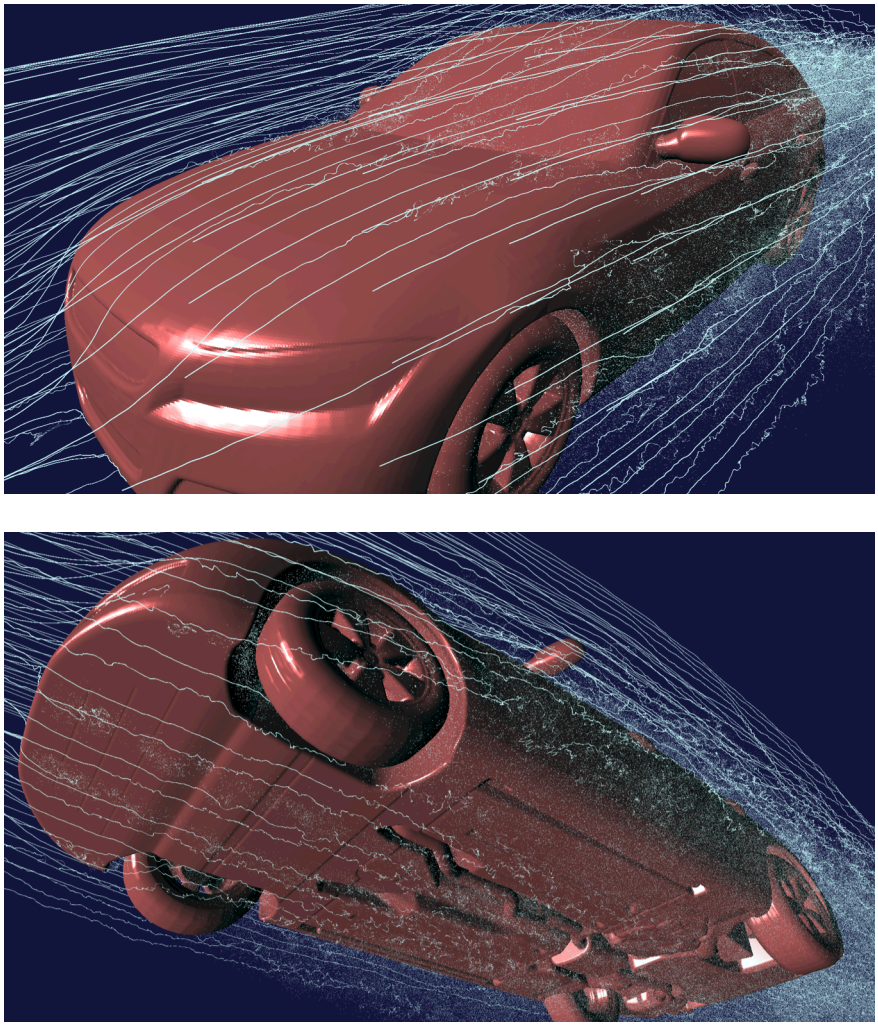

Figure 1: Snapshots of a turbulent flow around a car body.