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SHAPE REPRESENTATION BY SINGED DISTANCE FUNCTION FOR IMMERSED BOUNDARY METHOD

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ABSTRACT

The immersed boundary and immersed interface methods are available for the computation of flows around a complex shape on Cartesian grid. This removes the grid generation of the body-fitted meshes from CFD analysis. However, the arbitral shape defined by CAD needs to be represented on Cartesian grid.

In the present study, the signed distance function (SDF) is employed for the shape representation of the body with an arbitral shape and is combined with IBM. SDF is an implicit function and is defined by both the distance from the nearest surface and the sign corresponding to the inside or outside body[1]. The iso-surface of the zero distance represents the surface of the body. Further, the gradients of SDF on the surface indicate the normal vectors of the surface of the body. These features of SDF provide the approximated interfaces more accurately on the same grid as flow computation.

It is usually hard to obtain SDF from the surface data of CAD. Therefore the SDF generation library has been developing under the VCAD system research program of RIKEN (http://vcad-hpsv.riken.jp/). The algorithm of the library is based on the Multi-level Partition of Unity Implicits[2], which is able to generate SDF quickly. For example, when the surface data of the Asian dragon (21,657,135 points, 7,219,045 faces)[3] is converted to the SDF on the Cartesian mesh of 260x120x120 grids as shown in Fig.1, it takes only 53 seconds by the Intel Pentium D CPU 3.2GHz with 4GB memory. As shown in Fig.1(b), although the detail of the body seems drop off, the features of the body are enough to compute flows on the given grid resolution.

The basic equations for the incompressible viscous flows are solved in the present study, which include the LES turbulence model to reproduce the high Raynolds number flows. The immersed boundary method of the discrete forcing type[4] is employed, where the velocities of the cell near the surface is estimated from the velocity of both the body and fluids by using the normal vectors and distance provided by SDF. The equations are discretized by 4th-order central finite difference method. The fractional step method is employed with 2nd-order Adams-Bashforth method for the advection and viscous terms.

Figure 2 shows the result of flows around the Asian dragon with Re=10,000. As shown in Fig.2(a), the high turbulence viscosity regions can be observed in the wake of the body. To see the detail of the flows, the velocity vectors along with the surface are realized as shown in Fig.2(b). Thus, the present approach of IBM combined with SDF can simulate flows around the complex shape by using the SDF generation library, that decreases the time consuming task in the cycle of the design and analysis.

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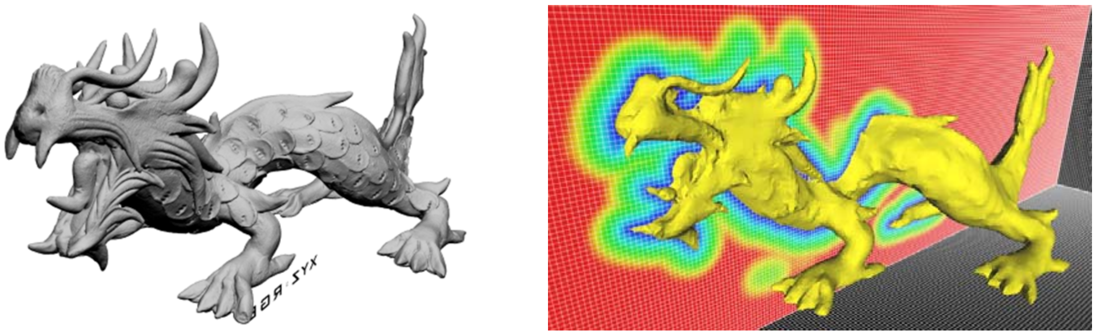
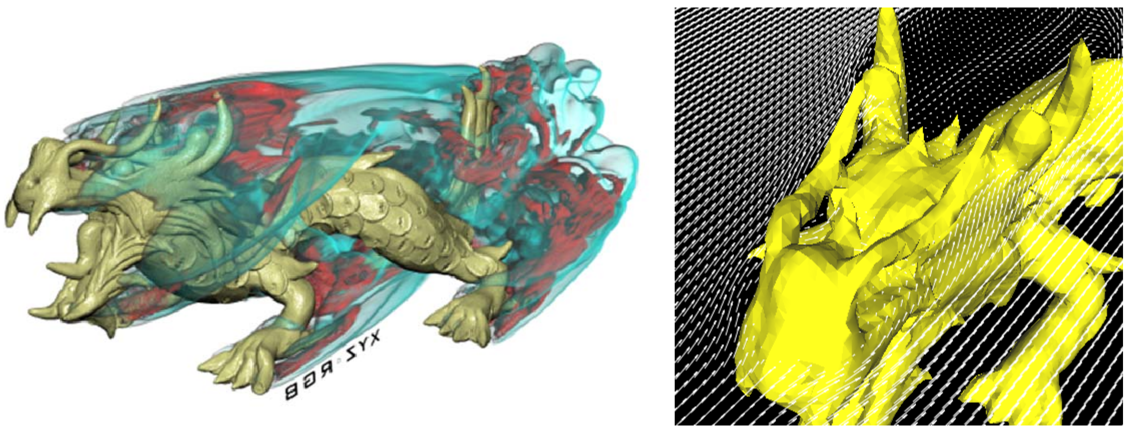


(a) Asian dragon (21,657,135 points, 7,219,045 faces)[3]

(b) Generated SDF on the Cartesian mesh of 260x120x120 grids (the shape represented by the iso-surface of SDF)

Fig.1: Conversion of the surface data by SDF generation library



(a) Turbulent viscosity visualized by the volume rendering with local shading model

(b)Velocity vector on the cross section

Fig.2: Flows around the Asian dragon with Re=10,000 computed by the immersed boundary method combined with the signed distance function.