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A HIERARCHICAL CARTESIAN IMMERSED BOUNDARY METHOD FOR CONJUGATE HEAT-TRANSFER INVOLVING MOVING SOLID BODIES

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The ignition process in oxy-fuel combustion is very sensitive to the heating rate of coal dust. Fully resolved particle simulations are expected to increase the understanding of the heat transfer within coal dust. Hierarchical Cartesian methods [1, 2] are well suited for adaptive mesh refinement and dynamic load balancing. In this study, we show that they also allow a very efficient coupling between different numerical methods when moving boundaries are present. The main idea of this work is to generate all grids from a common octree cell within a hierarchical Cartesian framework and to store all grids in the same balanced octree data structure (Fig. 1). This can be done by linking each tree node with a cell/element in each grid. In so doing, the connectivity between the cells of a given grid and between the cells of different grids can be efficiently computed. Furthermore, the connectivity information is implicitly maintained by the octree. That is, the connectivity information is automatically updated on all grids even when the grid changes due to boundary movement or adaptive mesh refinement. Common operations required for surface-based and volume-based coupling are, e.g., finding overlapping regions between different domains and finding cell neighbors between domains. Since all the cells are stored in the same balanced octree, these operations require less than a constant number of up and down traversals through the tree. The number of levels within the tree is $O(\log N)$ where N is the number of nodes. That is, most of the operations have $O(\log N)$ complexity. As shown in Fig. 1, to determine the solid boundary cell $\blacksquare$ that overlaps with the fluid boundary cell $*$ it suffices to traverse the tree up by a single level as depicted by the red arrows. To find the neighbor $\square$ of the fluid boundary cell $*$ three edges of the tree need to be traversed. A consequence of this storage scheme is that the memory requirements for storing multiple grids are significantly lowered since parts of the connectivity information are reused between the different grids. We demonstrate the approach with the simulation of a traversally moving two-dimensional spherical particle interacting with a hot jet at temperature $2T_\infty$, $\mathrm{Re}_\infty = 150$, and $M_\infty = 0.1$. The ratio

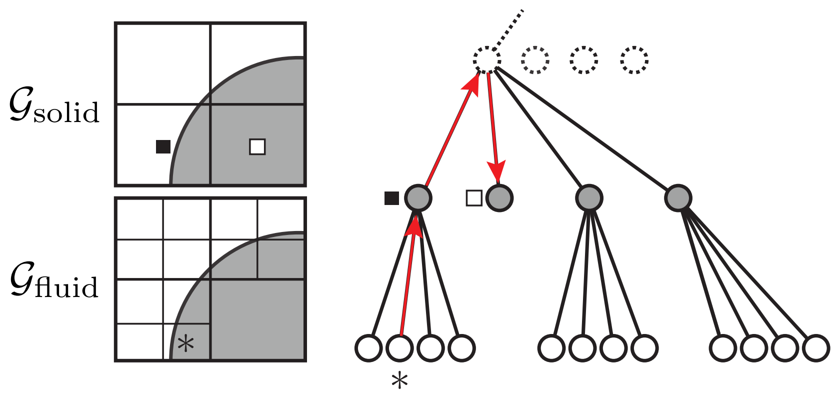

Figure 1: A cross section of the fluid and the solid mesh is displayed along with the octree data structure and the traversal required to identify common boundary cells between the fluid (white) and the solid (grey).

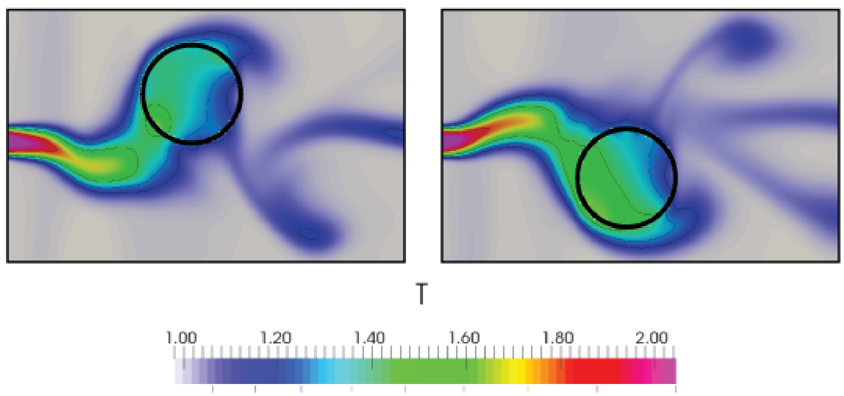

Figure 2: Temperature distribution T in the solid and fluid phases at two different acoustic times: $t = 48.6$ (left), and $t65.30$ (right).

between the heat diffusivities of the fluid and the solid is $\alpha_{\mathrm{f},0}/\alpha_{\mathrm{s}} = 1e^{-3}$. The fluid is modeled by the Navier-Stokes equations for an ideal gas and the unsteady heat equation in an Eulerian reference frame is used to model the solid. Both domains are discretized by two different finite-volume methods using two different grids. A weakly-coupled partitioned approach is used to solve the problem by requiring the temperatures at both sides of the fluid-solid interface to be equal. The thin black lines are the isocontours of the temperature which are continuous across the interface. The ability of the method to handle conjugated heat-transfer problems will be assessed.

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