A Level-Set Based Shell-Fluid Coupling Technique: Application to Airbag Deployment

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We introduce a computational procedure for explicit dynamic simulation of thin-shell structures interacting with compressible inviscid fluid flows. The nonlinear thin-shell response is computed with the Lagrangian subdivision finite element method [2] and the compressible fluid flow with an Eulerian finite volume solver operating on a Cartesian grid [1, 3].

The coupling between the shell and fluid solver is accomplished through the level set and ghost fluid methods. At each time step, on the Eulerian grid the signed distance function for the deformed shell configuration is computed using an optimal algorithm [4]. The fluid-shell interface is represented by the zeroth level set of the signed distance function. On the fluid side, the level set information and the shell vertex positions and velocities are used to extrapolate the velocity field in a narrow band of fluid cells across the fluid-shell interface. In the same narrow band the fluid velocity field is modified to enforce the zero-mass-flux condition through the interface [3]. The fluid solver feeds back pressures to the shell solver obtained by interpolation from the fluid mesh.

The developed parallel computational framework is used for deployment studies of airbags, such as used in the automobile industry. In the numerical experiments we consider the deployment of initially flat round shaped airbags as well as initially folded tube shaped airbags. The computations are performed on a 100 node Beowulf cluster at the Caltech ASCI Center for the Simulation of Dynamic Response of Materials.

References

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