Achieving Accurate Material Interfaces Through Patterned Interface Reconstruction

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The Patterned Interface Reconstruction algorithm will significantly improve the fidelity of multiple material simulations in [the code] ALEGRA and will reduce both the unphysical fragment emission and the unphysical distortion of bodies.

Computer simulations of challenging mechanics problems, such as explosive-armor interactions, are often performed using operator-split Eulerian hydrodynamics codes. In these codes, multiple materials are moved through the computational mesh via a Lagrangian step followed by a remap step. The position of materials is described by the volume of each material in the computational elements. Interface reconstruction algorithms are used to move (remap) the material volumes conservatively (i.e., the amount of material remains constant) through the mesh, and the shape of the materials changes only through physical interactions with other materials. This goal is more readily achieved with higher order methods. The Patterned Interface Reconstruction algorithm in the ALEGRA code [1, 2] is second order. Briefly, a method's order of accuracy describes the rate at which errors decrease as the element size of the computational mesh decrease. The order of accuracy is the exponent for the rate of reduction.

The challenge of interface reconstruction is to simulate material motion with as little artificial distortion as possible (i.e., distortion not associated with internal or external forces). These distortions can be observed as (i) changing the shape of the body, (ii) inducing a jagged, discontinuous outer boundary, and (iii) emitting unphysical fragments. A second-order interface reconstruction algorithm can exactly reproduce a planar material interface. While there are several interface reconstruction methods that can represent planar interfaces exactly, the much harder challenge is reconstructing curved material interfaces to second-order accuracy. Patterned Interface Reconstruction achieves this accuracy by modeling the interface with a planar pattern and a curved pattern. Each pattern is used to reproduce the volume fractions in the neighborhood of a target element, and an error is calculated. The error is the difference between the patterns' volume fraction prediction and the actual volume fractions. The pattern that produces the lowest error is locally chosen for further iteration. By choosing patterns locally rather than globally, materials that are composed of planar boundaries joining curved boundaries can be modeled by the appropriate local pattern.

Most interface reconstruction algorithms use material volume information in neighboring elements to reconstruct the interface in the central element. Patterned Interface Reconstruction also uses all the neighboring elements to compute an initial interface. The method then eliminates neighboring elements, which are judged to be part of a different interface of the material. This exclusion greatly improves the interface calculated near material corners and in thin material layers.

A comparison of a second-order and a lower-order interface reconstruction is illustrated in Figure 1.

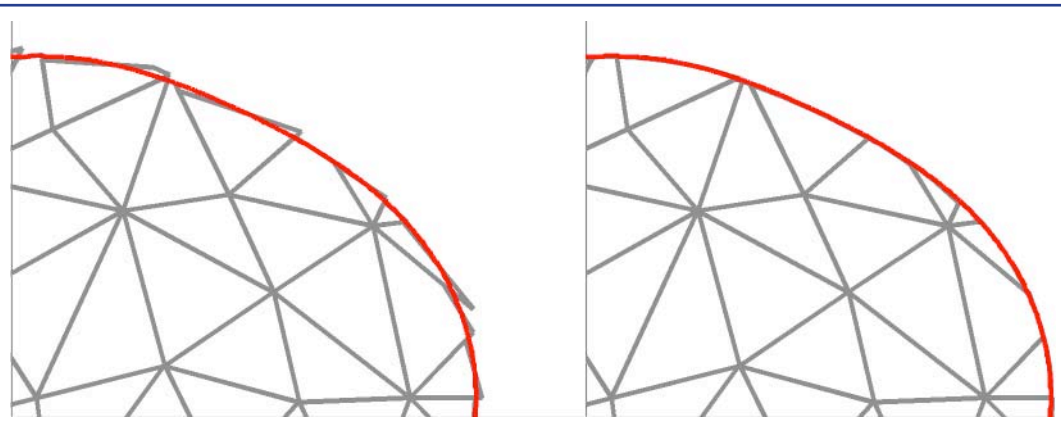

Figure 1. Low-order reconstructed interfaces (on the left) and second-order reconstructed interfaces (on the right) for a Cassini oval. The exact interface is the red line in both reconstructions.

Using planar interfaces for a curved interface will lead to distortion of the body as it moves through the mesh. The order of accuracy of the reconstructed interface also plays a large role. To illustrate this distortion, Figure 2 shows a circle that moves through the mesh using planar, unsmoothed interfaces on the left and circular arc interfaces that are smoothed (Patterned Interface Reconstruction) on the right. The exact answer is included in each result as the red interface. The overall shape of the lower accuracy circular body is distorted. This is in contrast to the higher accuracy reconstruction where the difference between the reconstructed interfaces and the exact answer is barely visible.

The Patterned Interface Reconstruction algorithm will significantly improve the fidelity of multiple material simulations in ALEGRA and will reduce both the unphysical fragment emission and the unphysical distortion of bodies.

References

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2. Mosso, S., Garasi, C., and Drake, R. (2007). A Smoothed Two- and Three-Dimensional Interface Reconstruction Method, *Computing and Visualization in Science*, accepted for publication.

This work's original support was from SNL's Laboratory Directed Research and Development (LDRD) Program. It is currently supported by the Army Research Laboratory.

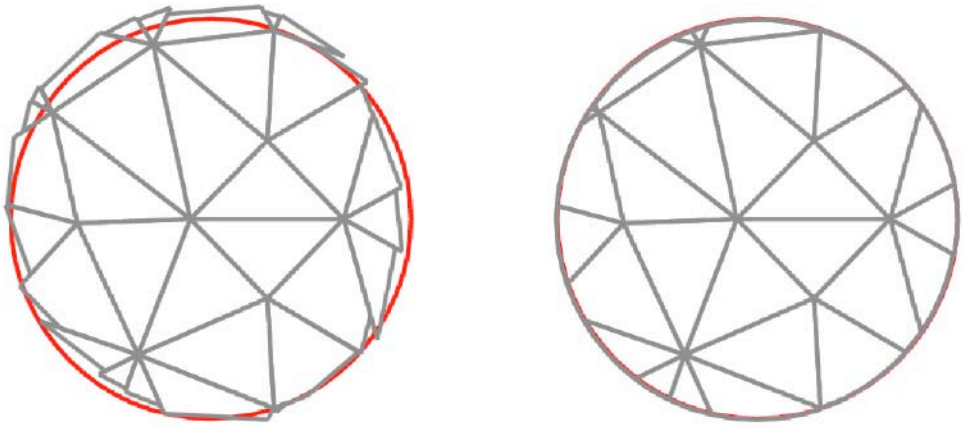

Figure 2. Planar interfaces are used (on the left) versus circular interfaces (on the right) to reconstruct a circle that has moved through a mesh. The exact result is shown as the red interface in both tests.