Front tracking with a twist: the eXtreme mesh deformation approach (X-MESH).

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The arbitrary Eulerian Lagrangian (ALE) formulation is a common approach for tracking fronts in finite element simulations. It is, however, difficult to track fronts over long distances because the mesh quality becomes poor on one side of the front. Moreover, traditional ALE front tracking cannot cope with changes in the front topology. To remedy the above problems (at least the first one), remeshing is required from time to time to maintain correct mesh approximation capability on both sides of the front. This remeshing requires projection of the field and updating of the database in the simulation, which is detrimental to the speed and accuracy.

We introduce a new approach in which the set of nodes located on the front evolves over time allowing the front to migrate through the mesh. Topological changes are easily considered. For example, a front can nucleate, propagate and merge with other fronts as it propagates.

For the new approach to work properly, we must accept that some elements become very small and possibly of zero measure. This means that the elements can deform in extreme ways, hence the acronym X-MESH. Surprisingly, as we shall show, this situation does not prevent simulations from being carried out.

In short, X-MESH simply uses node movements to propagate fronts over long distances, even in the event of topological changes. The mesh topology remains unchanged during simulation. The size and sparsity of the finite element matrices are therefore fixed throughout the simulation, and no field projection is required. As the simulation progresses, nodes arrive and depart from the front.

X-MESH's capability will be demonstrated for several important applications in mechanics and physics, such as front tracking in the Stefan phase change model or the simulation of immiscible two-phase flows.

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