Tangle-free Mesh Motion for Ablation Simulations

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Problems involving mesh motion—which should not be mistakenly associated with moving mesh methods, a class of adaptive mesh redistribution techniques–are of critical importance in numerical simulations of the thermal response of melting and ablative materials. Ablation is the process by which material vaporizes or otherwise erodes due to strong heating. Accurate modeling of such materials is of the utmost importance in design of passive thermal protection systems ("heatshields") for spacecraft, the layer of the vehicle that ensures suvival of crew and craft during re-entry.

In an explicit mesh motion approach, a complete thermal solve is first performed. Afterwards, the thermal response is used to determine surface recession rates. These values are then used to generate boundary conditions for an *a posteriori* correction designed to update the location of the mesh nodes. Most often, linear elastic or biharmonic equations are used to model this material response, traditionally in a finite element framework so that complex geometries can be simulated. A simple scheme for moving the boundary nodes involves receding along the surface normals. However, for all but the simplest problem geometries, evolution in time following such a scheme will eventually bring the mesh to intersect and "tangle" with itself, inducing failure. This presentation demonstrates a comprehensive and sophisticated scheme that analyzes the local geometry of each node with help from user-provided clues to eliminate the tangle and enable simulations on a wide-class of difficult problem geometries. The method developed is demonstrated for linear elastic equations but is general enough that it may be adapted to other modeling equations.

The presentation will explicate the inner workings of the tangle-free mesh motion algorithm for both two- and three-dimensional meshes. It will show abstract examples of the method's success, including a verification problem that demonstrates its accuracy and correctness. The focus of the presentation will be on the algorithm; specifics on how the techniques may be used in spacecraft design will be not discussed.

Keywords(optional): mesh motion, ablation, thermal response