LMS Seminar

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A new paradigm for the simulation of front propagation in mechanics and physics: X-MESH

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ABSTRACT

A number of models in mechanics and physics include moving surfaces whose positions are part of the unknowns of the problem. The Stefan model for solidification is an example. The solidification/melting front is at a continuous given temperature but has a jump in the temperature gradient (the jump in heat flow corresponds to the latent heat involved in the phase change).

Two main families of numerical algorithms exist for the resolution of moving front. The so-called "front capturing" approaches and the so-called "front tracking" approaches. In the first case, the mesh does not conform to the fronts and it can therefore be fixed. The presence of the front inside the elements is taken into account in an averaged or precise way (for example via integrations on both sides of the front and the addition of enrichment degrees of freedom as with the extended finite element method).

In the so-called tracking approaches, the mesh is deformed to fit the fronts and the algorithms can remain fairly standard (except for the convection term which must be added). The accuracy is very good because the gradient jump on the front (or other quantity) is directly taken into account by the separate approximation on both sides of the front. However, the tracking approach has important limitations: topological changes are not taken into account and the propagation of the front over large distances leads to a loss of mesh uniformity on both sides of the interface.

The X-MESH approach pushes tracking approaches to new possibilities: topological changes are taken into account and front tracking can be done over long distances. This is made possible by the fact that the nodes that locate the edge are not always the same. A node that carries the front can hand it over to one or more others (as in a relay race). In a continuous process, one must imagine that the elements pass through a zero size. The X-MESH approach allows an eXtreme deformation of the elements up to a zero size.

The X-MESH approach will be illustrated on the Stefan problem and on two-phase incompressible flows.

The collaborators on the X-MESH project are J.-F. Remacle and J. Lambrechts (UC Leuven, Belgium) and N. Moës, N. Chevaugeon and B. Le (EC Nantes).

BIOGRAPHY

Nicolas MOËS is professor at the Ecole Centrale de Nantes (France). He received his engineering degree from the University of Liège in 1992 and his PhD from the Ecole Normale Supérieure de Cachan under the supervision of Pierre Ladevèze in 1996. Before joining the Ecole Centrale of Nantes in 2001, he gained research experience in the United States: 2 years at the University of Texas at Austin in the group of Tinsley Oden and 3 years at Northwestern University in the group of Ted Belytschko where he initiated the eXtended Finite Element Method (X-FEM) with colleagues. His main area of expertise is computational mechanics: fracture and damage (X-FEM, Thick Level Set approach, Lip-field approach), contact mechanics (Inequality Level Set approach) and more recently a novel way to track front (X-MESH). His fundings are balanced between public funding from France and Europe (ERC Advanced grant in 2012, ERC Synergy Grant 2022) and collaborations with a dozen of industries in the past 20 yeas. He received the young investigator award from the IACM (International Association for Computational Mechanics) in 2006 and was declared IACM fellow in 2008. In 2014, he received the silver medal from CNRS. In 2019, he received the ONERA prize from the French academy of science, in which he was elected two years later. He is also currently member of the Institut Universitaire de France.

REFERENCES

[1] Moes, N., Remacle, J.-F., Lambrechts, J., Le, B., & Chevaugeon, N. (2021). The eXtreme Mesh deformation approach (X-MESH) for the Stefan phase-change model. doi:10.48550/ARXIV.2111.04179