Local adaptive refinement method applied to Cohesive Zone Models for heterogeneous materials

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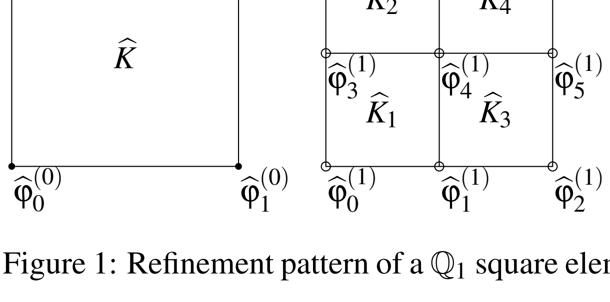
Adaptive mesh refinement devoted to crack propagation problems rely on an adjustement of a spatial resolution in the region of interest of the discretized domain in order to achieve higher accuracy. Two main issues arise from such a spatial refinement: an increase of the computational cost and a possible decrease of the shape quality of some elements located in the coarse-to-fine transition region. A solution consists in adjusting the density of the mesh by performing *local* refinement of an existing mesh. In this work, the CHARMS method (Conforming Hierarchical Adaptive Refinement MethodS [1]) is investigated and applied to the Cohesive Zone Models (CZM).

CHARMS is based on the refinement of basis functions rather than on the refinement of the finite elements and thus allows non conformities. These non conformities are geometrical: the approximation spaces remain H^1-conform. These possibly geometric non conformities of the adapted mesh are implicitly handled. To perform refinement with this method, a refinement pattern (see Figure 1) is localy and recursively applied in regions of interest which generate nested approximation spaces. Any basis function in a coarse approximation space can be written as a linear combinaison of finer basis functions. These linear combinations define child-parent relationships between basis functions of two consecutive refinement levels.



$$\begin{aligned}
\widehat{\varphi}_0^{(0)} &= \widehat{\varphi}_0^{(1)} + \tfrac{1}{2}\widehat{\varphi}_1^{(1)} + \tfrac{1}{2}\widehat{\varphi}_3^{(1)} + \tfrac{1}{4}\widehat{\varphi}_4^{(1)}\\
\widehat{\varphi}_1^{(0)} &= \widehat{\varphi}_2^{(1)} + \tfrac{1}{2}\widehat{\varphi}_1^{(1)} + \tfrac{1}{2}\widehat{\varphi}_5^{(1)} + \tfrac{1}{4}\widehat{\varphi}_4^{(1)}\\
\widehat{\varphi}_2^{(0)} &= \widehat{\varphi}_8^{(1)} + \tfrac{1}{2}\widehat{\varphi}_5^{(1)} + \tfrac{1}{2}\widehat{\varphi}_7^{(1)} + \tfrac{1}{4}\widehat{\varphi}_4^{(1)}\\
\widehat{\varphi}_3^{(0)} &= \widehat{\varphi}_6^{(1)} + \tfrac{1}{2}\widehat{\varphi}_3^{(1)} + \tfrac{1}{2}\widehat{\varphi}_7^{(1)} + \tfrac{1}{4}\widehat{\varphi}_4^{(1)}
\end{aligned}$$

Figure 1: Refinement pattern of a $\mathbb{Q}_1$ square element and associated refinement equations.

The CZM are based on a micromechanical approach and allow to perform a fine study of the crack initiation, crack propagation and other complex phenomena such as crack closure and crack branching. In this study, CZM are treated as a bulk-cohesive Finite Element method: the surface behavior is seen as a softening part which takes into account damage and the bulk hardening part that describes the bulk behavior. Whereas cohesive models give convenient results, this approach can be time consuming when the needed accuracy must be high. The aim of this study is to applied local adaptive refinement and introduce cohesive models in the refined regions to decrease computational time.

CHARMS has been implemented in the software Pelicans [3] and the CZM are handled by the softawre LMGC90 [4] to resolve contacts. Simulations are performed using Xper [2] that binds these two softwares.

To predict regions of interest (where cracks may propagate), a refinement criterion based on the gradient of energy is used. Once the refinement is performed, cohesive models are introduced at the interfaces of refined elements. Regions with cohesive models are solved using LMGC90 and the Non-Smooth Contact Dynamics method [5], and regions with no refinement are treated with the Finite Element method.

Using this strategy allows to obtain fine results in regions of interest while keeping a reasonable computational time.

References

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