Postdoctoral fellowship

Adaptive finite element computations for time-dependent wave propagation problems with dynamic meshes

Laboratory: Inria Lille (France)

Supervisors: Dr. Théophile Chaumont-Frelet (Inria Lille) https://team.inria.fr/rapsodi/ and Dr. Martin Vohralík (Inria Paris) https://team.inria.fr/serena/

Duration: 18 month
Start: Ideally January/February 2024
Funding: ANR JCJC grant APOWA

Key words: Numerical simulation, Finite element method, Wave propagation, Numerical analysis, Error estimation, Adaptivity

General context:

Accurate simulation of **wave propagation** phenomena is of central interest in many areas of physics and engineering. **Finite element** and **discontinuous Galerkin** methods have become very popular to perform such simulations, due to their ability to handle complex propagation media. The goal of this postdoctoral fellowship is to improve the reliability and efficiency of these discretization methods through the use of a posteriori **error estimators** and **adaptive mesh refinements**.

The postdoctoral fellowship takes place in the context of the **APOWA** project, funded by the French national research agency ANR. The APOWA project is concerned with the design of error estimators and adaptive schemes for **time-dependent** wave propagation problems. The postdoctoral fellow will be tasked with one research axis of the project: the design of a posteriori error estimators for **semi-discrete** schemes with **dynamic meshes**.

Description of the postdoctoral research project:

A posteriori error estimation for wave propagation is very involved; [1,3,4] are some pioneering contributions paving the way to a sound numerical analysis. A **novel approach** to a posteriori error estimation of finite element discretizations of time-dependent wave propagation problems has been recently introduced in [2]. A numerical illustration is provided in Figure 1. Currently, this approach is **limited to static meshes**, which can be adapted in space but are fixed in time. However, to deliver optimal performance, adaptive schemes requires dynamic meshes that are allowed to change as the wave propagates through the computational domain. **The goal of the postdoctoral project is therefore to develop a posteriori error estimators that are able to handle dynamic meshes**.

The first objective of postdoctoral project is to (i) **extend the analysis** in [2] to the case of dynamic meshes, and illustrate the **theoretical results** with a **one-dimensional implementation**. The postdoctoral fellow will then be asked to (ii) implement the error estimator and simple adaptive schemes in a **two-dimensional setting**. As a third goal, (iii) the **theoretical analysis of adaptive schemes** for dynamic meshes will be targeted. Libraries including basic routines for the management of meshes and finite element basis functions will be provided for the implementation tasks.

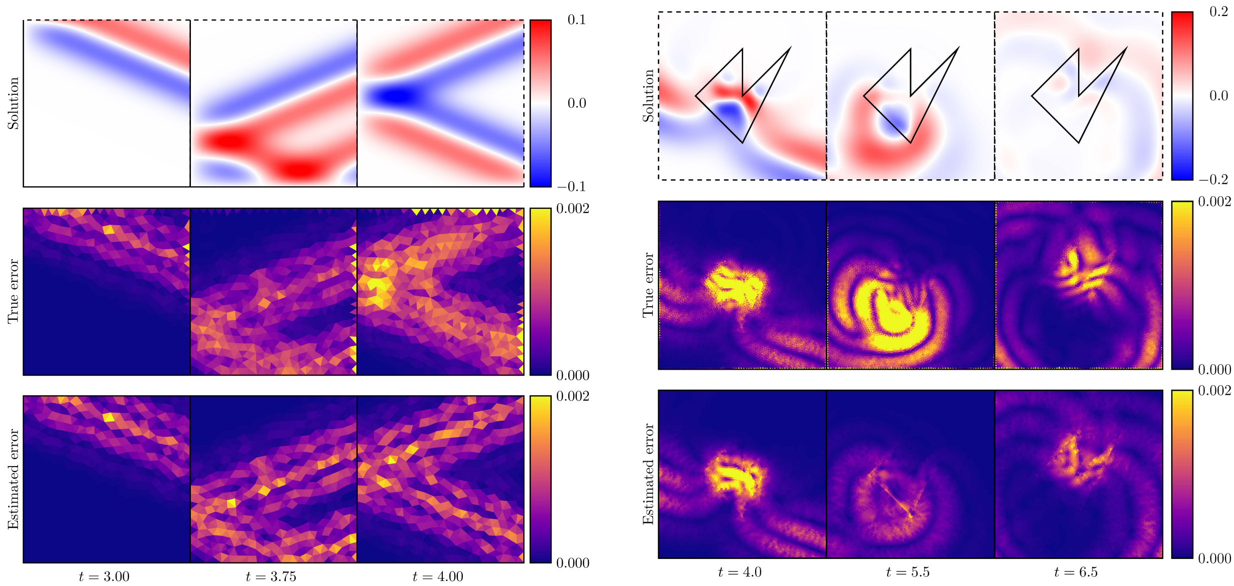

FIGURE 1. Numerical simulation of a wave reflected by two walls (left) and propagating through a penetrable obstacle (right). Numerical approximation (top), actual error (known for these model cases, middle), and a posteriori error estimate from [2] (bottom)

Profile of the candidate:

We are looking for a candidate with a PhD in applied mathematics and a strong expertise in the numerical analysis of finite element methods is required. A priori knowledge in wave propagation problems and/or a posteriori error estimation as well as programming skills are also appreciated.

Practical information for application:

Interested candidates should send an application letter along with a full CV, copies of PhD reports and reference letters to

- Dr. Théophile Chaumont-Frelet `theophile.chaumont@inria.fr`,
- Dr. Martin Vohralík `martin.vohralik@inria.fr`.

References:

[1] C. Bernardi, E. Süli, *Time and space adaptivity for the second-order wave equation.* Math. Models Methods Appl. Sci. **15** (2005), 199–225.

[2] T. Chaumont-Frelet, *Asymptotically constant-free and polynomial-degree-robust a posteriori estimates for space discretizations of the wave equation.* SIAM J. Sci. Comput. **45** (2023), A1591–A1620.

[3] T. Chaumont-Frelet, A. Ern, M. Vohralík, *On the derivation of guaranteed and p-robust a posteriori error estimates for the Helmholtz equation*, Numer. Math. **148** (2021), 525–573.

[4] W. Dörfler and S.A. Sauter, *A posteriori error estimation for highly indefinite Helmholtz problems*, Comput. Methods Appl. Math. **13** (2013), 333–347.