# Offer #2024-07374

# Post-Doctoral Research Visit F/M Virtual Element Methods for the cardiac EMI model (IDP 2024)

**Contract type :** Fixed-term contract

**Level of qualifications required :** PhD or equivalent

**Fonction :** Post-Doctoral Research Visit

## Context

It has been recently recognized that the micrometric scale may play a crucial role to explain cardiac arrhythmia occurring at the organ scale \cite{jaeger2021frommillimetricromet}. At this scale, the geometry of individual cells, and their spatial organization has to be taken into account, and a correct model is the extracellular, membrane, intracellular (EMI) model described in \cite{tveito2017cellbased}.

It is the aim of the MICROCARD project (ending in September 2024) to build an efficient high-performance computer software to solve the equations of the EMI model. To this aim, we are currently investigating the interest of finite volume methods, and have obtained some results for a standard scheme, adapted to the problem \cite{FVCA10.2023}. The methods studied up to now are restricted to triangular and tetrahedral mesh elements, and are low order approximations.

The variations of the electrical field may occur at a scale close to the cell length (see \cite{jaeger2021frommillimetricromet}), meaning that the approximation may require mesh elements having the size of the cells. Anyway, the cells have complex geometries, which discretization needs smaller tetrahedrons. We want to investigate how recent virtual elements method \cite{antonietti2022virtualelementmethodapplicat} or polytopal discretizations \cite{dipietro2020hybridhighorder} may be used to discretize the EMI equations with less mesh elements (of more general shape), while retaining their precise geometry, and a good accuracy.

## Assignment

The equations are Laplace equations within each cell, and the extracellular domain. They are coupled through time-dependent transmission conditions. These conditions involve additional state variables, that solve systems of nonlinear differential equations (ionic models). For this reason, the problem needs discretizing operators in the volume, but also integrals on the surface interfaces between subdomains. The discrete problem may be written in the
complete volume (with a large sparse linear system) or on the interfaces only (with a smaller full linear system).

The postdoctoral researcher will have to complete a literature survey of possible polytopal methods, including the VEM and variants of FVM, like hybrid high-order finite volume (HHO) methods. He or she will propose some approaches
to discretize the EMI model with such a method on general mesh elements. The objective is to define a method that can be used on very general meshes, with the fewer possible unknowns per cardiac cells. The researcher will have to
assess the feasibility, and accuracy of such approaches, as well as to guarantee relative ease of implementation of the numerical scheme. For this reason a prototypal implementation will have to be programmed, and tested (test cases
from the MICROCARD project may be used to this aim). In addition, the mathematical soundness of the method may be studied. Depending on the difficulty of the problem, it may include proving existence of the discrete solution,
uniqueness, and understanding its theoretical convergence if possible. This may be difficult because the regularity of solutions has not been studied.

## Main activities

Main activities:

- Survey of the literature, propose a solution to the discretization of the EMI model in the above context
- Assess the accuracy and convergence of the method, numerically or by analysis
- Implementation in a software code, run and analyse numerical test cases
- Write scientific article, present the work at conferences

## Skills

*Academic background:*

- Ph.D. in Applied mathematics.

*Required skills:*

- Strong knowledge of methods for elliptic PDE discretization (finite elements or finite volumes), in theory and in practice,
- Scientific computing, strong coding abilities (C, C++, or Fortan) and knowledge of scientific libraries
- Candidates are expected to write scientific journal papers in autonomy and to communicate their results in conferences.

*Relational skills:*

- Candidates will be asked to work in collaboration in a research team,
- Good abilities to communicate and manage project in a team are required.

*Language:*

- Spoken and written English.

## Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs
- Possibility of teleworking and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

## Remuneration

2788€ / month (before taxs)

## General Information

- **Theme/Domain :** Modeling and Control for Life Sciences
  Scientific computing (BAP E)
- **Town/city :** Talence
- **Inria Center :** Centre Inria de l'université de Bordeaux
- **Starting date :** 2024-10-01
- **Duration of contract :** 2 years
- **Deadline to apply :** 2024-05-03

## Contacts

- **Inria Team :** CARMEN
- **Recruiter :**
  Coudière Yves / Yves.Coudiere@inria.fr

## About Inria

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

**Warning** : you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.

## Instruction to apply

Thank you to send:
- CV
- Cover letter
- Support letters (mandatory)

- List of publication

**Defence Security :**
This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST).Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

**Recruitment Policy :**
As part of its diversity policy, all Inria positions are accessible to people with disabilities.