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Overview on the Cardiac ElectroPhysiology Simulator (CEPS)

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Goals

- Develop a modular code called CEPS (Cardiac ElectroPhysiology Simulator) useful for doctors and for applied mathematicians researchers.
- Develop a parallel code in order to take account multiple scales (from the macroscopic scale to the microscopic scale).
- Develop a kernel framework useful for researchers in medicine and in applied mathematics.
- Develop a parallel code in order to be efficient with clusters like Plafrim, Curie, or personal computer...
- Develop useful tools for installation of the code and validation test cases.

Actors

A lot of persons work in the CEPS code, see the not exhaustive list below:

- Juhoro Mehdi (old ADT), the foundation of CEPS with a lot of contribution of Nejib Zemmzi who contributes on the framework of CEPS.
- Marc Fuentes (SED), to help us on everything on the code (compilation, development, ...).
- Pierre Elliot Bécue works with CEPS for simulation at the microscopic scale
- Gerard Antoine, works with CEPS on the implementation of the bilayer atria model in CEPS.
- Florian Caro works on numerical methods and on microscopic scale with PE Bécue.
- Yves Coudière will works on high order Finite Volume methods, thanks to the framework of CEPS. Those schemes are devoted to be implemented in CEPS.
- Charlie Douanla-Iontsi works on high order time numerical schemes with Charles Pierre. Those schemes are devoted to be implemented in CEPS.
- Students and PhD thesis for the future.

What it is done currently in CEPS

- Mono domain model is developed in CEPS

\[
\begin{align*}
\sigma \nabla u + f(u,v) &= 0 \text{ dans } \Omega, \\
\sigma \nabla v - g(u,v) &= 0 \text{ dans } \Omega, \\
\nabla \cdot (\sigma \nabla u) &= 0 \text{ sur } \partial \Omega,
\end{align*}
\]

where \( u \) and \( v \) denote the unknown vector for the ionic variables and the electric potential. Parameters \( \gamma \) and \( C_m \) are physical data and \( \sigma \) denotes the conductivity tensor of the medium.

- About 11000 lines of C++ (within header files but without test files)

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- Validation
  - Unit test case.
  - Validation test case (comparison between exact solution and numerical solution).

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Project IDAM (Integration between Data And Models for cardiac electrophysiology)

- Treat pictures from doctors in order to generate meshes useful for applied mathematicians.
- Assign realistic tissue parameters for various cardiac structures, field directions of the fibers muscle, gradients apex-base or parameters transmural...
- Use CEPS simulator by using meshes obtained by the previous step
- Import and display simulation results and correlate these results with the experimental data and imaging electrical mapping.
- Development will be done in MedInria with the plugin Music and in collaboration with the Carmen team.

Perspectives

- Use Scotch instead of ParMets due to the non reactivity of ParMets team. Scotch is an equivalent of ParMets developed at INRIA to operate matrix decomposition.
- Run these tests on the clusters at bigger scales to identify scaling issues.
- Use CEPS to test high order Finite Volume scheme (Y. Coudière) and high order numerical scheme in time (C. Pierre and C. Douanla-Iontsi).
- Use CEPS for numerical simulation at the microscopic scale (P. Bécue and M. Potse).
- Use CEPS for the development of future research with students.
- Compare macroscopic bi-domain and monodomain model to homogenization-based methods achieved in CARMEN with the microscopic mode developed with P. Bécue and M. Potse.
- Integrate Bilayer Atria model in CEPS with A. Gérard and compare obtained results with those obtained by classical models.