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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 mathematician researchers.
• Develop a parallel code in order to take account multiple scales (from the macroscopic
scale to the microscopic scale).
• 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
• Juhoor Mehdi (old ADT), the foundation of CEPS with a lot of contribution of Nejib Zemzemi
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.
• Charlie Douanla-lontsi 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 is done currently in CEPS
• Mono domain model developed in CEPS

\[ \begin{align*}
    & (C_a \partial_t v + I_{Na}(u,v)) - div(\sigma \nabla v) = 0 \text{ dans } \Omega_H, \\
    & (C_m \partial_t u - g_m u + C_f v) - div(\sigma \nabla u) = 0 \text{ dans } \Omega_H, \\
    & u \cdot \nu = 0 \text{ sur } \partial \Omega_H, \\
    & \sigma v_n = 0 \text{ sur } \partial \Omega_H,
\end{align*} \]

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

About 11 000 lines of C++ (white header files but without test files)

<table>
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Validation

– Unit test case.

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

| 1/16 Test #1: utility.numeric  | 0.19 sec |
| 2/16 Test #2: linearAlgebra.distributedVector | 0.39 sec |
| 3/16 Test #3: linearAlgebra.distributedHaloVector | 1.12 sec |
| 4/16 Test #4: linearAlgebra.distributedMatrix | 1.24 sec |
| 5/16 Test #5: linearAlgebra.linearSystem | 1.17 sec |
| 6/16 Test #6: geometry.geometry | 1.18 sec |
| 7/16 Test #7: ode.ionicModels | 8.58 sec |
| 8/16 Test #8: pde.common | 0.12 sec |
| 9/16 Test #9: pde.boundaryConditions | 1.14 sec |
| 10/16 Test #10: pde.assemblers | 10.00 sec |

Perspectives

– Use Scotch instead of ParMetis due to the non reactivity of ParMetis team. Scotch is an
equivalent of ParMetis 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-lontsi).

– Use CEPS for numerical simulation at the microscopic scale (P. E. Bécue and M. Potse).

– Use CEPS for the development of future research with students.

– Compare macroscopic bi-domain and monodomain model to homogenization-based meth-
ods achieved in CARMEN with the microscopic mode developed with P.E. Bécue and M.
Potse.

– Integrate Bilayer Atria model in CEPS with A. Gérard and compare obtained results with
those obtained by classical models.