Fatemeh Chegini

Scientific Computing | High-Performance Computing | Numerical Methods

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Professional Summary

Scientific computing and high-performance computing researcher specializing in numerical methods and scalable scientific software for cardiac electrophysiology. Experienced in distributed-memory finite-element simulations, higher-order discretizations, domain-decomposition preconditioning, adaptive methods, communication compression, inverse problems, and PDE-constrained optimization. Strong background in **C++, MPI, PETSc, finite-element methods, numerical linear algebra, and parallel scientific software development**.

Research Experience

Postdoctoral Researcher **Apr 2021 – Present**
Zuse Institute Berlin (ZIB), Modeling and Simulation of Complex Processes
Berlin, Germany

- Conduct research and scientific software development within the MICROCARD project, focusing on scalable numerical methods for cellular-scale cardiac electrophysiology.
- Designed and developed a **distributed-memory EMI framework in openCARP**, following an initial shared-memory prototype in Kaskade.
- Developed key components of the distributed EMI simulation pipeline, including tag-based mesh partitioning, membrane-interface identification, decoupled-interface indexing, finite-element discretization, parallel data structures, matrix assembly, and memory-efficient simulation components.
- Developed a **hierarchical second-order finite-element (P2) formulation** for the EMI model, with separate first- and second-order degree-of- freedom blocks and a **two-level preconditioning strategy**.
- Work on **algebraic adaptivity** for selectively activating higher-order degrees of freedom to improve the trade-off between numerical accuracy and computational cost.
- Implemented **Spectral Deferred Correction (SDC)** for higher-order time integration of the EMI model in Kaskade and combined it with algebraic adaptivity.
- Integrated the SDC implementation with **BDDC domain-decomposition preconditioning** and algebraic adaptivity for scalable EMI simulations, reducing unnecessary refactorization as active degrees of freedom change.
- Developed a **block-oriented communication-compression strategy for BDDC** to reduce interface data exchange in large-scale distributed-memory simulations while controlling compression error and solver convergence.
- Integrated and evaluated solver backends based on **PETSc** and **Ginkgo**, supporting distributed-memory, manycore, and GPU-oriented experiments.
- Contribute to performance optimization, testing, validation, and debugging, and coordinate EMI development activities across work packages.

Technical Expertise

Programming	C++, C, Python, MATLAB
Parallel & HPC	MPI, PETSc, Ginkgo, distributed-memory computing, parallel scientific computing
Numerical Methods	Finite Element Method (FEM), higher-order FEM, Spectral Deferred Correction (SDC), BDDC, domain decomposition, iterative solvers, preconditioning, algebraic adaptivity, numerical linear algebra
Scientific Computing	openCARP, Kaskade, libMesh, FEniCS
Optimization	PDE-constrained optimization, inverse problems, trust-region methods, RMTR, L-BFGS, adjoint methods, multilevel and multifidelity optimization
Machine Learning	PyTorch, TensorFlow
Development Tools	Git, GitHub, Visual Studio Code

Education

PhD in Computational Science **2022**
Università della Svizzera italiana (USI), Switzerland
Dissertation: Multilevel Optimization Algorithms for Inverse Problems in Electrocardiography
Advisors: Prof. Rolf Krause and Dr. Martin Weiser

MSc in Intelligent Systems **2015**
Università della Svizzera italiana (USI), Switzerland
Thesis: *A Spectral Approach to Cross-Modal Information Retrieval*
Advisor: Prof. Michael Bronstein

BSc in Computer Science **2013**
Università della Svizzera italiana (USI), Switzerland
Thesis: *A GLR Parser Generator for Arbitrary Context-Free Grammars*
Advisor: Prof. Nate Nystrom

BSc in Electronic Engineering **2002**
Azad University, Karaj Branch, Iran
Thesis: *Soft Starter for Induction Motors*

Selected Publications

1. F. Chegini, A. Froehly, N.M.M. Huynh, L.F. Pavarino, M. Potse, S. Scacchi. *Efficient Numerical Methods for Simulating Cardiac Electrophysiology with Cellular Resolution.* International Conference on Computational Methods for Coupled Problems, 2023.
2. N.M.M. Huynh, F. Chegini, L.F. Pavarino, M. Weiser, S. Scacchi. *Convergence Analysis of BDDC Preconditioners for Hybrid DG Discretizations of the Cardiac Cell-by-Cell Model*, 2023.
3. F. Chegini, T. Steinke, M. Weiser. *Efficient Adaptivity for Simulating Cardiac Electrophysiology with Spectral Deferred Correction Methods*, 2022.
4. F. Chegini, A. Kopaničáková, M. Weiser, R. Krause. *Quantitative Analysis of Nonlinear Multifidelity Optimization for Inverse Electrophysiology.* Domain Decomposition Methods in Science and Engineering, 2022.
5. F. Chegini, A. Kopaničáková, R. Krause, M. Weiser. *Efficient Identification of Scars Using Heterogeneous Model Hierarchies.* EP Europace, 2021.

Selected Conference Talks

- **2026 – SIAM PP26, Berlin:** BDDC with Algebraic Adaptivity and Compressed Communication for Cardiac Electrophysiology.
- **2025 – Coupled Problems, Sardinia:** BDDC with Algebraic Adaptivity and Compressed Communication for Cardiac Electrophysiology.
- **2024 – WCCM, Vancouver:** Efficiency and Accuracy in Large-Scale Cardiac Simulations with Compressed Communication and Algebraic Adaptivity in BDDC Preconditioners.
- **2024 – ECCOMAS, Lisbon:** Efficient Simulation of Cardiac Electrophysiology with Algebraic Adaptivity.
- **2024 – WONAPDE, Concepcion, Chile:** Efficient Domain Decomposition Reconditioners For Time Stepping In EMI Models
- **2023 – ICIAM, Tokyo:** Higher-Order Time Integration for EMI Cardiac Electrophysiology Simulations with Nested Subset Selection and BDDC Preconditioning.
- **August 6, 2022 – International Multigrid Conference, Lugano:** Multilevel Optimization Algorithms for Inverse Problem in Electrocardiography

Earlier Engineering Experience

Electronic / Control Systems Engineer **2002 – 2010**
Elite (self-employed), TAK YAB ASIA / DMG Agency, and ALMASE SAZ, Iran
Designed and programmed PLC-based control systems for CNC machines; diagnosed and repaired electronic control boards, drivers, and power supplies; and designed industrial electrical panels. Worked with industrial systems including Siemens, HEIDENHAIN, Deckel, and ABB.

Additional Information

Research Interests: scientific computing, PDE-based Simulation, Cardiac Digital Twins, Physics-Based Deep Learning
Languages: Persian (native), English (professional), German (B1)
Certificates: Deep Learning Nanodegree (Udacity); Natural Language Processing Nanodegree (Udacity)