CURRICULUM VITAE

Ngoc Mai Monica Huynh

Università degli Studi di Pavia ⋄ ngocmaimonica.huynh@unipv.it ⋄ https://mate.unipv.it/huynh

EDUCATION

Joint Ph.D. in Computational Mathematics and Decision Sciences Oct 1, 2018 - Sept 30, 2021
University of Pavia (Italy) – Università della Svizzera Italiana (Switzerland)
Thesis "Newton-Krylov dual-primal methods for implicit time discretizations in cardiac electrophysiology".
Advisors: Prof. Simone Scacchi, Prof. Luca F. Pavarino
Discussion: December 23, 2021.

M.Sc. in Mathematics, *full marks cum laude* Oct 1, 2015 – Apr 11, 2018
University of Milano (Italy)
Thesis "Nonlinear FETI-DP Methods for Reaction-Diffusion Systems".
Advisor: Prof. Simone Scacchi.
Mark: 110/110 cum laude.

B.Sc. in Mathematics Oct 1, 2011 – Oct 21, 2015
University of Milano (Italy)

Diploma in Classical Guitar Sept 2006 – Sept 2013
ISSM Conservatorio "G.Cantelli", Novara (Italy)

CURRENT POSITION

Post-doctoral researcher (MAT/08) Oct 1, 2021 – ongoing
University of Pavia (Italy)
Advisor: Prof. Luca F. Pavarino
Project: EuroHPC MICROCARD

ABSENCES

Maternity leave Aug 22, 2023 – Jan 21, 2024

RESEARCH INTERESTS

- Iterative solvers and scalable domain decomposition preconditioners for computational biomechanics.
- High-performance computing.
- Nonlinear and parallel solvers for computational biomechanics and nonlinear constrained optimization.
- Mesh generation: from medical image segmentation to meshing and refinement procedures.

RESEARCH ACTIVITY

My research activity has been focused on the following topics.

Scalable Newton-Krylov domain decomposition preconditioners for cardiac biomechanics

- The main goal of this study was to develop suitable Domain Decomposition (DD) preconditioners for solving nonlinear systems arising from implicit time discretizations of models in cardiac biomechanics, with a focus on cardiac electrophysiology. The latter can be described by means of a system of degenerate parabolic reaction-diffusion equations coupled with a system of ordinary differential equations (ODEs) modeling the ionic dynamics. This model is known as Bidomain model. Choosing an implicit time discretization brings the advantage of more flexbility in the choice of the time step size, which is a turning point for multiscale and multiphysics problems such as in cardiac electromechanics. However, this choice requires to solve a nonlinear system at each time step.

In this perspective, Newton-Krylov methods effectively solve such large-scale nonlinear systems by combining the Newton-Raphson method for nonlinear problems with Krylov subspace methods for linear problems, which can be further improved with a suitable preconditioning technique. In papers [2, 3, 7] we considered the Balancing Domain Decomposition by Constraints (BDDC) and the Finite Element Tearing and Interconnecting Dual-Primal (FETI-DP) methods as preconditioners for the Conjugate Gradient (CG) iterative solver for the linearized system. We adopted a decoupled time strategy, where at each time step the ODEs are solved prior to the parabolic equations, resulting in a linearized symmetric and positive definite system. In particular, in [7] we proved the convergence of these preconditioned solvers, showing scalability and quasi-optimality; we also tested numerically their robustness with respect to jumps in the diffusion tensor (modeling an ischemic tissue scenario) in [6].

In [8] instead, we considered a fully coupled nonlinear system, leading to a non-symmetric linearized system. For this scenario, the generalized Minimal Residual (GMRES) iterative method was considered, and the BDDC-GMRES solver was proved to be scalable and quasi-optimal, both theoretically and numerically. More extensive numerical tests were collected in the doctoral thesis [1]. All the numerical experiments related to the above topic were performed on high-performance computing platforms.

Parallel nonlinear solvers for cardiac electromechanics

· As a natural continuation of the previous topic, and with the goal of reducing the computational costs associated with solving the linearized problem, we studied the performance of native nonlinear solvers in [4]. These solvers include the nonlinear GMRES, the nonlinear CG, and variants of Newton 's method that have lower convergence speed, such as inexact Newton and quasi-Newton methods. The numerical results obtained in [4] were promising, leading us to focus further on the BFGS quasi-Newton method and the nonlinear CG. In [10], we proved both theoretically and through extensive numerical tests that their expected convergence rates are achieved also for the Bidomain system.

Scalable domain decomposition preconditioners for cardiac electrophysiology at a cellular scale

· The objective of this study was to design appropriate scalable preconditioners for solving cardiac electrophysiology at a cellular scale. When considering models based on cell-by-cell coupling, the natural discontinuities in the electrical potential values pose a challenge that needs to be addressed in the design of solvers and preconditioners. Although DD preconditioners appear to be suitable for such problems, their application in this context is not straightforward. The fluxes across neighbouring subdomains (or subproblems) are discontinuous, and present jumps that change the preconditioner's constraints formulations.

In [9], we designed and theoretically analyzed a BDDC preconditioner, proving the convergence of the preconditioned iterative solver and testing it in a simplified two-dimensional scenario. Further tests in three-dimensional and more realistic geometries were conducted in [5].

Lastly, we designed and studied a generalized Dryja-Smith-Widlund (GDSW) preconditioner for such problems in [12].

Virtual Elements discretizations for cardiac reaction-diffusion equations

· The objective of this study was to investigate the stability of the Bidomain model when considering Virtual Elements discretizations in space. In particular, in [11], we proposed a theoretical convergence analysis for the semi-discrete system and validated numerically this result through two-dimensional experiments considering a decoupled solution strategy and an implicit-explicit time scheme for the time discretization of the parabolic equations.

PUBLICATIONS

– Submitted

[12] NMM Huynh, LF Pavarino, and S Scacchi. *GDSW preconditioners for composite Discontinuous Galerkin discretizations of multicompartment reaction-diffusion problems.* In: *arXiv preprint arXiv:2405.17601* (2024).

– Journal papers

[11] NMM Huynh. *Convergence analysis for virtual element discretizations of the cardiac Bidomain model.* 2024.

[10] NA Barnafi, NMM Huynh, LF Pavarino, and S Scacchi. *Robust parallel nonlinear solvers for implicit time discretizations of the Bidomain equations with staggered ionic models.* In: *Comput. Math. with Appl.* 167 (2024), pp. 134–149.

[9] NMM Huynh, F Chegini, LF Pavarino, M Weiser, and S Scacchi. *Convergence analysis of BDDC preconditioners for composite DG discretizations of the cardiac cell-by-cell model.* In: *SIAM J. Sci. Comput.* 45(6) (2023), A2836–A2857.

[8] NMM Huynh. *Newton-Krylov-BDDC deluxe solvers for non-symmetric fully implicit time discretizations of the Bidomain model.* In: *Numerische Matematik* 152(4) (2022), pp. 841–879.

[7] NMM Huynh, LF Pavarino, and S Scacchi. *Parallel Newton-Krylov-BDDC and FETI-DP deluxe solvers for implicit time discretizations of the cardiac Bidomain equations.* In: *SIAM J. Sci. Comput.* 44(2) (2022), B224–B249.

[6] NMM Huynh, LF Pavarino, and S Scacchi. *Scalable and robust dual-primal Newton-Krylov deluxe solvers for cardiac electrophysiology with biophysical ionic models.* In: *Vietnam J. Math.* 50(4) (2022), pp. 1029–1052.

– Proceedings

[5] F Chegini, A Frohely, NMM Huynh, LF Pavarino, M Potse, S Scacchi, and M Weiser. *Efficient numerical methods for simulating cardiac electrophysiology with cellular resolution.* In: *X International Conference on Computational Methods for Coupled Problems in Science and Engineering COUPLED PROBLEMS 2023.* 2023.

[4] NA Barnafi, NMM Huynh, LF Pavarino, and S Scacchi. *Parallel nonlinear solvers in computational cardiac electrophysiology.* In: *IFAC-PapersOnLine.* Vol. 50(20). 2022, pp. 187–192.

[3] NMM Huynh, LF Pavarino, and S Scacchi. *Dual-primal preconditioners for Newton-Krylov solvers for the cardiac Bidomain model.* In: *Domain Decomposition Methods in Science and Engineering XXVI.* Springer, 2022, pp. 689–696.

[2] N Huynh, L Pavarino, and S Scacchi. *Scalable Newton-Krylov-BDDC and FETI-DP Deluxe Solvers for Decoupled Cardiac Reaction-Diffusion Models.* In: *14th WCCM-ECCOMAS Congress 2020.* Vol. 400. 2021.

– Doctoral thesis

[1] NMM Huynh. *Newton-Krylov dual-primal methods for implicit time discretizations in cardiac electrophysiology.* PhD thesis. 2021.

GRANTS

– Research project management

· **INdAM Scholarship for Visiting periods, 2023** 3000 €
Project: *Numerical investigation of parallel nonlinear solvers for cardiac electromechanics* Role: PI

· **INdAM – GNCS Grants for Research Group, 2023** 3200 €
Project: *Risolutori PENSO (Paralleli, Efficienti, Nonlineari, Scalabili e Ottimali) per equazioni alle derivate parziali e applicazioni* Role: PI
· **INdAM – GNCS Grants for Young Researcher, 2021** 1500 €
Project: *Sviluppo e implementazione di precondizionatori paralleli scalabili per l'elettrofisiologia cardiaca a livello cellulare* Role: PI
· **INdAM – GNCS Grants for organization of schools, workshops and seminars, 2021** 1000 €
Workshop: *Young Researchers Workshop on Mathematical and Numerical Cardiac Modeling* Role: PI

– High Performance Computing project management

· **Cineca - ISCRA C, 2024** 20 000 hours
Project: *Nonlinear Solvers Towards Parallel computing* Role: PI
· **Cineca - ISCRA C, 2023** 30 000 hours
Project: *Parallel Efficient Nonlinear Scalable and Optimal solvers for cardiac cell-by-cell models* Role: PI

– Participation to research projects

· **PRIN 2022** Codice progetto MUR: 202232A8AN
Computational modeling of the human heart: from efficient numerical solvers to cardiac digital twins
· **PRIN 2022 PNRR** Codice progetto MUR: P2022B38NR
Efficient and sustainable numerical solvers for cardiac cell-by-cell models: scalable domain decomposition methods and deep operator learning
· **European High-Performance Computing Joint Undertaking** Grant Agreement No. 955495
MICROCARD: Numerical modeling of cardiac electrophysiology at the cellular scale

AWARDS

Scholarship "Ing. Vittorino Pollo e Dott.essa Zita Pollo", 2019 6000 €
Fondazione Agnelli, Torino
Post-lauream scholarship (link to article).

LIST OF COLLABORATORS IN ALPHABETICAL ORDER

Barnafi, Nicolás A.	Pontificia Universidad Católica de Chile
Benedusi, Pietro	Università della Svizzera Italiana
Botti, Sofia	Università della Svizzera Italiana
Centofanti, Edoardo	Università degli Studi di Pavia
Chegini, Fatemeh	Zuse Institute Berlin
Froehly, Algiane	Inria Bordeaux
Göbel, Fritz	Karlsruher Institut für Technologie
Kothari, Hardik	Università della Svizzera Italiana
Pavarino, Luca F.	Università degli Studi di Pavia
Potse, Mark	Université de Bordeaux
Scacchi, Simone	Università degli Studi di Milano

CONFERENCE TALKS

[17] *Cardiac electrophysiology at microscopic level: scalable preconditioners and parallel solvers.* ECCOMAS 2024. Lisbon, Portugal. June 2–7, 2024.

[16] *Tailoring preconditioners for enhanced efficiency in cardiac modeling: insights from Domain Decomposition.* INdAM Workshop "Mathematical and Numerical Modeling of the Cardiovascular System. Rome, Italy. Apr. 15–18, 2024.

[15] *Scalable multilevel preconditioners for hybrid-DG discretizations of nonlinear cell-by-cell cardiac models.* 10th International Congress on Industrial and Applied Mathematics (ICIAM 2023). Tokyo, Japan. Aug. 21–25, 2023.

[14] *Scalable BDDC preconditioners for composite DG discretizations of cardiac microscopic models.* ECCOMAS Young Investigator 2023. Porto, Portugal. June 19–21, 2023.

[13] *Robust preconditioned solvers for cardiac electrical models.* Math2Product 2023. Taormina, Italy. May 30–June 1, 2023.

[12] *BDDC preconditioners for hybrid discontinuous galerkin discretizations in cardiac electrophysiology.* SIAM CSE23. Amsterdam, Netherlands. Feb. 26–Mar. 3, 2023.

[11] *Efficient nonlinear solvers and domain decomposition preconditioners for cardiac reaction-diffusion equations.* 5th AfriComp. Cape Town, South Africa. Nov. 2–4, 2022.

[10] *Efficient and robust parallel solvers for cardiac reaction-diffusion models.* 15th WCCM – 8th APCOM Congress. Yokohama, Japan. July 31–Aug. 5, 2022.

[9] *Parallel nonlinear solvers in computational cardiac electrophysiology.* 10th Vienna International Conference on Mathematical Modeling (MATHMOD 2022). Vienna, Austria. July 27–29, 2022.

[8] *Scalable and parallel non-linear solvers for the cardiac Bidomain system.* First UMI meeting of PhD students, "100 years UMI – 800 years UniPD". May 23–27, 2022.

[7] *Alternative parallel nonlinear solvers for cardiac reaction-diffusion models.* COLIBRI Focus Workshop. Graz, Austria. Feb. 14–15, 2022.

[6] *Newton-Krylov-BDDC solvers for implicit discretizations of cardiac reaction-diffusion systems.* SIMAI Congress 2020+2021. Parma, Italy. Aug. 30–Sept. 3, 2021.

[5] *BDDC and FETI-DP preconditioners for Newton-Krylov solvers for the cardiac Bidomain model.* iHeart – Modelling the Cardiac Function. Virtual Congress. July 1–3, 2021.

[4] *Scalable Newton-Krylov Solvers for Cardiac Reacion-Diffusion Models.* 14th WCCM – ECCOMAS Congress 2020. Virtual Congress. Jan. 11–15, 2021.

[3] *Scalable Newton-Krylov Dual-Primal Solvers for Cardiac Reaction-Diffusion Models.* Domain Decomposition Conference, DD XXVI. Hong Kong, China (online event). Dec. 7–12, 2020.

[2] *Non-linear Scalable Solvers for Cardiac Reaction-Diffusion Models.* 2019 RISM Congress: iHeart – Modelling the Cardiac Function. Varese, Italy. July 22–24, 2019.

[1] *Non-linear Scalable Solvers for Cardiac Reaction-Diffusion Models.* 9th International Congress on Industrial and Applied Mathematics (ICIAM 2019). Valencia, Spain. July 15–19, 2019.

SEMINARS TALKS

[5] *Dual-primal domain decomposition preconditioners for composite discontinuous Galerkin discretizations.* Simula Research Laboratory. Oslo, Norway. May 9, 2023.

[4] *Scalable preconditioners for hybrid discontinuous Galerkin discretizations: an application to cardiac electrophysiology.* Very informal seminars. Pavia, Italy. Oct. 7, 2022.

[3] *Caridac modelling: from micro to macroscales.* First Conference of Young Applied Mathematicians. Santa Maria di Leuca, Italy. Sept. 13–17, 2021.

[2] *An Overview of Domain Decomposition methods for Cardiac Models.* Workshop ”Women in Maths”. Pavia, Italy (online event). May 12, 2020.

[1] *Non-linear Domain Decomposition Methods for Cardiac Models.* Spring Workshop in Computational Mathematics, Statistics and Machine Learning. Pavia, Italy. May 7–9, 2019.

PARTICIPATION TO SUMMER SCHOOLS

Summer School in Advanced DD Methods — Nov 24 – 26, 2021
Politecnico di Milano (Italy)

Data Science - Metodi Informatici per la Gestione dei dati in Biomedicina — Feb 22 – 26, 2021
Laboratory of Medical Statistics and Bioinformatics, Università degli Studi di Pavia (Italy)

FoMICS Winter School on Cardiac Simulations 2020 — Nov 30 – Dec 4 2020
Institute of Computational Science, Università della Svizzera Italiana (Switzerland)

Summer School in Computational Physiology SSCP 2019 — June – Aug 2019
Simula Research Laboratory (Norway) and University of California San Diego (USA)

EPSRC–InFoMM UK Graduate Modelling Camp — Apr 2–5, 2019
University of Oxford (UK)

ECMI Modelling Week 2018 — July 15–22, 2018
University of Novi Sad (Serbia)

ORGANIZATION AND SCIENTIFIC SERVICE ACTIVITY

Conference minisymposia organization

- *Novel mathematical and numerical models for multiphysics and multiscale systems*, at WCCM–PANACM 2024 (Vancouver, Canada).
- *Robust and scalable solvers in HPC: recent developments and future challenges*, at ECCOMAS 2024 (Lisbon, Portugal).
- *Efficient and scalable solvers and algorithms for multiscale phenomena*, at ICIAM 2023 (Tokyo, Japan).
- *Young researchers minisymposium on Multigrid and Multilevel methods*, at IMG2022 (Lugano, Switzerland).

Conference and workshop organization

- *COMPMAT - PhD Spring Workshop*, at the University of Pavia (2022, 2023 and 2024).
- *Young researchers workshop on mathematical and numerical cardiac modeling*, at the University of Pavia – Dec 14, 2021.
  Website: https://mate.unipv.it/workshop-young-cardiac/. Supported by INdAM-GNCS with 1000 €.
- *Doctoral seminar cycle “Se mi narri di Matematica”*, at the University of Pavia – 2020, 2021.
  Website: https://euler.unipv.it/seminaridott/.
  Highlight: *Women in Maths*, online workshop (May 12, 2020).

Review activity

- SIAM Journal of Scientific Computing
- Engineering Computations
- Physics of Fluids

Scientific community service

- Virtual Physiological Human Institute PhD Student Committee member, 2019 – 2021.

SCIENTIFIC VISITING PERIODS

Simula Research Laboratory May, 2023
SCAN group (Prof. M. Rognes, Dr. P. Benedusi).
Analysis and implementation of nonlinear solvers for nonlinear radiative systems.

Università della Svizzera Italiana (USI) March, 2023
Euler Institute (Prof. R. Krause, Dr. H. Kothari).
Implementation of nonlinear FETI-DP methods for nonlinear constrained optimization problems.

Zuse Institute Berlin (ZIB) October 2022
Laboratory of Computational Anatomy and Physiology (Dr. M. Weiser).
Analysis and numerical implementation of scalable BDDC preconditioners for cardiac cell-by-cell models.

Università della Svizzera Italiana (USI) Feb – July 2020
Institute of Computational Science (Prof. R. Krause).
Parallel nonlinear solvers for the cardiac Bidomain model.

TEACHING ACTIVITY

2023 – 2024

- Teaching assistant. Course "Finite element methods". Master degree in Biological Engineering. Faculty of Engineering, University of Pavia.

2022 – 2023

- Teaching assistant. Course "Finite element methods". Master degree in Biological Engineering. Faculty of Engineering, University of Pavia.
- Teaching assistant. Course "Mathematical Analysis I and Geometry". Bachelor degree in Management and Production Engineering. Politecnico of Milano.
- Lecturer. Preparatory course "Essential of Scientific Computing". Master degree in Civil Engineering. University of Pavia.
- Lecturer. Crash course "Mathematics". Master degree in Environmental and Food Economics. University of Milan.

2021 – 2022

- Teaching assistant. Course "Differential models". Master degree in Biological Engineering. Faculty of Engineering, University of Pavia.
- Tutor. Course "Elements of Scientific Computing". Bachelor degree in Civil Engineering. Faculty of Engineering, University of Pavia.
- Teaching assistant. Preparatory course. Bachelor degree in Biology. University of Pavia.

2020 – 2021

- Teaching assistant. Course "Dynamical Systems". Master degree in Biological Engineering. Faculty of Engineering, University of Pavia.
- Tutor. Course "Foundation of Mathematics and Statistics". Bachelor degree in Bioscience. Faculty of Science, University of Milan.
- Teaching assistant. Preparatory course. Bachelor degree in Biology. University of Pavia.

2019 – 2020

- Teaching assistant. Course "Dynamical Systems". Master degree in Biological Engineering. Faculty of Engineering, University of Pavia.

- Tutor. Course “Mathematics”. Bachelor degree in Business and Economics. University of Pavia.
- Teaching assistant. Preparatory course. Bachelor degree in Mathematics. University of Pavia.

LANGUAGES

Italian, Vietnamese	*Mothertongue*
English	*Fluent*

Pavia – July 8, 2024

Ngoc Mai Monica Huynh