Curriculum Vitae

Simone Scacchi

PERSONAL DATA

Born in Novara, Italy, November 22nd, 1980
Address: via Aldo Rossi 12, 27100 Pavia (PV), Italy
Italian citizenship
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CURRENT POSITION

Associate Professor
Department of Mathematics "Federigo Enriques"
University of Milan
Via Saldini 50, 20133 Milano MI, Italy
Tel: +39 02503 16162
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NATIONAL SCIENTIFIC QUALIFICATIONS

- **November 2017**. Italian Scientific Qualification as Full Professor, S.C. 01/A5 ANALISI NUMERICA (numerical analysis).
- **December 2013**. Italian Scientific Qualification as Associate Professor, S.C. 01/A5 ANALISI NUMERICA (numerical analysis).

PROFESSIONAL EXPERIENCE

- **February 1st 2015 - now**: Associate Professor, Department of Mathematics, University of Milan, Italy.
- **December 1st 2008 - January 31st 2015**: Assistant Professor, Department of Mathematics, University of Milan, Italy.
- **September 1st 2008 - November 30th 2008**: PostDoctoral Research Associate, Department of Mathematics, University of Pavia, Italy.
- **January 1st 2008 - August 31st 2008**: Research fellow, Department of Mathematics, University of Pavia, Italy.
- **November 1st 2007 - December 31st 2007**: Research fellow, Department of Mathematics, University of Milan, Italy.

EDUCATION

- **November 1st 2004 - January 14th 2008**: Ph.D. in Mathematics and Statistics. University of Pavia, Italy. Thesis: "Multilevel Schwarz preconditioners for the Bidomain system and applications to electrocardiology". Advisors: Prof. Piero Colli Franzone, Prof. Luca Pavarino.
- **October 1st 1999 - July 13th 2004**: Laurea in Matematica. University of Milan, Italy. Mark: 110/110. Thesis: "Modelli computazionali paralleli dell'attività bioelettrica nel miocardio ischemico". Advisor: Prof. Luca Pavarino.

- **September 1st 2001 - August 31st 2002**: Erasmus fellowship, Humboldt University, Berlin, Germany.

RESEARCH VISITING EXPERIENCE

- **March 2017**: Courant Institute, New York University, USA. (Development of BDDC preconditioners for isogeometric analysis of 3D elasticity; results published in one paper on SIAM J. Sci. Comput. 2017.)
- **April 2016**: Department of Physics and Astronomy, Gent University, Belgium. (Development of a finite element code for the solution of Bidomain equations on patient-specific voxel meshes.)
- **March 2007-May 2007**: Zuse Institute Berlin (ZIB), Germany. (Development of an adaptive finite element method for computational electrocardiology; results published in one ZIB technical report and a conference proceeding.)

RESEARCH INTERESTS

- Numerical methods for partial differential equations
- Domain Decomposition methods
- Parallel computing
- Computational electrocardiology
- Isogeometric Analysis
- Computational Mechanics

COMPUTER SKILLS

- **Operating systems**: MS Dos, Microsoft Windows, Linux, Unix
- **Programming languages**: C, C++, Fortran, Java, Matlab, Python
- **Productivity programs**: Microsoft Office (Excel, Word), Matlab, Latex, MPI, PETSc.

FOREIGN LANGUAGES

- **English**: Good written and oral knowledge.
- **German**: Good written and oral knowledge.

PARTICIPATION TO SUMMER SCHOOLS

- **CASPUR Summer school on High Performance Computing.** August 28th - September 8th, 2006, Castel Gandolfo, Roma, Italy.
- **CIME Summer school** on **Mixed Finite Elements, Compatibility Conditions and Applications.** June 26th - July 1st, 2006, Cetraro, Italy.

- **EMS Summer school** on **Mathematical Models of the Heart.** May 5th-12th, 2006, Longyearbyen, Svalbard Islands, Norway.
- **Mathematical Models in Life Science: Theory and Simulations.** July 1st-5th, 2005, Dobbiaco, Italy.

TEACHING ACTIVITY

2018-2019
- Lecturer, Faculty of Science, University of Milan. Course: "Biomathematics", Master degree in Mathematics.
- Lecturer, Faculty of Science, University of Milan. Course: "Mathematics", Bachelor degree in Biology.
- Lecturer, Faculty of Science, University of Milan. Course: "Mathematical Modeling", Master degree in Mathematics.

2017-2018
- Lecturer, Faculty of Science, University of Milan. Course: "Numerical Analysis", Bachelor degree in Computer Science.
- Lecturer, Faculty of Science, University of Milan. Course: "Numerical Methods for Partial Differential Equations", Master degree in Mathematics.

2016-2017
- Lecturer, Faculty of Science, University of Milan. Course: "Numerical Analysis", Bachelor degree in Computer Science.
- Lecturer, Faculty of Science, University of Milan. Course: "Biomathematics", Master degree in Mathematics.

2015-2016
- Lecturer, Faculty of Science, University of Milan. Course: "Numerical Analysis", Bachelor degree in Computer Science.
- Teaching Assistant, Faculty of Science, University of Milan. Course: "Numerical Analysis", Bachelor degree in Chemistry.
- Teaching Assistant, Faculty of Science, University of Milan. Course: "Numerical Methods for Partial Differential Equations", Master degree in Mathematics.

2014-2015
- Teaching Assistant, Faculty of Science, University of Milan. Course: "Biomathematics", Master degree in Mathematics.
- Lecturer, Faculty of Pharmacy, University of Milan. Course: "Mathematics and Statistics", Bachelor degree in Chemical Safety and Toxicological Environmental Sciences.
- Teaching Assistant, Faculty of Science, University of Milan. Course: "Numerical Analysis", Bachelor degree in Chemistry.

2013-2014
- Teaching Assistant, Faculty of Science, University of Milan. Course: "Numerical Analysis", Bachelor degree in Chemistry.
- Teaching Assistant, Faculty of Science, University of Milan. Course: "Numerical Methods for Partial Differential Equations", Master degree in Mathematics.

2012-2013
- Teaching Assistant, Faculty of Science, University of Milan. Course: Numerical Analysis, Bachelor degree in Mathematics.

- Lecturer, Faculty of Pharmacy, University of Milan. Course: "Mathematics and Statistics", Bachelor degree in Chemical Safety and Toxicological Environmental Sciences.

2011-2012
- Teaching assistant of Numerical Analysis (48 hours), Bachelor of Chemistry, University of Milan
- Mathematical Modeling (24 hours), Master of Applied Mathematics, University of Milan

2010-2011
- Teaching assistant of Numerical Analysis (24 hours), Bachelor of Chemistry, University of Milan
- Teaching assistant of Biomathematics (24 hours), Master of Applied Mathematics, University of Milan
- Teaching assistant of Numerical Methods for PDEs (34 hours), Master of Applied Mathematics, University of Milan

2009-2010
- Teaching assistant of Numerical Analysis (48 hours), Bachelor of Chemistry, University of Milan

2008-2009
- Teaching assistant of Numerical Analysis I (48 hours), Bachelor of Mathematics, University of Milan
- Mathematical Modeling (12 hours), Master of Applied Mathematics, University of Milan
- Teaching assistant of Mathematical Analysis A, Bachelor of Engineering, University of Pavia

2007-2008
- Teaching assistant of Mathematical Analysis A, Bachelor of Engineering, University of Pavia
- Teaching assistant of Calculus I, Bachelor of Biology, University of Pavia

2006-2007
- Teaching assistant of Calculus I, Bachelor of Biology, University of Pavia

2005-2006
- Teaching assistant of Calculus I, Bachelor of Biology, University of Pavia
- Teaching assistant of Numerical Analysis, Bachelor of Chemistry, University of Pavia
- Teaching assistant of Calculus I, Bachelor of Scienze Naturali, University of Pavia

ADVISOR ACTIVITY

- Co-advisor of the PhD student Lorenzo Mascotto, PhD program in Mathematics, University of Milan, 2018. Title: "The HP version of the Virtual Element Method".
- Co-advisor of the PhD student Fabrizio Del Bianco, PhD program in Biomedical Engineering, University of Pavia, 2017. Title: "Simulating the electromechanical response of the cardiac tissue: insights on pathophysiology and tissue engineering".
- Advisor of a total of 15 Master theses in Mathematics:
  - (15) Silvia Caligari. Title: "Numerical Simulations of Brugada Syndrome in Three-dimensional Models of Right Ventricular Tissue". April 8, 2019.
  - (14) Alessandro Landoni. Title: "BDDC preconditioners with deluxe scaling for the cardiac Bidomain model". February 27, 2019.
  - (13) Ngoc Mai Monica Huynh. Title: "Non-linear FETI-DP methods for reaction-diffusion systems". April 11, 2018.

(12) Erica Nicchio. Title: "Precondizionatori di Schwarz per discretizzazioni Virtual Element del modello Monodominio" April 11, 2018.

(11) Fjorela Gegaj. Title: "Numerical approximation of incompressible Navier-Stokes equations using a mixed finite element method". Febraury 28, 2018.

(10) Chiara Laura. Title: "Simulazioni numeriche parallele di aritmie cardiache connesse alla sindrome del QT lungo in modelli tridimensionali di ventricolo sinistro". September 27, 2017.

(9) Valeria Luppi. Title: "Implementazione parallela di elementi finiti Q^2 per un modello di accoppiamento elettro-meccanico cardiaco". October 19, 2016.

(8) Arianna Zanette. Title: "Precondizionatori Additive Schwarz e a blocchi per la meccanica cardiaca". September 26, 2016.

(7) Chiara Proverbio. Title: "Precondizionatori BDDC per l'accoppiamento elettromeccanico cardiaco in forma mista". February 24, 2016.

(6) Federica Casale Rossi. Title: "Precondizionatori BDDC per il metodo degli elementi virtuali". February 24, 2016.

(5) Muhammad H. Kabir. Title: "A tridomain model for myocyte-fibroblast electrical coupling in a cardiac fiber". April 15, 2015.

(4) Federica M. Sandri. Title: "Precondizionatori BDDC per l'analisi isogeometrica del problema dell'elasticità lineare". February 25, 2015.

(3) Claudia Matrone. Title: "Metodo degli elementi virtuali per il modello Bidominio dell'elettrocardiologia". July 21, 2014.

(2) Mohamed Jebini. Title: "Operator splitting methods for the Monodomain model of electrocardiology". April 9, 2014.

(1) Daniela Ottino. Title: "Precondizionatore BPX per il modello Bidominio dell'elettrocardiologia". October 17, 2013.

AWARDS

Best Paper Award presented at the *Fifth International Conference on Functional Imaging and Modeling of the Heart (FIMH 2009)*, Nice (France), June 3rd-5th, 2009, for the paper *Effects of anisotropy and transmural heterogeneity on the T-wave polarity of simulated electrograms*, coauthored with P. Colli Franzone, L. F. Pavarino and B. Taccardi.

EDITORIAL AND COMMITTEE ACTIVITY

- Reviewer for the following international journals: Numerische Mathematik, Computer Methods in Applied Mechanics and Engineering, Mathematical Biosciences, Journal of Computational Physics, Europace, Medical & Biological Engineering & Computing, SIAM Journal on Scientific Computing, Computers in Medicine and Biology, Computational and Mathematical Methods in Medicine, Chaos, PLOS ONE, International Journal of Numerical Methods in Biomedical Engineering, Frontiers in Physiology, Mathematical Modeling of Natural Phenomena, Computers and Mathematics with Applications, Medical Engineering & Physics, Applied Mathematics and Computation.
- Reviewer of 2 PhD theses: Diana Bonomi (Polytechnic of Milan, 2017), Nicola Giuliani (Sissa Trieste, 2017).
- Member of the PhD committee of the Department of Mathematics, University of Milan, Italy.

ORGANIZING ACTIVITY

- Co-organizer of the International Workshop "Mathematical and Numerical Modeling of the Cardiovascular System", April 16-19, 2018, Istituto Nazionale di Alta Matematica (INdAM), Rome, Italy. (about 50 participants)
- Co-organizer of the International Conference "European Finite Element Fair 2017", May 26-27, 2017, University of Milan, Italy. (about 100 participants)
- Co-organizer of the International Conference "Mathematical and Numerical Modeling of the Cardiovascular System and Applications", February 21-22, 2017, University of Pavia, Italy. (about 80 participants)
- Co-organizer of eight Minisymposia at International Conferences.

FUNDING ID

On-going grants

Project 12	Project title	Adaptive BDDC preconditioners for the Bidomain model
	Funding source	University of Milan
	Amount (Euros)	2500
	Period	1/6/2018-31/12/2019
	Role	PI
Project 11	Project title	Numerical assessment of cardiac non-invasive mechanical markers of electrical activation
	Funding source	CINECA supercomputing laboratory
	Amount (CPU hours)	35000
	Period	7/2/2019-7/11/2019
	Role	PI

Past grants

Project 10	Project title	Non-overlapping domain decomposition methods for isogeometric analysis of the Stokes system
	Funding source	University of Milan
	Amount (Euros)	2500
	Period	1/11/2017-31/12/2018
	Role	PI
Project 9	Project title	Dual-Primal methods for cardiac electro-mechanical simulations of ventricular arrhythmias
	Funding source	CINECA supercomputing laboratory
	Amount (CPU hours)	50000
	Period	11/04/2018-11/01/2019
	Role	PI
Project 8	Project title	Scalable solvers for electro-mechanical simulations of human left ventricles affected from infarct scars
	Funding source	CINECA supercomputing laboratory
	Amount (CPU hours)	50000
	Period	6/07/2017-6/04/2018
	Role	PI
Project 7	Project title	Domain decomposition methods for mixed finite element discretizations of cardiac mechanics
	Funding source	University of Milan
	Amount (Euros)	2500
	Period	01/11/2016-31/12/2017
	Role	PI
Project 6	Project title	Scalable preconditioners, high order time integration schemes and immersed boundary methods for computational electrocardiology
	Funding source	Istituto Nazionale di Alta Matematica (INdAM)
	Amount (Euros)	4100
	Period	03/02/2016-02/02/2017
	Role	PI
Project 5	Project title	Scalable preconditioners for the cardiac electro-mechanical coupling
	Funding source	University of Milan
	Amount (Euros)	2500
	Period	01/11/2015-31/12/2016
	Role	PI
Project 4	Project title	Domain Decomposition methods for Isogeometric Analysis
	Funding source	University of Milan
	Amount (Euros)	3000
	Period	01/11/2014-31/12/2015
	Role	PI

Project 3	Project title	Isogeometric analysis for the cardiac electro-fluid-mechanical coupling
	Funding source	Istituto Nazionale di Alta Matematica (INdAM)
	Amount (Euros)	3500
	Period	17/02/2014-16/02/2015
	Role	PI
Project 2	Funding source	University of Milan
	Amount (Euros)	4500
	Period	2009-2011
	Role	PI
Project 1	Funding source	Istituto Nazionale di Alta Matematica (INdAM)
	Amount (Euros)	2000
	Period	2008-2009
	Role	PI

PLENARY LECTURES

[1] *Scalable multilevel preconditioners for cardiac electro-mechanics.* 24th International Conference on Domain Decomposition Methods (DD24). February 6-10, 2017, Longyearbyen, Norway.

CONFERENCE TALKS

[30] *Block FETI-DP Preconditioners for Isogeometric Discretizations of Three-dimensional Stokes Equations.* Finite Elements in Fluids (FEF 2019). March 31-April 3, 2019, Chicago, USA.

[29] *BDDC preconditioners for isogeometric analysis of scalar elliptic problems.* International Conference on Isogeometric Analysis (IGA 2017). September 11-13, 2017, Pavia, Italy.

[28] *A conforming virtual element method for the two-dimensional Cahn-Hilliard model.* Workshop on Polytopal Element Methods in Mathematics and Engineering (POEMS 2017). July 5-7, 2017, Milano, Italy.

[27] *BDDC Preconditioners for Isogeometric Analysis.* Workshop on Domain Decomposition: Past, Present and Future. February 24-25, 2017, New York, USA.

[26] *Scalable Newton-Krylov-BDDC methods for cardiac electromechanics.* The Mathematics of Finite Elements and Applications (MAFELAP 2016). July 14-17, 2016, Uxbridge, UK.

[25] *Influence of Mechano-Electric Feedbacks on the cardiac bioelectrical activity: a simulation study.* European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2016). June 5-10, 2016, Crete Island, Greece.

[24] *High performance computing for computational electrocardiology: scalable solvers.* MHPC Workshop on High Performance Computing. February 24-26, 2016, Trieste, Italy.

[23] *Precondizionatori scalabili per l'accoppiamento elettromeccanico cardiaco.* Congresso dell'Unione Matematica Italiana (UMI 2015). September 7-12, 2015, Siena, Italy.

[22] *BDDC Preconditioners for Cardiac Electromechanics.* 8th International Congress on Industrial and Applied Mathematics (ICIAM 2015). August 10-14, 2015, Beijing, China.

[21] *Scalable preconditioners for cardiac electromechanics and applications.* Coupled Problems 2015. May 18-20, 2015, Venice, Italy.

[20] *Domain Decomposition methods for Isogeometric Analysis and applications to computational electrocardiology.* Workshop on PDE's and Biomedical Applications. December 4-6, 2014, Lisbon, Portugal.

[19] *Scalable multilevel preconditioners for the cardiac electro-mechanical coupling.* 22nd International Conference on Domain Decomposition Methods (DD22). September 16-20, 2013, Lugano, Switzerland.

[18] *Parallel Solvers for the Cardiac Electro-Mechanical Coupling.* COUPLED PROBLEMS 2013. June 17-19, 2013, Ibiza, Spain.

[17] *Parallel Multilevel Solvers for the Cardiac Electro-Mechanical Coupling.* 4th Chilean Workshop on Numerical Analysis of Partial Differential Equations (WONAPDE 2013). January 14-18, 2013, Concepcion, Chile.

[16] *A BDDC preconditioner for Isogeometric Analysis of elliptic problems.* 10th World Congress on Computational Mechanics (WCCM 2012). July 8-13, 2012, San Paolo, Brazil.

[15] *Parallel Bidomain solvers for cardiac excitation.* 21st International Conference on Domain Decomposition Methods (DD21). June 25-29, 2012, Rennes, France.

[14] *Precondizionatori paralleli a blocchi per il sistema Bidominio dell'elettrocardiologia.* 19th Congress of Unione Matematica Italiana (UMI 2011). September 12-17, 2011, Bologna, Italy.

[13] *The anisotropic Bidomain model of electrocardiology: a comparison of coupled and uncoupled parallel preconditioners.* 8th European Conference on Mathematical and Theoretical Biology (ECMTB 2011). June 28-July 2, 2011, Krakow, Poland.

[12] *Parallel Block Preconditioners for the Bidomain Model of Electrocardiology.* 4th International Conference on Computational Methods for Coupled Problems in Science and Engineering (Coupled Problems 2011). June 20-22, 2011, Kos Island, Greece.

[11] *Anode make and break excitation mechanisms and strength-interval curves: bidomain simulations in 3D rotational anisotropy.* 6th International Conference on Functional Imaging and Modeling of the Heart (FIMH 2011). May 25-27, 2011, New York, USA.

[10] *Parallel Bidomain preconditioners for cardiac excitation.* 8th International Conference on Numerical Analysis and Applied Mathematics (ICNAAM 2010). September 19-25, 2010, Rhodes, Greece.

[9] *A multilevel Newton-Krylov-Schwarz method for the Bidomain system.* SIMAI 2010 Conference. June 21-25, 2010, Cagliari, Italy.

[8] *Scalable preconditioners for the bidomain model of electrocardiology and applications to ischemic pathological modeling.* IV International Symposium on Modeling of Physiological Flows. June 2-5, 2010, Chia Laguna (Cagliari), Italy.

[7] *A multilevel Newton-Krylov-Schwarz method for the Bidomain reaction-diffusion system.* SIAM Conference on Parallel Processing & Scientific Computing (PP10). February 24-26, 2010, Seattle, USA.

[6] *A scalable two-level Newton-Krylov-Schwarz method for the Bidomain system of electrocardiology.* Prospettive di sviluppo della matematica applicata in Italia 2009. Convegno SIMAI in memoria di Angelo Marcello Anile. October 9, 2009, Rome, Italy.

[5] *Anisotropic dynamical modeling of the mechanisms of the ST and QT segment during subendocardial ischemia.* World Congress on Medical Physics and Biomedical Engineering. September 7-12, 2009, Munich, Germany.

[4] *A two-level Newton-Krylov-Schwarz method for the Bidomain reaction-diffusion system.* 8th European Conference on Numerical Mathematics and Advanced Application (ENUMATH 2009). June 29-July 3, 2009, Uppsala, Sweden.

[3] *Effects of anisotropy and transmural heterogeneity on the T-wave polarity of simulated electrograms.* 5th International Conference on Functional Imaging and Modeling of the Heart (FIMH 2009). June 3-5, 2009, Nice, France.

[2] *Performance evaluation of cardiac repolarization markers derived from monophasic action potentials and unipolar electrograms: a simulation study.* Computers in Cardiology 2008. September 14-17, 2008, Bologna, Italy.

[1] *Multilevel Schwarz and Multigrid preconditioners for the Bidomain system.* 17th International Conference on Domain Decomposition Methods. July 3-7, 2006, St. Wolfgang/Strobl, Austria.

SEMINAR TALKS

[10] *Effects of mechano-electric feedbacks on the cardiac bioelectrical activity.* USI Lugano. May 9, 2017, Lugano, Switzerland.

[9] *Effects of mechano-electric feedback on the cardiac bioelectrical activity: a simulation study.* Courant Institute. March 7, 2017, New York, USA.

[8] *Finite element solvers in computational electrocardiology.* Gent University. April 4, 2016, Gent, Belgium.

[7] *Non-Overlapping Domain Decomposition preconditioners for Isogeometric Analysis.* NIMS Summer School on Isogeometric Analysis. July 10-12, 2013, Daejeon, South Korea.

[6] *Precondizionatori di Schwarz multilivello in elettrocardiologia computazionale.* MOX, Politecnico di Milano. November 4th, 2008, Milan, Italy.

[5] *Parallel simulations of normal and pathological cardiac tissue: effects of a subendocardial ischemic region.* Summer school "Mathematical and numerical models for the cardiovascular system." August 25th, 2008, Cortona, Italy.

[4] *Parallel simulations of normal and pathological cardiac tissue: activation and repolarization extra-cellular markers.* Summer school "Mathematical and numerical models for the cardiovascular system." August 25th, 2008, Cortona, Italy.

[3] *Simulazioni parallele di patologie ischemiche subendocardiche.* Department of Biology, University of Parma. March 27th, 2008, Parma, Italy.

[2] *Precondizionatori di Schwarz multilivello per il sistema Bidominio e applicazioni in elettrocardiologia.* Department of Mathematics, University of Pavia. July 13th, 2007, Pavia, Italy.

[1] *Dynamical effects of myocardial ischemia in anisotropic cardiac models in three dimensions.* Konrad-Zuse-Zentrum fuer Informationstechnik Berlin. May 29th, 2007, Berlin, Germany.

PUBLICATIONS

My research activity focuses on numerical methods for partial differential equations. Since the beginning of my career, I have worked on the construction, analysis and numerical validation of domain decomposition methods for the Bidomain model of electrocardiology. The parallel code developed, based on such methods, have made it possible for the first time large scale accurate Bidomain simulations of the entire ventricular bioelectrical activity during a heartbeat. When I became Assistant Professor, I have started working on domain decomposition methods for isogeometric analysis of elliptic problems. These works yielded the first scalable preconditioners in the field of isogeometric analysis. Since the last four years, I have started working on cardiac mechanics and I have focused in particular on the development of scalable solvers for non-linear elasticity systems arising from these models and on the modeling and simulation of mechanical feedback on the cardiac bioelectrical activity. In the last years, I have also worked on the development of the recent virtual element method, applied in particular to the Cahn-Hilliard equation and to topology optimization problems.

CITATION RECORD (March 2019)

- h-index: 12 (Web of Science), 14 (Scopus), 10 (MathSciNet), 19 (Google Scholar).
- Total citation counts: 494 (Web of Science), 563 (Scopus), 332 (MathSciNet), 1058 (Google Scholar).

Detailed description of the research activity

- **Multilevel Schwarz preconditioners for the Bidomain model of electrocardiology (publications [a4,a5,a9,a11,a13,a18])**

  In this series of papers, some in collaboration with Luca F. Pavarino (University of Pavia) and Marilena Munteanu (Banca Intesa San Paolo), we studied and developed Overlapping Schwarz Domain Decomposition methods for the solution of the large-scale and ill-conditioned linear systems arising from the discretization by finite elements in space and semi-implicit finite differences in time of the Bidomain model of electrocardiology. This model consists of a reaction-diffusion system of parabolic non-linear Partial Differential

Equations, coupled with a system of stiff Ordinary Differential Equations. The linear systems are solved by the Conjugate Gradient method preconditioned by Domain Decomposition techniques, in particular the Multilevel Additive or Hybrid Schwarz preconditioners. Scalability and optimality estimates were theoretically established and validated by numerical tests, through the implementation of a FORTRAN code based on the MPI and PETSc parallel libraries. Numerical tests were performed on LINUX cluster up to 30000 processors.

- **Dynamical effects of myocardial ischemia in anisotropic cardiac models in three-dimensions (publication [a2])**

  In this study, in collaboration with Piero Colli Franzone (University of Pavia) and Luca F. Pavarino (University of Pavia), we investigated the interaction between the presence of moderate or severe subendocardial ischemic regions and the anisotropic structure of the cardiac muscle, by means of numerical simulations based on anisotropic Bidomain and Monodomain models. The ischemic effects on cardiac excitation, recovery and distribution of action potential duration are discussed, showing the presence of ischemic epicardial markers. Extracellular potential distributions during the ST and TQ intervals are computed separately using non-stationary models. During the ST interval, the extracellular potential patterns differ from those simulated with stationary models used in the literature. These differences are explained by decomposing the cardiac current sources into conormal, axial and orthogonal components and by determining which component is dominant during the ST and TQ intervals.

- **Theoretical validation of extracellular markers of cardiac repolarization time (publications [a1,a3,a8,a10])**

  In these two papers, in collaboration with Piero Colli Franzone (University of Pavia), Luca F. Pavarino (University of Pavia) and Bruno Taccardi (University of Utah), we investigated theoretically, by means of numerical simulations, the reliability of extracellular markers of cardiac repolarization time. The mathematical model adopted for the simulation of the cardiac bioelectrical activity was the Bidomain model of electrocardiology, solved by our parallel finite element code, based on highly scalable Domain Decomposition preconditioners. The main novelty of this study was to have shown, in both normal and pathological situations, that markers of repolarization time, derived from measurements of extracellular potential, are reliable estimates of the *gold-standard* repolarization time, derived from the transmembrane action potential, that can not be measured *in vivo*.

- **Effects of cardiac tissue anisotropy and cellular heterogeneities on the T wave of electrocardiograms (publications [b1,a7])**

  In this series of papers, in collaboration with Piero Colli Franzone (University of Pavia), Luca F. Pavarino (University of Pavia) and Bruno Taccardi (University of Utah), we studied by means of numerical simulations the effects of cardiac tissue anisotropy, due to fiber rotation and presence of *gap junctions*, and of transmural cellular heterogeneities, due spatial modulations of some ionic currents, on the origin of the T wave in the electrocardiogram. The mathematical model adopted for the simulation of the cardiac bioelectrical activity was the Bidomain model of electrocardiology, coupled with the Laplace equation for the electrical activity of the torso. The main novelty of this study was to have shown that cardiac tissue anisotropy, neglected by the classical theory of electrocardiogram, might explain the presence of positive T wave, even in presence of realistic cellular heterogeneities, more in agreement with experimental measurements than those typically used in previous simulation studies.

- **Three-dimensional numerical simulations of the cardiac virtual electrode phenomenon (publications [a12,a14])**

  In these two papers, in collaboration with Piero Colli Franzone (University of Pavia) and Luca F. Pavarino (University of Pavia), we investigated, by means of parallel three-dimensional simulations based on the Bidomain model electrocardiology, the cardiac excitation mechanisms associated with the phenomenon of *virtual electrode*. In case of extracellular cathodal stimulations, two excitation mechanisms might occur: *cathode make*, when the current is applied during diastole, or *cathode break*, when the current is applied during systole. In case of extracellular anodal stimulations instead, two further excitation mechanisms might occur: *anode make*, when the current is applied during diastole, or *anode break*, when the current is applied during systole. Our simulations showed, for the first time in a three-dimensional model, that, in presence of tissue anisotropy and low current intensity, both cathode break and anodel break excitation mechanisms might occur also in diastole. These findings validated some previously published controversial experimental results.

- **Domain Decomposition preconditioners for Isogeometric Analysis (publications [a15,a16,a17,a21,a22,a27,a34,a35])**

  In this series of papers, in collaboration with Lourenco Beirao da Veiga (University of Milano-Bicocca), Durkbin Cho (Dongguk University), Luca F. Pavarino (University of Pavia), Olof B. Widlund (Courant Institute) and Stefano Zampini (KAUST), we studied and developed Overlapping Additive Schwarz and Balancing Domain Decomposition by Constraints (BDDC) preconditioners for the solution of linear systems deriving from the discretization of elliptic and saddle point problems with spline and Non-Uniform Rational B-Spline (NURBS) functions, according to the Isogeometric Analysis paradigm. The scalability and optimality of these methods were established theoretically and validated by two- and three-dimensional numerical tests on domain geometries described by NURBS parameterizations. The numerical results also showed that the methods considered are robust with respect to discontinuity in the diffusion or elastic coefficients.

- **Parallel solvers for cardiac mechanics (publications [a24,a25,a37])**

  In this series of papers, in collaboration with Piero Colli Franzone (Univesrity of Pavia), Luca F. Pavarino (University of Pavia) and Stefano Zampini (KAUST), we developed a parallel solver for the non-linear elasticity system, describing the cardiac contraction and relaxation process. In this model, the myocardium is considered as a nearly-incompressible transversely isotropic or orthotropic hyperelastic material. The finite element discretizations of the finite elasticity equations yields at each time step the solution of a large scale non-linear system. The parallel solver developed consists of solving such algebraic non-linear system with a Newton-Krylov method, where the Jacobian system at each Newton iteration is solved by GMRES preconditioned by Algebraic Multigrid or BDDC preconditioners. Three-dimensional parallel numerical tests on Linux clusters showed the scalability of the proposed non-linear solver.

- **Effects of mechano-electric feedbacks on the cardiac bioelectrical activity (publications [a26,a28,a31,a32,a36])**

  In this series of papers, in collaboration with Piero Colli Franzone (Univesrity of Pavia), Fabrizio Del Bianco (University of Pavia), Lorenzo Fassina (University of Pavia) and Luca F. Pavarino (University of Pavia), we investigated the influence of tissue deformation on the cardiac bioelectrical activity. We developed a three-dimensional strongly coupled electromechanical Bidomain model posed on an ideal monoventricular geometry, including fiber direction anisotropy and stretch-activated currents (SACs). The cardiac mechanical deformation influences the bioelectrical activity with two main mechanical feedback: (a) the geometric feedback (GEF) due to the presence of the deformation gradient in the diffusion coefficients and in a convective term depending on the deformation rate and (b) the mechano-electric feedback (MEF) due to SACs. We investigated the relative contribution of these two factors both in normal tissue and pathological situations, such as hypertrophy and ventricular tachycardia.

- **A C^1 Virtual Element method for the Cahn-Hilliard equation with polygonal meshes (publication [a29])**

  In this paper, in collaboration with Paola F. Antonietti (Politecnico of Milan), Lourenco Beirao da Veiga (University of Milano-Bicocca) and Marco Verani (Politecnico of Milan), we introduced and analyzed a C^1 virtual element method (VEM) for the approximate solution of the CahnHilliard equation. VEM is a recently introduced numerical method for the approximation of Partial Differential Equations, characterized by the capability of dealing with very general polygonal/polyedral meshes and the possibility of easily implementing highly regular discrete spaces. Indeed, by avoiding the explicit construction of the local basis functions, the VEM can easily handle general polygons/polyhedrons without complex integrations on the element. The proposed method has the advantage of being conforming in H^2 and making use of a very simple set of degrees of freedom, namely, three degrees of freedom per vertex of the mesh. Moreover, although the present method is new also on triangles, it can make use of general polygonal meshes. As a theoretical and practical support, we proved the convergence of the semidiscrete scheme and investigated the performance of the fully discrete scheme through a set of numerical tests

- **On the virtual element method for topology optimization on polygonal meshes: A numerical study (publication [a30])**

  This study was a joint work with Paola F. Antonietti (Politecnico of Milan), Matteo Bruggi (Politecnico of Milan) and Marco Verani (Politecnico of Milan). It is well known that the solution of topology optimization problems may be affected both by the geometric properties of the computational mesh, which can steer the minimization process towards local (and non-physical) minima, and by the accuracy of the method employed to discretize the underlying differential problem, which may not be able to correctly capture the physics of the problem. In light of the above remarks, in this paper we considered polygonal meshes and employed the virtual element method (VEM) to solve two classes of paradigmatic topology optimization problems, one governed by nearly incompressible and compressible linear elasticity and the other by Stokes equations. Several numerical results showed the virtues of our polygonal VEM based approach with respect to more standard methods.

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