# Curriculum Vitae et Studiorum
Christian Vergara

Professor in Numerical Analysis at LABS - Dipartimento di Chimica, Materiali e Ingegneria Chimica "Giulio Natta"
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## 1 Personal information

### Personal Data

Born in Trento (Italy), February 13, 1976
Italian Citizenship
Married, two daughters
ORCID identifier: https://orcid.org/0000-0001-9872-5410

### Education

**July 1995.** Liceo Scientifico "G. Galilei", Trento (Italy). Graduated from high school (scientific oriented). Mark: 58/60.

**June 14, 2002.** Graduated in Biomedical Engineering, Politecnico di Milano, Italy, 5 years degree curriculum, final mark: 93/100. Advisor: A. Veneziani.

**April 28, 2006.** PhD in Mathematical Engineering, Dipartimento di Matematica, Politecnico di Milano, Italy. Title of the thesis: "Numerical Modeling of Defective Boundary Problems in Incompressible Fluid-Dynamics - Applications to Computational Haemodynamics". Advisor: A. Veneziani. Final mark: *A cum laude*.

### Current Academic Position

**March 1, 2021 - onwards.** Professor in Numerical Analysis (MAT/08) at LABS – Laboratory of Biological Structure Mechanics, Dipartimento di Chimica, Materiali e Ingegneria Chimica "Giulio Natta", Politecnico di Milano, Italy.

### Past Academic Positions

**June 1, 2006 - October 31, 2006.** Postdoctoral fellow at CMCS - Ecole Polytecnique Federale de Lausanne (EPFL). Assistant of A. Quarteroni.

**November 1, 2006 - April 30, 2007.** Postdoctoral fellow at MOX, Dipartimento di Matematica, Politecnico di Milano (Italy). Project: *Modellistica Matematica di Materiali Microstrutturati per Dispositivi a Rilascio di Farmaco*, funded by Fondazione Cariplo.

**May 1, 2007 - October 31, 2007.** Postdoctoral fellow at MOX, Dipartimento di Matematica, Politecnico di Milano (Italy). Project: *Modellazione multiscala di distretti venosi*, funded by Policlinico di Milano.

**November 1, 2007 - February 15, 2015.** Assistant Professor in Numerical Analysis (MAT/08) at Dipartimento di Ingegneria Gestionale, dell'Informazione e della Produzione, Università degli Studi di Bergamo, Italy.

**February 16, 2015 - December 31, 2018.** Associate Professor in Numerical Analysis (MAT/08) at MOX – Laboratory for Modeling and Scientific Computing, Dipartimento di Matematica, Politecnico di Milano, Italy.

**January 1, 2019 - February 28, 2021.** Associate Professor in Numerical Analysis (MAT/08) at LABS – Laboratory of Biological Structure Mechanics, Dipartimento di Chimica, Materiali e Ingegneria Chimica "Giulio Natta", Politecnico di Milano, Italy.

### Foreign Languages

**English.** Good written and oral knowledge.

## 2 Teaching Activity

### Current activity - A.Y. 2022-2023

- Lecturer. Mathematical and Numerical Methods for Engineering - section Numerical Methods. MSc in Biomedical and Nuclear Engineering. Politecnico di Milano (42 hours).
- Lecturer. Advanced numerical methods for coupled problems with application to living systems. MSc in Mathematical Engineering. Politecnico di Milano (52 hours).
- Lecturer. Calcolo Numerico. BSc in Biomedical Engineering. Politecnico di Milano (30 hours).

### Past activity

#### Lecturer

- 10× Calcolo Numerico [$'07 -' 08 \rightarrow' 14 -' 15/'18 -' 19 \rightarrow' 19 -' 20$]. MSc in Engineering. Universita' degli Studi di Bergamo (32 hours)
- 5 × Geometria e Algebra Lineare - sezione di Metodi Numerici [$'10 -' 11 \rightarrow' 14 -' 15$]. BSc in Civil, Mechanical, Information and Financial Engineering. Università degli Studi di Bergamo (42 hours).
- 10 × Mathematical and Numerical Methods for Engineering - section Numerical Methods [$'12 -' 13 \rightarrow' 21 -' 22$]. MSc in Biomedical and Nuclear Engineering. Politecnico di Milano (42 hours);
- 4 × Curve e superfici per il Design [$'15 -' 16 \rightarrow' 18 -' 19$]. BSc in Design della Comunicazione. Politecnico di Milano (32 hours);
- 4 × Calcolo Numerico [$'17 -' 18, '19 -' 20 \rightarrow' 21 -' 22$]. BSc in Biomedical Engineering. Politecnico di Milano (30 hours);
- 4 × Advanced numerical methods for coupled problems with application to living systems [$'18 -' 19 \rightarrow' 21 -' 22$]. MSc in Mathematical Engineering. Politecnico di Milano (52 hours).

#### Lecturer for PhD Courses

- 10 × Numerical Methods for Engineering [$'07 -' 08 \rightarrow' 10 -' 11/'16 -' 17 \rightarrow' 21 -' 22$]. PhD programme in "Research in Technologies for the Energy and the Environment" (4x30 hours) and in "Engineering and Applied Sciences" (4x20 hours). Università di degli Studi Bergamo;
- 9 × Lecturer within the PhD course Cardiovascular Mathematics [$'11 -' 12 \rightarrow' 14 -' 15/'16 -' 17 \rightarrow' 20 -' 21$] . Doctoral program in "Mathematical models and methods in Engineering". Politecnico di Milano (1 x 6, 2 x 9, 4 x 10 and 2 x 12 hours);
- 4 × Numerical Methods for Fluid Structure Interaction [$'18 -' 19 \rightarrow' 21 -' 22$] . Doctoral program in "Mathematical models and methods in Engineering". Politecnico di Milano (25 hours).
- Lecturer within the PhD course Mathematical and Numerical Modelling of the Human Cardiovascular System [$'20 -' 21$]. Doctoral program in "Scienza Matematiche". Universita' degli Studi di Padova (10 hours).

#### Head Assistant

24 times as head assistant in courses of Numerical Analysis (2003-2016).

### Other teaching activities

**1.** Head assistant and responsible of the laboratories at the Summer School "Mathematical Modelling and Computation: The Fluid-Structure Interaction problem", held at the Institute of Computational Mathematics, Academy of Maths and Systems Sciences, Beijing, China (18 hours). Lecturer: F. Nobile. August 02-14, 2010.

**2.** Lecturer of the mini-course "Numerical solution of fluid-structure interaction problems in haemodynamics", within the Intensive Programme "If Fluid-dynamics turns to Biology", L'Aquila, Italy (9 hours). July 03-05, 2013.

**3.** Collaborator, lecturer and responsible of laboratories for the course "Integrated models for computational medicine - Geometrical multiscale models of the cardiovascular system", Cortona (AR), Italy. July 20-25, 2015. Lecturer: L. Formaggia.

**4.** Lecturer of the lesson "Heterogeneous Domain Decomposition for Cardiovascular Problems" (1 hour) within the "Summer school on advanced DD methods", MOX, Dipartimento di Matematica, Politecnico di Milano. November 24-26, 2021.

## 3 Research Activity

### Research Interests

**Main research field.** Numerical discretization of partial differential equations, numerical algorithms for the fluid-structure interaction problem, geometric multiscale modeling of the cardiovascular system, computational hemodynamics for clinical applications, numerical modeling of the heart function, Optimized Schwarz Method, Finite Elements methods for unfitted meshes, numerical modeling of atheromasic plaque progression.

**Main keywords.** Defective boundary conditions, partitioned algorithms for the fluid-structure interaction, added mass effect, geometric multiscale approach, Lagrange multipliers, Nitsche method, Optimized Schwarz Method, Extended Finite Elements, Large Eddy simulations, cardiovascular parameter estimation, bicuspid aortic valve, human carotid arteries, abdominal aortic aneurysms, stenotic coronaries, Purkinje network, data-driven cardiac fluid-dynamics and electro-physiology, cardiac perfusion, plaque progression.

### National scientific qualifications

1. National scientific qualification as Associate Professor in Numerical Analysis, 2013;
2. National scientific qualification as Full Professor in Numerical Analysis, 2016;

### Honors and Awards

1. "Young Researcher Prize" at the 5th European Symposium of Vascular Biomaterials held in Strasbourg, France, 26 - 27 April 2007. Title of the study: "Computer modelling of stent implantation: expansion, fluid-dynamics and drug release" by F. Gervaso, C. Capelli, R. Balossino, C. Vergara, P. Zunino and F. Migliavacca;
2. Winner of the prize "Anile - INDAM-SIMAI 2009" for the best Italian Ph.D. thesis in applied mathematics in the period 2006-2008;
3. Winner of a funding of 1500 Euro for the best research activity at Dipartimento di Ingegneria dell'Informazione e Metodi Matematici, Università degli Studi di Bergamo. 2011;
4. Winner of the prize "Gian Giacomo Drago e Fausta Rivera Drago 2015/2016 for an under 40 researcher who gave important contributions in mathematical methods for medicine". Istituto Lombardo Accademia di Scienze e Lettere;

## Collaborations

**2003-onwards.** Veneziani A. (Department of Mathematics and Computer Science, Emory University, Atlanta), Formaggia L. (MOX, Dipartimento di Matematica, Politecnico di Milano) and Zunino P. (MOX, Dipartimento di Matematica, Politecnico di Milano). Defective boundary conditions in incompressible fluid-dynamics and for the fluid-structure interaction problems;

**2004-onwards.** Formaggia L., Quarteroni A. (MOX, Dipartimento di Matematica, Politecnico di Milano, and CMCS, MATHICSE, Ecole Polytecnique Federale de Lausanne) and Veneziani A. Geometric multiscale modeling of the cardiovascular tree;

**2005-2010.** Redaelli A. (Dipartimento di Bioingegneria, Politecnico di Milano), Ponzini R. (Cineca, Milano), Veneziani A., Parodi O. (ex CNR, Pisa). Flow rate estimation based on Doppler technique;

**2006-2009.** Zunino P., C. D'Angelo. Mathematical modeling of drug release from stents;

**2006-onwards.** Nobile F. (CMCS, MATHICSE, Ecole Polytecnique Federale de Lausanne, Switzerland), Badia S. (Universitat Politica de Catalunya), L. Gerardo-Giorda (Basque Center for Applied Mathematics). Developments and analysis of new algorithms for the fluid-structure interaction problem;

**2007-2011.** Domanin M. (MD, Division of Vascular Surgery, Policlinico di Milano), Passerini T., Veneziani A. and Formaggia L. Mathematical modeling of the venous tree;

**2008-2009.** Corno A. (MD, Alder Hey Children Hospital, Liverpool), Passerini T., Veneziani A., Formaggia L. and Quarteroni A. Numerical study of the assisted Fontan procedure;

**2008-onwards.** Domanin M., Biondetti G. and Forzenigo L. (MD, Division of Radiology, Policlinico di Milano), Trimarchi S. (MD, Director of Division of Vascular Surgery, Policlinico di Milano), Casana R (Istituto Auxologico, Milan), Antiga L. (Orobix s.r.l - Bergamo), Piccinelli M., Faggiano E. (University of Pavia, Italy), Morbiducci U. and Gallo D. (Politecnico di Torino). Patient specific computational studies with imaging processing of the blood flow in the abdominal aorta and in the carotids;

**2008-onwards.** Antiga A., Faggiano E., Luciani G. (MD, Division of Cardio-surgery, Ospedale Borgo Trento, Verona), Puppini G. (MD, Division of Radiology, Ospedale Borgo Trento, Verona), and Redaelli A. Patient specific computational studies of the blood flow in the aorta in presence of a bicuspid aortic valve;

**2009-2011** Perego M. (Florida State University) and Veneziani A. Parameter estimation in cardiovascular mathematics;

**2012-onwards** Scrofani R. (Cardiosurgery Division, Ospedale Sacco, Milan), Ippolito S. (Radiology Division, Ospedale Sacco, Milan). Patient-specific computational studies of stentless aortic valves and multiple coronary by-passes;

**2012-onwards.** Catanzariti D., Del Greco M., Maines M. (MD, Division of Cardiology, Ospedale S. Maria del Carmine, Rovereto (TN), Italy), Centonze M. (MD, Director of Division of Diagnostic Radiology, Presidio Ospedaliero di Borgo Valsugana (TN), Italy), Faggiano E., Nobile F. Numerical modelling of the electrical activity of the heart for the study of the ventricular dyssynchrony;

**2012-onwards** Gigante G. (Università degli Studi di Bergamo). Optimized Schwarz Methods for elliptic problems and fluid-structure interaction;

**2013-2016** Frangi A. and his group (Sheffield University). Computational electrocardiology with detailed Purkinje networks;

**2014-2016** Bose S. (Institute for Computational and Mathematical Engineering (ICME), Stanford University, Stanford (CA)), Valdettaro L. (MOX, Dipartimento di Matematica, Politecnico di Milano), Quadrio M. (Dipartimento di Ingegneria Aerospaziale, Politecnico di Milano). Large Eddy Simulation for hemodynamics;

**2015-onwards** Scardulla C. (ISMETT, Palermo), Pasta S. (Fondazione Ri.MED). Hemodynamics in presence of Flow Left Ventricular Assist Device;

**2015-onwards** Formaggia L., Antonietti P. and Verani M. (MOX, Dipartimento di Matematica, Politecnico di Milano). Unfitted method for fluid-structure interaction and contact;

**2017-onwards** Prouse G. and Giovannacci L. (EOC-Ente Ospedaliero Cantonale, Lugano, Switzerland). Hemodynamics for arteriovenous fistulae.

**2017-onwards** Pontone G, Baggiano A., Fusini L. (Centro Cardiologico Monzino) and Valbusa G (Bracco S.p.A). Modeling the cardiac perfusion.

**2017-2021** Corwave SA (Clichy, France). Fluid-structure interaction in wave membrane blood pump.

**2017-onwards** Quarteroni A., Dede' L., Fedele M. (MOX, Politecnico di Milano). Modeling and numerical approximation of the heart function.

**2018-2021** Tuveri M. (General and Pancreatic Surgery Unit, Pancreas Institute, University of Verona Hospital Trust). Hemodynamics in liver and pancreas.

**2019-onwards** Pontone G, Fusini L. (Centro Cardiologico Monzino) and I. Fumagalli (MOX). Modeling the and Transcatheter Aortic Valve Implantation (TAVI) procedure.

## Working groups

**2004 - 2019** Working in the project for the development of the 3D finite element library *LIFEV* (www.lifev.org). Leading partners: MOX, Dipartimento di Matematica, Politecnico di Milano - CMCS, Ecole Polytecnique Federale de Lausanne (EPFL) - INRIA, Rocquencourt and Université Paris-6 - Dept. of Mathematics and Computer Science, Emory University, Atlanta.

## International research fellowships

**1.** Long-term visiting professor (1 month), Istitute Henri-Poincare', Paris, FR. Research Fellowship given by Fondation Sciences Mathematiques de Paris, September 2016.

## Research visits

**1.** Department of Aeronautics, Imperial College, London, UK. Host of J. Peiró. August 7 - October 7, 2005.

**2.** Department of Mathematics and Computer Science, Emory University, Atlanta (GA), USA. Invited by A. Veneziani. August 31 - September 28, 2008.

**3.** Department of Mathematics and Computer Science, Emory University, Atlanta (GA), USA. Invited by A. Veneziani. September 4 - 19, 2010

**4.** Centre de Recerca Matematica, Facultat de Ciénces UAB, Barcelona, Spain. Invited by B. Ayuso. January 25-30, 2012

**5.** CMCS, Ecole Polytecnique Federale de Lausanne (EPFL), Switzerland. Invited by F. Nobile. November 25-26, 2013

**6.** CMCS, Ecole Polytecnique Federale de Lausanne (EPFL), Switzerland. Invited by F. Nobile. December 15-16, 2014

**7.** Johann Radon Institute RICAM, Linz, Austria. Invited by R. Ramlau. January 29, 2020.

## Research Funding and Grants

### Principal investigator or local coordinator

1. *Caritro research project* "Numerical modelling of the electrical activity of the heart for the study of the ventricular dyssynchrony". Funding agency: CARITRO. Budget: 48,405 Euros. January 2012 - June 2014. PI: D. Catanzariti. Role: scientific coordinator.

2. *GNCS research project* "Algorithms and methods for the fluid-structure interaction problem with application to the micro-circulation". Funding agency: INDAM. Budget: 2,400 Euros. February 2016 - February 2017. Role: PI.

3. *H2020-MSCA-ITN-2017, EU project 765374* "ROMSOC - Reduced Order Modelling, Simulation and Optimization of Coupled systems". Funding agency: European Community. Total budget: 2,740,000 Euros. Local budget: 249,000 Euros. September 2017 - August 2022. Role: PI of the local unit.

4. *Consultancy contract.* Grant agreement No. 20 07 21 04, FLUIDODINAMIC-AUX "Studio pilota di fluidodinamica computazionale in stenosi critiche della biforcazione carotidea in relazione a differenti tipologie di placca e differenti modalità di rivascolarizzazione carotidea", Funding: Istituto Auxologico Italiano. Budget: 5,000 Euros. July - October 2020. Role: scientific coordinator.

5. *Consultancy contract.* "Computational analysis of hemodynamics in artero-venous fistolae". Funding: Ospedale Cantonale Lugano, Switzerland. Total budget: 6,500 Euros. Starting February 2022. Role: PI.

6. "Calibration of a computational model for the estimate of cardiac blood flow maps". Funding: PNNR Ministry of Education program, Bracco Spa, CNR. Total budget: 74,195 Euros. Starting November 2022. Role: PI.

7. "Computational prediction of TAVI degeneration". Funding: Monzino Cardiology Center, Milan. Total budget: 74,195 Euros. Starting November 2022. Role: PI.

### Participant

(Complete list at `www1.mate.polimi.it/~vergara/funding.html`)

1. Participant to 2 ERC Advanced Grants (PI: A. Quarteroni), role: responsible of tasks and steering commettee member;

2. Participant to 1 ERC PoC (Proof of Concept) Grant (PI: A. Quarteroni);

3. Participant to 1 European Research Training Network;

4. Participant to Italian MIUR research projects: 5 PRIN, 1 FISR;

5. Participant to 1 INDAM grant.

### Other

3 Funded HPC Projects

## Publications

### Books

B1. Quarteroni A., Dede' L., Manzoni A., Vergara C., Mathematical Modelling of the Human Cardiovascular System - Data, Numerical Approximation, Clinical Applications, *Cambridge Monographs on Applied and Computational Mathematics*, Cambridge University Press, 2019.

B2. Miglio E., Parolini N., Scotti A., Vergara C., Matematica e Design, *La Matematica per il 3+2*, Springer-Verlag Mailand, 2019.

### Peer-reviewed Journal Papers

J1. Veneziani A., Vergara, Flow rate defective Boundary Conditions in Haemodynamics Simulations, *Int. Journ. Num. Meth. Fluids*, 47, 803–816, 2005.

J2. Ponzini R., Vergara C., Redaelli A., Venenziani A., Reliable CFD-based estimation of flow rate in haemodynamics measures, *Ultrasound in Med. and Biol.*, 32(10), 1545–1555, 2006.

J3. Veneziani A., Vergara C., An approximate method for solving incompressible Navier-Stokes problem with flow rate conditions, *Comp. Meth. Appl. Mech. Eng.*, 196(9-12), 1685-1700, 2007.

J4. Nobile F., Vergara C., An effective fluid-structure interaction formulation for vascular dynamics by generalized Robin conditions, *SIAM J. Sc. Comp.*, 30(2), 731-763, 2008.

J5. Vergara C., Zunino P., Multiscale modeling and simulation of drug release from cardiovascular stents, *SIAM Multiscale Modeling and Simulation.*, 7(2), 565-588, 2008.

J6. Badia S., Nobile F., Vergara C., Fluid-structure partitioned procedures based on Robin transmission conditions, *J. Comp. Phys.*, 227, 7027-7051, 2008.

J7. Formaggia L., Veneziani A., Vergara C., A new approach to numerical solution of defective boundary problems in incompressible fluid dynamics, *SIAM J. Num. Anal.*, 46(6), 2769-2794, 2008.

J8. Zunino P., D'Angelo C., Petrini L., Vergara C., Capelli C., Migliavacca F., Numerical simulation of drug eluting coronary stents: mechanics, fluid dynamics and drug release, *Comp. Meth. Appl. Mech. Eng.*, 198(45-46), 3633-3644, 2009.

J9. Badia S., Nobile F., Vergara C., Robin-Robin preconditioned Krylov methods for fluid-structure interaction problems, *Comp. Meth. Appl. Mech. Eng.*, 198 (33-36), 2768-2784, 2009.

J10. Vergara C., Ponzini R., Veneziani A., Redaelli A., Neglia D., Parodi O., Womersley number-based estimation of flow rate with Doppler Ultrasound: Sensitivity analysis and first clinical application, *Computer Methods and Programs in Biomedicine*, 98(2), 151-160, 2010.

J11. Formaggia L., Veneziani A., Vergara C., Flow rate boundary problems for an incompressible fluid in deformable domains: formulations and solution methods, *Comp. Meth. Appl. Mech. Eng.*, 199 (9-12), 677-688, 2010.

J12. Ponzini R., Vergara C., Rizzo G., Veneziani A., Redaelli A., Roghi A., Vanzulli A., Parodi O., Computational Fluid Dynamics-based estimation of blood flow rate in Doppler analysis: In vivo validation by means of Phase Contrast Magnetic Resonance Imaging, *IEEE Transaction on Biomedical Engineering*, 57 (7), 1807-1815, 2010.

J13. Vergara C., Nitsche's method for defective boundary value problems in incompressibile fluid-dynamics, *Journal of Scientific Computing*, 46, 100-123, 2011.

J14. Viscardi F., Vergara C., Antiga L., Merelli S., Veneziani A., Puppini G., Faggian G., Mazzucco A., Luciani G.B., Comparative finite-element model analysis of ascending aortic flow in bicuspid and tricuspid aortic valve, *Artificial Organs*, 34(12), 1114-1120, 2010.

J15. Gerardo-Giorda L., Nobile F., Vergara C., Analysis and optimization of Robin-Robin partitioned procedures in fluid-structure interaction problems. *SIAM J. Num. Anal.*, 48(6), 2091-2116, 2010.

J16. Vergara C., Modular algorithms for the numerical solution of the flow rate boundary value problem, *Communications in Applied and Industrial Mathematics*, 1(1), 237-257, 2010;

J17. Perego M., Veneziani A., Vergara C., A variational approach for estimating the compliance of the cardiovascular tissue: An Inverse fluid-structure interaction problem. *SIAM J. Sc. Comp.*, 33(3), 1181-1211, 2011.

J18. Dubini G. et al., Trends in biomedical engineering: focus on Patient Specific Modeling and Life Support Systems. J. Appl. Biomater. Biomech., 9(2), 109 - 117, 2011.

J19. Vergara C., Viscardi F., Antiga L., Luciani G.B., Influence of bicuspid valve geometry on ascending aortic fluid-dynamics: a parametric study. *Artificial Organs*, 36(4), 368-378, 2012.

J20. Porpora A., Zunino P., Vergara C., Piccinelli M., Numerical treatment of boundary conditions to replace lateral branches in haemodynamics. *Int. J. Num. Meth. Biomed. Eng.*, 28(12), 1165-1183, 2012.

J21. Formaggia L. and Vergara C., Prescription of general defective boundary conditions in fluid-dynamics. *Milan Journal of Mathematics*, 80(2), 333-350, 2012.

J22. Nobile F. and Vergara C., Partitioned algorithms for fluid-structure interaction problems in haemodynamics. *Milan Journal of Mathematics*, 80(2), 443-467, 2012.

J23. Formaggia L., Quarteroni A., Vergara C., On the physical consistency between three-dimensional and one-dimensional models in haemodynamics. *Journal of Computational Physics*, 244, 97-112, 2013.

J24. Faggiano E., Antiga L., Puppini G., Quarteroni A., Luciani G.B., Vergara C., Helical flows and asymmetry of blood jet in dilated ascending aorta with normally functioning bicuspid valve. *Biomechanics and Modeling in Mechanobiology*, 12(4), 801-813, 2013.

J25. Piccinelli M., Vergara C., Antiga L., Forzenigo L., Biondetti P., Domanin M., Impact of hemodynamics on lumen boundary displacements in abdominal aortic aneurysms by means of dynamic computed tomography and computational fluid dynamics. *Biomechanics and Modeling in Mechanobiology*, 12(6), 1263-1276, 2013.

J26. Nobile F., Pozzoli M., Vergara C., Time accurate partitioned algorithms for the solution of fluid-structure interaction problems in haemodynamics. *Computer and Fluids*, 86, 470-482, 2013.

J27. Gigante G., Pozzoli M., Vergara C., Optimized Schwarz Methods for the diffusion-reaction problem with cylindrical interfaces. *SIAM J. Num. Anal.*, 51(6), 3402-3430, 2013.

J28. Nobile F., Pozzoli M., Vergara C., Inexact accurate partitioned algorithms for fluid-structure interaction problems with finite elasticity in haemodynamics. *Journal of Computational Physics*, 273, 598-617, 2014.

J29. Vergara C., Palamara S., Catanzariti D., Pangrazzi C., Nobile F., Centonze M., Faggiano E., Maines M., Quarteroni A., Vergara G., Patient-specific generation of the Purkinje network driven by clinical measurements of a normal propagation. *Medical & Biological Engineering & Computing*, 52(10), 813–826, 2014.

J30. Palamara S., Vergara C., Catanzariti D., Faggiano E., Centonze M., Pangrazzi C., Nobile F., Maines M., Quarteroni A., Computational generation of the Purkinje network driven by clinical measurements: The case of pathological propagations. *Int. J. Num. Meth. Biomed. Eng.*, 30(12), 1558–1577, 2014.

J31. Gigante G., Vergara C., Analysis and optimization of the generalized Schwarz method for elliptic problems with application to fluid-structure interaction. *Numer. Math.*, 131(2), 369–404, 2015.

J32. Palamara S., Vergara C., Faggiano E., Nobile F., An effective algorithm for the generation of patient-specific Purkinje networks in computational electro-cardiology. *J. Comp. Phys.*, 283, 495–517, 2015.

J33. Bonomi D., Vergara C., Faggiano E., Stevanella M., Conti C., Redaelli A., Puppini G., Faggian G., Formaggia L., Luciani G.B., Influence of the aortic valve leaflets on the fluid-dynamics in aorta in presence of a normally functioning bicuspid valve. *Biomechanics and Modeling in Mechanobiology*, 14(6), 1349–1361, 2015.

J34. Guerciotti B., Vergara C., Azzimonti L., Forzenigo L., Buora A., Biondetti P., Domanin M., Computational study of the fluid-dynamics in carotids before and after endarterectomy. *Journal of Biomechanics*, 49(1), 26–38, 2016.

J35. Vergara C., Lange M., Palamara S., Lassila T., Frangi A.F., Quarteroni A., A coupled 3D-1D numerical monodomain solver for cardiac electrical activation in the myocardium with detailed Purkinje network. *J. Comp. Phys.*, 308, 218–238, 2016.

J36. Quarteroni A., Veneziani A., Vergara C., Geometric multiscale modeling of the cardiovascular system, between theory and practice. *Comp. Meth. Appl. Mech. Eng.*, 302, 193–252, 2016.

J37. Nestola M.G.C., Faggiano E., Vergara C., Lancellotti R.M., Ippolito S., Filippi S., Quarteroni A., Scrofani R., Computational comparison of aortic root stresses in presence of stentless and stented aortic valve bio-prostheses. *Computer Methods in Biomechanics and Biomedical Engineering*, 20(2), 171-181, 2017.

J38. Guerciotti B., Vergara C., Ippolito S., Quarteroni A., Antona C., Scrofani R., Computational study of the risk of restenosis in coronary bypasses. *Biomechanics and Modeling in Mechanobiology*, 16(1), 313-332, 2017.

J39. Lange M., Palamara S., Lassila T., Vergara C., Quarteroni A., Frangi A.F., Improved hybrid/GPU algorithm for solving cardiac electrophysiology problems on Purkinje networks. *Int. J. Num. Meth. Biomed. Eng.*, 33(6), e2835, 2017.

J40. Lancellotti R.M., Vergara C., Valdettaro L., Bose S., Quarteroni A., Large Eddy Simulations for blood fluid-dynamics in real stenotic carotids. *Int. J. Num. Meth. Biomed. Eng.*, 33(11), e2868, 2017.

J41. Quarteroni A., Manzoni A., Vergara C., The Cardiovascular System: Mathematical Modeling, Numerical Algorithms and Clinical Applications. *Acta Numerica*, 26, 365-590, 2017.

J42. Scardulla S., Pasta S., D'Acquisto L., Sciacca S., Agnese V., Vergara C., Quarteroni A., Clemenza F., Bellavia D., Pilato M., Shear Stress Alterations in the Celiac Trunk of Patients with Continuous-Flow Left Ventricular Assist Device by In-Silico and In-Vitro Flow Analysis. *Journal of Heart and Lung Transplantation*, 36(8), 906-913, 2017.

J43. Domanin M., Buora A., Scardulla F., Guerciotti B., Forzenigo L., Biondetti P., Vergara C., Computational fluid-dynamic analysis of carotid bifurcations after endarterectomy: closure with patch graft versus direct suture. *Annals of Vascular Surgery*, 44, 325-335, 2017.

J44. Guerciotti B., Vergara C., Ippolito S., Quarteroni A., Antona C., Scrofani R., A computational fluid-structure interaction analysis of coronary Y-grafts. *Medical Engineering & Physics*, 47, 117-127, 2017.

J45. Vergara C., Le Van D., Quadrio M., Formaggia L., Domanin M., Large Eddy Simulations of blood dynamics in abdominal aortic aneurysms. *Medical Engineering & Physics*, 47, 38-46, 2017.

J46. Domanin M., Bissacco D., Le Van D., Vergara C., Computational fluid-dynamic comparison between patch-based and direct suture closure techniques after carotid endarterectomy. *Journal of Vascular Surgery*, 67(3), 887-897, 2018.

J47. Zonca S., Vergara C., Formaggia L., An unfitted formulation for the interaction of an Incompressible fluid with a thick structure via an XFEM/DG approach. *SIAM J. Sc. Comp.*, 40(1), B59–B84, 2018.

J48. Landajuela M., Vergara C., Gerbi A., Dede' L., Formaggia L., Quarteroni A., Numerical approximation of the electromechanical coupling in the left ventricle with inclusion of the Purkinje network. *Int. J. Num. Meth. Biomed. Eng.*, 34, e2984, 2018.

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J51. Gigante G., Vergara C., Optimized Schwarz methods for the coupling of cylindrical geometries along the axial direction. *Mathematical Modelling and Numerical Analysis (M2AN)*, 52, 1597-1615, 2018.

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* These authors equally contributed to the work

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Papers Submitted to peer-reviewed international journals (now Technical Reports)

S1. Lucca A., Fraccarollo L., Fossan F.E., Braten A.T., Pozzi S., Vergara C., Muller L.O., Impact of pressure guidewire on model-based FFR prediction. *MOX Report* n. 46/2022.

S2. Ruffino L., Santoro A., Sparvieri, S., Regazzoni, F. Adebo D.A., Quarteroni A., Vergara C., Corno A.F., Computational analysis of cardiovascular effects of COVID- 19 infection in children. *MOX Report* n. 57/2022.

S3. Bucelli M., Geraint Gabriel M., Gigante G., Quarteroni A., Vergara C., A stable loosely-coupled scheme for cardiac electro-fluid-structure interaction. *arXiv:2210.00917*, 2022.

S4. Quarteroni A., Dede' L., Regazzoni F., Vergara C., A mathematical model of the human heart suitable to address clinical problems. *MOX Report* n. 04/2023.

S5. Fumagalli I., Vergara C., Novel approaches for the numerical solution of fluid-structure interaction in the aorta. *MOX Report* n. 05/2023.

S6. Marcinno' F., Vergara C., Giovannacci L., Quarteroni A., Prouse G., Computational fluid-structure interaction analysis of the end-to-side radio-cephalic arteriovenous fistula. *MOX Report* n. 19/2023.

S7. Bennati L., Giambruno V., Renzi F., Di Nicola V., Maffeis C., Puppini G., Luciani G.B., Vergara C., Turbulence and blood washout in presence of mitral regurgitation: a computational fluid-dynamics study in the complete left heart, bioR$\chi$iv doi:10.1101/2023.03.19.533094.

Peer-reviewed Conference Proceedings, Lecture Notes, Book Chapters

P1. Fernandez M., Moura A., Vergara C., Defective Boundary Conditions Applied to Multiscale Analysis of Blood Flow, *ESAIM ESAIM Proceedings & Surveys, CEMRACS 2004*, 14, 89-99, 2005;

P2. Moura A., Vergara C., Flow rate boundary conditions and multiscale modelling of the cardiovascular system in compliant domains, in *Modelling in Medicine and Biology VI*, (eds. Ursino, Brebbia, Pontrelli, Magosso), 351-359, related to *Sixth International Conference on Modelling in Medicine and Biology*, Bologna - September 7-9, 2005;

P3. Veneziani A., Vergara C., Flow Rate Boundary Conditions in Fluid-Dynamics, *PAMM Proceedings in Applied Mathematics and Mechanics (Proceedings of the GAMM meeting 2006, Berlin)*, 6, 35–38, 2006;

P4. Ponzini R., Vergara C., Rizzo G., Veneziani A., Redaelli A., Vanzulli A., Parodi O., Computational fluid dynamics-based estimation of blood flow rate in Doppler analsys: in vivo validation by means of phase contrast magnetic resonance imaging, Proceedings of the *ASME summer conference*, 227-228, 2009;

P5. Arimon A., Balossino R., D'Angelo C., Doorly D., Dubini G., Fernandez M., Gerbeau J.F.,Giordana S., Migliavacca F., Pennati G., Peiro' J., Prosi M., Sherwin S., Vergara C., Vidrascu M., Zunino P.,Applications and test cases, in *Cardiovascular Mathematics*, Formaggia L., Quarteroni A., Veneziani A. eds., Springer, 2009;

P6. D'Elia M., Mirabella L.,Passerini T., Perego M., Piccinelli M., Vergara C., Veneziani A., Applications of variational data assimilation in computational hemodynamics, in *Modeling of Physiological Flows*, Ambrosi D., Quarteroni A., Rozza G. eds., Springer, 2011.

P7. Pozzoli M., Vergara C., Nobile F., Efficient algorithms for the solution of fluid-structure interaction problems in haemodynamic applications, Proceedings of the Conference *Numerical Methods for Hyperbolic Equations Theory and Applications*, Santiago de Compostela, Taylor and Francis group, 355-364, 2012;

P8. Gigante G., Vergara C., Optimized Schwarz method for the fluid-structure interaction with cylindrical interfaces. *Domain Decomposition Methods in Science and Engineering XXII - Lecture Notes in Computational Science and Engineering - Proceedings of the 22nd International Conference on Domain Decomposition Methods*, 104, 521-529, 2016.

P9. Lange M., Palamara S., Lassila T., Vergara C., Quarteroni A., Frangi A.F., Efficient Numerical Schemes for Computing Cardiac Electrical Activation over Realistic Purkinje Networks: Method and Verification, in "Functional Imaging and Modeling of the Heart", *Proceedings of the 8th International Conference, FIMH 2015*, Springer, 430-438, 2015.

P10. Guerciotti B., Vergara C., Computational comparison between Newtonian and non-Newtonian blood rheologies in stenotic vessels. In "Biomedical Technology", Lecture Notes in Applied and Computational Mechanics 84 (P. Wriggers and T. Lenarz eds.), Springer, 169-183, 2018.

P11. Vergara C., Zonca S., Extended Finite Elements method for fluid-structure interaction with an immersed thick non-linear structure. In "Mathematical and Numerical Modeling of the Cardiovascular System and Applications", SEMA SIMAI Springer Series (D. Boffi, L. Pavarino, G. Rozza, S. Scacchi, C. Vergara eds.), 209-243, 2018.

P12. Formaggia L., Vergara C., Defective boundary conditions for PDEs with applications in haemodynamics. In "Numerical Methods for PDEs", SEMA SIMAI Springer Series (D. Di Pietro, A. Ern, L. Formaggia eds.), 15, 285-312, 2018.

P13. Quarteroni A., Vergara C., Landajuela M., Mathematical and Numerical Description of the Heart Function. In "Imagine Math 6" (M. Emmer and M. Abate eds.), Springer, 171-177, 2018.

P14. Pozzi S., Vergara C., Mathematical and numerical models of atherosclerotic plaque progression in carotid arteries. In "Numerical Mathematics and Advanced Applications ENUMATH 2019" - Lecture Notes in Computational Science and Engineering, 139, 2021.

Editorials

E1. Veneziani A., Vergara C., Inverse problems in Cardiovascular Mathematics: toward patient-specific data assimilation and optimization, Editorial of the special issue "Inverse Problems in Cardiovascular Mathematics", *International Journal for Numerical Methods in Biomedical Engineering*, 29(7), 723-725, 2013.

E2. Pavarino L., Rozza G., Scacchi S., Vergara C., Advances in cardiovascular modeling and simulation, Editorial of the Special Issue "Advances in cardiovascular modeling and simulation", *International Journal for Numerical Methods in Biomedical Engineering*, 38, e3631, 2022

Peer reviewed Abstracts, Short Communications and Letters to Editors

6 short communications, 1 abstract, 2 letters to Editor

### H-index and citation overview (Source Scopus, March 2023)

- H-index = 27;
- Total number of documents = 107;
- Total number of citations = 2197;
- Total number of citations excluding self citations of all authors = 1511.

## 4 Popularization of the research

### Invited Contributions at International Conferences, Workshops and Seminars

A) Plenary lectures and mini-courses

1. *Computational studies of haemodynamics in ascending aorta and human carotids.* 1st UK National Conference on Patient-Specific Modelling (PSM) and Translational Research, Cathays Park, Cardiff University, UK, January 9-10, 2013;
2. *Numerical solution of coupled problems in the cardiovascular field.* Mini-course at LACIAM 2023, Rio de Janeiro, January 30 - February 3, 2023.

B) 14 Invited Lectures and Keynote Lectures

Selected list:

- *Fluid-structure interaction and large eddy simulations for complex blood flow scenarios.* Lecture within the symposium "Simulation and Optimization of Extreme Fluids", organized by T. Richter, B. Vexler, D. Meidner, S. Frei, R. Rannacher. Internationales Wissenschaftsforum Heidelberg, Germany, October 10-12, 2016.
- *La fluidodinamica computazionale nella patologia carotidea: risultati, problematiche, prospettive.* XVIII Congresso Nazionale della Societa' Italiana di Chirurgia Vascolare ed Endovascolare. Firenze, 21-23 October, 2019.
- *Numerical solution of fluid-structure interaction for cardiovascular applications.* Numerical methods for hyperbolic problems, NumHyp 2021. Trento, July 26-30, 2021.
- *Fluid-structure interaction problems in computational hemodynamics.* Portugal-Italy Conference on Nonlinear Differential Equations and Applications (PICNDEA22), Evora, Portugal, July 4-6, 2022.
- *A multi-physics model for myocardial perfusion in the human heart.* Keynote lecture within the mini-symposium "Computational biomechanics: Advanced methods and emerging areas", organized by D.E. Hurtado, A. Gizzi, M. Marino, and C.J. Cyron, World Congress of Computational Mechanics (WCCM XV - APCOM VII), on-line event, August 1-5, 2022.

### C) 17 Invited Seminars

Selected list:

- *La matematica del sistema cardiovascolare: fondamenti di interazione fluido-struttura.* Dipartimento di Ingegneria Aerospaziale, Università degli Studi di Napoli, June 7, 2011.
- *Partitioned algorithms for the numerical solution of the fluid-structure interaction problem in haemodynamics.* Centre de Recerca Matematica, Facultat de Ciénces UAB, Barcelona, Spain, January 27, 2012.
- *The computational mathematics in medicine: quantitative answers to clinical problems.* Istituto Lombardo Accademia di Scienze e Lettere, Milan, June 23, 2016.
- *The mathematics around and inside us.* Math in Heart Day - Event in the framework of the ERC Advanced Grant N.227058 "iHEART - An integrated heart model for the simulation of the cardiac function", PI A. Quarteroni, MUSE, Trento, Italy, November 5, 2019.
- *Modeling blood flow and cardiac electrophysiology: numerical methods and applications.* Johann Radon Institute RICAM, Linz, Austria, January 29, 2020.
- *Modellazione matematica e studi computazionali del sistema Cardiovascolare.* On-line seminar within the event "Co.Scienza 2021", Trento, Italy, April 19, 2021.

### C) 28 Invited Talks in Minisymposia

List of the last talks:

- *On the stability and efficiency of domain-decomposition algorithms for fluid-structure interaction.* Talk within the minisymposium "Heterogeneous Domain Decomposition Methods: Theoretical Developments and New Applications", organized by M.J. Gander and T. Vanzan. 26nd International Conference on Domain Decomposition Methods (DD26). On-line conference, December 7-11, 2020.
- *On the stability and efficiency of domain-decomposition algorithms for fluid-structure interaction with application to hemodynamics.* Talk within the minisymposium "High performance algorithms and applications in computational biomechanics", organized by X.C. Cai, R. Chen, L.F. Pavarino. WCCM-ECCOMAS 2020. On-line conference, January 11-15, 2021.
- *Numerical modelling of the cardiac perfusion.* Talk within the minisymposium "Mathematical and Computational Modelling of Blood Flow", organized by N. Hill and M. Olufsen. BMC-BAMC Meeting, 2021. On-line conference, April 6-9, 2021.
- *Efficient loosely-coupled segregated solvers for fluid-structure interaction.* Talk within the minisymposium "Effective solvers for innovative discretizations of partial differential equations and applications", organized by P. Antonietti, L.F: Pavarino, S. Scacchi. XV SIMAI Biannual Conference 2020, Parma, Italy, August 30-September 3, 2021
- *Fluid-structure interaction problems for blood flow in carotids.* Talk within the minisymposium "Fluid-Structure Interface (FSI) Modelling", organized by D. Nordsletten and A. Quarteroni. 9th World Congress of Biomechanics (WCB22). On-line conference (and in presence in Taipei), July 10-14, 2022

### D) 20 Contributed Talks in mini-simposia

## Organization of events

### A) Co-chair and Organization of Workshops and Conferences

1. Organizer of the workshop "Stents a Rilascio di Farmaco. Aspetti clinici e tecnologici", MOX, Dipartimento di Matematica, Politecnico di Milano, May 9, 2007. Co-organizers: F. Gervaso and P. Zunino;
2. Local organizing committee member of XIII SIMAI (Italian Society of Mathematics Applied to Industry) Biannual Conference 2016, Milan, Italy, September 13-16, 2016;

3. Organizer of the PRIN workshop and conference in honor of Piero Colli Franzone "Mathematical and Numerical Modeling of the Cardiovascular System and Applications", Pavia, Italy, February 21-22, 2017. Co-organizers: D. Boffi, L. Pavarino, G. Savaré, S. Scacchi;

4. Organizer of the INDAM workshop "Mathematical and Numerical Modeling of the Cardiovascular System", Roma, April 16-19, 2018. Co-organizers: L. Pavarino, G. Rozza, S. Scacchi;

5. Conference co-chair and Organising Committee member at the "7th International Conference on Computational and Mathematical Biomedical Engineering (CMBE21)", Politecnico di Milano, Italy, June 27-29, 2022.

B) 5 times Scientific and Programme Committee Member of Workshops and Conferences

C) Organization of 15 Mini-symposia within international conferences

List of last mini-symposia:

1. Organizer of the minisymposium "Mathematical and Numerical Modelling of COVID-19 Epidemic", 8th European Congress on Computational Methods in Applied Sciences and Engineering - ECCOMAS22, Oslo, Norway, June 5-9, 2022. Co-organizers: L. Dede' and N. Parolini.

2. Organizer of the minisymposium "Integration of clinical data and numerical methods for cardiovascular problems", 7th International Conference on Computational and Mathematical Biomedical Engineering (CMBE22), Politecnico di Milano, June 27-29, 2022. Co-organizers: M. Fedele, S. Niederer, S. Pagani, M. Strocchi. 15 speakers.

3. Organizer of the minisymposium "Image-based computational models for predicting disease progression and for risk stratification", 7th International Conference on Computational and Mathematical Biomedical Engineering (CMBE22), Politecnico di Milano, June 27-29, 2022. Co-organizers: E. Votta, A. Redaelli. 12 speakers.

4. Organizer of the minisymposium ": Domain Decomposition for Multi-Physics Problems", 27th International Conference on Domain Decomposition Methods (DD27), Prague, July 25-29, 2022. Co-organizers: P. Gervasio. 11 speakers.

5. Organizer of the minisymposium ": Recent advances on numerical methods and parallel solvers for the cardiac function", World Congress of Computational Mechanics (WCCM XV - APCOM VII), on-line event, August 1-5, 2022. Co-organizers: L. Pavarino and S. Scacchi. 8 speakers.

## 5 Student Advising

(Complete list at www1.mate.polimi.it/ vergara/thesis.html)

- Advisor of 4 Post-Doc and post-Lauream Research Fellows

- Advisor of 10 PhD Students and Co-Advisor of 2 PhD Students:

    1. January 2009 - March 2012. M. Pozzoli. Thesis title: *Efficient partitioned algorithms for the solution of fluid-structure interaction problems in haemodynamics*, Ph.D in Mathematical Models and Methods in Engineering, Politecnico di Milano. Other advisor: F. Nobile;

    2. January 2012 - February 2015. S. Palamara. Thesis title: *Numerical approximation of the electrical activity in the left ventricle with the inclusion of Purkinje fibers*, Ph.D in Mathematical Models and Methods in Engineering, Politecnico di Milano. Funded by Caritro. Other advisor: A. Quarteroni;

    3. November 2012 - October 2015. M. Lancellotti. Thesis title: *Large Eddy simulations in haemodynamics: models and applications*, Ph.D in Mathematical Models and Methods in Engineering, Politecnico di Milano. Other advisor: A. Quarteroni;

    4. November 2014 - January 2017. B. Guerciotti, Ph.D in Mathematical Models and Methods in Engineering, Politecnico di Milano. Topic of the thesis: Numerical modelling and simulations of the fluid-dynamics in coronary by-passes.

5. November 2014 - October 2017. S. Zonca. Thesis title: *Unfitted numerical methods for fluid-structure interaction arising between an incompressible fluid and an immersed thick structure*, Ph.D in Mathematical Models and Methods in Engineering, Politecnico di Milano. Other advisor: L. Formaggia;
6. November 2017 - October 2020. S. Pozzi. Thesis title: *Image-based fluid-structure interaction mathematical models for the simulation of atherosclerosis*, Ph.D in Mathematical Models and Methods in Engineering, Politecnico di Milano.
7. November 2017 - October 2020. S. Di Gregorio. Thesis title: *A multi-physics mathematical and numerical model for the simulation of myocardial perfusion.* Ph.D in Mathematical Models and Methods in Engineering, Politecnico di Milano. Funded by EU (iHEART project). Advisor: A. Quarteroni. Co-advisors: C. Vergara, P.Zunino.
8. March 2018 - August 2021. M. Martinolli. Thesis title: *Numerical Solution of Fluid-Structure Interaction Arising in Blood Pumps Based on Wave Membranes.* Ph.D in Mathematical Models and Methods in Engineering, Politecnico di Milano. Funded by EU (ROMSOC project). In collaboration with Corwave, Paris.
9. November 2018 - October 2021. S. Stella. Thesis title: *Data-driven mathematical and numerical models for the ventricular electromechanics with application to cardiac resynchronization therapy.* Ph.D in Mathematical Models and Methods in Engineering, Politecnico di Milano.
10. November 2018 - October 2021. R. Piersanti. Thesis title: *Mathematical and Numerical Modeling of Cardiac Fiber Generation and Electromechanical Function: Towards a Realistic Simulation of the Whole Heart.* Ph.D in Mathematical Models and Methods in Engineering, Politecnico di Milano. Funded by EU (iHEART project). Advisor: A. Quarteroni. Co-advisors: L. Dede', C. Vergara.
11. November 2020 - onwards. L. Bennati. Topic of the research: *Image-based numerical modeling of ventricular blood dynamics in presence of rigurgitant mitral valve.* Ph.D in Scienze Cardiologiche, Universita' di Verona. Other advisor: G.B. Luciani, MD.
12. October 2021 - onwards. F. Renzi. Topic of the research: *Right ventricular hemodynamics: models and applications.* Ph.D in Cardiovascular Sciences, Universita' di Verona. Other advisor: G.B. Luciani.

- Advisor of 38 MSc final theses in Mathematical, Biomedical and Aeronautic Engineering
- Advisor of 8 BSc final theses in Mathematical and Biomedical Engineering
- Tutor for 14 projects of the course Numerical Analysis of PDE II and 3 projects of the course Advanced programming for scientific computing, Mathematical Engineering
- Tutor for 9 final BSc degree projects in Biomedical Engineering

# 6 Editorial duties, Referee and Commissions of Trust Activity

## Editorial board

1. Associate Editor for *ETNA - Electronic Transaction on Numerical Analysis*
2. Associate Editor for *Frontiers in Bioengineering and Biotechnology* - section *Biomechanics.*

## Editor for special issues in peer-reviewed journals and Lecture Notes

1. *Inverse Problems in Cardiovascular Mathematics*, Int. J. Num. Meth. Biomed. Eng., 29(7), 2013. Co-editor: A. Veneziani;
2. *Mathematical and Numerical Modelling of the Cardiovascular System and Applications*, SEMA SIMAI Springer Series. Co-editors: D. Boffi, L. Pavarino, G. Rozza, S. Scacchi, 2018.
3. *Advances in Cardiovascular Modeling and Simulation*, Int. J. Num. Meth. Biomed. Eng., 38, e3631, 2022. Co-editors: L. Pavarino, G. Rozza, S. Scacchi.

## Hiring committees for academic positions

1. Member of the committee for the comparative selection of an assistant professor position in numerical analysis, Dipartimento di Matematica, University of Trento, autumn 2018.

## Reviewer for funding agencies

1. Reviewer for the Executive Board of the Austrian Science Fund (2 projects);
2. Reviewer for the National Science Center of Poland (2 projects);
3. Reviewer for the Italian Government "Ministero dell'Istruzione, dell'Universita' e della Ricerca" (1 project);
4. Reviewer for the Croatian Science Foundation (1 project);
5. Reviewer for the French National Research Agency (ANR) (2 projects).
6. Reviewer for the Netherlands Organisation for Scientific Research (NWO) (2 projects).
7. Reviewer for the Czech Science Foundation (2 projects).
8. Reviewer for the Swiss National Science Foundation (1 project).

## Reviewer and Committee member for PhD and MSc Theses

1. Reviewer of 9 PhD theses and member of 7 PhD thesis commissions (Ecole Polytecnique Federale de Lausanne (EPFL), Università di Trento, Politecnico di Milano, Università Statale di Milano, L'Université Pierre et Marie Curie - Paris VI, Sorbonne Universite', University of Groningen).
2. Reviewer of 17 MSc theses in the field of numerical analysis and computational methods in bioengineering

## Refereeing activity for scientific journals

**Numerical analysis**

- Journal of Computational Physics, 7 papers
- Numerische Matematik, 2 papers
- SIAM Journal of Numerical Analysis, 2 papers
- SIAM Journal of Scientific Computing, 5 papers
- Computer Methods in Applied Mechanics and Engineering, 12 papers
- International Journal for Numerical Method in Engineering, 2 papers
- ESAIM: Mathematical Modelling and Numerical Analysis (M2AN), 4 papers
- International Journal for Numerical Method in Biomedical Engineering, 16 papers
- Communications in Computational Physics, 1 paper
- Computers and Mathematics with Applications, 4 papers
- Journal of the Royal Society Interface, 1 paper
- Numerical Methods for Partial Differential Equations, 3 papers
- Finite Elements in Analysis & Design, 3 papers
- Journal of Mathematical Biology, 2 papers
- Journal of Fluids and Structures, 1 paper
- International Journal for Numerical Methods in Fluids, 2 paper
- Computer and fluids, 2 papers
- Computer and structure, 2 papers
- Applied Numerical Mathematics, 2 papers
- Applied Mathematical Modelling, 1 paper
- Journal of Computational Science, 2 papers
- Mathematical Biosciences, 1 paper
- Mathematical Biosciences and Engineering, 1 paper
- Applications and Applied Mathematics, 1 paper
- Theoretical and Computational Fluid Dynamics, 2 papers
- Journal of Theoretical Biology, 1 paper

- Inverse Problems and Imaging, 1 paper
- Water, 1 paper
- Applied Mathematics and Computation, 4 papers
- Journal of Computational and Applied Mathematics, 2 papers
- Communications in Numerical Methods in Engineering, 1 paper
- Mathematical Methods in the Applied Sciences, 4 papers
- Mathematical Problems in Engineering, 1 paper
- Mathematics and Computers in Simulation, 3 papers
- Journal of Mathematical Fluid Mechanics, 2 papers
- International Journal of Advances in Engineering Sciences and Applied Mathematics, 1 paper
- Mathematical Modelling of Natural Phenomena, 1 paper
- European Journal of Mechanics / B Fluids, 1 paper
- Bulletin of Mathematical Biology, 1 paper
- International Journal of Applied Nonlinear Science, 1 paper
- Vietnam Journal of Mathematics, 2 papers
- Computation, 1 paper
- Fluids, 1 paper
- Entropy, 1 paper
- Progress in Computational Fluid Dynamics, 2 papers
- Computational and Mathematical Methods in Medicine, 2 papers
- Proceedings of the International Conference on Domain Decomposition Methods, 1 paper
- Esaim Proceedings, 2 papers
- Parallel Computational Fluid Dynamics, 2 papers
- Modelling of Physiological Flows (eds. Springer), 2 chapters

**Bioengineering, Clinical, and Transdisciplinary Journals**

- Biomechanics and Modeling in Mechanobiology, 11 papers
- Journal of Biomechanics, 4 papers
- Annals of Biomedical Engineering, 4 papers
- ASME - Journal of Biomechanical Engineering, 4 papers
- Medical Image Analysis, 2 papers
- Nature - Scientific Reports, 5 papers
- Medical & Biological Engineering & Computing, 1 paper
- Medical Engineering & Physics, 5 papers
- Computers in Biology and Medicine, 6 papers
- IEEE Transactions on Medical Imaging, 1 paper
- PLOSONE, 3 papers
- Cardiovascular Engineering and Technology, 4 papers
- Frontiers in Bioengineering, 2 papers
- American Journal of Neuroradiology, 1 paper
- American Journal of Physiology, 3 papers
- Biomedicines, 1 paper
- Journal of the Mechanical Behavior of Biomedical Materials, 1 paper
- Computer Methods in Biomechanics and Biomedical Engineering, 3 papers
- Health and Technology, 1 paper
- Journal of Engineering in Medicine, 2 papers
- Computational and Mathematical Methods in Medicine, 1 paper
- Chronic Diseases and Translational Medicine, 1 paper
- Cardiology Research and Practice, 1 paper

## Other

- Reviewer of 35 papers for the *American Mathematical Society (AMS)*.

# 7 Institutional and Professional Activities

## Institutional Services at Politecnico di Milano

**1.** President or member of the thesis evaluation committee for the BSc and MSc in Mathematical and Biomedical Engineering. 2014-onwards.

**2.** Speaker at the event "Incontro con le famiglie", MOX, Dipartimento di Matematica, March 21st, 2015.

**3.** Responsible of MOX, Dipartimento di Matematica, internal seminars. 2015-onwards;

**4.** President or member of the evaluation committee for research fellowships or PhD positions (6 times). 2017-onwards.

**5.** President or member of the evaluation committee for positions of teaching assistant (2 times). 2018-onwards.

**6.** Member of the board of the PhD School on Bioengineering. 2022-onwards.

## Institutional Services at Università degli Studi di Bergamo (until February 2015)

**1.** Member of the thesis evaluation committees for the BSc and MSc in Information, Civil, Financial and Mechanical Engineers. 2008-2015;

**2.** Member of evaluation committees for research fellowships (2 times). 2009-2011;

**3.** Assistant at the admission test, Engineering Faculty. December 2010-2015;

**4.** Member of the committee for the choice of the criteria to assign the faculty fundings within the *Dipartimento di Ingeneria dell'Informazione e Metodi Matematici*. May 24, 2012.

**5.** Responsible of the TOLC exam for the admission of the new students to the Faculty of Engineering. December 2012 - December 2014.

## Professional Societies

- Member of SIAM - Society for Industrial and Applied Mathematics (2012-2013);
- Member of the GNCS-IndAM "Gruppo Nazionale per il Calcolo Scientifico" (since 2003);
- Member of SIMAI "Society for Industrial and Applied Mathematics" (since 2004);
- Member of UMI "Italian Mathematical Union" (since 2012);
- Member of European Society of Biomechanics (ESB) (since 2023).

# 8 Patents

- Di Gregorio S., Pontone G., Quarteroni A., Vergara C., Metodo implementato mediante computer per la simulazione del flusso sanguigno miocardico in condizioni di stress, Italian Patent n. 102021000031475, 2021.

# 9 Description of the research activity

**A) Prescription of defective boundary conditions in computational fluid-dynamics**
Period of activity: 2003 - onwards
Related publications: [B1,J1,J3,J7,J11,J13,J16,J20,J21,J36,J41,J49,P1,P2,P3,P12].

In many fluid-dynamic applications, often only average data are available from measurements at the artificial sections, for example the flow rate or the mean pressure. This is the case of haemodynamics. These data are not enough to make well-posed the underlying differential problem which needs conditions at each point of the sections. To prescribe these defective conditions it is therefore necessary to introduce ad-hoc mathematical strategies.

Starting from the Lagrange multiplier technique developed for the steady-Stokes problem in *Formaggia, Gerbeau, Nobile e Quarteroni, Numerical treatment of Defective Boundary Conditions for the Navier-Stokes equation, SIAM J Num An, 2002,* for the management of a flow rate condition, in [J1] we studied and analyzed the unsteady, non-linear case and in [J3] we introduced an approximate technique to speed-up the computational time, see also [J16]. The technique proposed in [J1] has been then successfully applied to cases of clinical interest, see [J2, J14, J19, J25, J34].

In [J7] we proposed and analyzed a new strategy based on the introduction of a suitable functional to be minimized by means of the optimal control theory for partial differential equations. This technique is very versatile, since it allows to treat both the flow rate and the mean pressure conditions.

In [J11] we studied for the first time the case of prescribing defective conditions in the case of compliant vessels (fluid-structure interaction - FSI). In particular, we extended to the FSI case the approaches based on the Lagrange multipliers and on the control theory.

In *Zunino, Numerical approximation of incompressible flows with net flux defective boundary conditions by means of penalty technique, CMAME, 2009*, it has been proposed how to treat the flow rate conditions by means of a "defective" Nitsche technique. In [J13] I extended and analyzed this formulation for a general resistance defective boundary condition, given by a linear combination of flow rate and mean pressure. This kind of condition is very important for clinical applications. 2D numerical results highlighted the effectiveness of this strategy. In [J20] we applied this technique to a real case of an aortic arch and we studied the effect of cutting lateral branches on the solution.

In [J21] we developed a review of the three techniques proposed so far, in particular we extended the approaches based on Lagrange multipliers and control theory to the case of a general resistance defective condition.

For extended reviews about this topic, see [B1,J36,J41,J49,P12].

**B) Geometric multiscale modeling of the cardiovascular system.**
Period of activity: 2004 - onwards.
Related publications: [B1,J1,J23,J36,J41,J49,J66,J75,J80].

The geometrical multiscale approach consists in the coupling of 3D models with reduced (1D or 0D) models to take into account for the rest of the system and to prescribe suitable boundary conditions at the artificial sections of the 3D model. In [J1] we considered a simple 3D-0D coupling to describe the arterial system and we compared the results with those obtained by a full 0D model. In [J23] we derived an energy estimate of the 3D-1D coupled problem allowing to identify which interface conditions guarantee the preservation of the total energy. Moreover, we studied the effect of the inclusion of the surrounding tissue and of the tapering in the 1D model and we provided a systematic comparison between 3D and 3D-1D results obtained in real cases. The geometrical multiscale approach has been also successfully applied to cases of real interest, such as for the study of the effect of COVID-19 [J66], the 3D electromechanical/0D fluid-dynamic coupling [J75], and the study of hemodynamics in the pulmonary artery [J80].

For extended reviews about this topic, see [B1,J36,J41,J49].

**C) Numerical algorithms for the solution of the fluid-structure interaction problem.**
Period of activity: 2006-onwards.
Related publications: [B1,J4,J6,J9,J11,J15,J22,J26,J28,J31,J41,J47,J49,J50,J53,J55,J63,J68,J70,J79,S3,P7,P8,P11].

The numerical solution of the fluid-structure interaction problem (FSI) is very important in haemodynamics where the blood interacts with the vessel exchanging a significant quantity of energy. The

resulting coupled problem is highly non-linear and suitable effective numerical strategies are mandatory for its solution. Among them, partitioned strategies, based on the successive solution of the fluid and of the structure subproblems in an iterative framework, are very common in haemodynamics. However, the most classical Dirichlet-Neumann scheme features very poor convergence properties in the haemodynamic context, due to the high added mass effect.

In [J4] we developed a new membrane model for the description of the thin vascular wall based on the vessel curvatures, and we proposed a scheme where the structure problem is entirely embedded into the fluid one as a Robin-type boundary condition, thus avoiding interface sub-iterations.

In [J6] we used the model proposed in [J4] to build new partitioned schemes based on Robin interface conditions for the case of a thick structure. We studied analytically the convergence properties of such schemes. The numerical results confirmed the effectiveness of these schemes if the interface parameters are suitably chosen, in particular no relaxation is needed to reach convergence.

In [J9] we applied the Robin-Robin preconditioner to the case of the GMRes method applied to the interface equation. This allowed to develop new Robin-Robin schemes which highlighted an increased robustness with respect to the interface parameters. For the optimization problem related to the choice of the interface parameters, see [J15,J31,J55,P8] in Section E.

In [J22] we provided a stability analysis of partitioned schemes in the case of a general BDF scheme for the fluid and for the structure, of any order for the temporal discretization. In [J26,P7] we studied the case of a non-linear structure, in particular we compared different partitioned schemes to deal also with the structure non-linearity and we applied them to real cases of clinical interest. In [J28] we considered inexact variants of such schemes which featured a big saving in the computational time while preserving a good accuracy. Moreover we provided an analytical study of the accuracy of such inexact schemes.

In [J68,J70] the issue of stability and accuracy of explicit (loosely-coupled) algorithm is addressed. In particular, in [J68] a stability analysis is provided for the explicit Robin-Neumann scheme, whereas in [J70] the choice of suitable interface parameters is addressed.

A comparison among different numerical strategies in the context of cardiac FSI has been reported in [J79] and in [S3] we propose a new loosely-coupled scheme for the electro-fluid-structure cardiac problem

In [J47,J50,P11] we consider a unfitted Extended-FEM (XFEM) approach to manage non-conforming composite fluid and structure meshes as happens e.g. for heart valves. In particular, we consider a thick structure immersed in an incompressible fluid and a Discontinuous Galerkin (DG) approach for the mortaring. In [J53] instead of using the XFEM approach, we consider the DG method directly on the polygons generated by the intersection between the meshes. See also [J63] for an extension to the case of contact between immersed structures.

For an extended review about this topic, see [B1,J41,J49].

**D) Applications of clinical interest**.
Period of activity: 2008 - onwards.
Related publications: [J14,J18,J19,J24,J25,J33,J34,J37,J38,J40,J42,J43,J44,J45,J46,J52,J54,J56,J57,J58, J59,J64,J65,J67,J69,J71,J72,J73,J74,J81,J83, S1,S6,P10,P14,L1].

The technique introduced in [J1] to prescribe a flow rate boundary condition has been successfully applied to cases of clinical interest [J14,J19,P6]. In particular, in collaboration with the Cardio-Surgery and Radiology Divisions of Ospedale Borgo Trento, Verona, Italy, and with Orobix srl (Bergamo, Italy) we studied the fluid-dynamics in ascending aorta in presence of a bicuspid aortic valve, to understand the relation between abnormal fluid-dynamics and formation of a dilated (and possibly aneurismatic) aorta. The results of these works highlighted a big asymmetry of the sistolic jet entering the aorta, high localized wall shear stresses (WSS) and formation of helicoidal vortices, see also [J24]. The influence of the inclusion of the leaflets is studied in [J33].

In collaboration with the Vascular Surgery and Radiology Divisions of Ospedale Ca' Granda, Policlinico di Milano, Italy, we studied the influence of the sistolic jet in the abdominal aorta in presence of aneurysms, finding correlations between high WSS and wall displacements, the latter being acquired through medical images [J25], see [J57] for the case after the endograft insertion. With the same clinical partner we also provided a comparison of the fluid-dynamics before and after the plaque removal in carotids, to study the benefit of the endarterectomy and of the use of a patch [J34,J43,J46,J52,J59,L1], and a comparison of different plaque typologies by means of a fluid-structure interaction problem [J65,J81].

In [J64] we propose a surrogate model for plaque description and estimate plaque parameters by means of CINE MRI images. In [J40,J45] we studied by means of Large Eddy Simulations models the transitional effect occurring in a real stenotic carotid and abdominal aortic aneurysms.

In [J69,P14], we provided firs steps towards the modeling of the plaque progression by means of a

system of PDE's accounting for FSI at short time scales and diffusion-reaction problems for the cellular events at the large time scales.

In collaboration with the Cardio-surgery and Radiology Divisions at Ospedale Sacco in Milan, we studied the mechanical performance of stentless and stended bio-prostheses through fluid-structure interaction simulations of the blood and aortic root [J37]. Moreover, together with the same partner, we studied the fluid-dynamics in aorto-coronary by-passes to highlight the risk of restenosis as a function of the original stenosis degree [J38,J44] and the blood dynamics in the left ventricle in presence of the Systolic Anterior Motion (SAM) [J58] and hypertrophic cardiomyopathy [J73]. In this context, and for stenotic carotids, we also studied the influence of the blood rheology model on the fluid-dynamics in terms of quantities of interest [P10]. For what concerns coronaries, we studied the influence of the guide-wire in the estimation of FFR [S1].

Regarding blood pumps, in collaboration with ISMETT we studied the shear stress alterations in the celiac trunk of patients with continuous-flow left ventricular assist device [J42], whereas in [J67,J72] we analyzed the behaviour of a wave membrane pump.

In collaboration with the Vascular surgery division of Lugano's hospital (Ente Ospedaliero Cantonale Lugano) we studied for different virtual scenario the disturbed flow and transition to turbulence in arteriovenous fistulae [J54,J56,S6].

With Centro Cardiologico Monzino in Milan, we have active collaborations on estimating cardiac blood flow maps [J74] and on degenration of TAVI for the replacement of the aortic valve [J83].

Finally, we mention a study of the hemodynamics in the portal confluence in patients with cancer of the pancreatic head in collaboration with the Pancreas Institute at University of Verona [J71].

**E) Optimized Schwarz Methods**.
Period of activity: 2009 - onwards
Related publications: [J15,J27,J31,J51,J55,P8].

In the context of coupled (possibly heterogeneous) problems, a very effective Domain Decomposition strategy is based on the exchange of Robin-type conditions at the interfaces. The convergence properties of such schemes are governed by the choice of the interface parameters in such conditions. The search of an optimal choice of such parameters in a proper subset leads to a minimization problem (Optimized Schwarz Method).

In [J15] we performed a convergence analysis and optimization of the FSI problem, highlighting with 2D numerical results the effectiveness of the proposed interface parameters.

In many physical problems, the interface is a given by a cylindrical surface. For this reason, in [J27] we developed an optimization analysis for the diffusion-reaction problem in the case of cylindrical interfaces, confirming the theoretical findings with 3D numerical results. Moreover, in [J31,P8], we developed a general analysis for elliptic problems with any kind of interface (flat, cylindrical or spherical), and we applied it to the 3D FSI problem. 3D Numerical results for cylindrical interfaces confirmed the theoretical findings, see also [J55] for the case of spherical interfaces. In [J511], we addressed the case of circular flat interfaces and geometric heterogeneous coupling.

**F) Modeling the cardiac function**.
Period of activity: 2012 - onwards
Related publications: [B1,J29,J30,J32,J35,J39,J41,J48,J49,J58,J60,J61,J62,J66,J74,J75,J76,J77,J78,J79,J82,S3,S4,S5,S7,

The electrical activity of the heart allows the heart contraction and thus the ejection of blood in the arterial system. In the left ventricle, this activity consists in a front which starts from the atrio-ventricular node and then travels along the Purkinje network, a specialized conduction system which brings the signal to the heart muscle. The mathematical description of the activity of the Purkinje network is then crucial for an accurate description of the electrical activity of the heart. However, the identification of this network is not possible from the medical images, since these fibers are very thin.

In [J32] we proposed a new method for the generation of the Purkinje network driven by available clinical data of the electrical activity of the heart. This is the first attempt to generate a patient-specific Purkinje network. We tested this algorithm in synthetic cases with an ideal geometry, which highlighted the effectiveness and accuracy of the method. In [J29], we applied this strategy to 3 real cases related to a normal electrical propagation, whereas in [J30] we applied it to 4 real cases characterized by pathological conductions, such as the Wolff-Parkinson-White syndrome and the Left-Bundle-Branch-Block. In [J35,J39,P9] we considered the monodomain model to describe the activation both in the myocardium and

in the Purkinje network, and the related coupled problem. In [J48,P13] the coupling between the Purkinje network activation and the electro-mechanical activity of the myocardium is adressed. In [J62,J78] we integrated measures coming from epicardial veins mapping in the numerical simulations in order to provide a validation of the latter in presence of a normal propagation and to provide estimation of the electrical mapping.

In [J60] a multiscale model of cardiac perfusion is proposed, based on Navier-Stokes equations for large coronaries and on a multi-compartment Darcy model for intramural vessels. This model has been extended to the poro-elasticity case in [J76], whereas in [J74] it has been applied to estimate patient-specific perfusion maps. In [J58] a pipeline to describe the blood dynamics in the left ventricle by using MRI data for the ventricle and valves motion is proposed and in [J82,S7] an imaged-based CFD analysis has been performed for the mitral regurgitation.

In [J61] the problem of fibers generation for the atria and ventricle is discussed with the revision of existing methods and the proposals of new ones. In [J75] we introduced a closed-loop 3D-0D model for electro-mechanics in the biventricular myocardium, whereas in [J77] a fast electro-mechanical model based on the Eikonal-reaction model. In [J79] we compare different strategies to solve the FSI problem in the cardiac context and in [S3] we propose a new loosely-coupled scheme for the electro-fluid-structure cardiac problem.

In [J66] we provided preliminary result about possible COVID-19 effects on the cardiovascular system.

For extended reviews about these topics, see [B1,J41,J49,S4,S5].

**G) Finite Elements methods for unfitted meshes.**
Period of activity: 2016 - onwards
Related publications: [J47,J50,J53,J63,J67,P11].

The numerical simulation of homogeneous or heterogeneous coupled problems involving unfitted meshes (i.e. meshes that do not match at their interface) is very usefull in many contexts and applications. For example, in the case of the interaction of an immersed structure in a surrounded fluid, when the displacements are large the use of conforming meshes (like in the ALE approach) is not feasible.

To numerically treat this situation, we consider *cut-FEM* strategies where a background fixed mesh is cut by a foreground (possibly moving) mesh. To manage the intersected polygons generated by the cut of the background mesh, we propose an *Extended Finite Elements* (XFEM) approach in [J50], where the immersed mesh is 3D but with thickness small in comparison to the background mesh element size, so that a doubling of the degrees of freedom for the interface elements is considered. This strategy has been extended to the more complex case of fluid-structure interaction problem in [J47,P11]. In [J53], instead of using the XFEM approach, we consider a Discontinuous Galerkin method applied directly on the polygons generated by the intersection between the meshes. See also [J63] for an extension to the case of contact between immersed structures. THe proposed XFEM strategy has been applied to the study a wave membrane pump in [J67].

**H) Parameter estimation in cardiovascular mathematics.**
Period of activity: 2009-onwards
Related publications: [B1,J17,J41,J49,J62,J64,J74,J78,P6,E1].

The estimation of physical parameters in haemodynamics is of crucial importance in view of performing accurate numerical simulations [E1]. To this aim, we proposed a variational approach for the estimation of the Young modulus of an artery where a suitable functional is minimized with the constraint given by the FSI problem. The functional is built thanks to available clinical data concerning the vessel displacement. We showed the well-position of the resulting inverse problem and performed several 2D and 3D simulations [J17,P6]. For an extended review about this topic, see [B1,J41,J49].

In [J64] we perform a parameter estimation with real data of vessel wall displacements of three patients obtained by CINE MRI images. In particular, we estimate the elastic properties of the surrounding tissues and of the plaque. Instead, in [J62,J78] we considered the case of estimating the conduction velocities in cardiac electro-physiology starting from measures of activation times acquired in patients.

In [J74] we estimate perfusion myocardial maps of 9 patients by means of a calibration of the parameters of a coupled model (Navier-Stokes/Multi-compartment Darcy) developed in [J60].

**I) Flow rate estimation starting from Doppler measurements.**
Period of activity: 2006 - 2010.

Related publications: [J2,J10,J12,P4].

The knowledge of the flow rate in a vascular district is of crucial interest for clinical purposes. This could be acquired by means of measurements. Among the non-invasive methods, some of the most common are based on the Doppler technique (Doppler Ultrasound, EcoColoDoppler, ...). With this technique, one has at disposal at each time step the value of the maximum velocity on a section. To pass from this information to the flow rate, one needs to know the velocity spatial profile, which is unknown.

We developed a method to relate the maximum velocity to the flow rate, by introducing a relation which depends on the pulsatility of the signal [J2]. We then applied this technique to a real dataset [J10] and performed an in-vivo validation, by comparing the estimates obtained by our technique with the ones obtained with PC-MRI used as gold-standard [J12]. The results of the validation showed a great improvement in the accuracy given by our technique in comparison with the ones obtained with classical techniques.

**L) Modeling the drug release from biomedical stents**.
Period of activity: 2006 - 2009.
Related publications: [J5,J8,P5].

A stent is a medical device implanted in occluded arteries such as coronaries in order to facilitate the opening and thus the normal conditions of blood flow. Often, the presence of such devices induces a re-stenosis, that is a further occlusion of the lumen. For this reason, in the last years these devices allow to release a drug in the vessel wall which avoids re-stenosis. The mathematical and numerical modeling of the drug release could provide important information about the rate of release and the optimal configuration of the stent.

In [J5], we studied new interface conditions for the drug release which allowed to avoid sub-iterations between the stent and the artery vessel. This is a very interesting feature of our model since the coupling is characterized by different spatial scales (some microns for the stent, some millimeters for the artery). We developed an analysis of such sheme and performed 3D numerical results.

In [J8,B1], we provided a review of the complete process starting from the medical images of the vessel and of the stents, and describing the expanding process obtained with a finite elasticity model and the release process.

Milano

Christian Vergara