

Andrea Borio

Curriculum Vitæ

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Born on May 11, 1989
Updated on May 9, 2024



Current position

2024 – **Associate professor in Numerical Analysis**, *Politecnico di Torino*, Turin, Italy.

Previous positions

2021 – 2024 **Tenure-track assistant professor in Numerical Analysis**, *Politecnico di Torino*, Turin, Italy.

2018 – 2021 **Assistant professor in Numerical Analysis**, *Politecnico di Torino*, Turin, Italy.

2017 – 2018 **Postdoctoral fellowship on “Development and implementation of innovative numerical methods for the simulation of stresses and strains in underground basins”**, *Politecnico di Torino*, Turin, Italy.

Education

2014 – 2017 **PhD in Applied Mathematics**, *Politecnico di Torino*, Turin, Italy.
Thesis title Advanced numerical techniques for the simulation of flows in fractured media (DOI: 10.6092/polito/porto/2667805).
Supervisor Prof. Stefano Berrone (Politecnico di Torino).

2011 – 2013 **Master degree in Mathematical Modeling in Engineering**, *Politecnico di Torino*, Turin, Italy, *110/110 cum laude*.
Thesis title An adaptive approach to underground flows simulation in fractured media.
Supervisor Prof. Stefano Berrone (Politecnico di Torino).

2008 – 2011 **Bachelor degree in Mathematics for Engineering**, *Politecnico di Torino*, Turin, Italy, *110/110*.

Scientific collaborations

2019 – **Collaboration with the Subsurface Flow and Transport Group**, *Lawrence Livermore National Lab*, Livermore, CA (USA).
Collaboration on the implementation of Virtual Element Methods in GEOS (www.geos.dev), an open-source, multiphysics simulator developed cooperatively by Lawrence Livermore National Laboratory, Stanford University, TotalEnergies, and Chevron.

Research projects

- 12/03/2024 - Member of the INdAM-GNCS project “Metodi numerici avanzati per la poromeccanica: proprietà teoriche ed aspetti computazionali”, funded by Gruppo Nazionale per il Calcolo Scientifico (INdAM). Coordinator: Michele Visinoni, Politecnico di Milano
- 01/01/2024 - Member of PRIN-PNRR project “Polyhedral Galerkin methods for engineering applications to improve disaster risk forecast and management: stabilization-free operator-preserving methods and optimal stabilization methods”. Principal investigator: Stefano Berrone. The project is funded by the European Union through project Next Generation EU, M4C2.
- 28/09/2023 - Member of PRIN 2022 project “FREYA - Fault REactivation: a HYbrid Numerical Approach”. Principal investigator: Anna Scotti.
- 01/09/2023 - Member of the National Center for High Performance Computing - Spoke “Multiscale modeling & Engineering Applications”. The project is funded by the European Union through project Next Generation EU, M4C2.
- 30/01/2023 - 30/01/2024 Member of the INdAM-GNCS project “Numerical methods for the study of complex parametrical geometric structures”, funded by Gruppo Nazionale per il Calcolo Scientifico (INdAM). Coordinator: Maria Strazzullo, Politecnico di Torino
- 24/05/2022 - 31/05/2023 Member of the INdAM-GNCS project “Advanced numerical methods VEM e VEM-BEM for PDEs: theoretical properties and computational aspects”, funded by Gruppo Nazionale per il Calcolo Scientifico (INdAM). Coordinator: Luca Desiderio, Università di Parma
- 12/02/2020 - 31/12/2021 Coordinator of INdAM-GNCS project “Study of advanced numerical methods for differential problems on domains characterized by high geometrical complexity”, funded by Gruppo Nazionale per il Calcolo Scientifico (INdAM).
- 2/02/2019 - 22/02/2020 Coordinator of INdAM-GNCS project “Study of advanced numerical methods for simulations of physical phenomena, even non-linear, on domains characterized by high geometrical complexity”, funded by Gruppo Nazionale per il Calcolo Scientifico (INdAM).
- 18/10/2017 - 18/10/2018 Young Researcher Grant “Virtual Element Method applied to simulations on fractured media”, funded by Gruppo Nazionale per il Calcolo Scientifico (INdAM).
- 11/11/2016 - 11/11/2017 Young Researcher Grant “Virtual Element Method applied to simulations of flows in Discrete Fracture Networks”, funded by Gruppo Nazionale per il Calcolo Scientifico (INdAM).
- 22/01/2016 - 22/01/2017 Member of the INdAM-GNCS project “Advanced numerical techniques for simulations of flows poro-fractured geological media”, funded by Gruppo Nazionale per il Calcolo Scientifico (INdAM). Coordinator: prof. Stefano Berrone, Politecnico di Torino.
- 19/01/2015 - 19/01/2016 Member of the INdAM-GNCS project “Numerical techniques for simulations of flows in large Discrete Fracture Networks”, funded by Gruppo Nazionale per il Calcolo Scientifico (INdAM). Coordinator: prof. Sandra Pieraccini, Politecnico di Torino.

Prizes

- 2017 Quality Award of the Doctoral School of Politecnico di Torino (for the PhD program in Applied Mathematics – XXIX cycle).

- 2014 Premio Optime of “Unione Industriale di Torino” (for the best master graduate students of the universities of Piedmont in the academic year 2012/13).

Teaching

PhD teaching activity

- 2024 Collaborator to the course “Sobolev space on non-smooth domains and applications”. PhD program in Pure and Applied Mathematics, Politecnico di Torino.
- 2023 Holder of the course “Solving PDEs on polygonal or polyhedral meshes: Virtual Element Methods”. PhD program in Pure and Applied Mathematics, Politecnico di Torino.
- 2021 Collaborator to the course “Recent developments of finite elements: virtual element methods on polygonal and polyhedral grids, theory and implementation”. PhD program in Pure and Applied Mathematics, Politecnico di Torino.

PhD candidates supervision

- 2022 - Davide Fassino, PhD program in Pure and Applied Mathematics, Politecnico di Torino.

Conferences and talks

- January 2024 **Seventh Chilean Workshop on Numerical Analysis of Partial Differential Equation (WONAPDE 2024)**, *Concepción, Chile*, Invited speaker
Title of the talk: *Stabilization-Free Virtual Element Methods in primal form*
- September 2023 **XII Congresso UMI**, *Pisa, Italy*, Invited speaker
Title of the talk: *Stabilization free Virtual Element methods in primal and mixed form*
- August 2023 **SIMAI 2023**, *Matera, Italy*, Invited speaker
Title of the talk: *Hybrid mimetic finite difference and virtual element formulation for poromechanics*
- June 2023 **SIAM Conference on Mathematical & Computational Issues in the Geosciences (GS23)**, *Bergen, Norway*, Invited speaker
Title of the talk: *Hybrid mimetic finite difference and virtual element formulation for poromechanics*
- May 2023 **Math2Product 2023**, *Taormina, Italy*, Invited speaker
Title of the talk: *Hybrid mimetic finite difference and virtual element formulation for coupled poromechanics*
- September 2022 **GIMC-SIMAI Young 2022 Workshop**, *Pavia, Italy*, Invited speaker
Title of the talk: *Hybrid mimetic finite difference and virtual element formulation for coupled poromechanics*
- August 2022 **IMG 2022**, *Lugano, Switzerland*, Invited speaker
Title of the talk: *Hybrid mimetic finite difference and virtual element formulation for coupled poromechanics*
- July 2022 **11th European Solid Mechanics Conference**, *Galway, Ireland*, Invited speaker
Title of the talk: *Stabilization free Virtual Element Methods*

- June 2022 **Convegno del Gruppo Nazionale per il Calcolo Scientifico, Montecatini Terme, Italy**, Invited speaker
Title of the talk: *Virtual Element Methods with stabilization-free bilinear forms*
- July 2021 **USNCCM16, online**, Invited speaker
Title of the talk: *Adaptive Virtual Element Methods for Simulations of Flow in Fractured Media*
- June 2021 **SIAM Conference on Mathematical & Computational Issues in the Geosciences (GS21), online**, Invited speaker
Title of the talk: *Hybrid Mimetic Finite-Difference and Virtual Element Formulation for Coupled Poroelasticity*
- May-June 2021 **13th InterPore Annual Meeting (InterPore2021), online**, Invited speaker
Title of the poster: *Adaptive Virtual Element Methods for simulations in Discrete Fracture Matrix models*
- January 2021 **14th Virtual Congress WCCM & ECCOMAS 2020, online**, Invited speaker
Title of the talk: *Adaptivity in Geophysical Simulations Using the Virtual Element Method*
- December 2020 **Computational Methods in Water Resources 2020, online**
Title of the talk: *Mixed Hybrid Finite-Volume and Virtual Element Formulation for Coupled Poromechanics*
- August 2020 **12th InterPore Annual Meeting (InterPore2020), online**, Invited speaker
Title of the talk: *Adaptive Virtual Element Method for simulations of flow in fractured media*
- February 2020 **Convegno del Gruppo Nazionale per il Calcolo Scientifico, Montecatini Terme, Italy**, Invited speaker
Title of the talk: *Adaptive Virtual Element Method for simulations in fractured media*
- June 2019 **Conference on The Mathematics of Elements and Applications (MAFE-LAP 2019), Brunel University London, UK**, Invited speaker
Title of the talk: *The Virtual Element Method for geophysical simulations*
- May 2019 **11th InterPore Annual Meeting (InterPore2019), Valencia, Spain**, Invited speaker
Title of the talk: *The Virtual Element method for simulations of physical phenomena on Discrete Fracture Matrix models*
- July 2018 **XIV SIMAI 2018 Biannual Congress, Roma, Italy**, Invited speaker
Title of the talk: *Simulation of underground phenomena in heterogeneous soils using the Virtual Element Method*
- May 2018 **10th InterPore Annual Meeting (InterPore2018), New Orleans, US**, Invited speaker
Title of the talk: *Applications of standard and mixed Virtual Elements to the simulation of physical phenomena in poro-fractured media*
Title of the poster: *Simulation of elasto-plastic phenomena in heterogeneous soils using the Virtual Element Method*

- February 2018 **Convegno del Gruppo Nazionale per il Calcolo Scientifico, Montecatini Terme, Italy**, Invited speaker
 Title of the talk: *The Virtual Element Method for transport simulations in Discrete Fracture Networks*
- September 2017 **European Conference on Numerical Mathematics and Advanced Applications (ENUMATH 2017)**, Voss, Norway, Invited speaker
 Title of the talk: *The Virtual Element Method for the transport of passive scalars in Discrete Fracture Networks*
- September 2017 **SIAM Conference on Mathematical & Computational Issues in the Geosciences (GS17)**, Erlangen, Germany, Invited speaker
 Title of the talk: *A general framework for DFN flow simulations with the Virtual Element Method*
- July 2017 **POEMS 2017 Workshop**, Milano, Italy, Invited speaker
 Title of the talk: *VEM for transport of passive scalars in Discrete Fracture Networks*
- June 2017 **X-DMS 2017 (eXtended Discretization Methods)**, Umeå, Sweden, Invited speaker
 Title of the talk: *Applications of Virtual Element Methods to Discrete Fracture Network flow simulations*
- September 2016 **XII SIMAI 2016 Biannual Congress**, Milano, Italy, Invited speaker
 Title of the talk: *A Posteriori Error Estimate for the Virtual Element Method*
- June 2016 **Conference on The Mathematics of Elements and Applications (MAFE-LAP 2016)**, Brunel University London, UK, Invited speaker
 Title of the talk: *A Posteriori Error Estimate for the Virtual Element Method*
- Organization of minisymposia in international conferences**
- June 2024 **9th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2024)**, Lisbon, Portugal, Minisymposium “Advances in numerical methods on polytopal grids for coupled problems”, co-organizers: Stefano Bonetti, Francesca Marcon, Ilario Mazzieri.
- June 2023 **SIAM Conference on Mathematical & Computational Issues in the Geosciences**, Bergen, Norway, Minisymposium “Recent Advances in Polytopal Methods for Applications in Geosciences”, co-organizers: Franco Dassi, Ilario Mazzieri, Giuseppe Vacca.
- May 2023 **Math2Product 2023**, Taormina, Italy, Minisymposium “Numerical methods for coupled problems in geometrically complex domains”, co-organizers: Francesco Ballarin, Fabio Vicini.
- June 2021 **SIAM Conference on Mathematical & Computational Issues in the Geosciences**, virtual conference, Minisymposium “Advances in Polygonal Methods for Applications in Geoscience”, co-organizers: Franco Dassi, Stefano Scialò, Anna Scotti.
- January 2021 **14th World Congress in Computational Mechanics (WCCM) and ECCOMAS Congress 2020**, virtual conference, Minisymposium “Advances in polygonal and polyhedral methods”, co-organizers: Simon Lemair, Ilario Mazzieri, Giuseppe Vacca.

Publications

- [1] S. Berrone, A. Borio, and F. Marcon. “A stabilization-free Virtual Element Method based on divergence-free projections”. In: *Computer Methods in Applied Mechanics and Engineering* 424 (2024), pp. 1–19. DOI: 10.1016/j.cma.2024.116885.
- [2] A. Borio, M. Busetto, and F. Marcon. “SUPG-stabilized stabilization-free VEM: a numerical investigation”. In: *Mathematics in Engineering* 6.1 (2024), pp. 173–191. DOI: 10.3934/mine.2024008.
- [3] A. Borio, C. Lovadina, F. Marcon, and M. Visinoni. “A lowest order stabilization-free mixed Virtual Element Method”. In: *Computers & Mathematics With Applications* 160 (2024), pp. 161–170. DOI: 10.1016/j.camwa.2024.02.024.
- [4] F. Ballatore, G. Lucci, A. Borio, and C. Giverso. “An Imaging-Informed Mechanical Framework to Provide a Quantitative Description of Brain Tumour Growth and the Subsequent Deformation of White Matter Tracts”. In: *Mathematical Models and Computer Simulations for Biomedical Applications*. Vol. 33. Springer, 2023, pp. 131–169. ISBN: 978-3-031-35714-5. DOI: 10.1007/978-3-031-35715-2_5.
- [5] S Berrone, A Borio, F Marcon, and G Teora. “A first-order stabilization-free Virtual Element Method”. In: *Applied Mathematics Letters* 142 (2023), pp. 1–6. DOI: 10.1016/j.aml.2023.108641.
- [6] P. F. Antonietti, S. Berrone, A. Borio, A. D’Auria, M. Verani, and S. Weisser. “Anisotropic a posteriori error estimate for the virtual element method”. In: *IMA Journal of Numerical Analysis* 42.2 (2022), pp. 1273–1312. DOI: 10.1093/imanum/drab001.
- [7] M. F. Benedetto, A. Borio, K. Felix, J. Mollica, and S. Scialo’. “An arbitrary order Mixed Virtual Element formulation for coupled multi-dimensional flow problems”. In: *Computer Methods in Applied Mechanics and Engineering* 391 (2022). DOI: 10.1016/j.cma.2021.114204.
- [8] S. Berrone, A. Borio, and F. Marcon. “Comparison of standard and stabilization free Virtual Elements on anisotropic elliptic problems”. In: *Applied Mathematics Letters* 129 (2022). DOI: 10.1016/j.aml.2022.107971.
- [9] S. Berrone, A. Borio, A. D’Auria, S. Scialo, and F. Vicini. “A robust VEM-based approach for flow simulations in poro-fractured media”. In: *Mathematical Models and Methods in Applied Sciences* 14 (2021), pp. 1–31. DOI: 10.1142/S0218202521500639.
- [10] S. Berrone, A. Borio, and A. D’Auria. “Refinement strategies for polygonal meshes applied to adaptive VEM discretization”. In: *Finite Elements in Analysis and Design* 186 (2021). DOI: 10.1016/j.finel.2020.103502.
- [11] S. Berrone, A. Borio, and F. Marcon. *Lowest order stabilization free Virtual Element Method for the Poisson equation*. 2021.
- [12] A. Borio, F. P. Hamon, N. Castelletto, J. A. White, and R. R. Settgest. “Hybrid mimetic finite-difference and virtual element formulation for coupled poromechanics”. In: *Computer Methods in Applied Mechanics and Engineering* 383 (2021). DOI: 10.1016/j.cma.2021.113917.
- [13] S. Berrone, A. Borio, V. Rocca, A. Rovere, C. Serazio, M. Tamburini, and F. Verga. “Subsidence and safety analysis”. In: *IL MARE TERZA EDIZIONE OTTOBRE 2020*. Vol. Numero speciale del Bollettino ufficiale degli idrocarburi e delle georisorse - Ottobre 2020. Roma: Ministero dello Sviluppo Economico, 2020. ISBN: 978-88-943669-6-9.
- [14] A. Borio, A. Fumagalli, and S. Scialo. “Comparison of the response to geometrical complexity of methods for unstationary simulations in discrete fracture networks with conforming, polygonal, and non-matching grids”. In: *Computational Geosciences* 1 (2020). DOI: 10.1007/s10596-020-09996-9.

- [15] S. Berrone, A. Borio, and F. Vicini. “Reliable a posteriori mesh adaptivity in discrete fracture network flow simulations”. In: *Computer Methods in Applied Mechanics and Engineering* 354 (2019), pp. 904–931. DOI: 10.1016/j.cma.2019.06.007.
- [16] S. Berrone, M. F. Benedetto, A. Borio, S. Pieraccini, and S. Scialo’. “The Virtual Element Method for the Transport of Passive Scalars in Discrete Fracture Networks”. In: *Numerical Mathematics and Advanced Applications ENUMATH 2017*. Vol. 126. Springer, 2019, pp. 501–508. ISBN: 978-3-319-96414-0. DOI: 10.1007/978-3-319-96415-7_45.
- [17] S. Berrone, A. Borio, S. Pieraccini, and S. Scialo’. “New strategies for the simulation of the flow in three dimensional poro-fractured media”. In: *Numerical Mathematics and Advanced Applications - ENUMATH 2017*. Vol. 126. Springer, 2019, pp. 715–723. ISBN: 978-3-319-96414-0. DOI: 10.1007/978-3-319-96415-7_66.
- [18] S. Berrone, A. Borio, C. Fidelibus, S. Pieraccini, S. Scialò, and F. Vicini. “Advanced computation of steady-state fluid flow in discrete fracture-matrix models: FEM-BEM and VEM-VEM fracture-block coupling”. In: *GEM 9.2* (2018), pp. 377–399. DOI: 10.1007/s13137-018-0105-3.
- [19] S. Berrone, A. Borio, and G. Manzini. “SUPG stabilization for the nonconforming virtual element method for advection–diffusion–reaction equations”. In: *Computer Methods in Applied Mechanics and Engineering* 340 (2018), pp. 500–529. DOI: 10.1016/j.cma.2018.05.027.
- [20] M. F. Benedetto, A. Borio, and S. Scialo’. “Mixed Virtual Elements for discrete fracture network simulations”. In: *Finite Elements in Analysis and Design* 134 (2017), pp. 55–67. DOI: 10.1016/j.finel.2017.05.011.
- [21] S. Berrone and A. Borio. “A Residual A Posteriori error estimate for the Virtual Element Method”. In: *Mathematical Models and Methods in Applied Sciences* 27.8 (2017), pp. 1423–1458. DOI: 10.1142/S0218202517500233.
- [22] S. Berrone and A. Borio. “Orthogonal polynomials in badly shaped polygonal elements for the Virtual Element Method”. In: *Finite Elements in Analysis and Design* 129 (2017), pp. 14–31. DOI: 10.1016/j.finel.2017.01.006.
- [23] M. F. Benedetto, S. Berrone, and A. Borio. “The virtual element method for underground flow simulations in fractured media”. In: *Advances in Discretization Methods*. Springer, 2016, pp. 167–186. ISBN: 978-3-319-41245-0. DOI: 10.1007/978-3-319-41246-7_8.
- [24] M. F. Benedetto, S. Berrone, A. Borio, S. Pieraccini, and S. Scialo’. “Order preserving SUPG stabilization for the Virtual Element formulation of advection-diffusion problems”. In: *Computer Methods in Applied Mechanics and Engineering* 311 (2016), pp. 18–40. DOI: 10.1016/j.cma.2016.07.043.
- [25] M. F. Benedetto, S. Berrone, A. Borio, S. Pieraccini, and S. Scialo’. “A hybrid mortar virtual element method for discrete fracture network simulations”. In: *Journal of Computational Physics* 306 (2016), pp. 148–166. DOI: 10.1016/j.jcp.2015.11.034.
- [26] M. F. Benedetto, S. Berrone, A. Borio, S. Pieraccini, and S. Scialo’. “The virtual element method for Discrete Fracture Network flow and transport simulations”. In: *ECCOMAS Congress 2016 - Proceedings of the 7th European Congress on Computational Methods in Applied Sciences and Engineering*. Vol. 2. National Technical University of Athens, 2016, pp. 2953–2970. ISBN: 9786188284401. DOI: 10.7712/100016.2008.6334.
- [27] S. Berrone, A. Borio, and S. Scialo’. “A posteriori error estimate for a PDE-constrained optimization formulation for the flow in DFNs”. In: *SIAM Journal on Numerical Analysis* 54.1 (2016), pp. 242–261. DOI: 10.1137/15M1014760.

- [28] M. F. Benedetto, S. Berrone, A. Borio, S. Pieraccini, and S. Scialo'. "The Virtual Element Method for large scale Discrete Fracture Network simulations: fracture-independent mesh generation". In: *Special issue: 86th annual meeting of the international association of applied mathematics and mechanics (GAMM)*. Wiley, 2015, pp. 19–22. DOI: 10.1002/pamm.201510006.

Reviewing activity

Reviewer for Engineering Analysis with Boundary Elements, Computer and Mathematics with Applications, Finite Elements in Analysis & Design, Advances in Computational Mathematics, Mathematics in Engineering, Calcolo, Numerical Mathematics: Theory, Methods and Applications, Computational Mechanics

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