

# Patrick E. Farrell

+44 1865 270743  
patrick.farrell@maths.ox.ac.uk  
<https://pefarrell.org>  
orcid:0000-0002-1241-7060



## Employment history

- 2016–date **Associate Professor**, Mathematical Institute, University of Oxford.
- 2016–date **Tutorial Fellow in Applied Mathematics**, Oriel College, University of Oxford.
- 2013–2018 **EPSRC Early Career Research Fellow**, Mathematical Institute, University of Oxford.
- 2013–2016 **Postdoctoral Research Fellow**, Christ Church College, University of Oxford.
- 2012–2017 **Adjunct Research Scientist**, Simula Research Laboratory, Oslo.
- 2010–2013 **Postdoctoral Research Associate**, Earth Science & Engineering, Imperial College London.

## Academic history

- 2006–2009 **PhD in Computational Physics**, Imperial College London.
  - Thesis *Galerkin projection of discrete fields via supermesh construction*. Viva: 27 Nov 2009.
  - Prizes Association of Computational Mechanics in Engineering award, 2010; Finalist, European Community on Computational Methods in Applied Sciences award, 2010; Imperial College Research Excellence Award, 2010; Janet Watson award, Imperial College London, 2009.
- 2002–2006 **BSc (Hons) in Mathematics**, National University of Ireland, Galway.
  - Thesis *Cryptographic applications of polycyclic groups*.
  - Prizes Hamilton Prize, Royal Irish Academy, 2006; Blayney Exhibition, National University of Ireland, 2006.

## Notable prizes

- 2018 **G-Research DPhil Prize**, £10K awarded to Florian Wechsung for our joint work on preconditioners for the Navier–Stokes equations.
- 2015 **Wilkinson Prize for Numerical Software**, for the development of dolfin-adjoint, with D. A. Ham, S. W. Funke and M. E. Rognes.
- 2015 **Leslie Fox Prize in Numerical Analysis**, second place, for the development of deflation techniques for partial differential equations.

## Research funding

- 2019–2020 **Leverhulme Trust Visiting Professorship for Prof. Panayotis Kevrekidis**, VP2-2018-007, £85,390, PI.
- 2018–2023 **PRISM: Platform for Research In Simulation Methods**, EPSRC EP/R029423/1, £1,612,965, Co-I, Platform grant.
- 2015–2018 **A new simulation and optimisation platform for marine technology**, EPSRC EP/M011151/1, £557,545, Co-I, Software for the Future II.
- 2014–2015 **Scalable automated parallel PDE-constrained optimisation for dolfin-adjoint**, EPSRC eCSE02-03, £60,298, PI, Embedded CSE support.

- 2013–2018 **Automating optimisation subject to partial differential equations on high-performance computers**, EPSRC EP/K030930/1, £487,241, PI, Fellowship.
- 2012–2013 **Optimising the layout of tidal turbines for marine renewable energy**, EPSRC, £35,572, Researcher Co-I, Pathways to Impact award.

## Teaching

- 2019 **Departmental Teaching Award**, Mathematical Institute, University of Oxford.
- 2017–2021 **C6.4 Finite Element Methods for PDEs**, Mathematical Institute, University of Oxford.
- 2018 **PMR5426 Adjoint for Sensitivity, Optimisation and Control**, Escola Politécnica, Universidade de São Paulo.
- 2017–2018 **PMR5412 Modelling and Numerical Simulation via Variational Calculus**, Escola Politécnica, Universidade de São Paulo.
- 2016–date **Tutorials in Linear Algebra, Geometry, Differential Equations I, Numerical Analysis, Calculus of Variations, Constructive Mathematics**, Oriel College, University of Oxford.
- 2016 **Frontiers in PDE-constrained Optimization**, Institute for Mathematics and its Applications, University of Minnesota.
- 2014 **ANADE Summer School on Receptivity, Sensitivity Analysis and Uncertainty Quantification**, Engineering Department, University of Cambridge.

## Research supervision

- PDRA Teresa Kyrke-Smith, Alberto Paganini, Thomas Roy.
- PhD Florian Wechsung, Matteo Croci, Pablo Alexei Gazca Orozco, Hamza Alawiye, Ioannis Papadopoulos, Jingmin Xia, Fabian Laakmann, Francis Aznaran, Alexander van Brunt, Nicolas Boullé, Gonzalo Gonzalez de Diego, Pablo Brubeck.
- MSc 11 students on the Mathematical Modelling and Scientific Computing MSc.

## Administrative & editorial activities

- 2021 Lead organiser for *Efficient simulation algorithms for viscoelastic and viscous non-Newtonian fluids*, Banff International Research Station.
- 2019–date Member of the Copper Mountain Conference on Iterative Methods committee.
- 2017–2020 Editor of the SIAM *Fundamentals of Algorithms* book series.
- 2018–date Departmental open access coordinator.
- 2017–date Departmental colloquium organiser.
- 2017–date Numerical analysis representative on the Oxford MSc in Mathematical Sciences committee.
- 2016–date Examiner's committee for the MSc in Mathematical Modelling and Scientific Computing.
- 2015–date Member of the IMA Conference on Numerical Methods for Simulation committee.
- 2013–date Member of the EPSRC Peer Review College, reviewed grants for EPSRC.
- 2013–date PhD examiner for the University of Oxford, Politecnico di Milano, Katholieke Universiteit Leuven, Queen Mary University of London, University of Bath, Imperial College London, Charles University Prague.
- 2010–date Peer reviewer for 15 journals in computational science and engineering.

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## Articles in review

- [65] A. J. Ellingsrud, N. Boullé, **P. E. Farrell**, and M. E. rogues (2021). *Accurate numerical simulation of electrodiffusion and water movement in brain tissue*. arXiv:2102.02539
- [64] J. Xia, S. MacLachlan, T. J. Atherton, and **P. E. Farrell** (2021). *Structural transitions in geometrically frustrated smectics*. arXiv:2102.00129
- [63] **P. E. Farrell**, P. A. Gazca Orozco, and E. Süli (2020). *Finite element approximation and augmented Lagrangian preconditioning for anisothermal implicitly-constituted non-Newtonian flow*. arXiv:2011.03024
- [62] **P. E. Farrell**, R. C. Kirby, and J. Marchena-Menendez (2020). *Irksome: automating Runge–Kutta time-stepping for finite element methods*. arXiv:2006.16282
- [61] A. Van-Brunt, **P. E. Farrell**, and C. Monroe (2020). *Augmented saddle point formulation of the steady-state Stefan–Maxwell diffusion equations*. arXiv:2006.03321
- [60] **P. E. Farrell**, L. Mitchell, L. R. Scott, and F. Wechsung (2020). *Robust multigrid for nearly incompressible elasticity using macro elements*. arXiv:2002.02051
- [59] M. Croci, M. B. Giles, and **P. E. Farrell** (2019). *Multilevel quasi Monte Carlo methods for elliptic PDEs with random field coefficients via fast white noise sampling*. arXiv:1911.12099

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## Refereed journal articles

- [58] **P. E. Farrell**, L. Mitchell, L. R. Scott, and F. Wechsung (2021). “A Reynolds-robust preconditioner for the Scott–Vogelius discretization of the stationary incompressible Navier–Stokes equations”. In: *SMAI Journal of Computational Mathematics*. arXiv:2004.09398
- [57] K. Tūma, M. Rezaee-Hajidehi, J. Hron, **P. E. Farrell**, and S. Stupkiewicz (2021). “Phase-field modelling of multivariant martensitic transformation at finite-strain: computational aspects and large-scale finite-element simulations”. In: *Computer Methods in Applied Mechanics and Engineering*. arXiv:2011.08802
- [56] I. A. P. Papadopoulos, **P. E. Farrell**, and T. M. Surowiec (2021). “Computing multiple solutions of topology optimization problems”. In: *SIAM Journal on Scientific Computing*. arXiv:2004.11797
- [55] **P. E. Farrell**, M. G. Knepley, L. Mitchell, and F. Wechsung (2020). “PCPATCH: Software for the topological construction of multigrid relaxation methods.” In: *ACM Transactions on Mathematical Software*. arXiv:1912.08516
- [54] J. Xia, **P. E. Farrell**, and F. Wechsung (2020). “Augmented Lagrangian preconditioners for the Oseen–Frank model of cholesteric liquid crystals”. In: *BIT Numerical Mathematics*. arXiv:2004.07329
- [53] **P. E. Farrell**, L. F. Gatica, B. P. Lamichhane, R. Oyarzuá, and R. Ruiz-Baier (2020). “Mixed Kirckhhoff stress–displacement–pressure formulations for incompressible hyperelasticity”. In: *Computer Methods in Applied Mechanics and Engineering* 374, p. 113562. DOI: 10.1016/j.cma.2020.113562
- [52] J. H. Adler, T. Benson, E. C. Cyr, **P. E. Farrell**, S. MacLachlan, and R. Tuminaro (2020). “Monolithic multigrid for magnetohydrodynamics”. In: *SIAM Journal on Scientific Computing*. arXiv:2006.15700
- [51] N. Boullé, E. G. Charalampidis, **P. E. Farrell**, and P. G. Kevrekidis (2020). “Deflation-based Identification of Nonlinear Excitations of the 3D Gross–Pitaevskii equation.” In: *Physical Review A* 102 (5), p. 053307. DOI: 10.1103/PhysRevA.102.053307
- [50] **P. E. Farrell** and P. A. Gazca-Orozco (2020). “An augmented Lagrangian preconditioner for implicitly-constituted non-Newtonian incompressible flow”. In: *SIAM Journal on Scientific Computing* 42.6, B1329–B1349. DOI: 10.1137/20M1336618

- [49] J. G. Williams, A. A. Castrejon-Pita, B. W. Turney, **P. E. Farrell**, S. J. Tavener, D. E. Moulton, and S. L. Waters (2020). "Cavity flow characteristics and applications to kidney stone removal". In: *Journal of Fluid Mechanics* 902, A16. DOI: 10.1017/jfm.2020.583
- [48] H. A. Alawiye, **P. E. Farrell**, and A. Goriely (2020). "Revisiting the wrinkling of elastic bilayers II: post-bifurcation analysis". In: *Journal of the Mechanics and Physics of Solids* 143, p. 104053. DOI: 10.1016/j.jmps.2020.104053
- [47] **P. E. Farrell**, Y. He, and S. P. MacLachlan (2019). "A local Fourier analysis of additive Vanka relaxation for the Stokes equations". In: *Numerical Linear Algebra with Applications*, e2306. DOI: 10.1002/nla.2306
- [46] M. Croci and **P. E. Farrell** (2020). "Complexity bounds on supermesh construction for quasi-uniform meshes." In: *Journal of Computational Physics* 414, p. 109459. DOI: 10.1016/j.jcp.2020.109459
- [45] E. G. Charalampidis, N. Boullé, **P. E. Farrell**, and P. G. Kevrekidis (2020). "Bifurcation analysis of stationary solutions of two-dimensional coupled Gross-Pitaevskii equations using deflated continuation". In: *Communications in Nonlinear Science and Numerical Simulation* 87, p. 105255. DOI: 10.1016/j.cnsns.2020.105255
- [44] J. Xia, **P. E. Farrell**, and S. G. P. Castro (2020). "Nonlinear bifurcation analysis of stiffener profiles via deflation techniques". In: *Thin Walled Structures* 149, p. 106662. DOI: 10.1016/j.tws.2020.106662
- [43] E. Medina, **P. E. Farrell**, K. Bertoldi, and C. Rycroft (2020). "Navigating the landscape of nonlinear mechanical metamaterials for advanced programmability." In: *Physical Review B* 101.6, p. 064101. DOI: 10.1103/PhysRevB.101.064101
- [42] **P. E. Farrell**, P. A. Gazca-Orozco, and E. Süli (2020). "Numerical analysis of unsteady implicitly constituted incompressible fluids: three-field formulation". In: *SIAM Journal on Numerical Analysis* 58.1, pp. 757–787. DOI: 10.1137/19M125738X
- [41] **P. E. Farrell**, L. Mitchell, and F. Wechsung (2019). "An augmented Lagrangian preconditioner for the 3D stationary incompressible Navier–Stokes equations at high Reynolds number". In: *SIAM Journal on Scientific Computing* 41 (5), A3073–A3096. DOI: 10.1137/18M1219370
- [40] **P. E. Farrell**, M. Croci, and T. M. Surowiec (2019). "Deflation for semismooth equations." In: *Optimization Methods and Software* 35.6, pp. 1248–1271. DOI: 10.1080/10556788.2019.1613655
- [39] M. Croci, M. B. Giles, M. E. Rognes, and P. E. Farrell (2018). "Efficient white noise sampling and coupling for multilevel Monte Carlo with nonnested meshes". In: *SIAM/ASA Journal on Uncertainty Quantification* 6.4, pp. 1630–1655. DOI: 10.1137/18M1175239
- [38] A. Paganini, F. Wechsung, and Patrick E. Farrell (2018). "Higher-order moving mesh methods for PDE-constrained shape optimization". In: *SIAM Journal on Scientific Computing* 40.4, A2356–A2382. DOI: 10.1137/17m1133956
- [37] T. M. Kyrke-Smith, G. H. Gudmundsson, and **P. E. Farrell** (2018). "Relevance of detail in basal topography for basal slipperiness inversions: a case study on Pine Island Glacier, Antarctica". In: *Frontiers in Earth Science* 6, p. 33. DOI: 10.3389/feart.2018.00033
- [36] T. M. Kyrke-Smith, G. Hilmar Gudmundsson, and **P. E. Farrell** (2017). "Can seismic observations of bed conditions on ice streams help constrain parameters in ice flow models?" In: *Journal of Geophysical Research: Earth Surface* 122.11, pp. 2269–2282. DOI: 10.1002/2017JF004373
- [35] E. G. Charalampidis, P. G. Kevrekidis, and **P. E. Farrell** (2018). "Computing stationary solutions of the two-dimensional Gross-Pitaevskii equation with deflated continuation." In: *Communications in Nonlinear Science and Numerical Simulation* 54, pp. 482–499. DOI: 10.1016/j.cnsns.2017.05.024

- [34] M. E. Rognes, **P. E. Farrell**, S. W. Funke, J. E. Hake, and M. M. C. Maleckar (2017). "cbcbeat: an adjoint-enabled framework for computational cardiac electrophysiology". In: *The Journal of Open Source Software* 2.13. DOI: 10.21105/joss.00224
- [33] S. W. Funke, **P. E. Farrell**, and M. D. Piggott (2017). "Reconstructing wave profiles from inundation data". In: *Computer Methods in Applied Mechanics and Engineering* 322, pp. 167–186. DOI: 10.1016/j.cma.2017.04.019
- [32] D. B. Emerson, J. H. Adler, **P. E. Farrell**, S. P. MacLachlan, and T. J. Atherton (2017). "Computing equilibrium states of cholesteric liquid crystals in elliptical channels with deflation algorithms." In: *Liquid Crystals* 45.3, pp. 341–350. DOI: 10.1080/02678292.2017.1365385
- [31] S. J. Chapman and **P. E. Farrell** (2017). "Analysis of Carrier's problem." In: *SIAM Journal on Applied Mathematics* 77.3, pp. 924–950. DOI: 10.1137/16M1096074
- [30] M. Robinson, C. Luo, **P. E. Farrell**, R. Erban, and A. Majumdar (2017). "From molecular to continuum modelling of bistable liquid crystal devices." In: *Liquid Crystals* 44.14-15, pp. 2267–2284. DOI: 10.1080/02678292.2017.1290284
- [29] **P. E. Farrell** and J. W. Pearson (2016). "A preconditioner for the Ohta-Kawasaki equation". In: *SIAM Journal on Matrix Analysis and Applications* 38.1, pp. 217–225. DOI: 10.1137/16M1065483
- [28] A. Beskos, M. Girolami, S. Lan, **P. E. Farrell**, and A. M. Stuart (2016). "Geometric MCMC for infinite-dimensional inverse problems". In: *Journal of Computational Physics* 335, pp. 327–351. DOI: 10.1016/j.jcp.2016.12.041
- [27] J. H. Adler, D. B. Emerson, **P. E. Farrell**, and S. P. MacLachlan (2017). "Combining deflation and nested iteration for computing multiple solutions of nonlinear variational problems". In: *SIAM Journal on Scientific Computing* 39.1, B29–B52. DOI: 10.1137/16M1058728
- [26] **P. E. Farrell** and C. Maurini (2016). "Linear and nonlinear solvers for variational phase-field models of brittle fracture". In: *International Journal for Numerical Methods in Engineering* 109.5, pp. 648–667. DOI: 10.1002/nme.5300
- [25] **P. E. Farrell** (2016). "The number of distinct eigenvalues of a matrix after perturbation". In: *SIAM Journal on Matrix Analysis and Applications* 37.2, pp. 572–576. DOI: 10.1137/15M1037603
- [24] **P. E. Farrell**, Á. Birkisson, and S. W. Funke (2015). "Deflation techniques for finding distinct solutions of nonlinear partial differential equations". In: *SIAM Journal on Scientific Computing* 37.4, A2026–A2045. DOI: 10.1137/140984798
- [23] **P. E. Farrell**, C. J. Cotter, and S. W. Funke (2014). "A framework for the automation of generalised stability theory". In: *SIAM Journal on Scientific Computing* 36.1, pp. C25–C48. DOI: 10.1137/120900745
- [22] J. R. Maddison and **P. E. Farrell** (2014). "Rapid development and adjoining of transient finite element models". In: *Computer Methods in Applied Mechanics and Engineering* 276.0, pp. 95–121. DOI: 10.1016/j.cma.2014.03.010
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- [20] S. W. Funke, **P. E. Farrell**, and M. D. Piggott (2014). "Tidal turbine array optimisation using the adjoint approach". In: *Renewable Energy* 63.0, pp. 658–673. DOI: 10.1016/j.renene.2013.09.031

- [19] A. G. Buchan, **P. E. Farrell**, G. J. Gorman, A. J. H. Goddard, M. D. Eaton, E. T. Nygaard, P. L. Angelo, R. P. Smedley-Stevenson, S. R. Merton, and P. N. Smith (2014). "The immersed body supermeshing method for modelling reactor physics problems with complex internal structures". In: *Annals of Nuclear Energy* 63.0, pp. 399–408. DOI: 10.1016/j.anucene.2013.07.044
- [18] C. M. J. Baker, A. G. Buchan, C. C. Pain, **P. E. Farrell**, M. D. Eaton, and P. Warner (2013). "Multimesh anisotropic adaptivity for the Boltzmann transport equation". In: *Annals of Nuclear Energy* 53.0, pp. 411–426. DOI: 10.1016/j.anucene.2012.07.023
- [17] P. E. Farrell, D. A. Ham, S. W. Funke, and M. E. Rognes (2013). "Automated derivation of the adjoint of high-level transient finite element programs". In: *SIAM Journal on Scientific Computing* 35.4, pp. C369–C393. DOI: 10.1137/120873558
- [16] A. Viré, J. Xiang, F. Milthaler, P. E. Farrell, M. D. Piggott, J.-P. Latham, D. Pavlidis, and C. C. Pain (2012). "Modelling of fluid–solid interactions using an adaptive mesh fluid model coupled with a combined finite discrete element model". In: *Ocean Dynamics* 62.10–12, pp. 1487–1501. DOI: 10.1007/s10236-012-0575-z
- [15] J. R. Maddison and **P. E. Farrell** (2012). "Directional integration on unstructured meshes via supermesh construction". In: *Journal of Computational Physics* 231.12, pp. 4422–4432. DOI: 10.1016/j.jcp.2012.02.009
- [14] G. J. Gorman, J. Southern, P. E. Farrell, M. D. Piggott, G. Rokos, and P. H. J. Kelly (2012). "Hybrid OpenMP/MPI anisotropic mesh smoothing". In: *Procedia Computer Science* 9.0, pp. 1513–1522. DOI: 10.1016/j.procs.2012.04.166
- [13] J. Southern, G. J. Gorman, M. D. Piggott, and **P. E. Farrell** (2012). "Parallel anisotropic mesh adaptivity with dynamic load balancing for cardiac electrophysiology". In: *Journal of Computational Science* 3.1–2, pp. 8–16. DOI: 10.1016/j.jocs.2011.11.002
- [12] **P. E. Farrell**, S. Micheletti, and S. Perotto (2011). "An anisotropic Zienkiewicz-Zhu error estimator for 3D applications". In: *International Journal for Numerical Methods in Engineering* 85.6, pp. 671–692. DOI: 10.1002/nme.2980
- [11] **P. E. Farrell** (2011). "The addition of fields on different meshes". In: *Journal of Computational Physics* 230.9, pp. 3265–3269. DOI: 10.1016/j.jcp.2011.01.028
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- [6] **P. E. Farrell**, M. D. Piggott, G. J. Gorman, D. A. Ham, C. R. Wilson, and T. M. Bond (2011). "Automated continuous verification for numerical simulation". In: *Geoscientific Model Development* 4.2, pp. 435–449. DOI: 10.5194/gmd-4-435-2011
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- [3] F. Fang, C. C. Pain, I. M. Navon, G. J. Gorman, M. D. Piggott, P. A. Allison, P. E. Farrell, and A. J. H. Goddard (2009). "A POD reduced order unstructured mesh ocean modelling method for moderate Reynolds number flows". In: *Ocean Modelling* 28.1-3, pp. 127–136. DOI: 10.1016/j.ocemod.2008.12.006
- [2] P. E. Farrell, M. D. Piggott, C. C. Pain, G. J. Gorman, and C. R. G. Wilson (2009). "Conservative interpolation between unstructured meshes via supermesh construction". In: *Computer Methods in Applied Mechanics and Engineering* 198.33-36, pp. 2632–2642. DOI: 10.1016/j.cma.2009.03.004
- [1] F. Fang, C. C. Pain, I. M. Navon, M. D. Piggott, G. J. Gorman, **P. E. Farrell**, P. A. Allison, and A. J. H. Goddard (2008). "A POD reduced-order 4D-Var adaptive mesh ocean modelling approach". In: *International Journal for Numerical Methods in Fluids* 60.7, pp. 709–732. DOI: 10.1002/flid.1911