Alex Townsend
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Research resume

I have broad interests in numerical analysis, scientific computing, computational physics, and theoretical aspects of deep learning. My research focuses on spectral methods, low rank approximation, the mathematics of deep learning, and dynamical systems.

Education

DPhil in Numerical Analysis University of Oxford Oct 2010 – July 2014

Supervised by Prof. L. N. Trefethen FRS
Thesis title: *Computing with functions in two dimensions*

MMath Mathematics University of Oxford Oct 2006 – July 2010

Awarded 1st class degree (ranked 2nd in the year)

Professional experience

Associate Professor Cornell University Feb 2022 – Present

Taught MATH 2210: Linear algebra

Assistant Professor Cornell University July 2016 – Jan 2022

Taught MATH 2220: Multivariable calculus
MATH 2310: Linear Algebra for Data Science
MATH 2930: Differential equations for engineers
MATH 2940: Linear algebra for engineers
MATH 4250: Numerical analysis and ODEs
MATH 7270: Top-ten algorithms of the 20th century
MATH 6220: Applied functional analysis

Applied Math Instructor MIT Aug 2014 – June 2016

Honors and prizes

- Best paper prize in Linear Algebra from SIAM in 2024
- Best paper prize in Computational Science and Engineering from SIAM in 2023
- Stephen H. Weiss award from Cornell for excellence in teaching and mentoring in 2022
- Simons Fellowship in Mathematics in 2022
- SIGEST award from SIAM Review for "The singular values of matrices with displacement structure" in 2019
- Junior Faculty Teaching Award from Cornell Math Department in 2018

- The SIAM Activity Group on Linear Algebra Early Career Prize in 2018
- Mentor of national Regeneron Science Talent Search winner in 2017
- Leslie Fox prize (1st place) for work on the discrete Hankel transform in 2015
- Leslie Fox prize (2nd place) for work on the ultraspherical spectral method in 2013
- SIAM UKIE prize for the best student research talk in 2011
- Junior Mathematics Prize in 2008 and 2009, and IMA prize in 2009 and 2010. Awarded through the University of Oxford for top undergraduate examination results

Research and curriculum grants

- Lead faculty organizer of ALI grant: 2024–2027
- DOE grant with Livermore: Aug. 2024 to Dec 2024
- DOE grant with Livermore: Dec. 2024 to May 2025
- ONR grant for SciAI center: Sept 2023 to Aug 2028
- Stephen H. Weiss award grant: Sept 2022 to Aug 2026
- DOE grant with LLNL: Jan. 2023 to July 2023
- DOE grant with LBNL: Sept. 2021 to Aug. 2022
- NSF CAREER DMS-2045646 (sole PI): July 2021 to June 2026
- NSF DMS-1952757 (lead PI): July 2020 to June 2023
- Data Science Curriculum Initiative grant (lead PI): Sept. 2019 to Sept. 2021
- FACE Foundation (lead PI): Sept. 2019 to Aug. 2021
- NSF DMS-1818757 (sole PI): June 2018 to July 2021
- Engaged Cornell curriculum grant (lead PI): Sept. 2018 to Aug. 2020
- NSF DMS-1645445 (sole PI): Aug. 2015 to July 2018

Journal publications

[63] .N Boullé, D. Halikias, S. E. Otto, and A. Townsend, *Operator learning without the adjoint*, accepted to JMLR, 2024.

[62] M. J. Colbrook and A. Townsend, *Avoiding discretization issues for nonlinear eigenvalue problems*, SIAM J. Matrix Anal. Appl.

[61] N. Boulle and A. Townsend, *A Mathematical Guide to Operator Learning*, Handbook of Numerical Analysis, 2024.

[60] J. Zvonek, A. Horning, and A. Townsend, *ContHutch++: Stochastic trace estimation for implicit integral operators*, to appear in SINUM.

[59] M. Meier, Y. Nakatsukasa, A. Townsend and M. Webb, *Are sketch-and-precondition least squares solvers numerically stable?*, SIAM J. Matrix Anal. Appl., 42, 2024

[58] M. J. Colbrook, Q. Li, R. V. Raut, and A. Townsend, *Beyond expectations: Residual Dynamic Mode Decomposition and Variance for Stochastic Dynamical Systems*, Nonlinear Dynamics, 112 (2024), pp. 2037–2061.

[57] A. Yu and A. Townsend, *Leveraging the Hankel norm approximation and block-AAA algorithms in reduced order modeling*, to appear in Lin. Alg. Appl.

[56] N. Boullé, D. Halikias and A. Townsend, *Elliptic PDE learning is provably data-efficient*, PNAS, 120 (39), 2023.

[55] D. Halikias and A. Townsend, Matrix recovery from matrix-vector products, Lin. Alg. Appl., 31 (1), 2023.

[54] M. J. Colbrook and A. Townsend, *Rigorous data-driven computation of spectral properties of Koopman operators for dynamical systems*, Comm. Pure Appl. Math., 77 (1), 2023.

[53] A. Yu and A. Townsend, *On the stability of unevenly spaced samples for interpolation and quadrature*, BIT Numer. Math., 63.2 (2023): 23.

[52] A. Yu, Y. Yang, and A. Townsend, *A Quadrature Perspective on Frequency Bias in Neural Network Training with Nonuniform Data*, ICLR, 2023.

[51] T. Shi, M. Ruth, and A. Townsend, *Parallel algorithms for computing the tensor-train decomposition*, SIAM J. Sci. Comput., 45.3 (2023), C101-C130.

[50] M. Lipton, S. Strogatz, and A. Townsend, *Exploring the electric field around a loop of static charge: Rectangles, stadiums, ellipses, and knots*, Phys. Rev. Res., 4 (2022), 033249.

[49] Y. Zhao, A. Townsend, and M. Udell, *Probabilistic Missing Value Imputation for Mixed Categorical and Ordered Data*, NeurIPs, 2022.

[48] N. Boullé, S. Kim, T. Shi, and A. Townsend, *Learning Green's functions associated with parabolic partial differential equations*, J. Mach. Learn. Res., 23 (2022) pp. 1–34.

[47] M. Kassabov, S. H. Strogatz, and A. Townsend, *A global synchronization theorem for oscillators on a random graph*, Chaos, 32 (2022), 093119.

[46] D. Rubin, A. Townsend, and H. Wilber, *Bounding Zolotarev numbers using Faber rational functions*, Constr. Approx., 2022, pp. 1-26.

[45] N. Boullé, C. J. Earls, and A. Townsend, *Data-driven discovery of Green's functions with human-understandable deep learning*, 12 (2022), pp. 1–9.

[44] N. Boullé and A. Townsend, *A generalization of the randomized singular value decomposition*, ICLR, 2022.

[43] H. Wilber, A. Damle, and A. Townsend, *Data-driven Algorithms for signal processing with rational functions*, SIAM J. Sci. Comput., 2022.

[42] N. Boulle and A. Townsend, *Learning elliptic partial differential equations with randomized linear algebra*, Found. Comput. Math., 2022.

[41] G. Li, A. Townsend, L. A. Archer, and D. L. Koch, *Suppression of electroconvective and morphological instabilities by an imposed cross flow of the electrolyte*, Phys. Rev. J.,6.3 (2021), 033701.

[40] G. Li, A. Townsend, L. A. Archer, and D. L. Koch, *Electroconvection and Electrodeposition on a Surface with Butler–Volmer Kinetics*, J. Fluid Mechanics, 930 (2022).

[39] Y. Yang, A. Townsend, and D. Appelö, *Anderson acceleration using the $\mathcal{H}^{-s}$ norm*, J. Comput. Appl. Math., 403 (2022), 113844.

[38] M. Kassabov, S. H. Strogatz, and A. Townsend, *Sufficiently dense Kuramoto networks are globally synchronizing*, Chaos, 31 (2021), 073135.

[37] M. J. Colbrook, A. Horning, and A. Townsend, *Computing spectral measures of self-adjoint operators*, SIAM Review, 63 (2021), pp. 489–524.

[36] D. Fortunato, N. Hale, and A. Townsend, *The ultraspherical spectral element method*, J. Comput. Phys., 436 (2021), 110087.

[35] T. Shi and A. Townsend, *On the compressibility of tensors*, SIAM J. Mat. Anal. Appl., 42 (2021), pp. 275–298.

[34] N. Boullé, Y. Nakatsukasa, and A. Townsend, *Rational neural networks*, NeurIPS, 33 (2020).

[33] Y. Nakatsukasa and A. Townsend, *Error localization of best L1 polynomial approximants*, SIAM J. Numer. Anal., 2020.

[32] A. Townsend, M. Stillman, and S. H. Strogatz, *Dense networks that do not synchronize and sparse ones that do*, Chaos, 30 (2020), 083142.

[31] N. Boulle and A. Townsend, *Computing with functions on the ball*, SIAM J. Sci. Comput., 42 (2020), C169–C191.

[30] A. Horning and A. Townsend, *FEAST for differential eigenvalue problems*, SIAM J. Numer. Anal., 58 (2020), pp. 1239–1262.

[29] S. Olver, A. Townsend, and G. M. Vasil, *Recurrence relations for a family of orthogonal polynomials on a triangle*, ICOSAHOM Proceedings, Springer 2020, pp. 79–92.

[28] D. Fortunato and A. Townsend, *Fast Poisson solvers for spectral methods*, IMA Numer. Anal., 40 (2020), pp. 1994–2018.

[27] S. Olver, A. Townsend, and G. Vasil, *A sparse spectral method on triangles*, SIAM J. Sci. Comput., 41 (2019), A3728–3756.

[26] K. N. Quinn, H. Wilber, A. Townsend, and J. P. Sethna, *Chebyshev approximation and the global geometry of sloppy models*, Physical Review Letters, 122, 158302.

[25] M. A. Gilles and A. Townsend, *Continuous analogues of Krylov methods for differential operators*, SIAM J. Numer. Anal., 57 (2019), pp. 899–924.

[24] B. Beckermann and A. Townsend, *Bounds on the singular values of matrices with displacement structure*, SIAM Review, 61 (2019), pp. 319–344.

[23] M. Udell and A. Townsend, *Why are big data matrices approximately of low rank?*, SIAM J. Math. Data Sci., 1 (2019), pp. 144-160.

[22] J. Słomka, A. Townsend, and J. Dunkel, *Stokes' second problem and an Einstein-de Haas analogue effect in active fluids*, Physical Review Fluids, 3 (2018).

[21] A. Townsend and H. Wilber, *On the singular values of matrices with high displacement rank*, Linear Alg. Appl., 548 (2018), pp. 19-41.

[20] D. Antoln–Ruiz and A. Townsend, *A nonuniform fast Fourier transform based on low rank approximation*, SIAM J. Sci. Comput., 40 (2018), A529–A547.

[19]A. Townsend, M. Webb, and S. Olver, *Fast polynomial transforms based on Toeplitz and Hankel matrices*, Math. Comp., 87, (2018).

[18] B. Beckermann and A. Townsend, *On the singular values of matrices with displacement structure*, SIAM J. Mat. Anal. Appl., 38 (2017), pp. 1227–1248.

[17] A. Townsend, H. Wilber, and G. B. Wright, *Computing with functions in spherical and polar geometries II. The disk*, SIAM J. Sci. Comput., 39 (2017), C238–C262.

[16] L. Demanet and A. Townsend, *Stable extrapolation of analytic functions*, Found. Comput. Math., (2016), pp. 1–35.

[15] V. Noferini, Y. Nakatsukasa, and A. Townsend, *Vector spaces of linearizations for matrix polynomials: A bivariate polynomial approach*, SIAM J. Mat. Anal. Appl., 38 (2016), pp. 1–29.

[14] N. Hale and A. Townsend, *A fast FFT-based discrete Legendre transform*, IMA Numer. Anal., 36 (2016), pp. 1670–1684.

[13] A. Townsend, H. Wilber, and G. B. Wright, *Computing with functions in spherical and polar geometries I. The sphere*, SIAM J. Sci. Comput., 38 (2016), C403–C425.

[12] V. Noferini and A. Townsend, *Numerical instability of resultant methods for multidimensional rootfinding*, SIAM J. Numer. Anal., 54 (2016), pp. 719–743.

[11] A. Townsend, T. Trogdon, and S. Olver, *Fast computation of Gauss quadrature nodes and weights on the whole real line*, IMA Numer. Anal., 36 (2016), pp. 337–358.

[10] A. Townsend and S. Olver, *The automatic solution of partial differential equations using a global spectral method*, J. Comp. Phys., 299 (2015), pp. 106–123.

[9] A. Townsend, *A fast analysis-based discrete Hankel transform using asymptotic formulas*, SIAM J. Numer. Anal., 53 (2015), pp. 1897–1917.

[8] Y. Nakatsukasa, V. Noferini, and A. Townsend, *Computing the common zeros of two bivariate functions via Bézout resultants*, Numer. Math., 129 (2015), pp. 181–209.

[7] A. Townsend and L. N. Trefethen, *Continuous analogues of matrix factorizations*, Proc. Roy. Soc. A., 471 (2015).

[6] N. Hale and A. Townsend, *An algorithm for the convolution of Legendre series*, SIAM J. Sci. Comput., 36 (2014), A1207–A1220.

[5] N. Hale and A. Townsend, *A fast, simple, and stable Chebyshev–Legendre transform using an asymptotic formula*, SIAM J. Sci. Comput., 36 (2014), A148–A167.

[4] A. Townsend and L. N. Trefethen, *An extension of Chebfun to two dimensions*, SIAM J. Sci. Comput., 35 (2013), C495–C518.

[3] N. Hale and A. Townsend, *Fast and accurate computation of Gauss–Legendre and Gauss–Jacobi quadrature nodes and weights*, SIAM J. Sci. Comput., 35 (2013), A652–A672.

[2] S. Olver and A. Townsend, *A fast and well-conditioned spectral method*, SIAM Review, 55 (2013), pp. 462–489.

[1] A. Townsend and H. Wendland, *Multiscale analysis in Sobolev spaces on bounded domains with zero boundary values*, IMA J. Numer. Anal., 33 (2013), pp. 1095–1114.

Submitted papers, conference proceedings, and technical reports

P. Abdalla, A. S. Bandeira, M. Kassabov, V. Souza, S. H. Strogatz, and A.Townsend, *Expander graphs are globally synchronizing*, submitted to CPAM.

C. Wang and A. Townsend, *Operator learning for hyperbolic partial differential equations*, submitted to JMLR.

S. Jeong and A. Townsend, *Extending Mercer's expansion to indefinite and asymmetric kernels*, submitted to ICLR.

E. Graf and A. Townsend, *Numerical instability of algebraic rootfinding methods*, submitted to SIAM J. Appl. Alg. Geom.

A. Damle, S. Glas, A. Townsend, and A. Yu, *How to reveal the rank of a matrix?*, submitted to SIAM Review

Selection of professional activities

Referee for numerous journals, including SIAM Review, CPAM, SINUM, SIMAX, SISC, JCOMP, and Numerische Mathematik. Also referee for SIAM Books and Cambridge University Press. Panelist for NSF grant proposals in 2016, 2017, 2019, 2021, 2022, and 2023. Panelist for NSF CAREER grants in 2024.

Editor SIMAX and LAA, leading journals in numerical linear algebra. Editor for Advances in Computational Mathematics, leading journal in computational mathematics. Editor for SIAM Review, leading applied math journal. Head judge for the Leslie Fox Prize. Editor of Handbook of Numerical Analysis 2024. On the UK MARS Advisory Committee.

Co-organize an undergraduate math modeling competition at Cornell with engagement from the local community and businesses. Lead PI on Engaged Cornell curriculum grant and the lead PI on the data science curriculum initiative in Arts & Sciences at Cornell University. Co-organized REU programs in the summer of 2020, 2021, and 2023. Part of an Active Learning Initiative for MATH 2210, linear algebra, in 2022. Lead PI on Active Learning Grant from 2024-2027.

Math consultant for the two episodes of PBS infinite series "Why Computers are Bad at Algebra" and "How to Generate Pseudorandom Numbers".

Co-organizer of Householder Conference in June 2024 at Cornell, leading numerical linear algebra conference.

Co-organizer for an online numerical linear algebra seminar (e-NLA) seminar with 1400 participants. Also, co-organizer for an online discussion seminar (CMC seminar) between numerical linear algebra and theoretical computer science with 600 participants.