Eduardo Corona

Applied mathematician dedicated to the development of groundbreaking numerical solvers, fast algorithmic physics simulation frameworks and scientific data compression methods.

- Extensive experience developing **efficient, high-fidelity modeling frameworks** in computational physics, featuring innovation in *algorithms*, *solvers* and *high performance computing implementation*.
- Expert in **numerical linear algebra**, **partial differential equations** and computational fluid dynamics, working on innovative techniques to dramatically speed-up methods in *optimization*, *statistical learning* and *data analysis*.
- Dynamic, self-taught scientist with strong record of interdisciplinary collaboration.

Employment Experience

2021-present **Assistant Professor of Applied Mathematics**, University of Colorado, Boulder.
- Ongoing partnership with **US Army** to implement novel scientific data compression techniques and multifidelity active learning methods for efficient learning from said compressed data.
- Development of fast integral equation methods for amphiphillic, electromagnetic and phoretic interactions in dense suspensions of Janus particles in viscous fluid media.
- Initiative to modernize curriculum in numerical methods and scientific computing for Boulder's applied mathematics programs.

2018–2021 **Assistant Professor of Mathematics**, New York Institute of Technology, New York.
- Project with **Flatiron Institute, Biophysical Modeling**: Software engineering, design and implementation of *high performance, distributed memory* methods for fluid suspension simulation and collision resolution.
- Partnership with **US Army** to accelerate high-fidelity soil mechanics simulations. Novel tensor decomposition preconditioning techniques for second order *optimization solvers*. Parallel distributed memory simulations of granular media (256 million particles).
- Interdepartmental effort to build a High Performance Computing Cluster (HPCC).
- Organization and curriculum development for NYIT's new Applied and Computational Mathematics major.
- Undergraduate and graduate student mentorship.

2014–2018 **James Van Loo Postdoctoral Fellow**, University of Michigan, Ann Arbor.
- Developed *modeling* (integral equations) and general-purpose *fast simulation tools* for rigid body suspensions in viscous flow. Target applications: biomechanics, microscopic swimming, smart material design.
- Adaptation of *memory-efficient linear solvers* for electromagnetic scattering with biomedical applications (collaboration with U of M Electrical Engineering).
- Collaboration with Hiroyuki Sugiyama (University of Iowa) to accelerate non-linear finite element tire modeling and mutiscale tire-vehicle mobility simulations.
- Scientific project management, student research mentoring and coordination.
- Teaching of diverse array of applied mathematics courses.

2008–2014 **Graduate Student**, Courant Institute, NYU, New York.
- Developed groundbreaking optimal complexity *direct solvers for structured linear equations* in integral equations, overcoming technical challenges that had been unaddressed for a decade.
- Software Matlab library development and public release of kernel independent fast multipole methods (KIFMM) and HSSC direct solvers for integral equations.

2008 **Research Intern**, University of New Mexico, Albuquerque.
- Developed a toolbox for *regression* and *statistical learning* on networks employing graph Laplacian methods and smooth spline models.
- Participation and collaboration with members of *Machine Learning Laboratory*, delivering applications to bayesian network structure set and protein data analysis.

Education

2008–2014 **Mathematics PhD**, Courant Institute, NYU, New York.

PhD Thesis, *Fast direct solvers for integral equations in two and three dimensions*, Advisor: Prof. Denis Zorin.

2003–2007 **Applied Mathematics BSc**, ITAM, Mexico City.

Awards

2014-2018 James Van Loo Post-Doctoral Fellowship Award at Michigan Center for Applied and Interdisciplinary Mathematics

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2008-2014 Henry MacCracken Graduate Scholarship

Teaching

2021–20XX **University of Colorado at Boulder:**.
- **APPM 4650 - Intermediate Numerical Analysis I:** Fall 2021

2018–2021 **New York Institute of Technology:**.
- **Math 455 - Numerical Analysis:** Fall 2019
- **Math 330 - Computational Analysis:** Fall 2020
- **Math 310 - Linear Algebra:** Fall 2018, 2019, 2020
- **Math 320 - Differential Equations:** Spring 2019
- **Math 260 - Calculus III:** Spring 2019
- **Math 180 - Calculus II:** Fall 2018, 2020
- **Math 170 - Calculus I:** Spring 2021

2014–2018 **University of Michigan:**.
- **Math 115 - Calculus I:** Fall 2014, 2016
- **Math 215 - Multivariate Calculus:** Winter 2015
- **Math 371 - Numerical Methods for Engineers:** Winter 2016
- **Math 471 -Introduction to Numerical Methods:** Fall 2017
- **Math 671 - Fast Algorithms (*Graduate*)** - Guest lectures & student mentoring, Fall 2015, 2016.

Curriculum development

- Re-design of CU Boulder APPM 4650 Intermediate Numerical Analysis I, Fall 2021.
- NYIT's Applied and Computational Mathematics (ACM) major head of curriculum committee and proposal organizer, 2019.
- Design and request to curriculum committee of new NYIT math courses:
  1. Math 330 Computational Analysis
  2. Math 410 Numerical Linear Algebra
  3. Math 440 Numerical Optimization
  4. Math 470 Mathematical Fluid Dynamics
  5. Math 490 Introduction to Mathematical Modeling.
- Re-design of Numerical Analysis course for NYIT Mathematics minor, 2019.

Scholarship

Recent Publications and Software Libraries

1. De, S., Corona, E., Jayakumar, P. and Veerapaneni, S. *Tensor-Train Compression of Large-Scale Discrete Element Simulation Data* (submission in preparation), SIAM Journal on Mathematics of Data Science (SIMODS) 2021.
2. Kohl, R., Corona, E., Cheruvu, V. and Veerapaneni, S. *Integral equation methods for dense suspensions of Janus particles in Stokes flow* (submitted to JCP, 2021), arxiv preprint 2104.14068.
3. Yan, W., Corona, E., Shelley, M., and Veerapaneni, S. *A scalable computational platform for particulate Stokes suspensions*, Journal of Computational Physics, 2020.
4. De, S., Corona, E., Jayakumar, P. and Veerapaneni, S. *Scalable Solvers for Cone Complementarity Problems in Frictional Multibody Dynamics* IEEE High Performance Extreme Computing conference, September 24-26 2019.
5. Corona, E., Gorsich, D., Jayakumar, P., and Veerapaneni, S. *A tensor train acceleration of nonsmooth rigid body dynamics*, Applied Mechanics Reviews, 2018.
6. Corona, E., Veerapaneni, S. *Boundary integral equation analysis for suspensions of spheres in Stokes flow*, Journal of Computational Physics 362, pp.327-345, 2018.
7. Corona, E., Gomez, L., Michielssen, E. *Quantized Tensor Train format for compression of electromagnetic volume integral equations*, submitted to Microwave and Optical Technology Letters, 2017.
8. Corona, E., Greengard, L., Rachh, M., and Veerapaneni, S. *An integral equation formulation for rigid bodies in Stokes flow in three dimensions*, Journal of Computational Physics 332: 504-519.
9. Corona, E., Rahimian, A., and Zorin, D. *A Tensor-Train accelerated solver for integral equations in complex geometries* , Journal of Computational Physics 334, 2015.
10. Corona, E., Martinsson, P.G., and Zorin, D. *HSSC Direct Solver* Matlab library for integral equations on 2D boundaries and 2D volume. Publicly available under a GNU general public license.
11. Corona, E., Martinsson, P.G., and Zorin, D. *An $O(N)$ direct solver for integral equations on the plane* Applied and Computational Harmonic Analysis 38 (2), 284-317, 2015.
12. Corona, E., Lane, T., Storlie, C. and Neil, J. *"Using Laplacian Methods, RKHS Smoothing Splines and Bayesian Estimation as a framework for Regression on Graph and Graph-Related Domains"* UNM Technical Report TR-CS-2008-06
13. Yackley, B., Corona, E. and Lane, T. *"Bayesian Network Score Approximation Using a Metagraph Kernel"* NIPS 2008: pp. 1833-1840

Research Grants

- *Tensor data compression and dimensionality reduction for autonomous mobility.* US Army GVSC / Automotive Research Center grant, 2019-2022 (Senior Personnel)
- *Efficient time integration methods for dense particulate flow simulation.* NYIT ISRC internal grant, 2019 (Principal Investigator) - **Award: $8994**.
- *Refraction Induced Error Quantification in Particle Image Velocimetry.* NYIT ISRC internal grant, 2019 (Co-Principal Investigator with Dr. Ahmardreza Baghaie) - **Award: $14,964**.
- *Fast numerical algorithms for high-fidelity simulation of terramechanics* US Army GVSC / Automotive Research Center grant, 2016-2019 (Senior Personnel) - **Award: $137,995**.

Recent Invited Talks and Presentations

- *Fast integral equation methods for Janus particle suspensions*, SIAM annual meeting 2021, Spokane WA, July 2021.
- *Metodos de Integrales en la Frontera, con applicaciones a simulacion de suspensiones densas en fluido Stokesiano*, Mathematical and Computational Engineering seminar, Pontifical Catholic University of Chile (PUC), May 2021.
- *Tensor data compression and dimensionality reduction for autonomous mobility*, ARC annual meeting, University of Michigan, May 2021.
- *A Crash Course on Boundary Integral methods with applications to complex fluid suspension simulation*, NYIT Applied Mathematics seminar, NYIT, August 2020.
- *Life at low Reynolds number: simulating microscopic swimmers and smart self-assembling materials in viscous flows*, Math and Physics seminar, NYIT, December 2019.
- *Integral equation methods for dense fluid suspensions*, Applied Interdisciplinary Mathematics seminar, University of Michigan, November 2019.
- *Fast algorithmic framework for dense Stokesian suspensions*, Fluids and Waves seminar, NJIT, October 2019.
- *Scalable Solvers for Cone Complementarity Problems in Frictional Multibody Dynamics* IEEE High Performance Extreme Computing conference, September 2019.
- *Fast and accurate methods for simulating self-assembly of Janus particles*,UMich MICDE symposium poster, April 10, 2019
- *Fast algorithms for dense suspensions in Stokes flow and their applications*, SIAM CSE Meeting 2019, Numerical methods for integral equations, February 2019.
- *A fast algorithms framework for rigid body suspensions in Stokes flow*, SIAM Meeting 2018, Numerical methods for integral equations, July 2018.
- *I Want It All: Achieving High Fidelity and Optimal Computational Complexity in Physics-Based Off-Road Mobility Simulations*, US Army Automotive Research Center meeting, May 16-17, 2018
- *Fast numerical algorithms for high-fidelity simulation of terramechanics*,US Army Automotive Research Center meeting, May 9-10, 2017
- *Fast numerical algorithms for high-fidelity simulation of terramechanics*,UMich MICDE symposium 2017, April 18, 2017
- *Tensor train acceleration for integral equation formulations for 3D high-contrast scatterers*, AIP 2017, Hangzhou, China, May 2017.
- *A tensor train acceleration for the ICVSIE for 3D high-contrast scatterers*, SIAM CSE 2017, Numerical methods for wave propagation and its applications mini-symposium, February 2017.
- *Fast algorithms for boundary integral equations with applications to particulate Stokes flow*, AIM Seminar, University of Michigan, October 28, 2016.
- *Tensor Train decomposition methods on tensorized arrays* Integral equations research group, University of Michigan, February 2, 2015
- *Fast Direct Solvers for Integral Equations in 3D: Recent developments and Challenges* CBMS-NSF Conference on Fast Direct Solvers for Elliptic PDEs, Dartmouth College, June 4-6, 2014

Service

- Member of NYIT Academic Senate, curriculum and library committees.
- Applied and Computational Math major proposal organizer, coordinator of curriculum development process.
- Hiring committee member for Old Westbury Mathematics, 2019.
- Tutoring service at the Math Resource Center, Old Westbury, NYIT 2018-Present.
- Organizing comittee and speaker for mathematics minor promotion day, NYIT.
- Journal referee for International Journal for Numerical Methods in Fluids.
- Journal referee for Journal of Computational Physics (top in the field).
- Journal referee for Applied Mechanics Reviews.
- Journal referee for Computers and Mathematics with Applications Elsevier journal.
- Invited reviewer of DOE Early Career proposals.

Student Mentoring (2014-present)

- **Undergraduate NYIT Student Mentoring: Hamad El-Kazha, Elec. Eng. Major / Math Minor** (2020-present) training in numerical methods towards a project on simulation of viscous flow and diffusion in filtration.
- **Graduate NYIT Student Mentoring: Boddu Manikanta (Mech. Eng.) and Naveen Holalin (CS)**(2019-present) ongoing collaboration with Prof. Ahmadreza Baghaie in numerical simulation of particle image velocimetry based on 4D blood flow Magnetic Resonance Imaging (MRI) data.
- **Undergraduate NYIT Student Mentoring: Samantha Rivera, Mech Eng. Major / Math Minor** (2019-present) began training on numerical methods and potential research prospects in Fall 2019.
- **Undergraduate NYIT Student Mentoring: Cameron Little, Mech Eng. Major / Math Minor** (2018-present) ongoing project to perform research in numerical methods for PDEs and adaptive timestepping for viscous particle flows.
- **Graduate Student mentoring: Ryan Kohl** (2018-present) ongoing project to develop fast algorithmic frameworks for simulation of Janus particles in viscous flow.
- **Graduate Student mentoring: Saibal De** (2017-present) collaboration and mentoring in two Automotive Research Center grant projects: *Fast numerical algorithms for high-fidelity simulation of terramechanics* (2016-2019) and *Tensor data compression and dimensionality reduction for autonomous mobility* (2019-2022).
  ongoing project to develop highly efficient distributed memory parallel code for frictional contact dynamics of rigid particles.
- **Graduate Student mentoring: Bowei Wu** (2014-2018) collaboration with the student in projects to develop periodization schemes in three dimensions for large-scale rigid body simulation, and to simulate electro and magneto-rheological flows in two and three dimensions.