Curriculum Vitae **Deep Ray**

CURRENT AFFILIATION

Department of Aerospace and Mechanical Engineering
Viterbi School of Engineering
University of Southern California
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INTERESTS

Data-driven computational physics, numerical methods for conservation laws, uncertainty quantification, multi-phase flow through porous media.

EMPLOYMENT

Postdoctoral researcher, Aerospace and Mechanical Engineering, USC
- July, 2020 to present
- Developing deep learning tools for Bayesian inference.

Postdoctoral researcher, CAAM, Rice University
- July, 2019 to June, 2020
- Developed high-resolution numerical methods to simulate multiphase flows through real rock structures at the pore scale.

Postdoctoral researcher, MCSS, EPFL
- July, 2017 to June, 2019
- Developed machine learning strategies to resolve bottle-necks in traditional numerical methods.

EDUCATION

Ph.D. in Mathematics, Tata Institute of Fundamental Research (TIFR-CAM)
- September, 2013 to May, 2017
- Advisors: Praveen Chandrashekar (TIFR-CAM) and Siddhartha Mishra (ETH Zürich and adjunct faculty TIFR-CAM)
- Developed and analysed a high-order entropy stable parallelized finite volume solver for the compressible Euler and Navier-Stokes equations on unstructured meshes.
- **Awarded** the Harish Chandra Memorial Award for the best Ph.D. thesis.

M.Phil in Mathematics, TIFR-CAM
- July, 2012 to September, 2013
- Advisor: Praveen Chandrashekar
- Analysed numerical schemes for the Euler and Navier-Stokes Equations that preserve entropy, kinetic-energy and vorticity, and performed multi-dimensional simulations for the same.

M.Sc in Mathematics, TIFR-CAM
- August, 2010 to May, 2012

B.Sc (Honours) in Mathematics, Hindu College, University of Delhi
- July, 2007 to June, 2010

RESEARCH VISITS

Visiting Research Student, Seminar for Applied Mathematics, ETH Zürich
- May to October, 2014 and August, 2015 to May, 2016
- Visited Siddhartha Mishra to work with him and his research group.

PUBLICATIONS

Journals

- *Deep learning observables in computational fluid dynamics*.
  K. O. Lye, S. Mishra, D. Ray.
  Journal of Computational Physics, Vol. 410 (2020).
- *Constraint-Aware Neural Networks for Riemann Problems*.
  J. Magiera, D. Ray, J. S. Hesthaven, C. Rohde.
  Journal of Computational Physics, Vol. 409 (2020).
- *Controlling oscillations in high-order Discontinuous Galerkin schemes using artificial viscosity tuned by neural networks*.
  N. Discacciati, J. S. Hesthaven, D. Ray.
  Journal of Computational Physics, Vol. 409 (2020).
- *Detecting troubled-cells on two-dimensional unstructured grids using a neural network*.
  D. Ray, J. S. Hesthaven.
  Journal of Computational Physics, Vol. 384 (2019).
- *Non-intrusive reduced order modelling of unsteady flows using artificial neural networks with application to a combustion problem.*
  Q. Wang, J. S. Hesthaven, D. Ray.
  Journal of Computational Physics, Vol. 384, pp. 289-307 (2019).
- *An artificial neural network as a troubled-cell indicator.*
  D. Ray, J. S. Hesthaven.
  Journal of Computational Physics, Vol. 367 (15), pp. 166-191 (2018).
- *An entropy stable finite volume scheme for the two dimensional Navier-Stokes equations on triangular grids.*
  D. Ray, P. Chandrashekar.
  Applied Mathematics and Computation, Vol. 314, pp. 257-286 (2017).
- *Convergence of fully discrete schemes for diffusive-dispersive conservation laws with discontinuous flux.*
  U. Koley, R, Dutta, D. Ray.
  ESAIM: Mathematical Modelling and Numerical Analysis, Vol. 50(5), pp. 1289-1331, (2016).
- *Entropy stable schemes on two-dimensional unstructured grids for Euler equations.*
  D. Ray, P. Chandrashekar, U. S. Fjordholm, S. Mishra.
  Communications in Computational Physics, Vol. 19(5), pp. 1111-1140, (2016).
- *A sign preserving WENO reconstruction method.*
  U. S. Fjordholm, D. Ray.
  Journal of Scientific Computing, Vol. 68(1), pp. 42-63, (2015).
- *Entropy stable schemes for compressible Euler equations.*
  D. Ray, P. Chandrashekar.
  Int. J. Numer. Anal. Model. Ser. B, no. 4, pp. 335-352 (2013).

Conference Proceedings

- *A Third-Order Entropy Stable Scheme for the Compressible Euler Equations.*
  D. Ray.
  Theory, Numerics and Applications of Hyperbolic Problems II. HYP 2016. Springer Proceedings in Mathematics and Statistics, vol 237, 2018
- *Kinetic energy preserving and entropy stable finite volume schemes for compressible Euler and Navier-Stokes equations.*
  D. Ray, P. Chandrashekar.
  14th Annual CFD Symposium - Aeronautical Society of India, IISc, Bangalore, 10-11 August, 2012.

Under Review

- *Multi-level Monte Carlo finite difference methods for fractional conservation laws with random data.* (to appear in SIAM/ASA Journal on Uncertainty Quantification, 2020)
  U. Koley, D. Ray, T. Sarkar.
- *Bayesian Inference in Physics-Driven Problems with Adversarial Priors.* (submitted, 2020)
  D. Patel, D. Ray, H. Ramaswamy, A. A. Oberai.
- *Iterative Surrogate Model Optimization (ISMO): An active learning algorithm for PDE constrained optimization with deep neural networks.* (submitted, 2020)
  K. O. Lye, S. Mishra, D. Ray, P. Chandrashekar.
- *A discontinuous Galerkin method for a diffuse-interface model of immiscible two-phase flows with soluble surfactant.* (submitted, 2020)
  D. Ray, C. Liu, B. Riviere.
- *Controlling oscillations in spectral methods by local artificial viscosity governed by neural networks*. (submitted, 2020)
  L. Schwander, D. Ray, J.S. Hesthaven.
- *On the approximation of rough functions with deep neural networks*. (submitted, 2019)
  T. De Ryck, S. Mishra, D. Ray.

TALKS AND POSTERS

Data-driven enhancements of numerical methods (2nd March, 2020)
Colloquium Talk, Department of Mathematical Sciences, Michigan Technological University.

Deep learning enhancements of numerical methods (12th February, 2020)
Colloquium Talk, Department of Mathematics, University of Florida.

Deep learning enhancements of numerical methods (9th September, 2019)
CAAM Colloquium, Rice University, Houston.

Using deep learning to overcome algorithmic bottlenecks (18th June, 2019)
Invited speaker at NumHyp 2019, Malaga.

Detecting discontinuities using deep learning (12th April, 2019)
Deep Learning Meetup, Zürich.

Controlling oscillations in high-order accurate methods through artificial neural networks (28th February, 2019)
SIAM-CSE 2019, Spokane.

A fully-discrete kinetic energy preserving and entropy conservative scheme for compressible flows (27th February, 2019)
SIAM-CSE 2019, Spokane.

Controlling spurious oscillations in high-order methods through deep neural networks (9th January, 2019)
TIFR-CAM Colloquium, Bangalore.

Controlling spurious oscillations in high-order methods through deep neural networks (15th November, 2018)
High-Fidelity Industrial LES/DNS symposium, Brussels.

An artificial neural network as a troubled-cell indicator (10th July, 2018)
SIAM Annual Meeting 2018, Portland.

Using neural nets to detect discontinuities (19th June, 2018)
MATHICSE Retreat, St. Croix.

An artificial neural network for detecting discontinuities (11th March, 2018)
7th International Conference on High Performance Scientific Computing, Hanoi.

An artificial neural network for detecting discontinuities (3rd January, 2018)
TIFR-CAM Colloquium, Bangalore.

A high-resolution energy preserving method for the rotating shallow water equation (27th September, 2017)
European Conference on Numerical Mathematics and Advanced Applications, Voss.

A third order entropy stable scheme for the compressible Euler equations (4th August, 2016)
XVI International Conference on Hyperbolic Problems (HYP2016), Aachen.

A sign preserving WENO reconstruction (23rd November, 2015)
Department of Mathematics, University of Würzburg.

A sign preserving WENO reconstruction (14th August, 2015)
International Conference on Industrial and Applied Mathematics, Beijing.

A sign preserving WENO reconstruction (11th June, 2015)
Department of Applied Mathematics, University of Washington, Seattle.

Entropy stable schemes for compressible flows on unstructured meshes (20th December, 2014)
Conference on Computational PDEs, Finite Element Meet, TIFR-CAM.

Entropy stable schemes for compressible flows on unstructured meshes (9th November, 2014)
The 5th International Conference on Scientific Computing and Partial Differential Equations, HKBU, Hong Kong.

Poster: *Entropy stable schemes for compressible flows on unstructured meshes* (9th September, 2014)
Workshop on the Analysis and Numerical Approximation of PDEs, ETH Zürich.

Entropy stable schemes for compressible flows (9th July, 2014)
Department of Mathematics, University of Würzburg.

WORKSHOPS

- *Academic Industry Modelling Week*, University of Zürich (9th-13th November, 2015)
- *Workshop on the Analysis and Numerical Approximation of PDEs*, ETH Zürich (8th - 10th September, 2014)
- *CIME-CIRM Workshop on Mathematical Models and Methods for Living Systems*, Levico Terme, Italy (1st - 5th September, 2014)
- *Workshop on Optimization with PDE constraints*, TIFR-CAM (25th November - 6th December, 2013)
- *Compact course on Discontinuous Galerkin method for time-dependent convection-dominant PDEs, by Prof. Chi-Wang Shu* , TIFR-CAM (4th - 5th July, 2013)
- *IFCAM Summer School on Numerics and Control of PDEs*, IISc, Bangalore (22nd July - 2nd August, 2013)

- *CIMPA Summer Research School on Current Trends in Computational Methods for PDEs*, IISc, Bangalore (24th June - 19th July, 2013)
- *Workshop on Theoretical and Computational Aspects of Nonlinear Waves*, NPDE-TCA, IIT-Bombay (27th - 31st May, 2013)
- *Advanced Workshop on Non-Standard Finite Element Methods*, NPDE-TCA, IIT Bombay (11th - 15th Febraury, 2013)
- *Data Assimilation Research Program*, TIFR-CAM (4th - 23rd July, 2011)
- *Visiting Students' Research Programme*, TIFR Mumbai (15th June - 10th July, 2009)

TEACHING EXPERIENCE

Instructor:

- MATH-459: Graduate course on Numerical Methods for Conservation Laws, at EPFL (September - December, 2020)
- Mini-course on the Application and Implementation of Deep Learning, at TIFR-CAM (January, 2019).

Course development:

- AME-599 (special topics): Course on Machine Learning and Computational Physics, at USC (August - December, 2020)

Teaching assistant:

- MATH-459: Graduate course on Numerical Methods for Conservation Laws, at EPFL (September - December, 2018)
- MATH-459: Graduate course on Numerical Methods for Conservation Laws, at EPFL (September - December, 2017)
- Graduate course on Computational Partial Differential Equations, at TIFR-CAM (January - May, 2015)
- Graduate course on Numerical Analysis, at TIFR-CAM (August - December, 2013)
- Graduate course on Numerical Analysis, at TIFR-CAM (August - December, 2012)

MENTORING EXPERIENCE

Master thesis co-supervision:

Niccolò Discacciati	EPFL/Politecnico di Milano	2018	Curr: PhD, EPFL
Andrea Romani	EPFL/Politecnico di Milano	2019	Curr: Sim. developer, Ferrari
Lukas Schwander	ETH	2019	Completed
Tim De Ryck	ETH	2019	Completed

Bachelors thesis co-supervision:

Moritz Reinders	ETH	2019	Completed

SERVICE

- Participated as a judge in the Science and Engineering Fair of Houston (February 2020).
- Led an interactive session on applied mathematics for high-school students visiting Rice University (July 2019).
- Organised numerical sessions for optimal control at the IFCAM Summer School on Numerics and Control of PDEs-2013, at the Indian Institute of Science, Bangalore.
- Organiser of the Students Seminar Series (S^3) at TIFR-CAM (2012 - 2013). The purpose of this committee was to organise and oversee talks by motivated students, on mathematical or other science oriented topics.
- General Secretary of the mathematics society ALPHA at Hindu College (2008 - 2009).
- Founding member of *Science Forum* at Hindu College (2008-2010). The mandate of this society was to bring together the students from various science departments, so that they could share the knowledge gathered in their respective fields and gain insights into other associated areas.

- Founding member of *Caucus* at Hindu College (2009-2010). The society served as a forum for discussing various burning national and global issues, and training students for the Model United Nations Co nferences.

Review for Journals

Journal of Computational Physics, SIAM Journal on Numerical Analysis, SIAM Journal on Scientific Computing, Communications in Computational Physics, Journal of Scientific Computing, Proceedings of the Royal Society A, Computers & Fluids, Boundary Value Problems, BIT Numerical Mathematics, Indian Journal of Pure and Applied Mathematics.

Computing Skills

Languages:	C++, Python, Fortran
Programming Software:	MATLAB
Visualisation Software:	Paraview, Gnuplot, VisIt, Paraview, Gmsh
Machine-Learning Software:	TensorFlow

Last updated on October 11, 2020