Abhinav Singh

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Skills

- **Programming Languages:** Proficient in C++, Python & API development; LaTeX
- Advanced proficiency in developing scalable simulation and AI frameworks
- **Software and Tools:** OpenFPM(maintainer), Paraview, Mathematica, PetSC, Eigen
- **Research Interests:** Active Turbulence, Distributed and High-Performance Computing on heterogeneous architectures, Numerical Simulations, Reinforcement Learning

Experience

Postdoctoral Fellow in Applied Mathematics, Harvard University 2024 – Present

- Coupled a C++ compile-time expression system with *Korali* that accelerates large scale reinforcement learning with PDE solvers for control of active fluids and active turbulence.
- Implemented multi-GPU simulations of the Fitz-Nagumo model for large scale biological neural network simulations.

Researcher and Software Developer, Technische Universität Dresden 2019 - 2024

- Engineered novel programming abstractions for scalable 3D simulations of active biological matter, characterizing active-turbulence regimes (spontaneous flow transitions, traveling waves, spatiotemporal chaos) in extensile polar fluids.
- Deployed explainable machine learning numerical methods (Unstructured convolution-nets on graphs) for up to 5x faster simulations in complex geometries by reducing the time complexity of the algorithm from $O(n^3)$ to $O(n^2)$ for 3D surfaces without the need of meshing.
- Led the integration of these models into the scalable OpenFPM library, resulting in a 30% improvement in processing time of large-scale 4D simulation data and 70% reduction in code development times via a custom built expression system for PDEs.
- Collaborated on interdisciplinary projects to bridge experimental and theoretical domains, specifically driving the experimental modeling of 3D active nematic droplets, confirming theoretical and numerical predictions and enhancing the predictive accuracy of the models.
- Successfully supervised multiple master's theses, mentoring students to advance their projects to PhD level.

Teaching Assistant, Technische Universität Dresden 2019 - 2023

- Instructed over 100 undergraduate and graduate students in Basic Numerical Methods and Particle Methods, achieving a 95% satisfaction rate for computational modeling and simulation track of the university.
- Designed and executed a comprehensive suite of lectures, assignments, and exams, enhancing student understanding and application of complex scientific concepts. Provided tailored support to students, significantly improving their academic performance and mastery of course material.

Research Intern, Indian Institute of Technology, Mumbai 2016 - 2019

- Researched DNA computing within reaction networks, utilizing high-performance GPU for simulation of large reaction networks to advance Hidden Markov Model training algorithms.
- Developed innovative computational schemes that increased simulation efficiency by 25%, significantly speeding up the data processing pipeline using CUDA and GPUs.
- Contributed to the academic community by presenting findings at three international conferences, enhancing the visibility of collaborative research efforts.

Visiting Researcher, University of Copenhagen, Denmark 2018

- Created a new machine learning algorithm for training Hidden Markov Models using chemical reaction networks.
- Collaborated with an international team, integrating diverse research methodologies and strengthening research experience.

Education

Center for Systems Biology, Dresden, Germany
Max Planck Institute of Molecular Cell Biology and Genetics
International Max Planck Research School, **Technische Universität Dresden**

Ph.D. in Computer Science, *2019-2024*, **Summa Cum Laude (Highest Distinction)**

- Thesis: Efficient and Scalable Simulations of Active Hydrodynamics in Three Dimensions

- Advisor: Prof. Dr. Ivo F. Sbalzarini
- Nominated for GI-Prize and Georg Helm Prize by TU-Dresden.

University of Mumbai, Centre for Excellence in Basic Sciences, Mumbai, India

Int. B.Sc.-M.Sc. Mathematics, *2014-2019*

- Cumulative Grade Point Average: **8.7/10**, *Rank 1*
- Thesis: Design and Engineering of Molecular Systems that can Solve Statistical Problems
- Advisor: Prof. Dr. Manoj Gopalkrishnan

Publications

1. Active Fréedericksz Transition in Active Nematic Droplets. 2024
   Salman Alam, Bibi Najma, **Abhinav Singh**, *Jeremy Laprade, Gauri Gajeshwar, Hannah G. Yevick, Aparna Baskaran, Peter J. Foster, and Guillaume Duclos*
   Physical Review X, doi:10.1103/PhysRevX.14.041002
   News/Media Coverage: PhysOrg, MSN
2. A numerical solver for active hydrodynamics in three dimensions and its application to active turbulence. 2023
   Abhinav Singh*, *Philipp Suhrcke*, Pietro Incardona, Ivo F. Sbalzarini*
   Physics of Fluids (Cover Article), doi:10.1063/5.0169546
   News/Media Coverage: PhysOrg, SciTechDaily, Altmetric+12 News articles
3. Spontaneous flow instabilities of active polar fluids in three dimensions. 2023
   Abhinav Singh, *Quentin Vagne, Frank Jülicher, Ivo F. Sbalzarini*
   Physical Review Research, doi:10.1103/PhysRevResearch.5.L022061
4. A reaction network scheme for hidden Markov model parameter learning. 2023
   Carsten Wiuf, Abhishek Behra*,* **Abhinav Singh*** *, Manoj Gopalkrishnan*
   Journal of the Royal Society Interface , doi:10.1098/rsif.2022.0877
5. A meshfree collocation scheme for surface differential operators on point clouds. 2023
   Abhinav Singh, *Alajandra Foggia, Pietro Incardona, Ivo F. Sbalzarini*
   Journal of Scientific Computing, doi:10.1007/s10915-023-02313-3
6. Entropically damped artificial compressibility for the discretization corrected particle strength exchange method in incompressible fluid mechanics. 2023
   Abhinav Singh, *Ivo F. Sbalzarini, Anas Obiedat*
   Computers & Fluids, doi:10.1016/j.compfluid.2023.106074
7. A C++ expression system for partial differential equations enables generic simulations of biological hydrodynamics. 2021
   Abhinav Singh, *Pietro Incardona, Ivo F. Sbalzarini*
   Advances in Computational Methods for Biological Physics -
   The European Physical Journal E, doi:10.1140/epje/s10189-021-00121-x
   Media Mentions (13 articles)
8. A reaction network scheme which implements inference and learning for hidden Markov models. 2019
   Abhinav Singh, *Abhishek Behra, Carsten Wiuf, Manoj Gopalkrishnan*
   DNA Computing Proceedings (DNA25), doi:10.1007/978-3-030-26807-7_4

*: Equal contribution of first authorship

Conference Participation, Talks and Poster Presentations

1. Invited Talk: California Institute of Technology, USA March, 2024
   - Streamlined Scalable Computing for Active Living Matter
2. Invited Talk: Harvard University, USA March, 2024
   - Elucidating 3D Active Matter Instabilities through Scalable Domain-Specific Programming and Particle Methods.
3. Invited Talk: Special MRSEC Seminar at the Brandeis University, USA March, 2024
   - Dynamical Instabilities in 3D Cytoskeletal Materials
4. Mechanics of Life II: Models and Methods, Flatiron Institute, NY, USA December, 2023
   - Poster: Three-Dimensional Wrinkling and Spontaneous Flow in Active Polar Fluids.

5. Talk at the Particles 2023 Conference, Milan, Italy — October, 2023
   - A Scalable Hybrid Particle-Mesh Method for Simulating Active Fluids in Three Dimensions.
6. 7th International Soft Matter Conference, Osaka, Japan — September, 2023
   - Poster: Three-Dimensional Wrinkling and Spontaneous Flow in Active Polar Fluids.
7. Invited Talk: MRSEC Seminar at the Brandeis University, USA — April, 2023
   - Navigating the complexities of 3D active matter with streamlined scalable computing.
8. Talk: APS March Meeting, Las Vegas, USA — March, 2023
   - Transition to Freedericksz-type flow and chaos in 3D active fluids.
9. Talk: PKS Circle Meeting, MPI-PKS, Dresden, Germany — January, 2023
   - Spontaneous Flow in Confined 3D Active Fluids
10. Summer School: Active Matter in Complex Media, Cargése, France — October, 2022
    - Flash Talk and Poster: A C++ expression system for active hydrodynamics.
11. Talk at the US National Congress on Theoretical and Applied Mechanics, Austin, USA — July, 2022
    - Efficient and scalable simulation of active fluids in 3D.
12. Invited Talk at the Lubensky and Jordan Group, University of Michigan, USA — July, 2022
    - Activity Induces Chaos in 3D Active Polar fluids.
13. Cell and developmental systems EMBO Workshop, Arolla, Switzerland — July, 2022
    - Participation and Poster Abstract: Scalable Simulaitons of Active Hydrodynamics.
14. Physics of Life Summer School: Non-Equilibrium Physics
    Higgs Centre for Theoretical Physics at the University of Edinburgh, UK — April, 2022
    - Poster Presentation: A C++ expression system for active hydrodynamics.
15. Qlife Quantitative Biology Winter School : Active Matter in Biology, Paris, France — February, 2022
    - Poster Presentation: A C++ expression system for active hydrodynamics.
16. EMBL Synthetic Morphogenesis Virtual Conference — March, 2021
    - Poster: An expression system for scalable simulations of PDEs.
17. Talk at DMV mini symposium on vector and tensor-valued surface PDEs — December, 2020
    - An expression system for scalable simulations of PDEs.
18. Poster at DNA24 Conference, Jinan, China — October, 2018
    - EM Algorithm with DNA Molecules.

Teaching

At Technische Universität Dresden

1. Basic Numerical Methods — 2019 - 2020
2. Particle Methods — 2020

Master Thesis Supervision

Philipp Suhrcke (Pursuing PhD at TU Dresden) — 2021-2022
- Computational Modeling and Simulation Masters' Thesis
  Thesis Title: Active turbulence in extensile polar fluids - A step into the third dimension
- Computational Modeling and Simulation Project
  Title: Vortex Methods for Active Fluids.

Birte Christine Geerds (Pursuing PhD at University of Geneva) — 2022-2023
- Physics Masters' Thesis at TU Dresden
  Thesis Title: Defect Dynamics in Active Fluids

Rushikesh Shinde (Pursuing PhD at Université Paris Cité) — 2021
- Computational Modeling and Simulation Team Project
  Title: Staggered Grid Solvers for Stokes Flow

Anton Rygin — 2023-2024
- Computational Modeling and Simulation Project
  Title: Scalable In-Situ Visualization with Paraview Catalyst and OpenFPM

Tim Pokart — 2022
- Physics Masters' Project
  Title: Preconditioners for 3D Active Hydrodynamic Solvers

Landfried Kraatz — 2022
- Computational Modeling and Simulation Project
  Title: Scalable Time Integration with OpenFPM and Odeint

Language Proficiency

English - Fluent
Hindi - Fluent
German - A2