Curriculum Vitae

Website
msg85@pitt.edu

Citizenship: India

Manraj Singh Ghumman

Education

PhD, University of Pittsburgh, GPA (till now): 4/4 **Aug 2022 — Aug 2027 (Expected)**

BS-MS (Integrated 5 years Bachelors and Masters degree),
Indian Institute of Science, Education and Research (IISER) Pune, GPA in Mathematics: 8.6/10.00 **Aug 2016 — July 2021**

Higher Secondary School (12th grade), Mount Carmel School, Chandigarh, Percentage (Cumulative): 93% **April 2015 — March 2016**

Technical and Mathematical Skills

Mathematics	Numerical Analysis and Numerical Techniques, Partial Differential Equations, Functional Analysis, Probability.
Physics	Lower division courses on classical mechanics, quantum mechanics and electromagnetism and waves. Upper undergraduate level courses on Electromagnetism and Mathematical Methods in Physics.
Languages	Active: C++, Python, Latex, Prior experience: MATLAB, C.
Comput.	Parallel computing (MPI), deal.ii, FreeFem++, Paraview
Dev.	VS Code, Eclipse, Slurm.

ACADEMIC ACHIEVEMENTS

Funding

- INSPIRE Scholarship 2016-2021, for pursuing bachelors and masters, funded by the Department of Science and Technology, India.
- TA/TF (Teaching Assistant/Fellow): Multiple terms, University of Pittsburgh.
- Arts and Science Graduate Fellowship, University of Pittsburgh Spring 2023. (Declined)
- GSR (Graduate Student Researcher, NSF): Multiple terms, University of Pittsburgh.

Schools/Conferences

- Summer School 2021, PDE in Mathematical Physics, Vienna Doctoral School in Physics (VDSP), Univ of Vienna, 23 Aug to 3 Sep.
- Recent Advances in Mathematical Fluid Dynamics, Duke University, May 2023.
- Mathematical Opportunity in Digital Twins, George Mason Univ. 11-13 Dec, 2023.
- Mathematical Problems in Industry hosted by SIAM at University of Vermont, 25-29 June, 2024.
- RIKEN International HPC Spring School, Jan 15-17, 2025 (Online)

Competitive Exams and Competitions

- National Graduate Physics Examination 2018: National Topper.
- Qualified the National Eligibility Test (NET, Dec 2019) and eligible for holding post of Assistant Professor in India.
- Qualified the National Eligibility Test (NET, June 2021) with All India Rank 110 and awarded Junior Research Fellowship by University Grants Commission to pursue Doctoral studies in India. (Declined)

Talks

- Lipschitz Extension Problem (Masters Thesis Defence), IISER Pune, June 2021.
- Infinity Harmonic Functions and Calculus of Variations, Analysis and Geometry Seminar, Math Department IIT Gandhinagar, Jan 2022.

Teaching Experience

- **Teaching Assistant, IISER Pune.** MT2123, Advanced Linear Algebra. Fall 2021

- **Teaching Fellow, Plaksha University.** Mathematics of Uncertainty: A course on Probability and Statistics for engineers with applications using MATLAB. Spring 2022
- **Teaching Fellow/ Assistant, University of Pittsburgh.**
  1. MATH 0220, Analytic Geometry and Calculus 1, 3.
  2. MATH 1800: A course on mathematics of Machine Learning

Projects

1. Mixed Finite Element Method (MFEM), with Prof. Ivan Yotov,Dept of Mathematics,Univ. of Pittsburgh, Dr. Manu Jayadharan, Northwestern University **Spring2024 — Current**

This project is concerned with the study of the Stokes-Biot system for poroelasticity using mixed finite elements. This is a multiphysics system and the solution is computed via a nonoverlapping domain decomposition approach as an alternative to the default monolithic or splitting schemes. The two systems are coupled at the interface with appropriate continuity conditions. The idea is to reduce the problem to a Linear problem on the interface where an action of the linear operator involves solving the individual Stokes and Biot subdomain problems in parallel. The linear problem on the interface is solved using an iterative method which allows for parallel implementation by leveraging the matrix-vector products with the interface operator. This formulation allows for efficient coupling for multiple different physical systems. The implementation is done using the deal.ii finite element library and parallel implementation using MPI.

2. System of Monge-Ampére equations and Convex Integration, with Prof. Marta Lewicka, Dept of Mathematics, Univ. of Pittsburgh **Jan 2023 — July 2023**

This project is concerned with studying and understanding convex integration techniques in arbitrary dimension d and codimension k for Monge-Ampére type equation. Convex integration is an important idea employed in both fluid dynamics and differential geometry. In dimension $d = 2$ the authors in [1] diagonalize the deficit to reduce the degrees of freedom to two. This improves on the degrees of freedom = 3 obtained in [2] which reduces the deficit to an upper triangular matrix. This will improve the flexibility in dimension 2 and arbitrary codimension from Hölder regularity $\frac{1}{1+6/k}$ (given by [2]) to $\frac{1}{1+4/k}$. This particular problem is also important due to its applications in elasticity.

1. Cao, W. and Székelyhidi Jr., L.: Very weak solutions to the two-dimensional Monge Ampére equation, in: Science China Mathematics, 62(6), pp. 1041–1056, (2019).
2. Lewicka, M: The Monge-Ampére System: Convex integration in arbitrary dimension and codimension; arXiv:2210.04363, Oct 2022.

3. Lipschitz Extension Problem (MS Thesis), with Prof. Anup Biswas, Department of Mathematics, IISER Pune **Aug 2020 — May 2021**

The main content of this thesis is Lipschitz extension property of functions from boundary of the domain to the interior of the domain with the property that it's absolutely minimizing Lipschitz extension. Existence and Uniqueness of absolutely minimizing Lipschitz extension have also been discussed in this thesis. One can show that Dirichlet problem of finding absolutely minimizing Lipschitz extension is equivalent to finding viscosity solutions to the Dirichlet problem of the infinity Laplacian. This provides interesting methods to study regularity of solutions. Savin has shown that these solutions are C^1 in $\mathbb{R}^2$. This paper and few other results are summarized. The infinity Laplacian with source term i.e., the so called infinity Poisson equation is also studied in this thesis. It is still an open problem to show that the viscosity solution to the Dirichlet problem of the infinity Laplacian (without source) has $C^{1,\frac{1}{3}}$ regularity. References have been provided for further work done after Savin in this direction. Key References during the preparation of this thesis include:

1. Aronsson, G., Crandall, M.G., Juutinen, P.: A tour of the theory of Absolutely Minimizing functions; Bull. Amer. Math. Soc. 41 (2004), 439-505 .
2. Lindqvist, P.: Notes on the Infinity Laplace equation. Springer Briefs in Mathematics, 2016.
3. O. Savin: C^1 regularity for infinity harmonic functions in two dimensions, Arch. Ration. Mech. Anal. 176 (3) (2005), 351–361.

4. Fractional Maps in Cryptography, with Prof. Varsha Gejji, Department of Mathematics, Savitribai Phule Pune University **Summer 2019**

- Methods of encryption using a chaotic system are widely studied. A novel way of encrypting using ergodic maps was given by Baptista[1]. Baptista's model uses symmetric key cryptography using the logistic map for encryption. Instead if one uses a fractional logistic map, it would increase the security by increasing the key size as now the order would also be another parameter.
- This project involved analysis of the fractional logistic map[2] as a toy model for this approach. The main problems with this were the unexpected behaviour of the fractional maps, where it is difficult to predict regions of chaos with respect to the initial condition, order and parameter value[3]. It was concluded that this map was not robust and practical for application. Key References:

1. Baptista, M. S. : Cryptography with chaos, Phys. Lett. A 240 (1998) 50.
2. Wu, G.C., Baleanu, D: Discrete fractional logistic map and its chaos,Nonlinear Dyn (2014) 75:283–287, DOI 10.1007/s11071-013-1065-7.
3. Peng, Y., Sun, K., He, S., Wang, L.: Comments on “Discrete fractional logistic map and its chaos” [Nonlinear Dyn. 75, 283–287 (2014)], Nonlinear Dyn.

Leadership and Diversity roles

- Event Coordinator: Member of Organising team Intra and Inter IISER Sports Events. (2018, 2019)
- Volunteer Mentor: International student mentor, Graduate global ties program, University of Pittsburgh. (2023-2024)
- GSO Officer: Math Graduate Student Organization Executive Committee, University of Pittsburgh.(2023-2025)
- Treasurer: SIAM Student Chapter University of Pittsburgh.(2024-2025)

References

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Dr. Michael Schneier
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