Curriculum Vitae

Website
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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**

Relevant Courses

Mathematics Partial Differential Equations, Functional Analysis, Probability, Numerical Analysis and Numerical Techniques.
Physics Lower division courses on classical mechanics, quantum mechanics and electromagnetism and waves. Upper undergraduate level courses on Electromagnetism and Mathematical Methods in Physics.
Programming C, MATLAB, Python and Latex.

ACADEMIC ACHIEVEMENTS

Funding

- INSPIRE Scholarship 2016-2021, for pursuing bachelors and masters, funded by the Department of Science and Technology, India.
- TA (Teaching Assistant): Fall 2022, 2023, University of Pittsburgh.
- GSR (Graduate Student Researcher, NSF): Spring, Summer 2023, University of Pittsburgh.

Schools/Conferences

- VIJYOSHI National Science Camp at IISc, Summer 2016.
- Winter School on Differential Equations at Savitribai Phule Pune University, Dec 2018.
- Summer School 2021, PDE in Mathematical Physics, Vienna Doctoral School in Physics (VDSP), Univ of Vienna, 23 Aug to 3 Sep.
- IWM Minicourse on Approximate Solutions of Operator Equations and Eigenvalue Problems by Prof. B.V. Limaye, 20-21 Nov 2021.
- Recent Advances in Mathematical Fluid Dynamics, Duke University, May 2023.

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

- Fall 2021: Teaching Assistant for MT2123, Advanced Linear Algebra at IISER Pune.
- Spring 2022: Teaching Fellow for FM122, Mathematics of Uncertainty: A course on Probability and Statistics for engineers with applications using MATLAB. Plaksha University.
- Fall 2022, 2023: Teaching Assistant for MATH 0220, Analytic Geometry and Calculus 1 at University of Pittsburgh.

Projects

1. 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 and codimension for Monge-Ampére type equation. Convex integration is an important idea employed in both fluid dynamics and differential geometry. The goal of this project is to understand these techniques in relation to the papers [1] and [2] and work on a formal research project building further on these works. This particular problem is also important due to its applications in elasticity and the isometric immersion problem.

1. Lewicka, M. and Pakzad, M.: Convex integration for the Monge-Ampére equation in two dimensions, Analysis and PDE, 10(3), pp. 695–727, (2017)
2. Lewicka, M: The Monge-Ampére System: Convex integration in arbitrary dimension and codimension; arXiv:2210.04363, Oct 2022.

2. Advanced PDE, Independent Study **July 2021 — Dec 2021**

This is an independent project where I am using several sources and trying to learn more PDE during the halt in inperson learning brought about by the pandemic.

- (July-Aug) I was briefly a part of Prof. Sombuddha Bhattacharyya's group at IISER Bhopal. Here I studied theory of distributions.
- (July-Oct) I enrolled in Prof. S. Kesavan's online graduate course on Sobolev spaces and PDE for a more detailed study of Sobolev spaces and basics of uniformly elliptic linear pde.
- (Sept-Oct) I also attended lectures by Prof. Sandeep Kunnath in his graduate course on Calculus of Variations at the TATA Institute of Fundamental Research, Bangalore.

3. Summer School on PDE in Mathematical Physics, Vienna Doctoral School of Physics, University of Vienna **Aug 2021**

Initially Prof. Roland Donninger did a recap of Measure theory and integration, Functional Analysis and Sobolev spaces. Then Prof. David Fajman took over and we studied the Cauchy problem in wave equation with bilinear source term. The main components were

- Local (in time) existence and uniqueness of solution: This included a breakdown criterion which characterizes a possible finite existence time depending on blow up of certain norms depending on the solution.
- Gave a particular example to show that global in time existence of solution is not always possible for nonlinear wave equation even with small initial data for $n = 3$. For $n \geq 4$, we proved global existence as a result of the dispersion.
- Finally, we studied the nonlinearity with null structure. Under this condition, we can get global existence for sufficiently small initial data for $n = 3$.

4. 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.

5. 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.

6. Winter School on Differential Equations, Department of Mathematics, Savitribai Phule Pune University **Dec 2018**

- Physical models of linear and nonlinear differential equations, general theory of initial value problems, qualitative analysis of linear and nonlinear systems, stable, unstable manifolds and related theorems, Frobenius theory (series solution)
- Boundary value problems, Sturm-Liouville theory, applications to controllability.
- Introduction to Fractional Calculus, and Fractional Differential Equations (FDEs), analysis of FDEs, special functions related to FDEs, nonlinear dynamical systems of fractional order.

EXTRA-CURRICULAR ACTIVITIES

- Member of Badminton College Team 2016,17,19 and Captain 2017.
- Member of Athletics College Team 2017, events- 5k and 10k.
- Member of Organising team Intra IISER badminton league(IBL) 2018.
- Member of Organising team Inter IISER Sports Meet 2019.
- University of Pittsburgh, Math Graduate Student Organization Executive Committee.