MIHIR SUNEEL DURVE

Postdoctoral researcher at
Center for Life Nano- & Neuro-Science, Fondazione Istituto Italiano di Tecnologia (IIT) - Rome, Italy

PERSONAL PROFILE

Name : Mihir Suneel
Surname : Durve
Contact details : 1) Mobile :
2) Email :
3) Skype :
Address :
Date of Birth
Gender
Marital Status
Nationality
Immigration status : Permanent resident in Italy

WORK EXPERIENCE (POST PH.D.)

1) **Postdoc researcher – 4 years 5 month and counting** *October 2020 - the present day*
Center for Life Nano- & Neuro-Science, Fondazione Istituto Italiano di Tecnologia (IIT) - Rome, Italy
Supervisor: Prof. Sauro Succi

2) **Visiting researcher – 6 months** *April 2020 - Sept. 2020*
Quantitative Life Sciences, Abdus Salam International Centre for Theoretical Physics, Trieste, Italy

EDUCATION

1) **Ph.D. in Physics – 3 years and 4 months** *November 2016 - March 2020*
Department of Physics, University of Trieste, Trieste, Italy.
Supervisor: Prof. Antonio Celani,
The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy.
Co-supervisor: Prof. Edoardo Milotti, University of Trieste, Trieste, Italy.
Thesis title: Study of multi-agent systems with reinforcement learning

2) **M.Phil. in Physics – 1 year and 10 months** *October 2014 - August 2016*
Department of Physics, Savitribai Phule Pune University, Pune, India.
Grade: A
Thesis title: Study of Phase Transition in the Model of Self-propelled Particles.

3) **M.Sc. in Physics – 3 years** *July 2010 - July 2013*
Department of Physics, University of Pune, Pune, India
Overall GPA: 4.05/6.00
Class Grade: B
Equivalent Percentage: 67.50 %

4) **B.Sc. in Physics – 3 years** *June 2007 - June 2010*
N.S.C. Science College, Nashik-Road, Affiliated to University of Pune, India
Percentage: 81.00 %
Class Grade: First class with distinction

PUBLICATIONS - AS A LEAD AUTHOR

1) *First-order phase transition in a model of self-propelled particles with variable angular range of interaction*
Mihir Durve and Ahmed Sayeed, Phys. Rev. E, **93** 052115, 2016.

2) *Active Particle Condensation by Nonreciprocal and Time-delayed Interactions*
Mihir Durve, Arnab Saha and Ahmed Sayeed, Eur. Phys. J. E, **41:** 49, 2018.

3) *Learning to flock with reinforcement*
Mihir Durve, Fernando Peruani and Antonio Celani, Phys. Rev. E, **102 (1)** 012601, 2020

4) *Collective olfactory search in a turbulent environment*
Mihir Durve*, Lorenzo Piro*, Massimo Cencini, Luca Biferale, Antonio Celani, Phys. Rev. E, **102 (1)** 012402, 2020, * Equal contribution.

5) *Study of multi-agent systems with reinforcement learning* Mihir Durve, Ph.D thesis–Università degli Studi di Trieste, 2020 [**Download link**]

6) *A fast and efficient deep learning procedure for tracking droplet motion in dense microfluidic emulsions*
Mihir Durve, Fabio Bonaccorso, Andrea Montessori, Marco Lauricella, Adriano Tiribocchi and Sauro Succi, Phil. Trans. R. Soc. A **379**, 20200400, 2021

7) *Tracking droplets in soft granular flows with deep learning techniques*
Mihir Durve, Fabio Bonaccorso, Andrea Montessori, Marco Lauricella, Adriano Tiribocchi and Sauro Succi, Eur. Phys. J. Plus **136**, 864, 2021

8) *DropTrack – automatic droplet tracking using deep learning for microfluidic applications*
Mihir Durve, Adriano Tiribocchi, Fabio Bonaccorso, Andrea Montessori, Marco Lauricella, Michal Bogdan, Jan Guzowski, Sauro Succi, Physics of Fluids **34 (8)**, 082003, 2022

9) *Benchmarking YOLOv5 and YOLOv7 models with DeepSORT for droplet tracking applications*
Mihir Durve, Sibilla Orsini, Adriano Tiribocchi, Andrea Montessori, Jean-Michel Tucny, Marco Lauricella, Andrea Camposeo, Dario Pisignano, Sauro Succi, The European Physical Journal E **46 (33)**, 1-7, 2023

10) *Measuring arrangement and size distributions of flowing droplets in microchannels through deep learning using DropTrack*
Mihir Durve, Sibilla Orsini, Adriano Tiribocchi, Andrea Montessori, Jean-Michel Tucny, Marco Lauricella, Andrea Camposeo, Dario Pisignano, Sauro Succi , Physics of Fluids **36 (2)**, 2024

11)*Minimal droplet shape representation in experimental microfluidics using Fourier series and autoencoders*
Mihir Durve, JM Tucny, S Orsini, et. al. Physics of Fluids 36 (11) 2024

12)*Droplet shape representation using Fourier series and autoencoders*
Mihir Durve, JM Tucny, D Bhamre, et. al. AIAA Journal, 1-5 2024

PUBLICATIONS - IN A SUPPORTIVE ROLE

13)*Crystallization and topology-induced dynamical heterogeneities in soft granular clusters*
M Bogdan, J Pineda, Mihir Durve, L Jurkiewicz, S Succi, G Volpe, J Guzowski Physical Review Research 6 (3), L032031 2024

14) *Dynamics of polydisperse multiple emulsions in microfluidic channels*
Adriano Tiribocchi, Andrea Montessori, Mihir Durve, Fabio Bonaccorso, Marco Lauricella, Sauro Succi, Phys. Rev. E **104 (6)**, 065112, 2021

15) *The crucial role of adhesion in the transmigration of active droplets through interstitial orifices*
Adriano Tiribocchi, Mihir Durve, Marco Lauricella, Andrea Montessori, Sauro Succi, Nature Communications **14**, 1096, 2023

16) *Spontaneous motion of a passive fluid droplet in an active microchannel*
Adriano Tiribocchi, Mihir Durve, Marco Lauricella, Andrea Montessori, Sauro Succi, Soft Matter **19 (34)**, 6556-6568, 2023

17) *Shapes and dynamic regimes of a polar active fluid droplet under confinement*
Adriano Tiribocchi, Mihir Durve, Marco Lauricella, Andrea Montessori, Davide Marenduzzo, Sauro Succi, Physics of Fluids **35 (6)**, 2023

18) *Thread-safe lattice Boltzmann for high-performance computing on GPUs*
Andrea Montessori, Marco Lauricella, Adriano Tiribocchi, Mihir Durve, Michele La Rocca, Giorgio Amati, Fabio Bonaccorso, Sauro Succi, Journal of Computational Science **74**, 102165, 2023

19) *Learning of viscosity functions in rarefied gas flows with physics-informed neural networks*
Jean-Michel Tucny, Mihir Durve, Andrea Montessori, Sauro Succi , Computers and Fluids **269**, 106114, 2023
20)*Lattice Boltzmann methods for soft flowing matter*

A Tiribocchi, Mihir Durve, M Lauricella, A Montessori, JM Tucny, S Succi, Physics Reports 1105, 1-52

21) *3D printing and artificial intelligence tools for droplet microfluidics: Advances in the generation and analysis of emulsions*
S Orsini, M Lauricella, A Montessori, A Tiribocchi, M Durve, S Succi, et. al, Applied Physics Reviews 12 (1), 2025

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RESEARCH INTERESTS

Machine learning applied to biological/physical systems, Computer vision, Reinforcement learning, Statistical modeling of active matter systems, Monte Carlo simulations of active matter systems, Computational physics

SKILL SETS

Programming languages: Fortran90, Python
Software: Matlab, PyTorch, OpenCV
Other: Expertise in developing full deep learning pipeline, computer vision – YOLO, DeepSORT, implementing deep neural networks for image classification, object detection, and features extraction. vast experience with using HPCs – training computer vision models on multi-node GPUs, Linux based operating systems

RESEARCH PROJECTS

1) iNSIGHT - Intelligent encapsulation & screening platform for precision delivery of probiotics to improve gut health

Funding agency: EIC Pathfinder Grant No: 101187428, 2025-2029
Over the past century, lifestyle changes have led to imbalanced gut microbiota, contributing to various health issues. Probiotics offer a promising solution, but their sensitivity to oxygen, heat, and gastric acid limits their effectiveness. iNSIGHT addresses this by developing precision probiotics through a novel microencapsulation approach. The goal is to create tunable, scalable bi-gel-based microcapsules that protect probiotics and ensure their targeted delivery post-stomach. We will use a gut-on-a-chip device to study capsule breakdown and probiotic release and apply machine learning for understanding digestion kinetics and microcapsule synthesis optimization. As a proof of concept, we will demonstrate personalized probiotic treatments under pharmacy legislation. iNSIGHT paves the way for precise probiotic delivery to prevent or treat gut microbiota-related health issues.

2) DropTrack - Droplet Tracking in dense emulsions with machine learning

PI : Prof. Sauro Succi, CLN2S, IIT-Rome, Italy
Funding agency: ERC PoC Grant No: 101081171, 2022-2024
Tracking droplets in microfluidic experiments involving dense or multi-core emulsions presents a significant challenge due to the presence of multiple droplets arranged in a dense configuration, all of which are transported by an external flow. In such experiments, a digital camera can directly capture the movement of the

droplets. From this visual data, obtaining the trajectories of individual droplets is crucial for understanding the underlying physics, including droplet-droplet interactions, droplet arrangement, and the physical observables that define droplet morphologies. However, manual tracking of even a few hundred droplets is practically unfeasible.
DropTrack addressed this challenge by providing a solution for real-time droplet tracking and the extraction of physical observables by integrating state-of-the-art computer vision algorithms into a single tool. The DropTrack tool is freely available at the following **link.**

3) Ph.D. project: Study of multi-agent systems with reinforcement learning
Adviser : Prof. Antonio Celani, ICTP, Trieste, Italy

I was involved in 3 scientific problems in my Ph.D. studies
1.1) Biological agents (such as a bird or a fish, etc) are 'slow' to respond to their changing environment. We adapted well-known Vicsek model from statistical physics to study collective behavior in systems with self-propelling units. Within the framework of the Vicsek model, we studied effects of sluggish and anisotropic agent-agent interactions on the collective behavior. Our main finding was that due to the delayed response and anisotropic interactions, agents without any implicit attractive forces acting on them, spontaneously formed a novel 'jammed state'. In this state, agents are constantly on the move but are highly localized in a high density cluster. We studied the structure of the formed cluster of agents and mechanism by which these agents form these jammed states.
1.2) We studied the collective behavior in multi-agent system as a decision making and optimization problem. The agents make decisions to achieve certain well-defined goals such as forming a flock and thereby maintaining number of neighbors. We implemented framework of multi-agent reinforcement learning with a penalty for individuals for decreasing their neighbors. Our main finding is that the agents form highly polar ordered state (as seen in real flocks) while minimizing the penalty for decreasing the neighbors. One of the policies that agents discover to minimize the penalty is nothing but well-know statistical physics model called the Vicsek model. Thus, the velocity alignment rule which is at the core of the Vicsek model can result from more simple rule to just maintain your neighbors. In short, to stay together, steer together! We carried out this work in collaboration with Dr. Fernando Peruani at University of Nice, France.
1.3) Biological agents frequently undertake a task of searching for their desired target using environmental cues. A male moth finding a female mate using pheromone trails released by her in the environment is one such example. Fluctuations in the environment makes the search, a complex task. Certain species of moths use ability to detect odor, environmental cues such as wind direction, and use this information to complete the search task. Based on observed counterturning strategies adapted by the male moths, Balkovsky and Shraiman [PNAS 99(20) 12598-12593 2002] proposed an efficient single-agent strategy for olfactory search that can work in a turbulent environment. We studied multi-agent system in which agents decide to move based on the private information such as detection of odor, wind direction etc and public information such as heading direction of its neighbors. We find that there exists optimal way to combine private and public information that allows a group of agents to locate the odor source in almost minimum possible time. This time is significantly shorter than the time it takes for individuals to locate the source using strategies studied by Balkovsky and Shraiman. Thus, we show that multi-agent search strategies can be more effective than individual search strategies. We carried out this work in collaboration with lab of Prof. Luca Biferale in University of Rome Tor Vergata, Italy.

CONFERENCE ATTENDED

1) Oral presentation in XXVII IUPAP Conference on Computational Physics, CCP2015, held at IIT Guwahati, Assam, India, *2-5 December 2015*
2) Oral presentation in Raman Memorial Conference 2016 held at Department of Physics, Savitribai Phule Pune University, Pune, India *12-13 Feb 2016*
3) Poster presentation in Collective behavior Conference 2018 held at Abdus Salam International Centre for Theoretical Physics, Trieste, Italy. *7-12 May 2018*
4) Oral presentation in Young Researchers Meeting Conference 2018 held at Department of Physics, University of Salerno, Salerno, Italy *10-13 July 2018*

5) Oral presentation in Raman Memorial Conference 2019 held at Department of Physics, Savitribai Phule Pune University, Pune, India *14-15 Feb 2019*
6) Oral presentation in Young Researchers Meeting Conference 2019 held at Department of Physics, University of Roma Tor Vergata, Rome, Italy *18-21 June 2019*
7) Oral presentation in Biophysical Conference 2019 held at Amfora Hotel, Hvar, Croatia. *20-23 Aug 2019*
8) Oral presentation in conference on Active matter and artificial intelligence 2019 held at EPFL-HQ, Lausanne, Switzerland *30 sept- 2 oct 2019*
9) Oral presentation, Raman memorial conference, Pune, India *Feb 2022*
10) Poster presentation in AMLD conference held at EPFL-HQ, Lausanne, Switzerland *March 2022*
11) Participation in Biochip conference, Berlin *2023*
12) Oral presentation, IUPAP CCP 2024 conference, Thessaloniki, Greece *2024*

SCHOOL / WORKSHOP ATTENDED

1) Winter School on quantitative systems biology, ICTP, Trieste, Italy *5-16 Dec 2016*
2) Winter School on quantitative systems biology, ICTS, Bangalore, India *4-22 Dec 2017*
3) Malpractices and ethics in research, University of Trieste, Trieste, Italy
4) Winter School on Learning and Artificial Intelligence, ICTP, Trieste, Italy *12-23 Nov 2018*
5) Workshop on Locomotion and Navigation from Flies to Robots, ICTP, Trieste, Italy *10-12 July 2019* 6) Workshop on Computational Design of Porous Mesoscale Materials, Rome, Italy *14-15 Sept 2022*

VISITS FOR SCIENTIFIC PROJECTS

1) Lab. J.A.Dieudonné, Université Nice Sophia Antipolis, Nice, France (15 April 2018 - 29 June 2018)
2) Department of Physics, University of Rome Tor Vergata, Rome, Italy (10 December 2018 - 15 December 2018)
3) Lab. J.A.Dieudonné, Université Nice Sophia Antipolis, Nice, France (14 July 2019 - 28 July 2019)

REFERENCES

Available on request.