

Danny Raj M

DOB: 08-08-1990

Office: Lab 10, Chemical engineering, IISc,
Bengaluru 560012, Karnataka, India

Res: F2 Panchajanya apartments, 119 New Bel road,
Ags layout, Bengaluru, 560094, Karnataka, India

Email: dannyraj@iisc.ac.in, dannyrajmasila@gmail.com; **Ph.:** (+91) 9500195720; **Webpage:** <https://www.dannyraj.com/>
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RESEARCH INTERESTS

My research interests broadly encompass **understanding the non-linear interactions and collective dynamics in natural and artificial systems**. I employ a complex systems approach to study these systems. The first step in this approach involves **developing models for the interaction among agents** from system-specific knowledge. Then, these models are incorporated into a suitable **agent-based framework** depending on the nature of the dynamics (deterministic or stochastic) to simulate the group level phenomena. However, to engineer a complex system or to understand how or why the interactions at the level of the agents lead to the observed collective behavior, we must tackle the challenge raised by the system's large degrees of freedom. To this end, I pose the questions as **optimization problems** and systematically analyze the parameter space to (i) find appropriate design and control measures to manipulate the agents as required, (ii) identify the 'correct' model (and parameters) that describes the observed phenomena, etc.

TOPICS OF INTEREST

Collective phenomena; droplet microfluidic systems; human traffic; collective social behavior in living agents; agent-based models, heat, mass and momentum transport in engineering systems.

ACADEMIC RECORD

PhD (2011-2017) Indian Institute of Technology Madras, Chennai, India
Dept. of Chemical Engineering; CGPA: 9.24/10

B Tech (2007- 2011) A.C.Tech., Anna University, Chennai, India
Dept. of Chemical Engineering; CGPA: 8.1/10

RESEARCH EXPERIENCE

1. **INSPIRE faculty fellowship: IISc Bengaluru, India (April 2018-present)**

Collective behavior in fish schools

- Spatial models for fish schooling and optimization studies, to identify alignment models that capture the features observed in experiments [collaboration: Dr. Vishwesh Guttal, CES, IISc].
- Developing a toolbox for extracting the characteristics of noise in data and testing it out on real-data sets from different controlled-experiments with fish schools [collaboration: Vishwesh Guttal, CES, IISc; Guy Theraulaz, CNRS, France – [ongoing project](#)].
- Understanding the effects of cohesive interactions in fish schools, that interact via simple pairwise interactions [student: Vivek Jadav – [ongoing project](#)].

Collective phenomena in traffic systems

- Engineering movement strategies in a dense crowd using insights from intruder movement through granular material etc. [collaboration: Prof. Kumaran V, Chemical Engineering, IISc – [ongoing project](#)].

- Collective dynamics in Indian traffic: experiments and modeling [Students: Aman Prasad, Karthikeya Sharma].

General problems in collective phenomena

- Investigating the effectiveness of mean-field analysis in the study of collective phenomena [collaboration: Dr. Vishwesh Guttal, CES, IISc – [ongoing project](#)].
- Observing and inferring a complex system: can measurements help one to accurately determine the characteristics of agents that make up a collective [student: Vijay Kumar – [ongoing project](#)].
- Understanding the effect of intelligence of agents in the emergence of intelligence at the group level [Student: Arvind Nayak].

Other

- Investigating the effect of different lockdown strategies, testing rates vs accuracy, student influx etc. on the spread of the COVID-19 using a network model [collaboration: Dr. Christina Danny, MSRIT, Bengaluru].

2. Post-doctoral fellow: IIT Madras Chennai, India (April 2017- April 2018)

- Dynamic modeling of an aluminum smelting process [collaboration: General Electric, Bengaluru; Supervisor: Prof. Raghunathan Rengaswamy].
- Experimental investigation of a spinning disk atomizer for production and collection of mono-dispersed particles- [IIT Madras Exploratory project; Supervisor: Prof. Raghunathan Rengaswamy].

3. Ph.D.: IIT Madras Chennai, India (July 2011-April 2017)

Thesis – Drops as agents: understanding complex behavior in 2D microchannels [Advisor: Prof. Raghunathan Rengaswamy]

- Self-organization of droplets: agent-based models were developed to simulate the flow of droplets in 2D microchannels. These models were used to optimize the design and operation of a microchannel-device to engineer droplet-ensembles for a variety of applications.
- Coalescence avalanches: stochastic agent-based models were developed to simulate the probabilistic propagation of a coalescence avalanche in tightly packed droplet ensembles. We showed that the propagation is autocatalytic in nature that either resulted in system-size spanning avalanches or those that hardly propagate.

4. Visiting scholar: University of West Virginia, Morgantown, USA (Sep 2014- Jan 2015)

Modeling health of refractories in gasifiers [Advisor- Dr. Debangshu Bhattacharya]

- A discrete-element model was developed to diagnose the health of a gasifier-refractory which is subject to extreme conditions—high temperature and corrosion.

5. B.Tech.: AC Tech, Anna University, Chennai, India (July 2009- May 2011)

Catalyst improvement studies [Advisor: Dr. Thiripuranthagan Sivakumar; UGC, India sponsored]

- We performed the controlled doping of (noble metals) and substrate immobilization of TiO_2 catalysts to synthesize visible-light active photocatalysts with high surface area. Their activity was tested based on their ability to degrade standard water pollutants from the textile industry.

PEER-REVIEWED PUBLICATIONS

Peer-reviewed journals:

1. Jitesh Jhawar, Richard G. Morris, U. R. Amith-Kumar, **M. Danny Raj**, Tim Rogers, Harikrishnan R., Vishwesh Guttal, 'Noise-Induced Schooling of Fish', **Nature Physics**, 16, 488–493, 2020.
2. C G Danny, **M Danny Raj**, Vvr Sai, 'Ray optics model for U-bent fibre optic sensors', accepted for publication in the **Journal of Lightwave technology**, vol. 38, no. 6, pp. 1580-1588, 2020.
3. **M. Danny Raj**, A. Gnanasekaran, R. Rengaswamy, "On the role of hydrodynamic interactions in the engineered assembly of droplet ensembles", **Soft Matter**, vol. 15, 7863, 2019.
4. **M. Danny Raj** and R. Rengaswamy, "Interacting coalescence avalanches in a 2D droplet assembly", **AIChE journal**, vol. 65, no. 3, 2019.
5. **M. Danny Raj** and R. Rengaswamy, "Averaged model for probabilistic coalescence avalanches in two-dimensional emulsions: Insights into uncertainty propagation", **Physical Review E**, vol. 95, no. 3, 032608, 2017.
6. **M. Danny Raj** and R. Rengaswamy, "Coalescence of drops in a 2D microchannel: critical transitions to autocatalytic behavior", **Soft Matter**, vol. 12, no. 1, pp. 115-122, 2016.
7. S. Thiripuranthagan, **M. Danny Raj**, and K. Kannan, "Photocatalytic Degradation of Congo-red on Silica Supported Ag Impregnated TiO₂", **J. Nanosci. Nanotechnol.** vol. 15, no. 6, pp. 4727–4733, 2015.
8. **M. Danny Raj** and R. Rengaswamy, "Investigating Arrangement of Composite Drops in Two-Dimensional Microchannels Using Multi-Agent Simulations: A Design Perspective", **Ind. Eng. Chem. Res.**, vol. 54, no. 43, pp. 10835-10842, 2015.
9. **M Danny Raj** and R. Rengaswamy, "Understanding drop-pattern formation in 2-D microchannels: a multi-agent approach", **Microfluid. Nanofluidics**, vol. 17, no. 3, pp. 527–537, Jan. 2014.

Conference proceedings:

1. Christina G Danny, **M Danny Raj**, Vvr Sai, "Ray Optics Model for Light Attenuation in U-Bent Fibre Optic Sensors", in IEEE SENSORS 2018, New Delhi, 2018, pp. 1-4.
2. **Danny Raj M** and R. Rengaswamy, "Understanding Control in Microchannels to Manipulate Drop-Drop Interactions", in 2014 European Control Conference (ECC), 2014, pp. 1055–1060.

To be submitted/under review:

1. *Danny Raj M and Kumaran V, 'Moving through a crowd: a nature inspired traffic rule', to be submitted.*
2. *Danny Raj M, 'Observing and inferring agents' behavior in a crowd made up of composite agents', to be submitted.*
3. *Danny Raj M and Vishwesh Guttal, 'Configuration space mixing in flocks and the effectiveness of mean-field models', to be submitted.*
4. *Danny Raj M and Danny C G, 'Which lock-down strategy is better to control the spread of COVID? -- a study using agents on a network', to be submitted.*

TEACHING EXPERIENCE

Taught a course on writing: cultivating the joy of writing in a research scholar (IISc 2020)

- Designed the course for scholars in the department of chemical engineering, IISc Bangalore.
- Offered it online during May-August 2020 as a non-credit course.
- Lectures: styles of writing, classic style, curse of knowledge, thought and language, visualizations etc.
- Assignments were given for each of the topics presented.

Teaching assistant for graduate course on Complex hydrodynamics (IIT Madras 2016)

- Holding tutorials for visualization of flow fields for point singularities in flow.

Teaching assistant for undergraduate course on Process control (IIT Madras 2013, 2014)

- Lectures on modeling physical systems for control, use of Laplace transforms in control.
- Holding tutorials on a weekly basis: preparing problem sets for demonstration and classwork.
- Setting up question papers for quizzes and end semester; grading answer sheets.

INVITED TALKS

1. A seminar on the topic, 'Observing and inferring the characteristics of a collective', as part of the department seminar series in the department of mechanical engineering, IISc Bangalore on the 18th December 2020.
2. A lecture on, 'Simple models for soft matter', in the Soft matter young investigators meet (SMYIM), held virtually on the 3rd December 2020.
3. Organised a special session on, 'Modelling collective phenomena' and presented an overview of the topic in the Synergies in computational, mathematical, statistical and physical sciences (FIM), held virtually on the 24th November 2020.
4. A lecture on, '*Engineering droplets in a microchannel*', for scholars and faculty attending a two-week certificate course, Centre for Micro Nano Design and Fabrication, Saveetha Engineering College, Chennai on 24th July 2020.
5. A lecture on, '*Droplet microfluidics: the science and engineering of small-scale flows*', for undergraduates and faculty at the Department of Chemical engineering, MVJ college of Engineering, Bangalore on 21st September 2019.
6. A talk on, '*Moving through a crowd: nature inspired traffic rule*', in the Center for Ecological Sciences, IISc Bangalore on 13th September 2019.
7. A lecture on, '*Simulating complex systems with MATLAB*', research scholars from Mathematics, Applied Mathematics and Computer science as a part of the workshop IWDAM 2019 (International workshop on Data Analytics and MATLAB) September 2019.
8. An invited talk at the 1st Indian Process Systems Engineering (IPSE) at IIT Madras on, '*A systems approach to droplet microfluidics*', 18th August 2019.
9. A lecture on, 'Collective behavior of a group of interacting agents: droplets, fishes and traffic', as part of the department seminar series in the department of chemical engineering, IISc Bangalore on the 15th November 2018.
10. A lecture on, '*A peek into chemical engineering*', to students in their high school and first year in bachelors, as part of Sanjog 2017, a program for children of the staff of Indian Army, held in IIT Madras on 6th June 2017.
11. A talk on, '*Understanding collective behavior of drops in 2D microchannels: an agent-based approach*', in the Department of chemical engineering, University of Florida, Gainesville on the 17th Nov 2015.

HONORS AND AWARDS

1. Awarded the **DST INSPIRE fellowship** (July 2017 call), offered by Department of science and technology, India (DST).
2. Best presentation award as chosen by the editor in chief of the *Journal of fluid mechanics (JFM)* during the **JFM symposium- Chennai edition (2017)**.
3. Best presentation award in the '*Present your research in two minutes*' competition held in IIT Madras during **Research scholars' day (2016)**.

EXTRA-CURRICULAR ACTIVITIES

1. Have passed the grade 8 piano and grade 5 theory examinations conducted by the *Associated Board of the Royal School of Music (ABRSM), London*.
2. I conduct choirs, involve myself in church choral music where I play the piano and sing bass. (Check out my blog post: <https://www.dannyraj.com/post/collective-nature-of-choral-singing>)