Pratiksha Trust Initiative on

Brain, Computation and Data Science

Activities 2021

Contents

Overview

The Brain, Computation and Data Science initiative is the brainchild of Mr. Kris Gopalakrishnan and Mrs. Sudha Gopalakrishnan, founders of the Pratiksha Trust, Bangalore. In June 2015, the Pratiksha Trust set up three Distinguished Chair Professorships at the Indian Institute of Science, Bangalore. The purpose of these Chair Professorships is to bring frontline researchers in the areas of neuromorphic computing, computational neuroscience, machine learning and data science to the IISc campus to help strengthen research and international collaboration in these important emerging areas. The mission of this initiative is to foster intense research collaboration leading to capacity building, ecosystem creation, and high impact research outcomes in brain, computation and data science in IISc and India.

The participating departments and centres of IISc include: Computer Science and Automation, Computational and Data Sciences, Neuroscience, Electrical Communication Engineering, Electrical Engineering, Electronic Systems Engineering, Mathematics, and Molecular Biophysics.

The research areas pursued include: Computational Neuroscience; Neuromorphic Computing and Engineering; Data Science; Machine Learning; Artificial Intelligence; Brain Inspired Algorithms; Neural Signal Processing; Image Analysis; Vision and Visualisation.

During 2016-2021, the activities of this initiative were shaped and anchored by the following members of the Scientific Advisory Committee: Profs. P.S. Sastry (Convener); Rishikesh Narayanan (Co-Convener); Shalabh Bhatnagar; K.V.S. Hari; Aditya Murthy; M. Narasimha Murty; Rajesh Sundaresan. Our grateful thanks for their precious time and efforts. From July 2021, the following committee has taken charge:
Profs. Prasanta Kumar Ghosh (Convener); Sridharan Devarajan (Co-Convener); Ambedkar Dukkipati; K.V.S. Hari; Ramesh Hariharan; Supratim Ray; and Yogesh Simmhan.

This booklet provides a bird's eye view of the activities undertaken as a part of this initiative in IISc during 2021.

Y. Narahari
Convener, Initiative on Brain, Computation, and Data Science

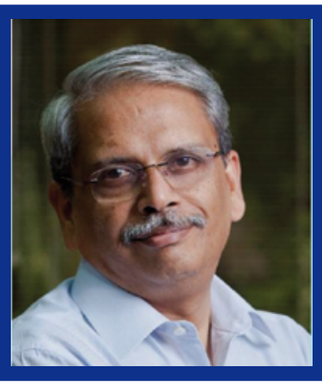
From Director, IISc

"We are immensely grateful to Shri. Kris Gopalakrishnan and Smt. Sudha Gopalakrishnan for choosing the Indian Institute of Science for these generously endowed chair professorships. These chairs intend to invigorate and accelerate extremely important emerging interdisciplinary research areas. I am sure the chair professors will add a new dimension to research collaboration between IISc researchers and star contributors to these areas anywhere in the world."

Govindan Rangarajan
Director, Indian Institute of Science, Bangalore

From Pratiksha Trust Founders

"We hope the launching of these distinguished chair positions will help push the frontiers in brain inspired research. It would be excellent if the collaborations lead to highly creative new computing architectures and algorithms inspired by the functioning of the brain."



Kris Gopalakrishnan
Founder, Pratiksha Trust, Bangalore

Sudha Gopalakrishnan
Founder, Pratiksha Trust, Bangalore

IISc Team

Scientific Advisory Committee

Prasanta Kumar Ghosh, EE (Convener, ex-officio)

Sridharan Devarajan, CNS (Co-Convener, ex-officio)

Ambedkar Dukkipati, CSA

K. V. S. Hari, ECE

Ramesh Hariharan, Strand Life Sciences

Supratim Ray, CNS

Yogesh Simmhan, CDS

Faculty Team (Brain, Computation and Data Science Group)

A.G. Ramakrishnan, EE

Aditya Murthy, CNS

Aditya Sadhanala, CeNSE

Akshay Singh, Physics

Anand Louis, CSA

Animesh Kuley, Physics

Anirban Chakraborty, CDS

Arindam Ghosh, CeNSE

Arjun Jain, CDS

Arkaprava Basu, CSA

Arnab Barik, CNS

Arnab Bhattacharyya, CSA

Arup Polley, ESE

Ashesh Dhawale, CNS

Balaji Jayaprakash, CNS

Banibrata Mukhopadhyay, Physics

Bharadwaj Amrutur, ECE

Chandra Murthy, ECE

Chandra Sekhar Seelamantula, EE

Chetan Thakur, ESE

Chirag Jain, CDS

D. Ambedkar, CSA

Deepak Subramani, CDS

Deepak Kumaran Nair, CNS

Hardik Pandya, ESE

K.V.S. Hari, ECE

Mayank Srivastava, ESE

P.S. Sastry, EE

Partha Talukdar, CDS

Phaneendra Yalavarthy, CDS

Prasanta Kumar Ghosh, EE

R. Venkatesh Babu, CDS

Rajesh Sundaresan, ECE

Rishikesh Narayanan, MBU

S.P. Arun, CNS

Santanu Mahapatra, ESE

Sashikumaar Ganesan, CDS

Shalabh Bhatnagar, CSA

Shayan G. Srinivasa, ESE

Shirish Shevade, CSA

Shishir Nadubettu Yadukumar Kolathaya, RBCCPS

Siddharth Barman, CSA

Siddhartha Gadgil, Mathematics

Soma Biswas, EE

Sridharan Devarajan, CNS

Srikanth Padmala, CNS

Sriram Ganapathy, EE

Sujit K. Sikdar, MBU

Sumantra Sarkar, Physics

Sundeep Prabhakar Chepuri, ECE

Supratim Ray, CNS

T.V. Prabhakar, ESE

Y. Narahari, CSA

Yogesh Simmhan, CDS

and all other interested faculty members

Pratiksha Distinguished Chairs

Pratiksha Trust Distinguished Chairs at IISc

Shri K. Vaidyanathan Distinguished Chair

Prof. Shihab Shamma

Professor, Institute of Systems Research, Univ. of Maryland

Education

BS – Imperial College – 1976

MS – Stanford University – 1977

Ph.D. – Stanford University – 1980

Expertise

Speech models of brain

Neural signal processing

Computational neuroscience

Robust control systems

Neuromorphic engineering

Awards and Distinction

Fellow, IEEE

Fellow, Acoustical Society of USA

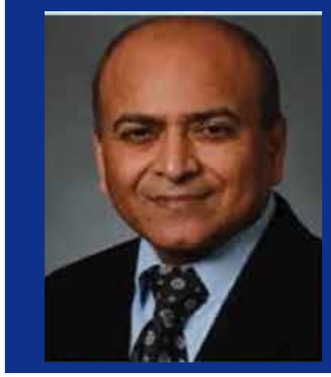
ISR Outstanding Faculty Award

NIH Advisory Board

PI of Advanced ERC Grant

Blaise Pascal Intl. Research Chair

Smt. Sudha Murty Distinguished Chair



Prof. Vasant Honavar

Pennsylvania State University
Director: Center for Big Data Analytics
Director: Artificial Intelligence Research Laboratory

Education

BE – BMS College, Bangalore, 1982, Electronics Engg

MS – Drexel, 1984, Electrical and Computer Engg

MS, PhD – Wisconsin, Madison, 1990, Computer Science

Expertise

Artificial Intelligence

Machine Learning

Knowledge Representation

Bioinformatics

Data Science

Health Informatics Neurocomputing

Awards and Distinction

National Science Foundation Director's Award for Superior Accomplishment

Edward Frymoyer Endowed Professorship

CRA Computing Community Consortium Council Member

Iowa State Univ. Regents Award for Faculty Excellence

Univ. Wisconsin ECE 125 People of Impact

Pratiksha Trust Distinguished Chair

Prof. Christos Papadimitriou

Donovan Family Professor of Computer Science Columbia University, New York, USA

Education

B.S - Athens polytechnic, 1972

MS - Princeton University, 1974

Ph.D. - Princeton University, 1976

Expertise

Theory of algorithms and complexity and its applications to optimization, databases, control, AI, robotics, economics and game theory, the Internet, evolution and the brain

Awards and Distinction

Member of National Academy of Sciences, USA

Member of National Academy of Engineering, USA

Member, American Academy of Arts and Sciences

Knuth prize, Gödel Prize

von Neumann Medal

Kalai prize for CS in Game Theory

EATCS Award (European Association for Theoretical Computer Science)

Author of Novels: "Turing", " Logicomix" and "Independence"

Honorary Doctorates from Nine Universities

Pratiksha Trust Distinguished Chair

Prof. Rajesh P N Rao

CJ and Elizabeth Hwang Professor, Paul G. Allen School of Computer Science and Engineering and Department of Electrical and Computer Engineering, University of Washington (UW), Seattle.

Co-Director, Center for Neurotechnology (CNT)

Adjunct Professor, Bioengineering Department

Faculty member, Neuroscience Graduate Program at UW.

Education

BS- Angelo State University - 1992

MS - University of Rochester - 1994

Ph.D. - University of Rochester - 1998

Expertise

Computational Neuroscience

Brain-Computer Interfacing

Artificial Intelligence

Awards and Distinction

Guggenheim Fellowship

Fulbright Scholar award

NSF CAREER award

ONR Young Investigator Award

Sloan Faculty Fellowship

David and Lucile Packard Fellowship

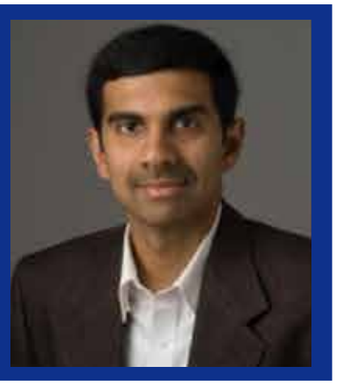
Pratiksha Trust Distinguished Chairs at IIT-Madras

Prof. H.N. Mahabala Chair

Prof. Partha Mitra
Cold Spring Harbor Lab

Dr. N.R.Narayana Murthy Chair

Prof. Mriganka Sur
Massachusetts Institute of Technology



Prof. Muthukrishnan Chair

Prof. Anand Raghunathan
Purdue University

Pratiksha Trust Young Investigators

Pratiksha Trust Young Investigators

These awards have been instituted to recognize and reward the accomplishments of young faculty members or prospective faculty members. The Pratiksha endowment now supports the award of up to five Young Investigator awards at any time. The awardees receive, for two years, a top-up salary of Rs 25000 per month and a research grant of Rs. 3 lakhs per year. Recognition as a Young Investigator will be based on academic achievement at the highest national and international level. Following is the list of Pratiksha Trust YIs

1. Dr. Sriram Ganapathy, Department of Electrical Engineering (2017-19)
2. Dr. Prasanta Kumar Ghosh, Department of Electrical Engineering (2017-19)
3. Dr. Sridharan Devarajan, Centre for Neuroscience (2017-19)
4. Dr. Chetan Singh Thakur, Department of Electronic Systems Engineering (2017-19)
5. Dr. Siddharth Barman, Department of Computer Science and Automation (2018-20)
6. Dr. Anirban Chakraborty, Department of Computational and Data Sciences (2018-20)
7. Dr. Anand Louis, Department of Computer Science and Automation (2019-21)
8. Dr. Sundeep Prabhakar Chepuri, Department of Electrical Communication Engineering (2019-21)
9. Dr. Arkaprava Basu, Department of Computer Science and Automation (2020-22)
10. Dr. Chirag Jain, Department of Computational and Data Sciences (2020-22)
11. Dr. Aditya Sadhanala, Centre for Nanoscience and Engineering (2020-22)
12. Dr. Arindam Khan, Department of Computer Science and Automation (2021-23)
13. Dr. Shishir Kolathaya, Robert Bosch Centre for CyberPhysical Systems and Department of Computer Science and Automation (2021-23)

Anand Louis

https://www.csa.iisc.ac.in/~anandl/

Anand Louis is an Assistant Professor in the Department of Computer Science and Automation, IISc since September 2016. He obtained his Ph.D. in "Algorithms, Combinatorics and Optimization" from the Georgia Institute of Technology in 2014. Following this he spent two years as a Postdoctoral Research Associate in the Department of Computer Science in Princeton University before starting his current position in CSA. His research interests lie in algorithms and optimization.

Research Highlight

Humans are increasingly relying on algorithms to make decisions. Depending on the data an algorithm is acting on, the output produced by the algorithm might inadvertently be biased towards some groups in the input. Moreover, algorithms trained using real-world data might inadvertently amplify biases present in the training data. This could have serious social, ethical and legal consequences. Therefore, for various such problems, the algorithms should be designed to ensure that their output is not biased towards any group in the input, while also optimizing the "cost" of the solution produced. We have been studying some such problems in the last few years.

Search and recommendation systems, such as search engines, recruiting tools, online marketplaces, news and social media output ranked lists of items. Our work [1] defined the notion of "underranking" and proved a lower bound on the trade-off achievable for simultaneous underranking and group fairness in ranking. This work also gave an algorithm that takes any given ranking and outputs another ranking with simultaneous underranking and group fairness guarantees comparable to our lower bound.

Our work [2] gave online and offine approximation algorithms for bipartite matching with group fairness constraints; this problem models several important real-world problems such as ad-auctions, scheduling, resource allocation, etc.

Another direction of our research has been in the "beyond worst-case analysis" of algorithms. For many computational problems, the best known algorithms provide a somewhat underwhelming performance guarantee, whereas simple heuristics perform remarkably well in practice. A possible explanation for this phenomenon could be that the instances arising in practice tend to have some inherent structure that makes them "easier" than the worst-case instances. Many attempts have been made by the research community to understand the structural properties of instances arising in practice, and to use them in designing algorithms specifically for such instances, which could perform much better than algorithms for general instances. This includes modelling real-world instances as families of random/semi-random instances, identifying structural properties that real-world instances typically satisfy, etc.

Our work made some important contributions in this direction for the hypergraph independent set problem [3].

[1] "On the problem of underranking in group-fair ranking" Sruthi Gorantla, Amit Deshpande, and Anand Louis. International Conference on Machine Learning (ICML), 2021.

[2] "Matchings with group fairness constraints: Online and offine algorithms" Govind S. Sankar, Anand Louis, Meghana Nasre, and Prajakta Nimbhorkar. International Joint Conference on Artificial Intelligence (IJCAI), 2021.

[3] "Independent sets in semi-random hypergraphs" Yash Khanna, Anand Louis, and Rameesh Paul. Algorithms and Data Structures Symposium (WADS), 2021.

Sundeep Prabhakar Chepuri

https://ece.iisc.ac.in/~spchepuri/

Sundeep Prabhakar Chepuri received his M.Sc. degree (cum laude) in electrical engineering and Ph.D. degree (cum laude) from the Delft University of Technology, The Netherlands, in July 2011 and January 2016, respectively. He was a Postdoctoral researcher at the Delft University of Technology, The Netherlands, a visiting researcher at University of Minnesota, USA, and a visiting lecturer at Aalto University, Finland. He has held positions at Robert Bosch, India, during 2007-2009, and Holst Centre/imec-nl, The Netherlands, during 2010-2011. Currently, he is an Assistant Professor at the Department of ECE at the Indian Institute of Science (IISc) in Bengaluru, India.

Dr. Chepuri was a recipient of the Best Student Paper Award at the IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) in 2015. He is currently an Associate Editor of the EURASIP Journal on Advances in Signal Processing, and an elected member of the EURASIP Technical Area Committee (TAC) on Signal Processing for Multisensor Systems.

Research Highlight

Many science applications deal with data having an underlying graph structure, e.g., social networks, transportation networks, brain networks, sensor networks, protein-protein interactions, and meshed surfaces in computer graphics, to list a few. For such applications, more recently, deep learning for graph-structured data, formalized as deep graph learning is receiving steady research attention. I will discuss two such specific research themes described as work packages (WP) that I have been pursuing with the Pratiskha Trust fellowship.

WP.1: Deep Learning for graph-structured data

Graph neural networks (GNNs) have become very popular for processing and analyzing graph-structured data in the last few years. GNN architectures learn low-dimensional graph-level or node-level embeddings useful for several downstream machine learning tasks by using message passing as their basic building block that aggregates information from neighborhoods. We propose GNN architectures that precompute the node features from different neighborhood depths using a bank of neighborhood aggregation graph operators simultaneously. We refer to such GNN architectures with parallel aggregation as PA-GNNs. Due to the precomputations, PA-GNNs have a natural advantage of reduced training and inference time. We also provide theoretical conditions under which a generic PA-GNN model is provably as powerful as the popular Weisfeiler-Lehman (WL) graph isomorphism test in discriminating non-isomorphic graphs. These results have been submitted for a journal publication and is currently under review:

- Doshi, S. and Chepuri, S.P., 2021. Graph Neural Networks with Parallel Neighborhood Aggregations for Graph Classification. arXiv preprint arXiv:2111.11482.

WP.2: Graph topology inference from data

Having a good quality graph is central to any graph-based signal processing or machine learning task. Depending on the nature of the application, most of the data analytics with graph-structured data assume that the graph is given. In some cases, graphs are not readily available, but based on the available training data a graph that best explains the data can be constructed.

In this work package, we focus on learning sparse graphs with a core-periphery structure. A core-periphery structure in graphs refers to the presence of densely connected groups of core vertices and sparsely connected periphery vertices. Core vertices are those vertices that have cohesive connections among them. Peripheral vertices, on the other hand, are not well connected to each other but are relatively well connected to core vertices. We propose several generative models for data associated with core-periphery structured networks to model the dependence of node attributes on core scores of the nodes of a graph through a latent graph structure. Using the proposed model, we jointly infer a sparse graph and nodal core scores that induce dense (sparse) connections in core (respectively, peripheral) parts of the network.

The results from the work package are published or under peer-review as:

- Gurugubelli, S. and Chepuri, S.P., 2021. Learning Sparse Graphs with a Core-periphery Structure. arXiv preprint arXiv:2110.04022. (ICASSP 2022)
- Gurugubelli, S. and Chepuri, S.P., 2022. Learning Core-Periphery Structures in Graphs from Node Attributes (in prep. for journal submission)

Arkaprava Basu

https://www.csa.iisc.ac.in/~arkapravab/

Arkaprava Basu joined the Indian Institute of Science (IISc), Bangalore in February 2016 as an Assistant Professor in the Department of Computer Science and Automation. His research focuses on building more efficient computing systems through better coordination between the hardware and the software.

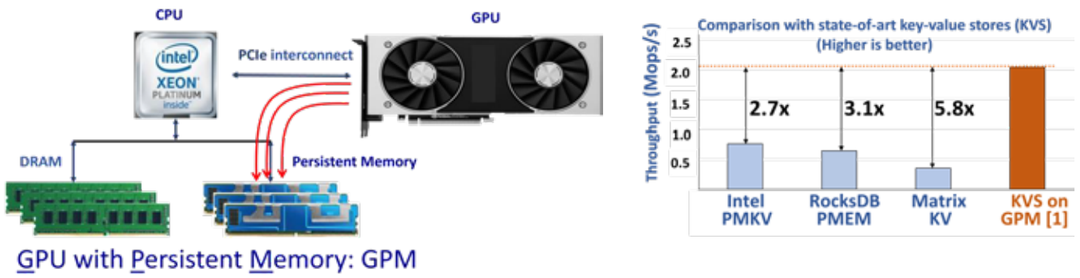
Arkaprava received the Intel Rising Star Faculty Award for 2021; he is one of the only 10 recipients of this award from universities across the globe and the only one from India. Arkaprava is also a recipient of the Google India Research Award 2022, Dr APJ Abdul Kalam young researcher HPC award 2021, besides the Pratiksha Trust Young Investigator Award.

Research Highlight

Harnessing the knowledge embedded in the massive amounts of data that the world produces everyday needs commensurately massive compute capability. Graphics Processing Units or GPUs that were originally designed for video gamers, are today the backbone for data-centric computing, including the deep learning. GPU's ability to process large amounts of data in parallel makes it an ideal choice.

However, GPUs are hamstrung by limited amount of on-board memory and the lack of direct access to high-capacity storage. A GPU's compute capability can go waste waiting for data to arrive. In an orthogonal trend, emerging persistent memory (PM) technology has recently become commercially available under the aegis of Intel Optane DC memory. PMs have significantly higher capacity than convention memory technologies, e.g., DRAM, and are also persistent like storage devices, e.g., SSD. Till now, however, only the CPUs have been able to leverage persistent memory to blur the long-held distinction between memory and storage.

In our recent work [1], we built the first known system that enables programs executing on GPUs to directly access data residing on the PM without the intervention of the CPU. Benefits of this system, which we name GPM (GPU with Persistent Memory), are manifold. GPM allows programs to leverage both the compute parallelism of GPU and the persistence and capacity of the PM. Important applications, such as persistent key-value stores that forms the backbone of many of today's internet services speed up by multiple times while executing on GPM (Figure below). Further, GPU-accelerated databases, checkpointing of partially trained weight in long-running DNN training, accelerate by 5-15X! We believe GPM has the potential become a key platform for large-scale data processing in the future.



[1] "Leveraging Persistent Memory from a GPU", Shweta Pandey, Aditya K. Kamath, Arkaprava Basu. In 27th International Conference on Architectural Support for Programming Languages and Operating Systems (ASPLOS) 2022.

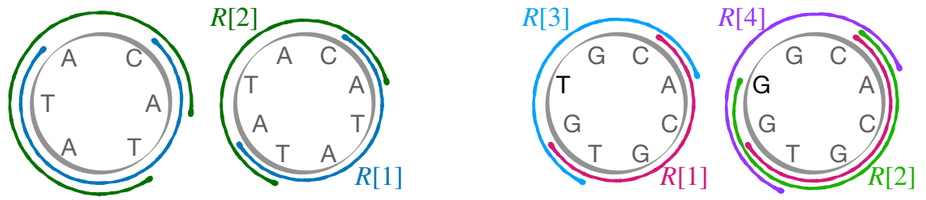
Chirag Jain

http://cds.iisc.ac.in/faculty/chirag

Chirag Jain is an assistant professor in the Department of Computational and Data Sciences at the Indian Institute of Science. He directs ATCG lab which develops efficient computational algorithms for data-intensive problems in biology. In response to challenging computational problems, the lab develops solutions that are provably-good, scalable in practice, and useful for life scientists to draw new insights from high-throughput data. Prior to his appointment at IISc, he worked as a post-doctoral fellow with Adam Phillippy at the National Institutes of Health. In 2019, he received Ph.D. at Georgia Tech, where he was advised by Srinivas Aluru. He did his bachelors in computer science at Indian Institute of Technology Delhi. He's a recipient of the Georgia Tech College of Computing Dissertation Award.

Research Highlight

The third-generation DNA sequencing technologies output fragments of a genome (referred to as long reads) which need to be assembled together to reconstruct the original genome. Read-overlap-based graph data structures play a central role in computing de novo genome assembly. Most long-read assembly tools use the string graph model to sparsify overlap graphs. Graph sparsification is crucial for high-quality genome assembly as it simplifies the graph significantly by removing redundant edges. However, a graph model must be coverage-preserving, i.e., it must ensure that each haplotype can be spelled as a walk in the graph. This property becomes even more important for polyploid genomes and metagenomes where there is a risk of losing haplotype-specific information during graph sparsification. In the first part of this project, we mathematically proved that the standard de Bruijn graph and overlap graph models are guaranteed to be coverage-preserving. However, using the same framework, we showed that the commonly used string graph model lacks the guarantee. To address this, our work introduced a novel sparse read-overlap-based graph model that is well-supported by our theoretical results. Finally, the practical advantage of this model was demonstrated experimentally using real human sequencing data. A preprint of this work is available at https://doi.org/10.1101/2022.03.17.484715



Aditya Sadhanala

http://www.cense.iisc.ac.in/aditya-sadhanala

Aditya Sadhanala is currently an Assistant Professor at the Centre for Nano Science and Engineering (CeNSE) at the Indian Institute of Science, Bengaluru since October 2019. He obtained his B.E. in Electronics from University of Mumbai, India in 2009, MSc in Nanoelectronics from University of Manchester, UK in 2010, followed by his Ph.D. degree in Physics (2015) from the University of Cambridge, UK. During his PhD he worked on investigating the photophysical properties of hybrid perovskites using photothermal deflection spectroscopy.

Aditya also holds several awards and recognitions, few notable ones being – 2021 International Science Council, 2020 MRS Nelson "Buck" Robinson Science and Technology Award for Renewable Energy, British Indian Award in the Science & Technology and Royal Society endorsed Exceptional Promise candidate. He also holds a distinction of being a highly cited researcher in the interdisciplinary field during the last three years 2019, 2020 and 2021 – Web of Science, Clarivate.

Research Highlight

Aditya's research currently focusses on nanostructured thin-film optoelectronics, ultra-sensitive spectroscopic techniques and to innovate pathways for low-cost decentralized manufacturing of emerging optoelectronics. These can be broadly classified under the following three themes:

1) Novel nano-structured/engineered thin-film semiconductors and photonics: To use novel & efficient nano-structured sustainable thin-film semiconductors and optoelectronic devices with feature sizes of functional elements down to 20nm that fall within the exciton diffusion or capture radius for most thin-film semiconductors.

2) Next-generation organic & 2D-perovskite hybrid sensing, memory and computation technologies: In-situ infiltration-based hybridisation of organic & 2D-perovskite semiconductors to enable hybrid bio-compatible sensors and neuromorphic computing applications. We are developing a low-cost atomic layer deposition (ALD) tool for such semiconductor hybridisation. Devices like - novel nanoparticles organic memory field-effect transistor (NOMFET) and nanoparticles hybrid memory field-effect transistor (NHFET) are being fabricated by using this low-cost, highly controlled and large area compatible infiltration synthesis methods. NOMFET & NHFET are devices that mimic biological synapses that can be triggered both by electrical and optical means. Much of this research work is ongoing and is being done under the Pratiksha Young Investigator position. As part of this effort we are close to finalising the development of a low-cost ALD tool (schematic shown in figure 1 below) to fabricate the above devices.

3) New methodologies for ultra-high sensitivity semiconductor spectroscopy: To develop the world's first photothermal deflection spectroscopy 2.0 (PDS 2.0) facility for ultra-high sensitivity of sub- and intra-band carrier studies at ambient, variable temperature & pressure conditions. This tool would act as a rapid screening tool for new semiconductors at both academic and industry level. Also, as a novel diagnostics tool for rapid and sensitive detection of bacteria and viruses (including COVID-19).

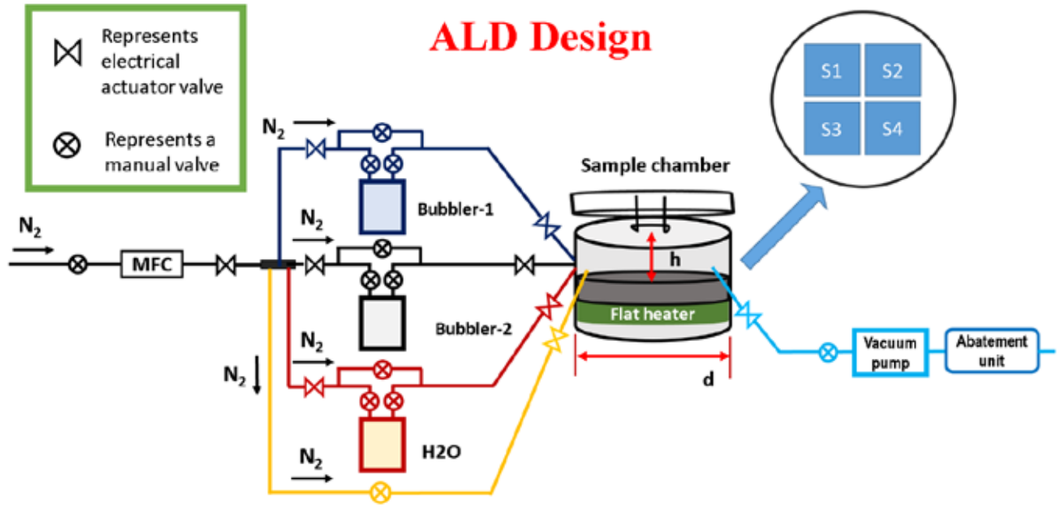


Figure 1: Schematic of the homemade atomic layer deposition (ALD) tool – to be used for semiconductor hybridisation

Arindam Khan

Arindam Khan is an Assistant Professor in the Department of Computer Science and Automation at the Indian Institute of Science. He did his PhD in Algorithms, Combinatorics, and Optimization (ACO) from Georgia Institute of Technology, Atlanta, USA. Before that, he obtained B. Tech and M. Tech (Dual Degree) from the Department of Computer Science and Engineering, Indian Institute of Technology (IIT), Kharagpur, India.
Arindam is a recipient of the Best Paper Award in MFCS 2020 and Google India Research Award 2021.

He is broadly interested in the design and analysis of algorithms and theoretical computer science. His current research interests include Approximation Algorithms, Online Algorithms, Online Learning, and Fairness. He is also interested in Algorithms for Big Data and Machine Learning.

https://www.csa.iisc.ac.in/~-arindamkhan/

Research Highlight

Optimization problems are ubiquitous in this modern era of science and technology. However, many optimization problems can be hard due to computational challenges (intractability) and/or the lack of knowledge about the input (uncertainty). Arindam's recent research has focused on finding efficient approximate solutions for such hard optimization problems. In their recent breakthrough result [1] in computational geometry, Arindam and his co-authors, made progress on Maximum Independent Set of Rectangles (MISR) -- a fundamental problem in computational geometry, approximation algorithms, and combinatorial optimization. In this problem, given a set of (possibly overlapping) rectangles on a plane, one needs to find the maximum number of non-overlapping set of rectangles. MISR finds numerous applications in practice, e.g., in map labeling, data mining, and resource allocation. This recent work develops new mathematical techniques and extends the present techniques to their limits.

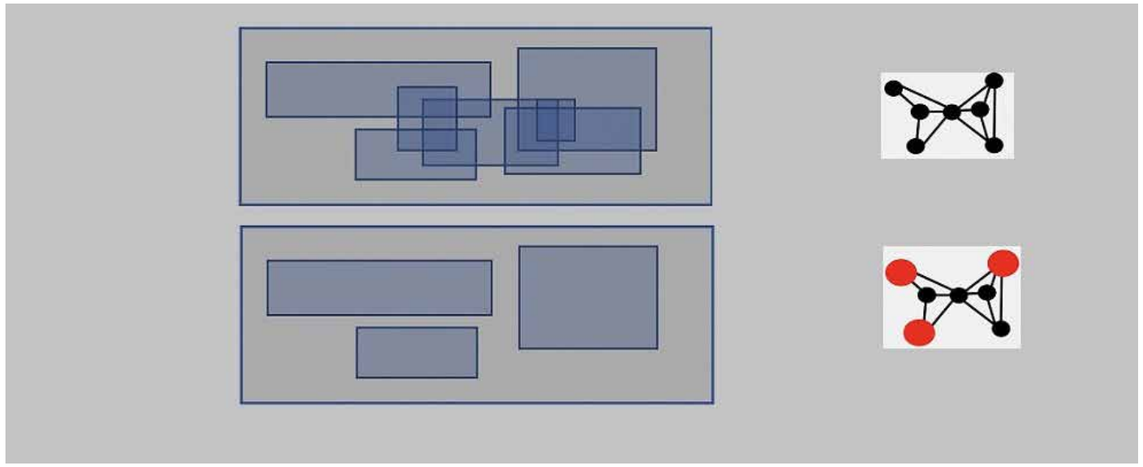
Arindam's another recent joint work resolved a two-decade-old conjecture on online bin packing under the i.i.d. model [2]. In online bin packing, a classical problem in online algorithms and combinatorial optimization, items arrive one by one and their sizes are revealed upon their arrival and they must be packed immediately and irrevocably in bins of unit size. The goal is to pack all items into the minimum number of bins. In the i.i.d. model, item sizes are sampled independently and identically from an unknown probability distribution. The paper [2] provided a near-optimal efficient algorithm for online bin packing under i.i.d. model, settling a long-standing open problem.

Arindam has also been studying foundational problems at the intersection of machine learning and algorithms for big data. Recent research [3] by his group studies the Stochastic Multi-armed Bandit problem under bounded arm-memory. Modern data science deals with massive data sets that may arrive rapidly and may not be fully stored. Streaming and dynamic algorithms deal with this large data stream by working in a few passes over the data and use limited memory. Multi-armed bandit is a classical exploration-exploitation framework in online learning. Their NeurIPS'21 paper [3] gave near-optimal guarantees for streaming algorithms for best-arm identification and regret

[1] Waldo Gálvez, Arindam Khan, Mathieu Mari, Tobias Mömke, Madhusudhan Reddy Pittu, Andreas Wiese: A 3-Approximation Algorithm for Maximum Independent Set of Rectangles. SODA 2022: 894-905.

[2] Nikhil Ayyadevara, Rajni Dabas, Arindam Khan, KVN Sreeenivas: Near-optimal Algorithms for Stochastic Online Bin Packing. To appear in ICALP 2022.

[3] Arnab Maiti, Vishakha Patil, Arindam Khan: Multi-Armed Bandits with Bounded Arm-Memory: Near-Optimal Guarantees for best-arm identification and regret minimization. NeurIPS 2021: 19553-19565



Shishir Kolathaya

Shishir is an Assistant Professor of the Robert Bosch Centre for Cyber Physical Systems (RBCCPS) and the Department of Computer Science and Automation (CSA) in IISc Bangalore. He received his Ph.D. degree in Mechanical Engineering (2016) from the Georgia Institute of Technology, M.S. degree in Electrical Engineering (2012) from Texas A&M University, and B.Tech. degree in Electrical Engineering (2008) from the National Institute of Technology Karnataka, Surathkal. He started his career in the field of robotics, especially in the domain of legged robots. His primary focus as a PhD student was on stability and control of walking robots. Shishir has now diversified to other fields like safety-critical control, and machine learning for all kinds of robotic platforms.

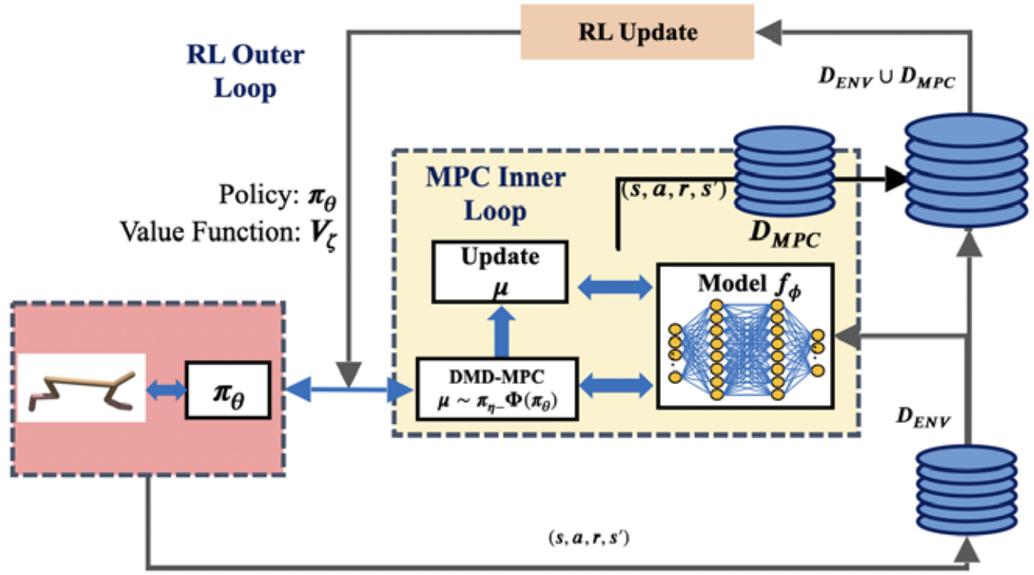
http://www.shishirny.com/

Research Highlight

Model-Free Reinforcement Learning (Mf-RL) algorithms are widely applied to solve tasks like dexterous manipulation and agile locomotion as they eliminate the need to model the complex dynamics of the system. However, these techniques are data hungry and require millions of interactions with the environment. Furthermore, these characteristics highly limit successful training on hardware as undergoing such high number of transitions in hardware environments is infeasible. Thus, to overcome this hurdle, various works have settled for a two-loop model based approach, typically referred to as Model-based Reinforcement Learning (Mb-RL). Such strategies take the benefit of the explored dynamics of the system by learning the dynamics model, and then determining an optimal policy in this model. Hence this "inner-loop" optimization allows for a better choice of actions before interacting with the original environment.

The process of planning with the learnt model is mainly motivated by the Model Predictive Control (MPC), which is a well-known strategy used in classical real-time control. Given the model and the cost formulation, a typical MPC structure can be formulated in the form of a finite horizon trajectory optimization problem. By exploiting this approach of using approximated dynamics, methods like Cross-Entropy Method (CEM) and Model Predictive Path Integral (MPPI) have been used to achieve high reward gains. Improvements were shown in the training time; however, these results are preliminary and yet to be completely formalized. With this viewpoint, we propose a generic framework that integrates a model-based optimization scheme with model free off-policy learning. Motivated by the success of online learning algorithms in RC buggy models, we combine them with off-policy Mf learning, thereby leading to a two-loop Mb-Mf approach. We implement dynamic mirror descent (DMD) algorithms on a model-estimate of the system, and then the outer loop Mf-RL is used on the real system. The main advantage with this setting is that the inner loop is computationally light; the number of iterations can be large without affecting the overall performance. Since this is a hierarchical approach, the inner loop policy helps improve the outer loop policy, by effectively utilizing the control choices made on the approximate dynamics. This approach, in fact, provides a more generic framework for some of the Mb-Mf approaches.

This work is accepted as a conference paper at the International Conference on Robotics and Automation (ICRA), 2022, to be held in Philadelphia in May.



M DeMo RL:

1. Uses dynamic mirror descent for solving the inner-loop MPC
2. This is a generic framework as opposed to existing Mb-Mf approaches

Symposium on Pratiksha Trust Young Investigators Projects

Back in 2017, Symposiums were offered as in-person sessions. Now in 2021, the Symposium on Young Investigators Projects was conducted in virtual mode on the 30th of July, 2021. The Symposium was attended by the Young Project Investigators/researchers, and the avid student community promoting mutual collaboration and exchange of knowledge.

The Symposium was meant for Young Researchers/Investigators to present their innovations within the field of neuroscience in a session-wise manner, with each session lasting for a period of 15-20 minutes.

The sessions were followed by queries and discussion at the end of the talk, which was dealt with by various Chairs of each session.

The Symposium featured several interesting talks by the Young Investigator speakers including:
Anand Louis, Assistant Professor, CSA
Siddharth Barman, Associate Professor, CSA
Sundeep Prabhakar Chepuri, Assistant Professor, ECE
Anirban Chakraborty, Assistant Professor, CDS
Chirag Jain, Assistant Professor, CDS
Arkaparva Basu, Assistant Professor, CSA

The Symposium also featured talks by the Pratiksha Trust Chair Professors, delivered by Prof. Vasant Honavar and Prof. Shihab Shamma, who gave a brief talk in connection with their research, followed by an interactive session of questions and answers.

Symposium on Exploratory Projects under the Pratiksha Trust Initiative

To benefit from synergistic interactions among neurobiologists and computer scientists, a symposium on exploratory projects was held on the 2nd of July, 2021. The symposium was aimed at creating a platform for researchers to present and discuss the most recent innovations, trends, and concerns, as well as practical challenges encountered and solutions adopted, helping researchers in a certain area to get exposed to concepts and methodologies in other areas. The symposium was chaired in two sessions and had presentations from the following IISc faculty members:

“Predicting The Naturalness Of Artificially Generated Videos”
Rajiv Soundararajan, Assistant Professor, ECE, IISc
SP Arun, Associate Professor, CNS, IISc

“Fabricating Novel Micro-Electrode Cannula Arrays to Design Neuroprotective Therapies for Acute Stroke and Epilepsy”
Hardik Pandya, Assistant Professor, ESE, IISc
Siddharth Jhunjhunwala, Assistant Professor, BSSE, IISc
Mahesh Jayachandra, Facility Technology Manager, BSSE, IISc

“Deep Neural Networks For 3D Understanding”
Venkatesh Babu, Professor, CDS, IISc
Vijay Natarajan, Professor, CSA, IISc

“HPC Framework for large scale study of Brain Networks”
Ambedkar Dukkipati, Professor, CSA, IISc
Sathish Vadhiyar, Associate Professor, CDS, IISc

“Time-Based Sampling of FRI Signals”
Chandra Sekhar Seelamantula, Professor, EE, IISc
Chetan Singh Thakur, Assistant Professor, ESE, IISc

“Characterizing spatiotemporal transformations between facial myoelectric signals and articulatory behavior during regular speech, silent speech and silent reading”
Prasanta Kumar Ghosh, Associate Professor, EE, IISc
Aditya Murthy, Professor, CNS, IISc

“Rapid, large-scale connectome estimation for mapping structure-function relationships in healthy and diseased brains”
Sridharan Devarajan, Assistant Professor, CNS & CSA, IISc
Partha Pratim Talukdar, Associate Professor, CDS & CSA, IISc

“Whole genome sequencing in human cohort studies informs the genetic architecture of complex phenotypes”
Bratati Kahali, Assistant Professor, CBR, IISc

The event featured high-quality scientific collaboration from every domain of modern brain research and provided a great opportunity to connect, despite being held virtually as a consequence of the COVID-19 pandemic.

Pratiksha Trust
Faculty Fellows

Cognitive map in the entorhinal-hippocampal network

Sachin Deshmukh

Dr. Sachin Deshmukh did his MSc in Biotechnology from MS University, Baroda and obtained his PhD in Neuroscience from National Centre for Biological Sciences (NCBS), Bangalore. He did his post-doctoral work at University of California, Berkeley, University of Texas Health Sciences Centre at Houston, and Johns Hopkins University, Baltimore. His Postdoctoral work involved characterizing entorhinal cortex inputs to the hippocampus by recording single neuron activity in awake, behaving rats. He joined Centre for Neuroscience in October 2014.

Hippocampus is a part of the brain involved in spatial navigation, learning, and memory. Hippocampal damage in Alzheimer's disease, epilepsy, traumatic brain injury, ageing etc. leads to a profound loss of ability to form and/or recall episodic memories. Knowledge of hippocampal computations is critical for devising strategies to mitigate the consequences of hippocampal damage. Understanding the nature of hippocampal computation requires knowledge of the information the hippocampus receives from its neuronal inputs, as well as the hippocampal output. The entorhinal cortex (EC) acts as a gateway to hippocampus – most of the cortical and subcortical information reaches the hippocampus via EC. Hippocampal neurons are hypothesized to derive their spatial selectivity from the medial EC (MEC) input and their non-spatial modulation from the lateral EC (LEC) input.

LEC projects strongly to proximal CA, while MEC projects trongly to distal CA1. This pattern led some to hypothesize that proximal CA1 (pCA1) is spatially more selective than distal CA1 (dCA1). While earlier studies support this hypothesis, I recently showed that under certain experimental conditions, this difference disappears. In a complex environment with circular track with distinct textures and global visual cues, pCA1 and dCA1 display comparable spatial selectivity. This work was published recently in the Journal of Neuroscience with the support of Pratiksha Trust. Correlated with the spatial selectivity differences, the earlier studies also showed differences in theta oscillatory dynamics between pCA1 and dCA1 neurons. Aditi Bishnoi in my lab shows that there are no differences in theta oscillatory dynamics between neurons in these two regions under the experimental conditions where pCA1 and dCA1 neurons are equally spatially selective. She also shows that dCA1 local field potentials (LFPs) show higher theta power compared to pCA1 LFPs. This work, done with Pratiksha Trust support, is currently under review in the Journal of Neuroscience. These findings suggest CA1 sub-networks represent space in task-dependent manner.

During this period, we also performed hippocampal recordings from rats foraging in large spaces – 16.5 m^2, using state of the art wireless recording systems. Indraja Jakhalekar in my lab shows that multiple place fields of the neurons are not randomly distributed in space, but the spacing between fields is overdispersed as compared to randomized field distribution. This indicates that the underlying network has attractive as well as repulsive processes governing place field locations in the environment.

Interdisciplinary PhD program in Brain and Artificial Intelligence

The interactions among the faculty members involved in the Brain, Computation and Data group formed under Pratiksha Trust initiatives, led to the proposal for an inter-disciplinary PhD program in Brain and Artificial Intelligence to give a thrust to research in this important area. This interdisciplinary PhD program is aimed at promoting research at the intersection of neuroscience and artificial intelligence, by providing wholesome training that spans both fields and blurs their distinctions. Its focus would be on computational approaches to understanding brain function and their synergistic interactions with artificial intelligence paradigms.

This unique program commenced its operations from the academic year 2020-21. Students with MSc or equivalent degree in any branch of Sciences or BE/BTech or equivalent degree in any discipline or 4-year Bachelor of Science degree (and who have qualified in national eligibility tests as needed) are eligible to apply to this program. The students are interviewed to assess both their background as well as aptitude for inter-disciplinary research. Each selected student will be working with two advisers belonging to two different departments, reflecting the inter-disciplinary flavor of the program. The following committee of faculty members are currently handling the academic administration of this program: Ambedkar Dukkipati, CSA; S.P. Arun, CNS; Chetan Singh Thakur, ESE; Rajiv Soundararajan, ECE; Rishikesh Narayanan, MBU; P.S. Sastry, EE; Siddhartha Gadgil, MA; R. Venkatesh Babu, CDS.

Areas of Research:
Brain Inspired Artificial Intelligence
Machine Learning
Signal Processing
Theoretical and Computational Neuroscience
Cellular, Systems and Cognitive Neuroscience
Sensory Systems: Vision, Speech
High-Level Cognitive Processes: Learning, Attention, Decision Making
Brain machine Interfaces
Neuromorphic Computation, Neuromorphic Hardware

The program started with an initial intake of 5 students per year and it is proposed to gradually increase the intake over a period of 5 years. It is expected that in the steady-state there will be 30 to 40 Ph.D. students on roll at any point of time. This unique program is expected to provide a significant boost to this important interdisciplinary area.

Activities Planned for 2022

Moonshot project
A moonshot project on the theme of Brain Co-Processors is being planned with the active involvement of multiple faculty, spanning several departments, at IISc.

Visits by Distinguished Chair Professors
Prof. Rajesh Rao will be visiting from June 13, 2022 till July 27, 2022. Visits by other chair professors are also being planned.

Joint Workshop with IIT-Madras Group
A joint workshop is planned with the Pratiksha Trust sponsored Brain, Computation, and Data Science Group at IIT-Madras

Workshop on Brain, Computation, and Learning, IISc Bangalore
Following the past versions of this workshop, the next one is being planned.

Organization of brainstorming workshops
Discussion on and around moonshot project problem to synergize different teams in this mission

Recruitment of Post-doctoral fellows
To accelerate the research activities related to moonshot project

Providing travel support to students
To encourage students to present their work at different conferences and workshops related to Brain, Computation and Data Science.

Organization of compact courses
Such courses by chair professors, national/international experts in this area will benefit faculty, students working in the BCD related areas

Recruitment of more students in the BAI PhD Program
This will gradually enable the activity in the BCD area through more focused problems through PhD students.

Exchange of graduate student visitors between IISc and other universities
Student exchange is aimed at benefiting from international collaborations

Research Publications

2022

Liza K and Ray S (2022) Local interactions between steady-state visually evoked potentials at nearby flickering frequencies. Journal of Neuroscience. Accepted.

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