Pratiksha Trust Initiative on

Brain, Computation and Data Science

INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

Activities
2023

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.
From January 2023, the committee has been changed to Profs. Rajesh Sunderasan (Convener); Prasanta Kumar Ghosh (Convener);
Sridharan Devarajan (Convener); Supratim Ray; Vijay Chandru
This booklet provides a bird's eye view of the activities undertaken as a part of this initiative in IISc during 2023.

Rajesh Sundaresan, ECE
Convener, Pratiksha Trust Initiative at IISc

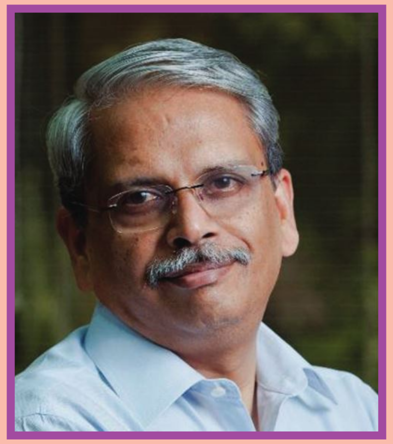
From Director, IISc

"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)

Vijay Chandru,
Strand Life Sciences

Supratim Ray, CNS

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

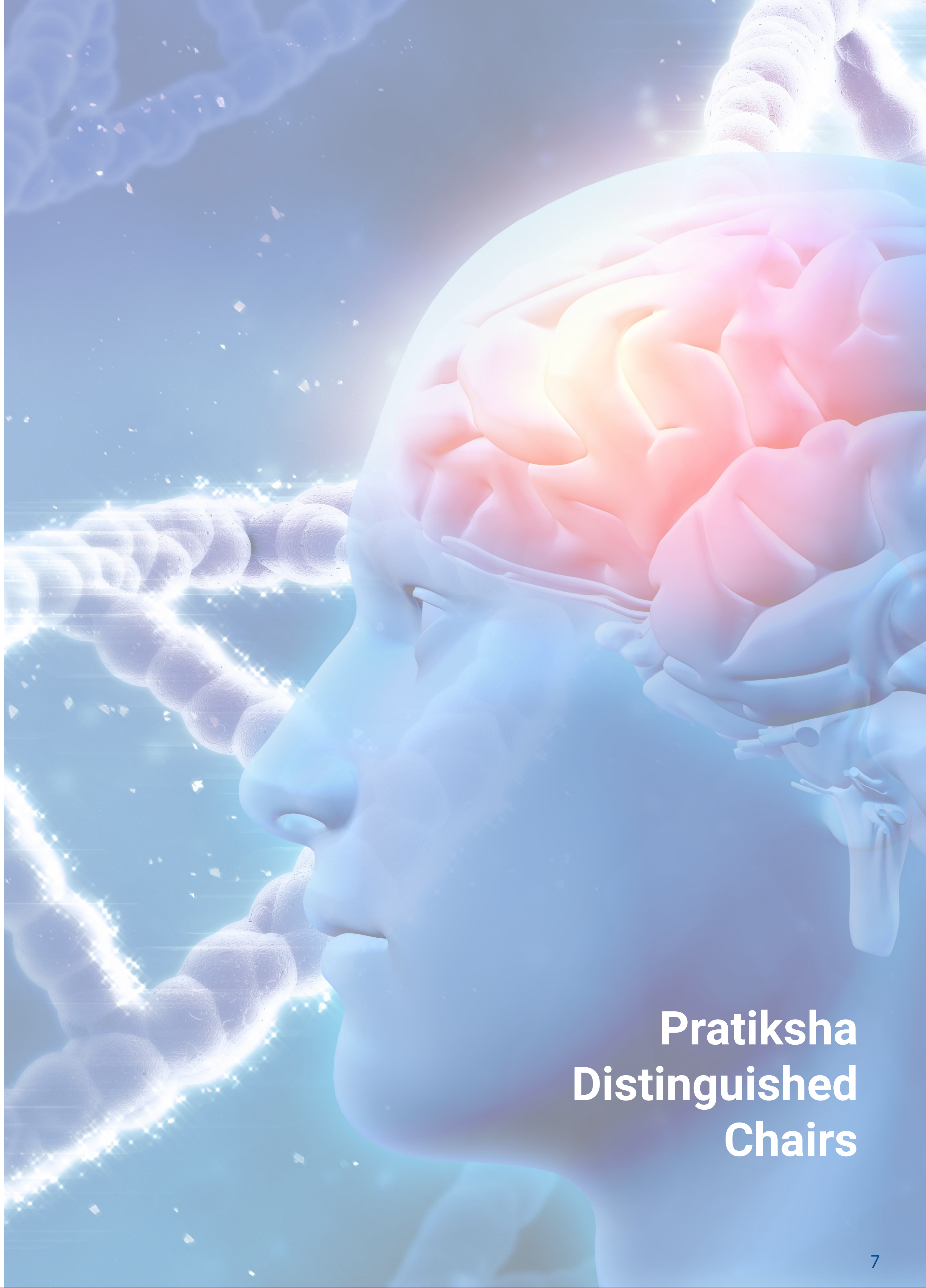
Supratim Ray, CNS

T.V. Prabhakar, ESE

Y. Narahari, CSA

Yogesh Simmhan, CDS

and all other interested faculty members



Pratiksha Distinguished Chairs

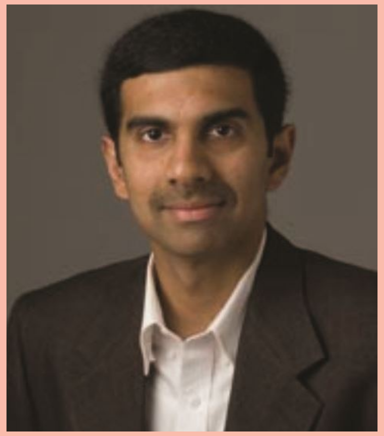
Pratiksha Trust Distinguished Chairs at IIT-Madras

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 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

Shri K. Vaidyanathan Distinguished Chair

Prof. Barbara Shinn-Cunningham

Director, Carnegie Mellon Neuroscience Institute
George A. and Helen Dunham Cowan Professor of Auditory Neuroscience, Biomedical Engineering, Psychology, and Electrical & Computer Engineering

Education

BSc – Brown University – 1986

MS – Massachusetts Institute of Technology – 1988

Ph.D. – Massachusetts Institute of Technology – 1994

Expertise

Characterization of Neural Circuits

Cognitive Neuroscience

Computational Neuroscience

Executive Control and Memory

Non-Invasive Brain Monitoring

Spatial Cognition and Attention

Awards and Distinction

Fellow, American Institute for Medical and Biological Engineering

Fellow, Acoustical Society of America

Member, Telluride Auditory Attention Team

Treasurer and Member, Council of the Association for Research in Otolaryngology

Biennial Mentorship Award from the Acoustical Society of America

Bernice Grafstein Award for Outstanding Accomplishments in Mentoring

Acoustical Society of America silver medal

Smt. Sudha Murty Distinguished Chair

Prof. Maneesh Sahani

Professor, University College, London
Director, Gatsby Computational Neuroscience Unit, University College, London

Education

BS – California Institute of Technology – 1993

Ph.D. – California Institute of Technology -1999

Expertise

Theoretical Neuroscience

Machine Learning

Computation and Neural Systems

Awards and Distinction

General Chair, Computational and Systems Neuroscience Conference (COSYNE)

Programme Chair, COSYNE

Member, Board of Directors, Computational Neuroscience Organization

Member, Society for Neuroscience

Member, Association for Research in Otolaryngology

Member, IEEE

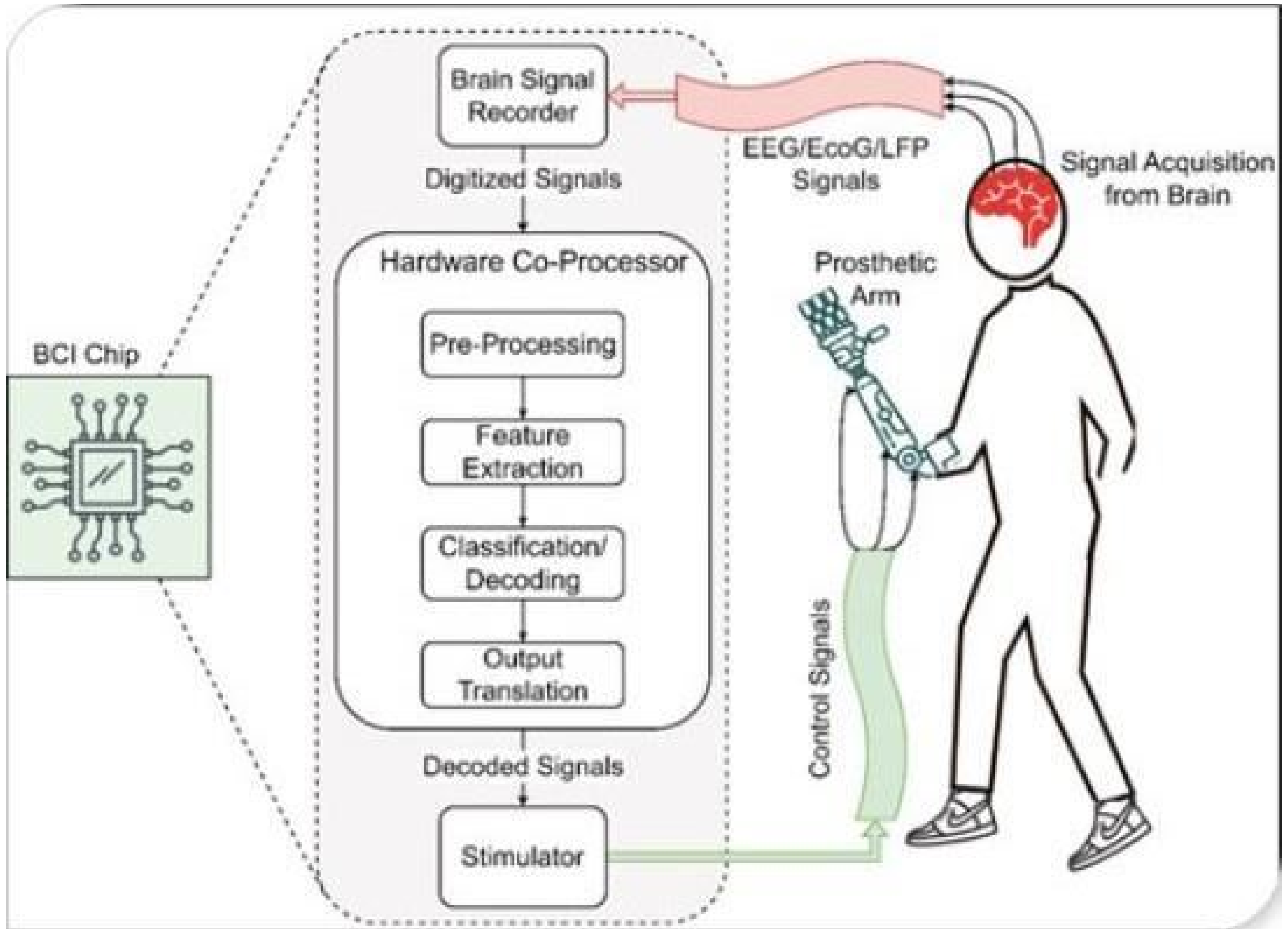
Brain Co-Processors – A Moonshot Project in India

"The moonshot project brings together talents in many different areas to share a common vision – there's AI, device development, electrode development, the animal aspects, neuroscience and the human clinical aspect. And in India, we have the resources, both on the engineering and the sciences side."

– Prof Rajesh Rao, Pratiksha Trust Distinguished Chair Professor, IISc

A moonshot project on brain co-processors has been initiated by the Brain, Computation, and Data Science group under the aegis of the Pratiksha Trust BCD Initiative at IISc. The aim of this project is to develop invasive (implantable) or non-invasive brain co-processors to enhance or restore brain functions such as memory, attention, vision, and motor skills. Such co-processors involve decoding activity from neural recordings, processing it with an AI (artificial intelligence) algorithm implemented in software or hardware, and re-encoding signals back into the brain, either directly with neural stimulation/neurofeedback or by actuating external devices, such as prosthetic arms. The figure shows a simplified view of a co-processor and its use-case of a motoric brain–computer interface.

The project derives its name from a 2019 paper on "neural co-processors" by Rajesh Rao, Cherng Jia and Elizabeth Yun Hwang Endowed Professor, and co-Director, Center for Neurotechnology at the University of Washington, and Pratiksha Trust Distinguished Chair Professor, Indian Institute of Science. The project commenced in October 2022, following a special call for proposals by the BCD Scientific Advisory Committee.



As a key element of novelty, the principal investigators (PIs) of the project have decided on cognitive rehabilitation of stroke patients as the target medical application for the co-processor. The rationale is that stroke patients are a good model for exploring rehabilitation across mutliple sub-themes that were initially envisaged (decoding vision, decoding attention, decoding decisions, decoding actions, and low-power decoding in real-time). Considering the current state-of-the-art and open possibilities, they decided to organize into three teams, each focusing on a different aspect: A) conducting invasive intracranial EEG (electroencephalogram) recordings in epilepsy patients, B) developing non-invasive brain co-processors for stroke patients, and C) developing invasive (implantable) brain co-processors in animal models as a precursor for stroke patients. Each team will tackle one facet of the project with immediately realizable goals.

The actualization of the project vision entails collaboration between basic science researchers and clinicians (neurologists and neurosurgeons) from different institutes and hospitals across the country. For instance, to study the normal brain activity in epilepsy patients when they are not having seizure episodes, IISc researchers work with clinicians. During their resting times, patients could be asked to do simple vision, attention, and motor tasks that are similar to those proposed in the moonshot project 1 (Team A). Similarly, clinicians' involvement will be critical in the field trials of both non-invasive (Team B) and invasive (Team C) co-processors with stroke patients.

Broadly, the project is envisioned to be carried out in two stages. The first phase (years 1–5) – "MindReader" – will focus on developing technologies for recording neural activity at high densities from different brain regions and decoding mental states (perceptual, cognitive, and motor) by developing customised AI algorithms in software and hardware. The second phase (years 6–10+) – "MindHacker" – will focus on developing technologies for re-encoding signals back into the brain using a combination of recording and neurostimulation technologies.

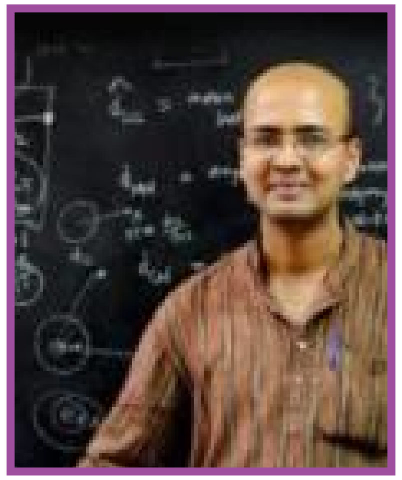
References

Report on Brain Co-processors by Krishnan Narayanan, Itihaasa Research and Digital

Team A: Stereo EEG in epilepsy patients

Principal Investigators

Sridharan Devarajan, IISc



S P Arun, IISc

Chandra R Murthy, IISc

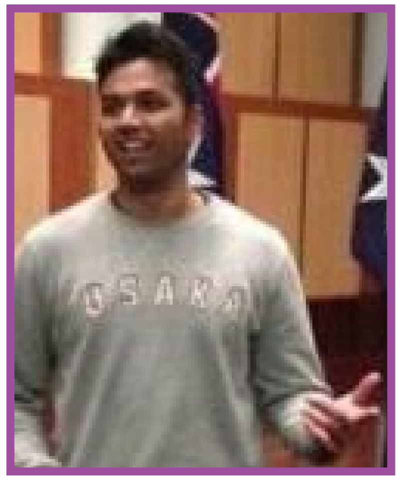
1. Goal 1: Collaborating with clinicians to develop a comprehensive sEEG database as a first step towards understanding the role of different brain regions in diverse cognitive functions (e.g. attention, decision making).
2. Goal 2: Exploring ways to combine different imaging modalities (e.g. dMRI, fMRI, scalp EEG) to develop a tool to enable better localization of epileptogenic networks.
3. Goal 3: A tertiary goal is testing the effect of intracortical stimulation on neural activity and behaviour.
4. These goals will pave the way for developing invasive co-processors in stroke patients.

Team B: Non-invasive brain co-processors for stroke patients

Principal Investigators

Arjun Ramakrishnan, IIT Kanpur

Sridharan Devarajan, IISc



Chetan Singh Thakur, IISc

1. Goal 1: Collecting scalp EEG recordings from healthy participants/stroke patients and developing models for decoding cognitive functions (e.g. attention or decision-making).
2. Goal 2: Developing passive controllers (including prosthetic devices e.g. switch that turns on or off based on decoding attention) and active neurofeedback systems (includes integrated neurostimulation e.g. tACS devices).
3. Goal 3: Integrating these into a neuromorphic device with a small form factor as wearable technology.
4. These goals can be piloted in healthy participants and then tested with stroke patients to understand challenges unique to such patients. This will require the involvement of clinicians who deal with stroke patients and with non-invasive rehabilitation.
5. These goals will also pave the way for hybrid or minimally invasive co-processors for stroke patients.

Team C: Invasive brain co-processors for stroke patients

Principal Investigators

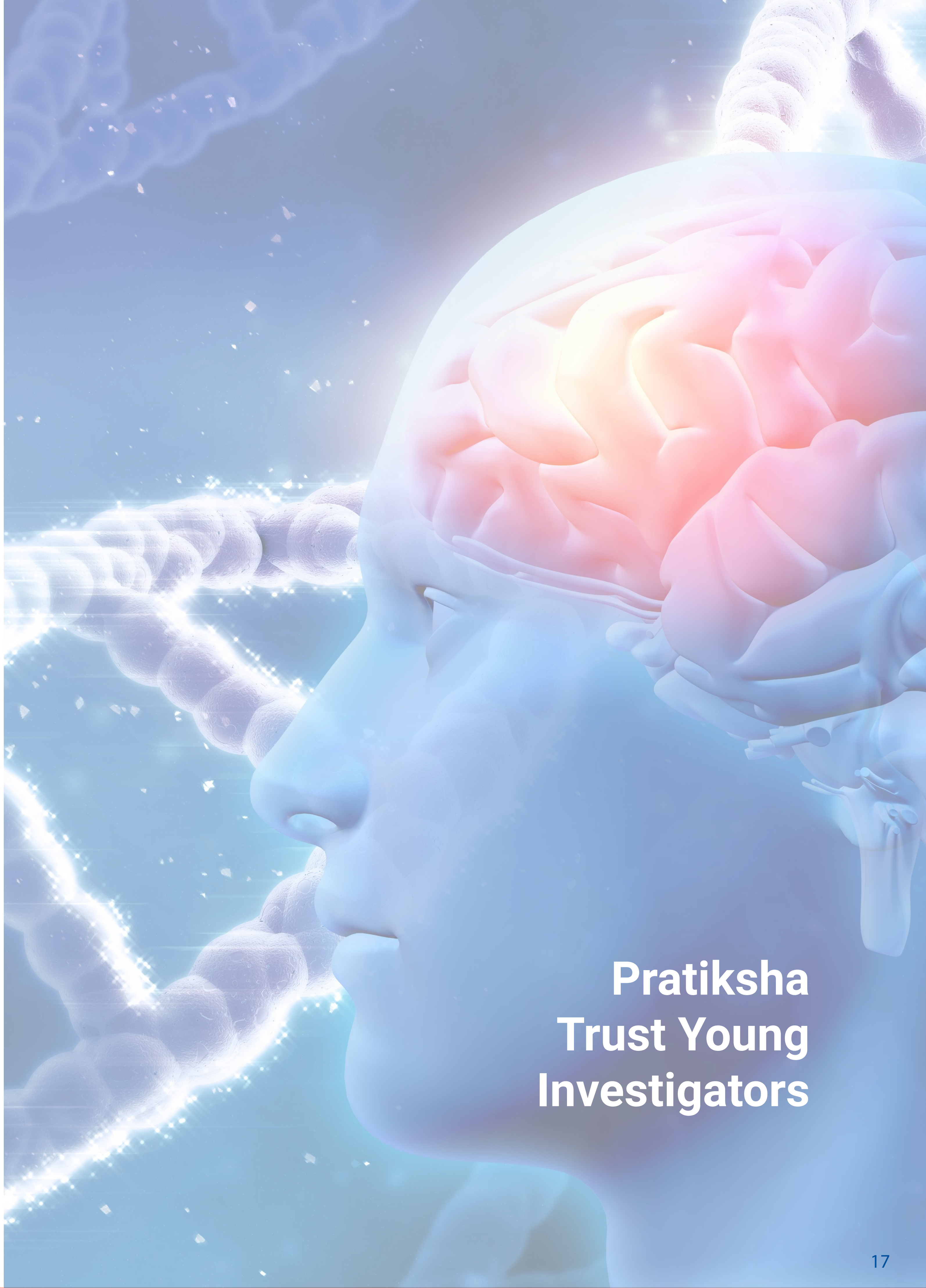
Hardik J Pandya, IISc

Supratim Ray, IISc

Arjun Ramakrishnan, IIT Kanpur

Chetan Singh Thakur, IISc

1. Goal 1: Building algorithms for decoding and re-encoding activity in the animal brain with existing, approved technologies (e.g. Utah arrays). As a first step, this could involve decoding activity in visuo-motor tasks because these are considerably simpler to train than cognitive tasks in either primate or rodent models.
2. Goal 2: Building low-cost, invasive electrodes for decoding and/or re-encoding activity back in animal brains. This will include development of biocompatible electrodes as well as novel, multi-contact electrode technologies for simultaneous recording and stimulation.
3. Goal 3: Building and testing invasive neuromorphic co-processors in animal models. Combining the deliverables of Goals 1 and 2, a neuromorphic co-processor will be developed for testing in animal models. As the ultimate aim is to translate the deliverables to human patients, in the long term, this goal will necessarily involve both animal and human (patient) work.



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)
14. Dr. Utsav Banerjee, Department of Electronic Systems Engineering (2022-24)
15. Dr. Gugan Thoppe, Department of Computer Science and Automation (2022-24)
16. Dr. Sreetosh Goswami, Centre for Nano Science and Engineering (2021-23)
17. Dr. Danish Pruthi, Department of Computational and Data Sciences (2023-25)
18. Dr. Debayan Das, Department of Electronic Systems Engineering (2023-25)
19. Dr. Vaanathi Sundaresan, Department of Computational and Data Sciences (2023-25)
20. Dr. Vini Gautam, Central for Nano Science and Engineering (2023-25)

Gugan Chandrashekhar Mallika Thoppe

https://sites.google.com/site/guganct h/

Gugan Chandrashekhar Mallika Thoppe is an Assistant Professor in the Computer Science and Automation department at the Indian Institute of Science since 2019. He is also an Associate Researcher at the Robert Bosh Centre, IIT Madras. He received his Ph.D. in 2016 from the Tata Institute of Fundamental Research (TIFR), Mumbai. Following this, he completed postdoctoral research at two places: Technion Institute of Technology, Israel (2015-17) and Duke University, USA (2017-19). His research is supported by the Cefipra Indo-French grant, the Walmart CSR grant, DST-SERB's core research grant, and the Pratiksha trust's young investigator award. He is also the winner of the IISc Award for Excellence in Teaching, the TIFR award for the best Ph.D. thesis, and two IBM Ph.D. fellowships. His research interests include reinforcement learning, online learning, stochastic approximation, and random topology.

Research Highlight

Random graphs, as models for binary relations, have had a deep impact in discrete mathematics, computer science, engineering, and statistics. Modern-day data analysis, however, has necessitated studying models with higher-order relations such as random simplicial complexes. Just as the Minimum Spanning Tree (MST) has provided valuable insights into the connectivity and structural properties of random graphs, its generalization---the Minimum Spanning Acycle (MSA) has aided in understanding of the behavior of random complexes. A lot has been known about the asymptotic behaviors of the sums of MST and MSA weights in random graphs and random complexes. However, the histogram or the distribution of the individual weights in an MST/MSA has been an open question for almost four decades. Gugan's recent research has focused on addressing this gap.

In a recent breakthrough [1], Gugan and his co-authors managed to show that the empirical distributions of the random MST/MA weights converge to a measure based on a concept called the shadow. The shadow of a graph is the set of all the missing transitive edges, and, for a simplicial complex, it is a related topological generalization. Figure 1 illustrates our main result pictorially.

This work has appeared in the prestigious discrete analysis journal founded by fields medalist Prof. Timothy Gowers. Recent publications in this journal include those by fields medalists Terrence Tao and Jean Bourgain, Abel prize winner László Lovász, Dijkstra and Rothschild prize winner Nathan Linial, and Euler medalist Peter Cameron. Finally, this is only the second paper in this journal with a resident Indian author.

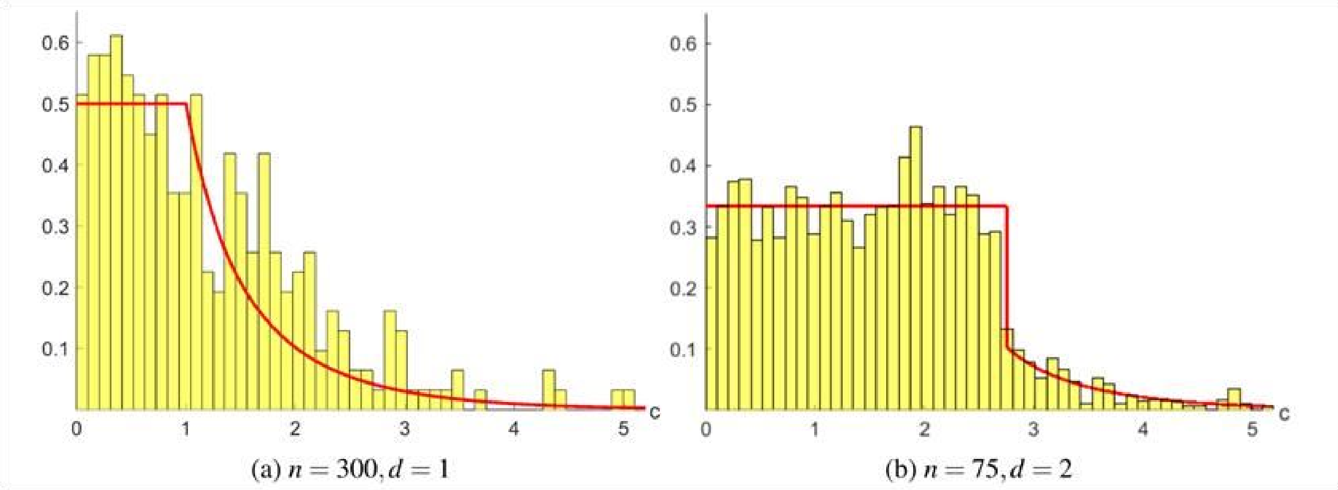


Figure 1: Normalized histogram (yellow) of the random MST weights (left) and random MSA weights (right) and the density (red) of the shadow-based measure.

[1] Fraiman, N., Mukherjee, S., Thoppe, G. "The Shadow Knows: Empirical Distributions of Minimum Spanning Acycles and Persistence Diagrams of Random Complexes", *Discrete Analysis*, 2023: 2

Sreetosh Goswami

Sreetosh Goswami is an assistant professor at the Centre for Nanoscience and Engineering (CeNSE) in the Indian Institute of Science (IISc), Bangalore. He completed his Ph.D. at the National University of Singapore and subsequently pursued a postdoctoral fellowship at the same institution before joining IISc. Sreetosh's research focuses on the development of energy and time-efficient neuromorphic hardware for artificial intelligence. Presently, he is developing accelerators to enhance deep learning, signal and image processing, as well as bioinformatics.

http://www.cense.iisc.ac.in/sreetosh-goswami

Artificial Intelligence (AI) is primarily hosted in resource-intensive data centers, restricting access to a select group of developers. Although neuromorphic hardware offers improved space and energy efficiency for AI, its current precision is limited to 2–6 equivalent bits. This precision challenge, stemming from physical non-idealities like nonlinear weight updates, asymmetric behavior, noise, conductance drifts, and device-to-device variability, confines its applications to low-accuracy operations like neural network inference. Crucial computing tasks, including signal processing, neural network training, and natural language processing, demand much higher computing resolution than existing neuromorphic circuit elements can provide. In 2023, our primary focus was on achieving a substantial leap in the accuracy of neuromorphic accelerators.

Research Highlight

We developed an analog memristive crossbar with a 14-bit resolution, approximately 16,500 distinct analog levels. A dot-product engine was developed using this cross bar, capable of performing vector-matrix multiplication in a single time-step, providing 8-bit higher precision than any report to date. This results in a signal-to-noise ratio of >73 dB, representing close to a four-order-of-magnitude improvement over the state-of-the-art, all while consuming 460× less energy than the best available digital computer today. Our key achievements include:

1. The discovery of the material enabling numerous distinct molecular levels.
2. Development of a circuit crossbar via nanofabrication capable of retaining bit precision, overcoming various fabrication and engineering challenges.
3. Development of a circuit platform and the integration of the crossbar for precisely accessing each analog state and assessing their stability over an extended period of months.

Accelerators using these molecular crossbars have the potential to revolutionize neuromorphic computing. The paper detailing these achievements is currently submitted and under review. Additionally, a perspective analyzing the future of molecular neuromorphic computing over the next decade has been accepted this year.

Ref: Sreebrata Goswami, R. Stanley Willaims and Sreetosh Goswami*, Molecular Redox Computing Redux. *Nature Materials*, 2024. Accepted for publication.

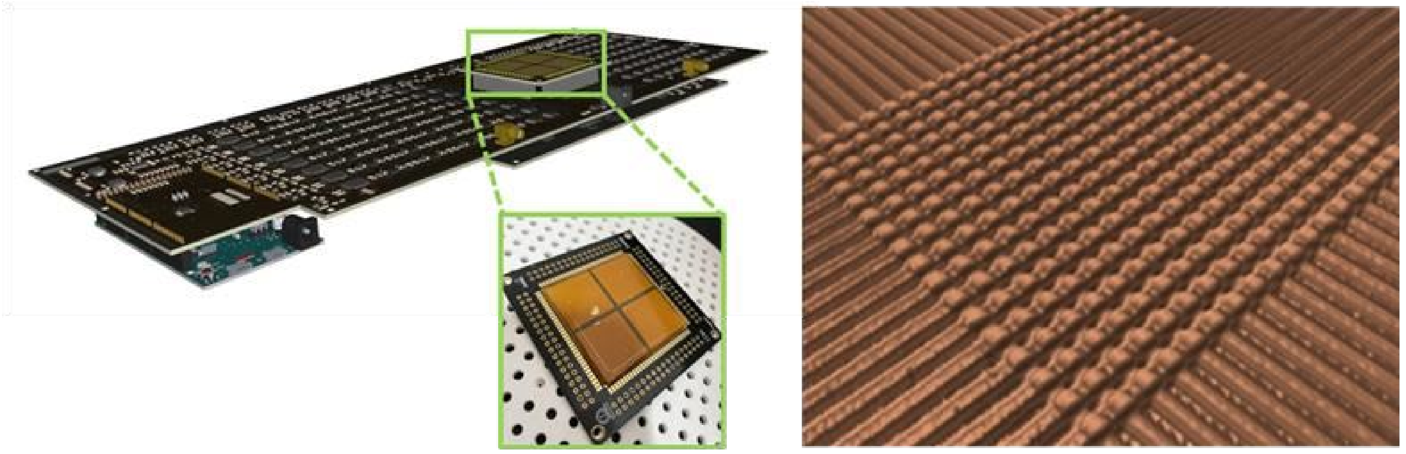


Figure: Our platform showcasing a high accuracy neuromorphic accelerator

Utsav Banerjee

https://banerjeeutsav.github.io/

Utsav Banerjee is an Assistant Professor in the Department of Electronic Systems Engineering at the Indian Institute of Science. He received his B.Tech. degree in electronics and electrical communication engineering from the Indian Institute of Technology Kharagpur in 2013, and his S.M. and Ph.D. degrees in electrical engineering and computer science from the Massachusetts Institute of Technology in 2017 and 2021 respectively.

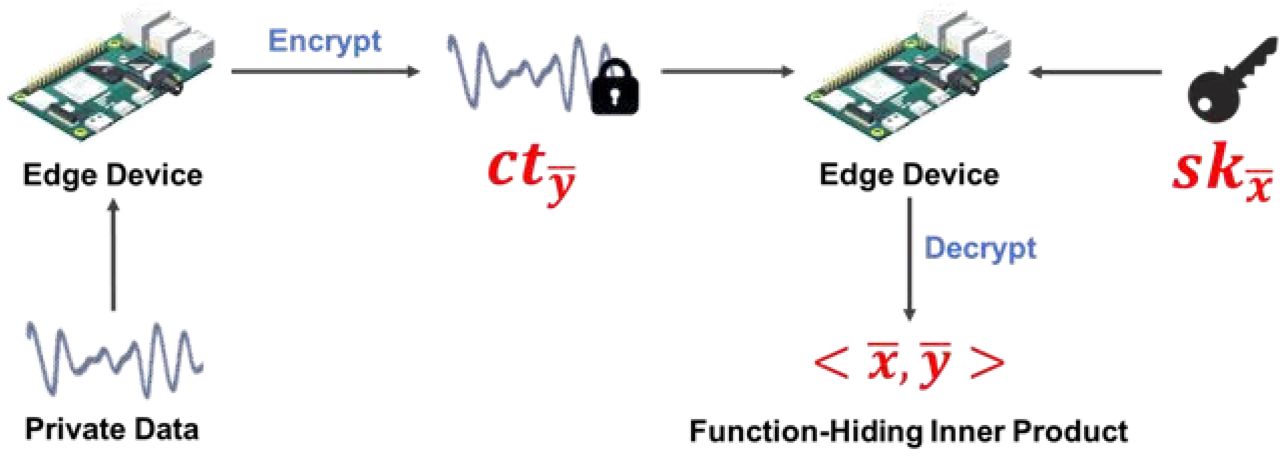
He currently leads the Secure Intelligent and Efficient Systems (SINESys) Lab at IISc. His research interests include cryptography, hardware security, digital circuits, embedded systems and VLSI chip design. He received the President of India Gold Medal from IIT Kharagpur in 2013, the Irwin and Joan Jacobs Presidential Fellowship from MIT in 2015, the Qualcomm Innovation Fellowship in 2016, the Pratiksha Trust Young Investigator Award from IISc in 2022, the ABB HvG Research Award in 2022 and the Intel Rising Star Faculty Award in 2023.

Research Highlight

Security and privacy of data communicated and processed by network-connected electronic devices has emerged as a major concern, especially with the advent of the Internet of Things (IoT). One of the most promising cryptographic tools for privacy-preserving computation is fully homomorphic encryption which allows arbitrary computationsin the encrypted domain without requiring any decryption of the data being computed upon. However, the implementation of such fully homomorphic encryption schemes is prohibitively expensive for typical edge devices with embedded micro-processors. Utsav and his group have explored the implementation of traditional elliptic curve cryptography and pairing-based cryptography to efficiently demonstrate a limited set of arithmetic computations in the encrypted domain which can enable interesting privacy-preserving applications in the context of IoT networks.

In their work from ANTS 2022 [1], elliptic curve-based additively homomorphic El Gamal public key encryption scheme has been used to develop a framework for the implementation of inner product computation and matrix multiplication in the encrypted domain. Efficient software implementation on ARM Cortex-M7, memory-time trade-offs, side-channel countermeasures, detailed performance analysis and application scenarios have been presented.

In their work from GLOBECOM 2023 [2], efficient software implementation of pairing-based function-hiding inner product encryption (FHIPE) using the recently proposed and widely adopted BLS12-381 pairing-friendly elliptic curve has been presented. Algorithmic optimizations provide 2.6× and 3.4×speedup in FHIPE encryption and decryption respectively, and extensive performance analysis is presented using a RaspberryPi 4B edge device. These optimizations enable the proposed implementation to achieve performance and ciphertextsize comparable to previous work despite being implemented on an edge device with a slower processor and supporting a curve at much higher security level with a larger primefield. Practical privacy-preserving edge computing applications such as encrypted biomedical sensor data classification and secure wireless fingerprint-based indoor localization are also demonstrated.



References:

[1] Faiek Ahsan and Utsav Banerjee, "Embedded Software Implementation of Privacy Preserving Matrix Computation using Elliptic Curve Cryptography for IoT Applications," *IEEE International Conference on Advanced Networks and Telecommunications Systems* (ANTS), 2022.

[2] Utsav Banerjee, "Privacy-Preserving Edge Computing fromPairing-Based Inner Product Functional Encryption," *IEEE Global Communications Conference (GLOBECOM)*, 2023.

Arindam Khan

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

Dr. 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, Kharagpur.

Arindam is a recipient of the Best Paper Award in MFCS 2020, Google India Research Award 2021, and Priti Shankar Teaching Award 2022.

He is broadly interested in the design and analysis of algorithms and theoretical computer science. His current research interests include Approximation Algorithms, Online Algorithms, Computational Geometry, Theoretical ML, and Fairness.

Research Highlight

Optimization problems are ubiquitous. However, many optimization problems can be hard due to computational challenges (intractability) and/or the lack of knowledge about the input (uncertainty). My recent research has focused on finding efficient approximate solutions for such hard optimization problems. Let me highlight two of my recent results.

In our recent SODA'24 paper [1], we made the first progress, after three decades, towards an importantopen problemin online algorithms. Bin packing is a classical problem in combinatorial optimization.Here,a set of items with associated sizes needs to be packed into the minimum number of unit-capacity bins.Best-Fit is one of the most prominent and practically used algorithms for the bin packing problem. Kenyon [SODA '96] studied online bin packing under random-order arrival, where the adversary chooses the list of items, but the items arrive one by one according to an arrival order drawn uniformly at random from the set of all permutations of the items. Kenyon's seminal result established an upper bound of 1.5 and a lower bound of 1.08 on the performanceguarantee (compared to the optimal solution) of Best-Fit and it was conjectured that the true ratio is around 1.15. The conjecture, if true, will also imply that Best-Fit (on randomly permuted input) has the best performance guarantee among all the widely-used simple algorithms for (offline) bin packing. However, despite the simplicity of the algorithm and efforts by many experts over the last three decades, the conjecture remained one of the major unsolved open problems in the area. In our SODA'24 paper, we show that Best-Fitachieves a random-order ratio of at most $1.5 - \epsilon$ for a small constant $\epsilon>0$. Furthermore, we establish an improved lower bound of 1.144, nearly reaching the conjectured ratio.

Geometric Set Cover and Hitting Set are fundamental problems in combinatorial optimization and computational geometry. In our SoCG'23 paper, we obtainimproved online and dynamic algorithms for them. In the online version of set cover (resp. hitting set), m sets (resp. n points) are given and n points (resp. m sets) arrive online, one-by-one. In the dynamic versions, points (resp. sets) can arrive as well as depart. Our goal is to maintain a set cover (resp. hitting set), minimizing the size of the computed solution. For online set cover for (axis-parallel) squares of arbitrary sizes, we present a tight O (logn) -competitive algorithm. For both dynamic set cover and hitting set with d-dimensional hyperrectangles, we obtain $(\log m)^{O(d)}$-approximation algorithms with $(\log m)^{O(d)}$ worst-case update time. This answers an important open question posed by Chan et al. [SODA'22]. Our main technical contributions are an extended quad-tree approach and a frequency reduction technique that reduces geometric set cover instances to instances of general set cover with bounded frequency.

Publications:

[1] Anish Hebbar, Arindam Khan, KVN Sreenivas: Bin Packing under Random-Order: Breaking the Barrier of 3/2, To appear in ACM-SIAM Symposium on Discrete Algorithms (SODA) 2024.

[2] Arindam Khan, Aditya Lonkar, Saladi Rahul, Aditya Subramanian, Andreas Wiese: Online and Dynamic Algorithms for Geometric Set Cover and Hitting Set. Symposium on Computational Geometry (SoCG) 2023: 46:1-46:17.

Shishir Kolathaya

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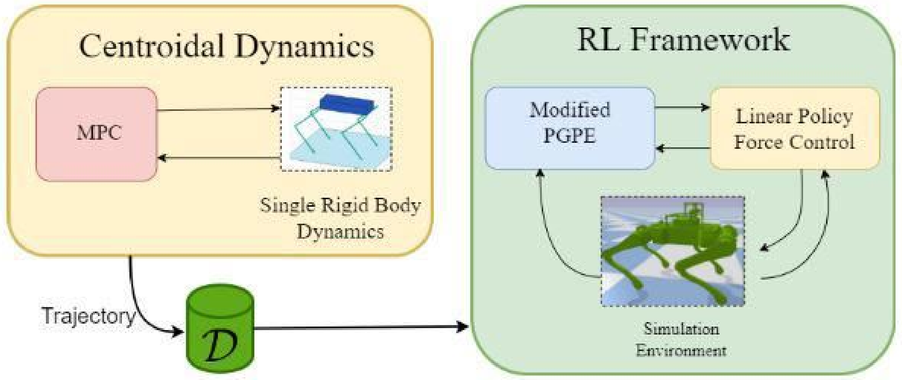
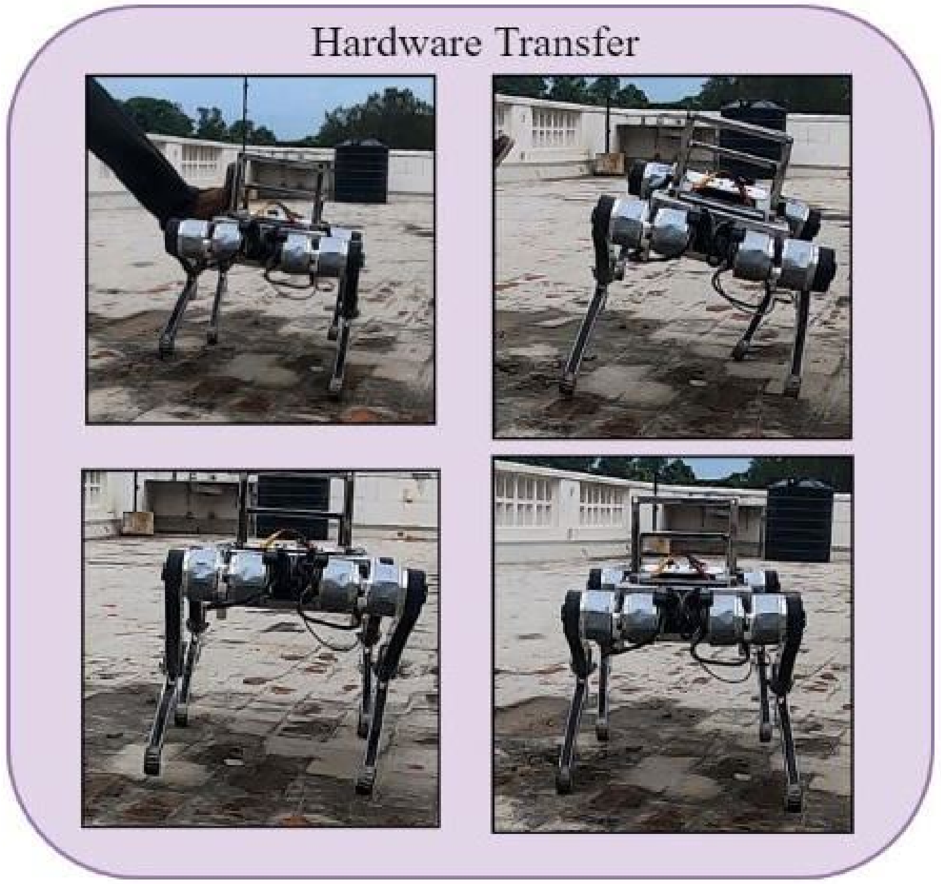
Shishir is an Assistant Professor of the Robert Bosch Centre for Cyber Physical Systems (RBCCPS) and the Department of Computer Science and Automation (CSA) in IISc Bangalore. He received his Ph.D. degree in Mechanical Engineering (2016) from the Georgia Institute of Technology, M.S. degree in Electrical 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.

Research Highlight

The domain of quadrupedal robot locomotion, despite having a high degree of underactuation, has reached a significant level of maturity today. There are classical control-based methods like Model Predictive Control (MPC) on one side of the spectrum, and end-to-end learning-based methods like Teacher-Student, Rapid Motor Adaptation on the other side. Classical control methodologies use system dynamics to get an optimal control policy by solving an optimization problem in real-time to realize a broad class of locomotion behaviors. Despite its success, MPC frameworks require extensive modeling and construction of the optimization problem in every time step. Learning-based methods, on the other hand, achieve locomotion by reinforcement learning (RL), i.e., learn a policy that maximizes some reward criterion by continuously interacting with the environment, thereby eliminating the need for modeling and optimization. It has been shown that RL control policies can learn to tackle unexpected contacts and slippage by exploring different types of actions with the environment. However, despite their ability to automatically realize walking in robots, they frequently suffer from sim-to-real transfer problems.

With a view to address the shortcomings of the two approaches above, we aimed to develop locomotion policies that are simpler than the MPC, and yet be effective enough for robust locomotion in quadrupeds. We have developed a learning based framework that can incorporate MPC based force controllers, but with a significantly lower computational load. In other words, instead of generating force controllers from a model based framework like the MPC, we learn a linear policy that generates the force, torque and trajectory commands directly, yielding a light-weight and a robust control framework for quadrupeds.





This work was accepted as a conference paper at the International Conference on Robotics and Automation (ICRA), 2023.

Danish Pruthi

https://danishpruthi.com/

Dr. Danish Pruthi is an Assistant Professor at the Indian Institute of Science (IISc), Bangalore. He received his Ph.D. from the School of Computer Science at Carnegie Mellon University. He is broadly interested in the areas of natural language processing and deep learning, with a focus towards inclusive development and evaluation of AI models. He has spent time doing research at Google AI, Facebook AI Research, Microsoft Research, Amazon AI and IISc. He is also a recipient of the AI2050 Schmidt Sciences Early Career Fellowship, Siebel Scholarship, Schmidt Sciences Fellowship, CMU Presidential Fellowship and Pratiksha Trust Young Investigator Award.

Research Highlight

Over the last year, my group and I have conducted research in the broad area of responsible language technologies. Thanks to the Young Investigator Award from the Pratiksha Trust, I was able to initiate a new research direction in my research group, wherein we intend to make language and vision models geographically more inclusive. In a short amount of time, this research thread has resulted in two publications, has received attention from international media and has been recognized with the AI2050 Early Career Fellowship from Schmidt Sciences (conferred to a total of 19 fellows worldwide).

The broad research agenda is to characterize and improve the geographical representativeness of AI models. For AI systems to be broadly useful, it is important that they are geographically inclusive—that is, they encode information about, and are sensitive to, different cultures and countries around the globe. Most current AI models are trained on large swaths of internet data, and therefore inordinately capture information about certain dominant groups and erase others. There is extensive literature that uncovers biases related to representation of gender, race, occupation, and (to some extent) sexual orientation. In comparison, there are only a few efforts that study how AI models may exhibit biases against certain geographical regions (or worse, erase them completely from the discourse).

Specifically, we have developed formalisms, benchmarks, and tools to study geographical erasure. Minimizing cultural and geographical identities is referred to as erasure, and has been studied by linguists and social scientists in the context of imperialism and colonialism, where "people are silenced in the historical record [...], their contemporary presence rendered invisible, and their existence written out of the future". We studied geographical erasure for two important classes of AI models: (1) language models; and (2) text-to-image generation models. For language models, we characterized the extent of underprediction of certain geographical regions when the context elicits geographical information [1] For example, we discovered that a GPT model assigns nine times higher likelihood to "I live in Canada" than "I live in Pakistan", whereas Pakistan's English-speaking population is almost four times that of Canada's. Similarly, for text-to-image generation models (e.g., DALLE), we studied the geographical representativeness by assessing whether models generate artifacts that reflect the surroundings of people from different nations in the world [2]. For instance, when tasked with generating an image of a house, do these models always generate houses that are typical of houses in the West, or the generated houses reflective of other parts of the world too? Our research study—published at ICCV—discovers that for many common objects (e.g., house, kitchen, parks), DALLE and Stable Diffusion do not generate content that people in 20+ countries find representative of their conditions.

Publications:

The following two papers communicate our research in this direction

1. Geographical Erasure in Language Generation by Pola Schwöbel, Jacek Golebiowski, Michele Donini, Cedric Archambeau, Danish Pruthi. Findings of the Conference on Empirical Methods in Natural Language Processing (EMNLP 2023) [CORE: A*]

2. Inspecting Geographical Representativeness of Images from Text-to-Image Models by Abhipsa Basu, R. Venkatesh Babu, Danish Pruthi. International Conference on Computer Vision (ICCV, 2023) [CORE: A*]

Press:

The above research was covered by international media in the following articles:

1. How AI reduces the world to stereotypes

2. AI image generators like DALL-E and Stable Diffusion have a representation problem

3. AI Image Generators Lack Global Diversity

Vaanathi Sundaresan

https://sites.google.com/view/dr-vaanathi-sundaresan/ABOUT

Dr. Vaanathi Sundaresan is an Assistant Professor at the Department of Computational and Data Sciences (CDS), Indian Institute of Science (IISc), Bangalore. She is also the convenor of Biomedical image Analysis (BioMedIA) laboratory at CDS, IISc. Prior to this appointment, she was working as a postdoctoral research fellow at Athinoula A. Martinos Centre, Department of Radiology, Harvard Medical School and Massachusetts General Hospital. She received her doctorate degree at Oxford Centre for function MRI of Brain (FMRIB), Wellcome Centre for Integrative Neuroimaging (WIN), University of Oxford, UK. Later, she continued her research at WIN as a Postdoctoral researcher, where she is currently affiliated as an Honorary Research Fellow.

Her research areas include computer vision and machine learning-based methods for identification of MR imaging biomarkers for various neurological diseases, semi-supervised and data-efficient techniques for analysis of various imaging modalities, explainability in medical imaging and data harmonisation/domain adaptation.

Research Highlight

Automated detection of imaging biomarkers is an essential step in disease quantification for their severity assessment. Our work focusses on identification of pathological signs on various imaging modalities for early diagnosis of diseases, further analysis and characterisation of various signs. We also develop methods for synthesis for anomalies for training data-efficient models, which are adaptable across different domains, for biomarker segmentation.

In our first work accepted at ISBI [1], we aim to develop an automated method for accurate grading of DR severity on ultra-wide optical coherence tomography angiography (UW-OCTA) images. Our method consists of various components such as UW-OCTA scan quality assessment, segmentation of vascular abnormalities and grading the scans for DR severity. We also performed a radiomics analysis and observed that the radiomics features (shape-based and texture-based) are significantly different for increasing levels of DR severity. We have also submitted this work to the Elsevier Image and Vision Understanding journal and is currently under first round of review.

In our second ISBI abstract [2], we propose aweakly supervised (WS) method for the accurate segmentationof intracranial hemorrhage (ICH) lesions in non-contrast computed tomography(NCCT) images using image-level labels.Unlike prior work in WS ICH segmentation [1], we effectivelyused inter-slice information across a 3-D volume. In addition, for the first time, we analyzedperformance across individual ICH subtypes in WS setting andobserved robust segmentation across subtypes. The extended manuscript has been submitted to Medical Physics journal and is under review.

In our final ISBI abstract [3], we propose a semi-supervised strategy to improve the anomaly detection performance by introducing variability using simulated lesions. We evaluated our method by using synthetic data in two settings: increasing the variability by augmenting the real-world training data pool (DA) and bootstrapping the model by initially pretraining it on simulated lesions (PT). Both settings performed better than when using only real data for supervised training.We trained the U-Net++ model using Dice + focal loss for downstream anomaly detection to evaluate our synthetic lesion generation method. The simulation was highly robust and could be adapted to multiclass anomalies.

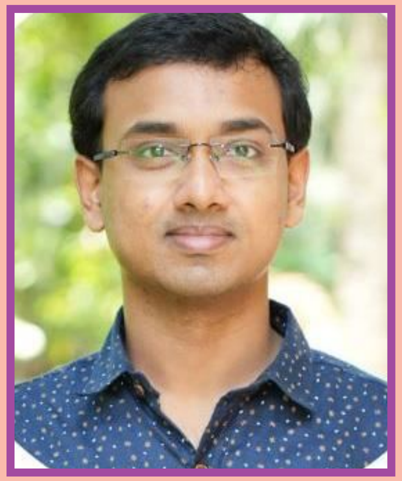
Publications:

1. Vivek Noel Soren, Prajwal H S, Vaanathi Sundaresan: ***Diabetic retinopathy grading using ultra-wide optical coherence tomography angiography and radiomics analysis,*** IEEE 21st International Symposium on Biomedical Imaging (ISBI), 2024.

2. Shreyas H Ramananda, Vaanathi Sundaresan: ***Weakly supervised intracranial hemorrhage segmentation in non-contrast computed tomography imaging***, IEEE 21st International Symposium on Biomedical Imaging (ISBI), 2024.

3. Ramanujam Narayanan, Vaanathi Sundaresan: ***Automated anomaly detection for neuroimaging: improving performance with synthetic lesion generation***, IEEE 21st International Symposium on Biomedical Imaging (ISBI), 2024.

Debayan Das



https://labs.dese.iisc.ac.in/csrl/

Dr. Debayan Das is an Assistant Professor with the Department of Electronic Systems Engineering (DESE) at the Indian Institute of Science (IISc), Bangalore. He received his PhD and MS in Electrical and Computer Engineering from Purdue University, USA, in 2021 and his Bachelor of Electronics and Telecommunication Engineering degree from Jadavpur University, India, in 2015. He has worked as a Security Researcher at Intel, USA, during 2021-22 and as a Research Scientist in the Intel Labs, USA, during 2022-23. Before his Ph.D., he worked as an Analog Design Engineer at a startup based in India. He has interned with the Security Research Lab, Intel Labs, USA, over the summers of 2018 and 2020. His research interests include mixed-signal IC design, biomedical circuits, and hardware security.

Research Highlight

In the first year of the funding, we worked on the development of mixed-signal circuits for hardware security and biomedical applications. On hardware security, we focused on the side-channel analysis (SCA) of 5G mobile communication security protocols like SNOW-V and the development of SCA countermeasures for FPGAs. In biomedical research, we are currently working on a wearable ultrasound transceiver design and hardware for brain cancer classification.

We have published 3 peer-reviewed research papers in the first year of this project.In our HOST 2024 paper [1], we performed a power side-channel analysis (SCA) on a 5G encryption algorithm SNOW-V and demonstrated successful key recovery from a 32-bit ARM microcontroller. This work utilized a combination of statistical correlational power analysis (CPA) along with linear discriminant analysis (LDA) to perform a machine-learning (ML) assisted SCA attack.

In the CHES 2024 paper [2] under review, we proposed a fully synthesizable low-overhead circuit-level countermeasure against power SCA attack on an FPGA. This work utilized a time-to-digital converter (TDC) to instantaneously sense the voltage fluctuations due to the crypto core operations. The TDC output is then fed to a digital FSM which turns ON or OFF the required number of ring oscillator (RO) slices acting as a bleeder circuit to compensate for the crypto current, making the overall supply current almost constant.

In the VLSID 2024 paper [3], we demonstrated a remote power SCA assessment framework using FPGAs. A TDC sensor was utilized to perform the power SCA assessment of the crypto cores. The optimal placement of the TDC sensor was analyzed in terms of the power grid layout on the FPGA.

Some of my technical contributions over the last year include: (1) Organized and served on the Executive Committee of the Workshop on Intelligent Computing and Systems at the Edge (ICE), co-located with the IEEE VLSID Conference 2024. (2) Currently serving as the co-editor for the special issue on "Spatial and Regional Mapping of Brain Neural Communication" for the Frontiers in Cellular Neuroscience journal. (3) Presented a tutorial on "EM/Power Side-Channel Analysis: Advanced ML attacks and Low-overhead Countermeasures" at the IEEE VLSID conference 2024. (4) Currently Serving as a Track Chair for the Hardware Security track for the IEEE ISLPED conference, 2024. (5) Served as the Judge for the best paper awards at the IEEE VLSID conference 2024.

Publications:

1. SNOW-SCA: ML-assisted Side-Channel Attack on SNOW-V, Harshit Saurabh, Anupam Golder, Samarth S T, Suparna Mondal, Chaoyun Li, Angshuman Karmakar, Debayan Das, presented and published in IEEE HOST 2024.

2. TYLOR: TDC-based Low-Overhead Synthesizable Circuit-Level Power SCA Countermeasure on FPGAs, Samarth S T, Harshit Saurabh, Debayan Das, submitted to IACR CHES 2024.

3. Optimal Placement of time-to-digital converter (TDC) Sensor for Enhanced Power Side-Channel Assessment on FPGAs, Debayan Das, Majid Sabbagh, Rana Elnaggar, Guang Chen, Sayak Ray, Jason Fung, IEEE VLSID 2024.

Vini Gautam

http://www.cense.iisc.ac.in/vini-gautam

Dr. Vini Gautam is an assistant professor in Centre for NanoScience and Engineering (CeNSE), IISc, Bangalore. She completed her PhD in Materials Science from Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR, Bangalore) in 2014. Following that, she spent a few post-PhD years in Australia, where she held various positions including Lectureship, ARC DECRA and Westpac research Fellowship at the Australian National University and the University of Melbourne. Her research has focused on developing optoelectronic interfaces for stimulation and recording of neuronal cells. Her key research interests are in neural tissue engineering, bioelectronics and neuroprosthetics.

Research Highlight

Damage to the brain due to an accident, stroke, tumour, infection, or neurodegenerative diseases results in various cognitive, physical and emotional disabilities. Brain damage disrupts the neural circuit connections in the brain, however, neurons in general cannot establish new connections to regain their circuit function. Even today, fundamental questions relating to how brain circuits form, regenerate and function remain unanswered. We are hence limited in creating solutions to guide neural circuits formation after brain injury and currently there are no drugs or treatments available to repair brain damage. My research is focused on creating 3D scaffolds with micro and nano scale features, which are used as a platform to grow, study, sense and stimulate the function of brain cells and neural networks. The research aim is to study how neurons grow, form connections and finally stimulate them to re-attain their physiological circuit functions.

In year 2023, we optimised fabrication techniques to obtain a range of scaffolds with micro/nanoscale features. Specifically, fabrication of micro/nano patterns were optimised for 3 sets of materials:

1. Silicon wafers (**Si**): scaffold with optoelectronic properties

2. Polydimethylsiloxane (**PDMS**): stretchable and flexible scaffold

3. Poly(vinylidene fluoride-trifluoroethylene) (**PVDF-TrFE**): scaffold with piezoelectric properties

Nanopillars of Si were created through a top-down fabrication method using Electron Beam Lithography (EBL) and Reactive Ion Etching (RIE). A negative resist was used in EBL for patterning along with a SiO2 hard mask to transfer the pattern to the semiconductor wafer. Micropillars were obtained using photolithography techniques. The morphology of pillars was confirmed using the Scanning Electron Microscope (SEM). Typically, the pillar size ranged between 200nm – 5um. Micro-pillars and nano-pillars of PDMS and PVDF-TrFE were obtained by replica moulding from a Si master, which was also prepared using photolithography or EBL and RIE.

Once obtained, the samples were prepared for growth of neurons. In 2023, the protocols for cell growth of neurons on scaffolds were optimised upon ethics approval for animal use [1]. Briefly, brain tissues were extracted and primary cortical and hippocampal neurons from rat (Wistar) pups were cultured on the scaffolds in standard culture media and maintained at 37degC in physiological conditions. Neuronal growth was studied and analyzed by immunocytochemistry (confocal microscopy) and SEM.

Figure 1 shows the growth of neurons on the 3 scaffolds. Our results show that neural networks can be engineered using nanowires as biophysical cues in optoelectronic scaffolds. Currently, further characterization, optimization and analysis of cell growth on micro/nano scaffolds is being carried out.

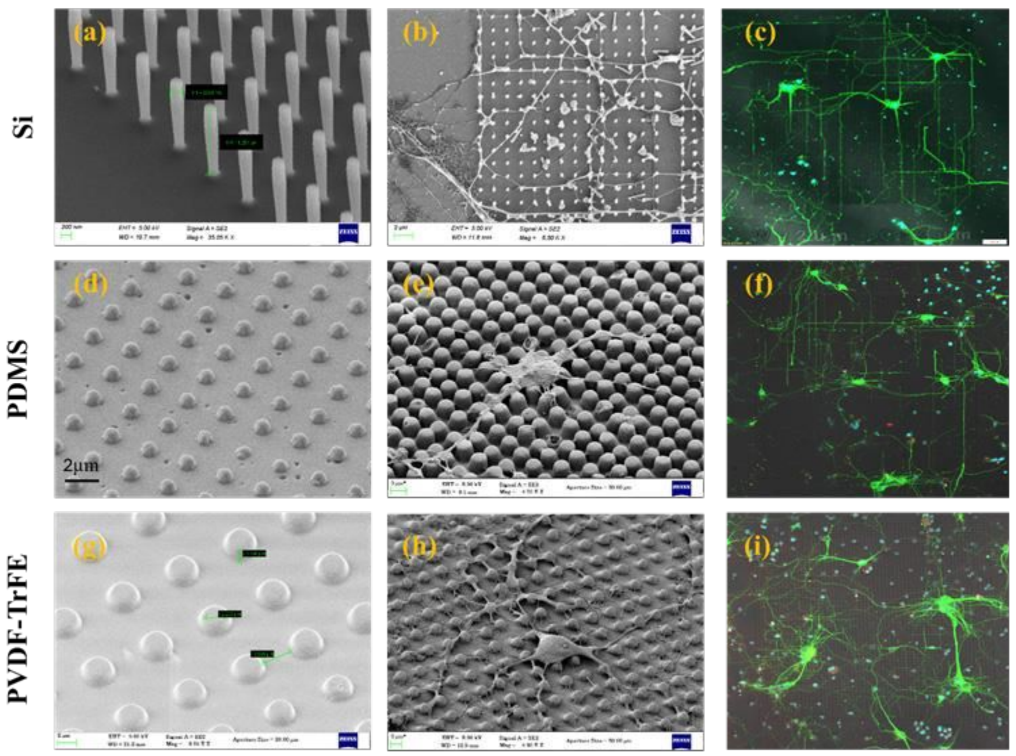


Figure 1: SEM images of fabricated micro/nano patterns; SEM images of patterns with cortical neurons; Fluorescence images of neurons growing on micro/nano patterns shown for three sets of samples: Silicon (a-c); PDMS (d-f) and PVDF-TRFE (g-i).

Publications:

1. CAF/Ethics/981/2023 "Developing optoelectronic platforms to study and modulate neuronal growth and function".

Interdisciplinary PhD program in Brain and Artificial Intelligence

The interactions among the faculty members involved in the Brain, Computation and Data Science group 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.

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

List of students:

Anjana S
Sveekruth Pai
Mainak Biswas
Satyapreet Singh Yadav
Kashmiri Manishrao Lande

Convener: Prof. Venkatesh Babu Radhakrishnan
DCC Chair: Prof. Supratim Ray

Activities Planned for 2024

i) Release of report on BCD Moonshot project on Brain CoProcessors by Itihaasa Digital, and update by BCD Moonshot PIs on project progress, in the presence of Prof. Govindan Rangarajan, Director, IISc; Prof. KVS Hari, Director, CBR and Mr. Kris Gopalakrishnan, Chairman of IISc Council

ii) Commencing the second phase of the BCD Moonshot project. As part of this a Memorandum of Understanding (MoU) will be signed between IISc, IIT Kanpur and 3 hospitals (Amrita Institute of Medical Sciences, Kochi; Deenanath Mangeshkar Hospitals, Pune and MS Ramaiah Hospitals, Bangalore) to enable intracranial EEG recordings from epilepsy patients as part of the BCD Moonshot project.

iii) Instituting and inviting applications for the IISc-UCL travel fellowships that will enable Ph.D. students from BCD faculty labs at IISc to spend 3 months at UCL, working under the mentorship of, and establishing collaborations with faculty at the Gatsby Computational Neuroscience Unit and the Sainsbury Wellcome Centre.

iv) Formal appointment of Prof. Barbara Shinn-Cunningham, as the K Vaidyanathan Chair Professor at IISc.

v) Assistance with conducting, including providing logistical and funding support for the Bangalore Cognition Workshop in June 2024, organized by faculty at the Centre for Neuroscience at IISc.

vi) Visits of the three Chair professors -- Prof. Rao, Prof. Sahani and Prof. Shinn-Cunningham -- to IISc to speak at the BCW workshop on June, and to engage in interactions with faculty and students in December.

Research Publications

2023

Sreebrata Goswami, R. Stanley Willaims and Sreetosh Goswami* (2023), Molecular Redox Computing Redux. Nature Materials, 2023. As the last and corresponding author.

Sruthi Gorantla, Anay Mehrotra, Amit Deshpande, Anand Louis (2023) "Sampling Individually Fair Rankings that are Always Group Fair." AIES 2023
Sruthi Gorantla, Amit Deshpande, Anand Louis (2023) "Sampling Ex-Post Group-Fair Rankings." IJCAI 2023

Sruthi Gorantla, Kishen N. Gowda, Amit Deshpande, Anand Louis (2023) "Socially Fair Center-Based and Linear Subspace Clustering." ECML/PKDD 2023
Arindam Khan, Eklavya Sharma: (2023) Tight Approximation Algorithms for Geometric Bin Packing with Skewed Items. Algorithmica 85(9): 2735-2778 (2023)

Waldo Gálvez, Fabrizio Grandoni, Afrouz Jabal Ameli, Klaus Jansen, Arindam Khan, Malin Rau: (2023) A Tight (3/2+ε)-Approximation for Skewed Strip Packing. Algorithmica 85(10): 3088-3109 (2023)
Max A. Deppert, Klaus Jansen, Arindam Khan, Malin Rau, Malte Tutas: (2023)

Peak Demand Minimization via Sliced Strip Packing. Algorithmica 85(12): 3649-3679 (2023)

Siddharth Barman, Arindam Khan, Sudarshan Shyam, K. V. N. Sreenivas: (2023) Finding Fair Allocations under Budget Constraints. AAAI 2023: 5481-5489
Siddharth Barman, Arindam Khan, Arnab Maiti, Ayush Sawarni: (2023) Fairness and Welfare Quantification for Regret in Multi-Armed Bandits. AAAI 2023: 6762-6769

Arindam Khan, Aditya Lonkar, Saladi Rahul, Aditya Subramanian, Andreas Wiese: (2023) Online and Dynamic Algorithms for Geometric Set Cover and Hitting Set. SoCG 2023: 46:1-46:17
Vishakha Patil, Vineet Nair, Ganesh Ghalme, Arindam Khan: (2023) Mitigating Disparity while Maximizing Reward: Tight Anytime Guarantee for Improving Bandits. IJCAI 2023: 4100-4108

Siddharth Barman, Arindam Khan, Sudarshan Shyam, K. V. N. Sreenivas: (2023) Guaranteeing Envy-Freeness under Generalized Assignment Constraints. EC 2023: 242-269

Ghanshyam Chandra, Chirag Jain. (2023) "Sequence to graph alignment using gap-sensitive co- linear chaining" International Conference on Research in Computational Molecular Biology. (RECOMB) 2023 https://doi.org/10.1007/978-3-031-29119-7_4

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U. Banerjee, (2023) "Privacy-Preserving Edge Computing from Pairing-Based Inner Product Functional Encryption," IEEE Global Communications Conference (GLOBECOM), pp. 2185-2190, December 2023

Fraiman, N., Mukherjee, S. and Thoppe, G., (2023) ``The Shadow Knows: Empirical Distributions of Minimum Spanning Acycles and Persistence Diagrams of Random Complexes", Discrete Analysis, 2023:2, 1-18

Ganesh, S., Deb, R., Thoppe, G. and Budhiraja, A., (2023) ``Does Momentum Help in Stochastic Optimization? A Sample Complexity Analysis", Conference on Uncertainty in Artificial Intelligence, 2023, pp. 602-612, PMLR.

Eshwar, S.R., Kolathaya, S. and Thoppe, G., (2023) ``Improving sample efficiency in evolutionary RL using off-policy ranking", EAI International Conference on Performance Evaluation Methodologies and Tools, pp. 33-50.

Ganesh, S., Reiffers-Masson, A. and Thoppe, G., (2023) ``Online Learning with Adversaries: A Differential-Inclusion Analysis", Conference on Decision and Control (CDC), 2023.

Naskar A. and Thoppe, G., (2023) ``Convergence of Momentum-based Distributed Stochastic

Approximation with RL Applications," Indian Control Conference, 2023.

A. Tripathi, R. R. Dani, A. Mishra, A. Chakraborty, (2023) "Multimodal query-guided object localization", Multimedia Tools and Applications (2023): 1-25.

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Suman Chatterjee, Rathin K Joshi, Tushar Sakorikar, Bhagaban Behera, Nitu Bhaskar, Shabari Girishan K V, Mahesh Jayachandra, and Hardik J Pandya, (2023) "Design and fabrication of a microelectrode array for studying epileptiform discharges from rodents." Biomedical Microdevices, 25, 31 (2023). DOI: https://doi.org/10.1007/s10544-023-00672-0

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