Pratiksha Trust Initiative on

Brain, Computation and Data Science

INDIAN INSTITUTE OF SCIENCE

भारतीय विज्ञान संस्थान

Activities

2020

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 Science, Centre for 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 Intellience; Brain Inspired Algorithms; Neural Signal Processing; Image Analysis; Vision and Visualisation.

For the past five years, the activities of this initiative have been 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.

This booklet provides a bird's eye view of the activities undertaken as a part of this initiative in IISc during 2020.

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

From Director, IISc

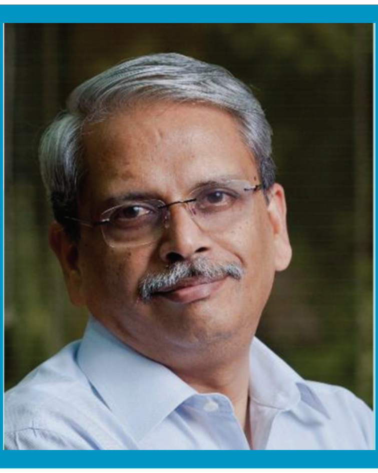
"We are immensely grateful to Shri. Kris Gopalakrishnan and Smt. Sudha Gopalakrishnan for choosing the Indian Institute of Science for these generously endowed chair professorships. These chairs intend to invigorate and accelerate extremely important emerging interdisciplinary research areas. I am sure 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

Sridharan Devarajan (CNS) (Co-Convener)

Ambedkar Dukkipati (CSA)

Prasanta Kumar Ghosh (EE) (Convener)

K.V.S. Hari (ECE)

Ramesh Hariharan (Strand Life Sciences)

Supratim Ray (CNS)

Yogesh Simmhan (CDS)

Faculty Team (Brain, Computation and Data Science Group)

Aditya Murthy, CNS

Aditya Sadhanala, CeNSE

D. Ambedkar, CSA

Anand Louis, CSA

Anirban Chakraborty, CDS

Arkaprava Basu, CSA

Arnab Bhattacharyya, CSA

S.P. Arun, CNS

Bharadwaj Amrutur, ECE

Chandra Murthy, ECE

Chandra Sekhar Seelamantula, EE

Chetan Thakur, ESE

Chirag Jain, CDS

Hardik Pandya, ESE

K.V.S. Hari, ECE

Mayank Srivastava, ESE

Y. Narahari, CSA

Partha Talukdar, CDS

Phaneendra Yalavarthy, CDS

T.V. Prabhakar, ESE

Prasanta Kumar Ghosh, EE

Rajesh Sundaresan, ECE

A.G. Ramakrishnan, EE

Rishikesh Narayanan, MBU

Santanu Mahapatra, ESE

P.S. Sastry, EE

Shalabh Bhatnagar, CSA

Shayan G. Srinivasa, ESE

Shirish Shevade, CSA

Siddharth Barman, CSA

Sridharan Devarajan, CNS

Sriram Ganapathy, EE

Sujit K. Sikdar, MBU

Sundeep Chepuri, ECE

Supratim Ray, CNS

R. Venkatesh Babu, CDS

Yogesh Simmhan, CDS

and all other interested faculty members

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

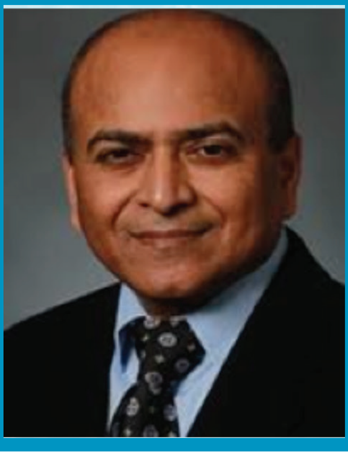
ISR Outstanding Faculty Award

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 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 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 Prakash 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)

Siddharth Barman

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

Siddharth Barman is an Associate Professor in the Department of Computer Science and Automation at the Indian Institute of Science. Before joining IISc, he was a post-doctoral scholar at Caltech and obtained his Ph.D. in Computer Science at the University of Wisconsin-Madison. Siddharth is a Ramanujan Fellow and a recipient of the Young Engineering Award, conferred by the Indian National Academy of Engineering (INAE). He is also an associate of the Indian Academy of Sciences (IASc).

Siddharth's research lies at the interface of Computer Science and Microeconomics. His work spans the forefront of multiple areas such as Approximation Algorithms, Game Theory, and Machine Learning. Siddharth's current work addresses fairness in the context of algorithmic decision making. Here, a specific goal of his research is to quantify tradeoffs between efficiency and fairness.

Research Highlight

Algorithms are being used increasingly as decision-making tools in social settings; examples include the use of machine learning (ML) models for hiring-related decisions, allocation of public resources, and even medical testing/vaccinations. The bias of such algorithms (and the resulting discrimination in their predictions) is a serious concern across many domains and it motivates a study of fairness with an algorithmic lens. Siddharth's current work contributes to the foundational aspects of this study and is focused, in particular, on fairness in AI and resource-allocation settings.

Specifically, a joint work of Siddharth (published at FORC 2020) develops a framework to audit as well as mitigate bias in classification settings. This work can be potentially applied in settings wherein automated (and data-driven) tools are used to make medical or insurance-related decisions.

Another recent publication [1] of Siddharth develops algorithmic results for the classic cake-cutting problem in which a divisible, heterogeneous resource (modeled as a cake) needs to be partitioned among agents with distinct preferences. The cake-division framework has been studied for over seventy years and while multiple hardness results exist in this setup for finding fair and efficient cake divisions, algorithmic results remain elusive in this setup. Addressing this gap, the work shows that, if the value densities of the agents satisfy the monotone likelihood ratio property (MLRP), then strong algorithmic results hold for various notions of fairness and economic efficiency. Given that MLRP holds for many distribution families, this result is able to address multiple settings in a unified manner.

Contributing to the intersection of Microeconomics and Computer Science, a work of Siddharth and Federico Echenique [2] revisits the connection between bargaining and equilibrium. Specifically, the paper develops a non-asymptotic version of the celebrated Edgeworth conjecture. The Edgeworth conjecture, or core convergence, is the economist's basic justification for this price-taking assumption. The work considers bargaining outcomes to be allocations that cannot be blocked by coalitions of small size and show that these allocations must be approximate Walrasian equilibria. Indeed, the work provides a novel prospective on a topic that has been studied in economics for over a hundred years.

[1] Fair Cake Division Under Monotone Likelihood Ratios. Siddharth Barman and Nidhi Rathi. ACM Conference on Economics and Computation (EC), 2020.

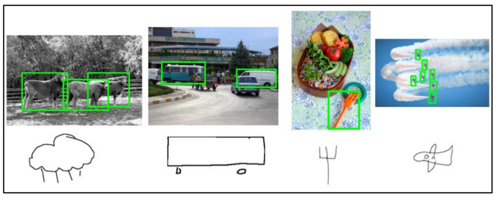
[2] The Edgeworth Conjecture with Small Coalitions and Approximate Equilibria in Large Economies. Siddharth Barman and Federico Echenique. ACM Conference on Economics and Computation (EC), 2020.

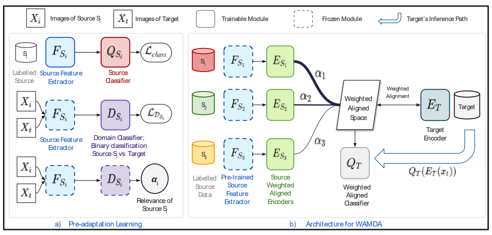
Anirban Chakraborty

http://visual-computing.in/wp-content/uploads/2017/08/anirban-chakraborty.html

Anirban Chakraborty received his Ph.D. in Electrical Engineering from the University of California, Riverside in 2014. Subsequently, he held research fellow positions with the National University of Singapore and Nanyang Technological University. After that, Anirban worked as a computer vision researcher at the Robert Bosch Research and Technology Centre, India. Currently, he is an assistant professor at the Dept. of Computational and Data Sciences, Indian Institute of Science. His research interests lie in the broad areas of computer vision, machine learning, optimization etc. and their applications in problems such as data association over large graphs, data fusion, video surveillance problems, video-based biometrics, multimedia etc. He is also keen to explore how visual analytics can be utilized in answering some of the most fundamental questions in biology and healthcare.

Research Highlight





Localizing objects in a natural image is a long-sought pursuit in computer vision. The traditional tool for this task, an 'Object Detector', requires large scale annotated training dataset, and is often limited to detecting a finite set of object categories. Moreover, it is challenging to extend these object detectors to localize novel classes seen only during testing - and these are just some of the many practical challenges associated to the object localization task in natural images. Due to the large-scale availability of touch screen devices, leveraging hand-drawn sketches of an object is a preferable alternative. In such cases, localizing an object in an image by utilizing a hand-drawn sketch is an important but unexplored problem. For the first time in the literature, we have explored the novel problem of *Sketch-guided Object localization in Natural Images*, in which given a crude hand-drawn sketch of a previously seen or unseen object type, we need to localize all the instances of the object on a given natural image. As a first attempt to solve this problem, we proposed a novel cross-modal attention mechanism that guides the region proposal network (RPN) to generate object proposals relevant to the sketch query, which are later scored against the query to obtain final localization. Our method is effective with as little as a single sketch query. Moreover, it also generalizes well to object categories not seen during training and is effective in localizing multiple object instances present in the image.

Multi-Source Domain Adaptation (MSDA) is a problem involving multiple data sources, which are of the same modality but follow different distributions. Domain adaptation is a task in machine learning that aims at learning a model from a labelled source dataset, such that the model performs well on samples drawn from an unlabeled target domain with a related but different data distribution. The problem of single-source unsupervised domain adaptation has been explored quite extensively. However, in practice, labelled data is often available from multiple, differently distributed sources - giving rise to the MSDA problem. Recent works in MSDA proposed to learn a domain-invariant space for the sources and the target. However, such methods treat each source to be equally relevant and are not sensitive to the intrinsic relations amongst domains. To handle some of these challenges, we provided a novel algorithm (WAMDA) for multi-source domain adaptation, which utilized the multiple sources based on their relative importance to the target. Our objective in this research was to dynamically explore the relevance of sources, and then to perform weighted alignment of domains. We experimentally validated the performance of our method on benchmark datasets and achieved state-of-the-art results.

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

The "unique games" problem is a central problem in algorithms and complexity theory. Given an instance of unique games, the "strong unique games" problem asks to compute the largest subset of vertices, such that the unique games instance induced on them is completely satisfiable. The joint work of Suprovat Ghoshal and Anand [1] gave new algorithmic and hardness results for the strong unique games problem.

The joint work of Deval Patel, Arindam Khan and Anand [2] studied the knapsack problem with "group fairness" constraints. The input of the problem consists of a knapsack of bounded capacity and a set of items. Each item belongs to a particular category and has an associated weight and value. The goal of this problem is to select a subset of items such that all categories are "fairly represented", the total weight of the selected items does not exceed the capacity of the knapsack, and the total value is maximized. We studied fairness parameters such as bounds on the total value of items from each category, total weight of items from each category, and the total number of items from each category. We gave bi-criteria approximation algorithms for these problems. The fair knapsack problems encompass various important problems, such as participatory budgeting, fair budget allocation, and advertising.

[1] "*Approximation Algorithm and Hardness for Strong Unique Games*"
Suprovat Ghoshal, Anand Louis ACM-SIAM Symposium on Discrete Algorithms (SODA), 2021.

[2] "*Group Fairness for Knapsack Problems*" Deval Patel, Arindam Khan, Anand Louis
International Conference on Autonomous Agents and MultiAgent Systems (AAMAS), 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

The availability of large volumes of biological data has enhanced the understanding of various biological systems. Data-driven computational techniques in fields like biology, medicine, genomics, and neuroscience are gaining attention due to advances in artificial intelligence and machine learning tools.

Specifically, we have proposed a graph neural network (GNN) model to capture local and structural information in a complex interaction network comprising drugs, diseases, genes, and anatomies as entities to repurpose already approved drugs for the 2019 novel coronavirus diseases (COVID-19). The proposed graph neural network model learns from known treatments of many diseases and complex interactions between the four entities and successfully predicts unknown links between approved drugs and novel diseases, such as COVID-19. The initial results are available as a pre-print:

- Doshi, S. and Chepuri, S.P., 2020. Dr-COVID: Graph Neural Networks for SARS-CoV-2 Drug Repurposing. arXiv preprint arXiv:2012.02151. (In prep. for journal submission)

WP.2: Topology inference with multi-view and multi-modal 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.

Specifically, in this work package, we focus on learning structured product graphs from multidomain multi-view data with applications to graph-based clustering, matrix completion, and denoising. With multi-modal data, we assume that the product graph is formed by the Cartesian product of two smaller graphs and that it has a specific structure, such as connectedness, bipartite, sparse, multicomponent, and regular. To do so, we pose the product graph learning problem as the factor graph Laplacian estimation problem assuming that the data is smooth on the underlying product graph. With multi-view data, we jointly estimate the graph Laplacian matrices of the individual graph layers and low-dimensional embedding of the common vertex set. We constrain the rank of the graph Laplacian matrices to obtain multi-component graph layers for clustering. The low-dimensional node embeddings, common to all the views, assimilate the complementary information present in the views.

The results from the work package are published or under peer-review and are available as pre-prints at:

- Kadambari, S.K. and Chepuri, S.P., 2020. Product Graph Learning from Multi-domain Data with Sparsity and Rank Constraints. arXiv preprint arXiv:2012.08090. (under review for IEEE Transactions on Signal Processing)
- Gurugubelli, S. and Chepuri, S.P., 2020. Graph Learning for Clustering Multi-view Data. arXiv preprint arXiv:2010.12301 (accepted for EUSIPCO 2021)

Arkaprava Basu

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

Arkaprava Basu joined the Indian Institute of Science (IISc), Bangalore, in February 2018 as an assistant professor in the Department of Computer Science and Automation. Arkaprava's research focuses on building more efficient computing systems through better coordination between the computing hardware and the software running atop it.

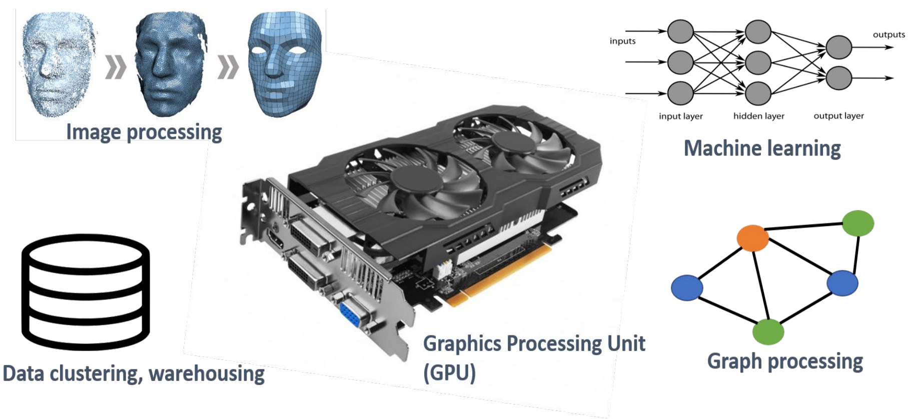
Before joining IISc, Arkaprava worked as a member of the research staff at AMD Research in Austin, USA, for four years (2014 - 2018). He obtained his Ph.D. in computer science from the University of Wisconsin-Madison.

Research Highlight

Advancement in data science and machine learning can be fully harnessed only if matched with a commensurate improvement in computing platforms that ultimately performs the computing required to draw knowledge from the data. Graphics Processing Units or GPUs that were originally designed to serve better 3D graphics (e.g., for video gamers) now form the backbone for big data computing, including machine learning. GPU's ability to process massive amounts of data in parallel makes it ideal for processing large amounts of data.

Unfortunately, GPUs are significantly more expensive than traditional CPUs. The economy of scale of public cloud infrastructure (e.g., Amazon AWS) can potentially bring down the cost of performing big data science by sharing GPUs across concurrent tenants. However, the GPU architecture -- both hardware and the software -- evolved to accelerate part of a single application at a time. Unsurprisingly, it fails to lend itself well to the controlled sharing of a physical resource amongst the co-resident tenants in a cloud.

A major thrust of our work is to enable low-cost data science for the masses by making GPUs better suited for public cloud deployment. Toward this, one of our recent works demonstrated how GPU's internal resources could be dynamically shared among concurrent tenants in a cloud. We showed it is possible to improve the cumulative computing throughput of a GPU when serving multiple concurrent tenants while ensuring fairness in resource utilization. This work was chosen as one of the best paper nominees at the 27th IEEE International Symposium on High-Performance Computer Architecture [1].



[1] *"Improving GPU Multi-tenancy with Page Walk Stealing"*, Pratheek B., Neha Jawalkar, Arkaprava Basu In the proceedings of 27th IEEE International Symposium on High-Performance Computer Architecture (HPCA), February 2021.

Chirag Jain

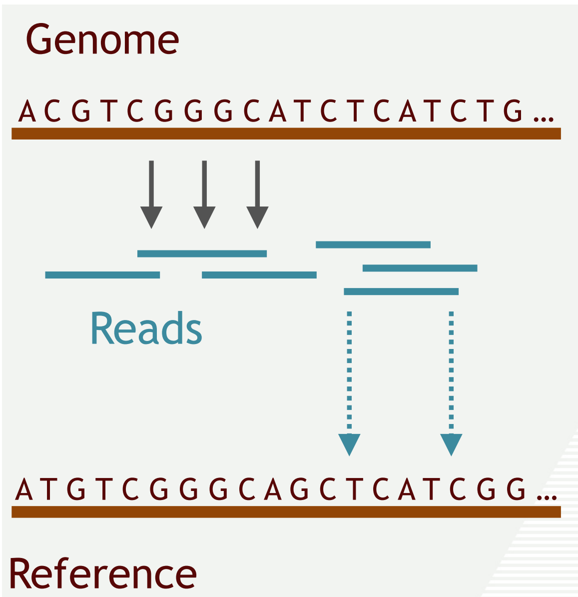
https://www.csa.iisc.ac.in/~anandl/

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

Nearly two thirds of the human genome is composed of sequence repeats, which becomes the biggest hurdle in confidently mapping DNA reads to the correct locus and detecting genetic variations. We are now at the cusp of the next revolution in sequencing due to the development of long and ultra-long single molecule sequencing technologies. Long reads (1 kb – 1 Mb) are attractive because they narrow the scale gap between sizes of genomes and sizes of sequenced reads, with the promise of avoiding assembly errors and repeat resolution challenges that plague short read assemblers. Mapping reads to a reference database, i.e., locating their closest match, is often the first computational step in deriving biological inference from genomic data. For time-critical applications in healthcare, it is important to develop fast and robust mapping algorithms that can keep pace with data generation. Desirable characteristics of a read mapper include (i) efficiency of the algorithm, (ii) high sensitivity and specificity, and (iii) scalability to large data sets and reference genome databases. It is hard to simultaneously achieve all of these objectives; typically, high accuracy comes at the cost of sacrificing run-time efficiency.

Inspired by the classic locality sensitive hashing technique, we reformulated the long-read mapping problem using Jaccard similarity metric as a proxy, and developed Mashmap algorithm. Mashmap is the first mapping algorithm to scale to the entire NCBI RefSeq database, containing > 60,000 genomes. Through appropriate modelling of sequencing errors, the algorithm is mathematically guaranteed to identify all desired mapping coordinates with high probability. This is a major departure from prior mapping algorithms which lack a rigorous mathematical characterization of algorithmic run-times and quality expectations. Currently, Mashmap is being used in the domain for many applications including metagenomic analyses , transcriptomics and whole-genome comparisons.



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. Since obtaining his Ph.D. he continued at Cambridge thereafter to study the photophysics of hybrid perovskites and their optoelectronic devices. He then received a Winton Cambridge – Berkeley postdoctoral fellowship position in University of California, Berkeley, USA in March 2018 and worked on synthesizing/fabricating novel lead-free perovskite nanostructures for optoelectronic applications. Thereafter, he joined the Clarendon Laboratory, University of Oxford, UK in August 2018 and worked on a Strategic University Network to Revolutionise Indian Solar Energy (SUNRISE) project to develop perovskite semiconductor based tandem solar cell architectures and luminescence applications.

Alongside his research, Aditya is a member of Institute of Physics, UK and the Indian National Young Academy of Sciences, (INYAS), India. He is also keenly supporting professional development of young researchers and developing award winning new public engagement tools to "take lab science to streets" attracting global media attention. Aditya also holds several awards and recognitions, few notable ones being - 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 for the years 2019 and 2020 – 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. Such, nanostructures would be used for fabrication of efficient nanostructured solar cell & light emitting diodes (LEDs) based on back-contact architectures with 100% device active area utilization. These nanostructured back contact device architectures would also be used to fabricate thin-film photodetectors for sensitive & portable rapid bio/chemical-sensing (novel way of detecting COVID-19 virus).

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. We are also using the hybrid multifunctional organic/2D-perovskite semiconductors with high mobility, long carrier diffusion length for fabricating high-performance sensing (including bio-sensing) applications.

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).

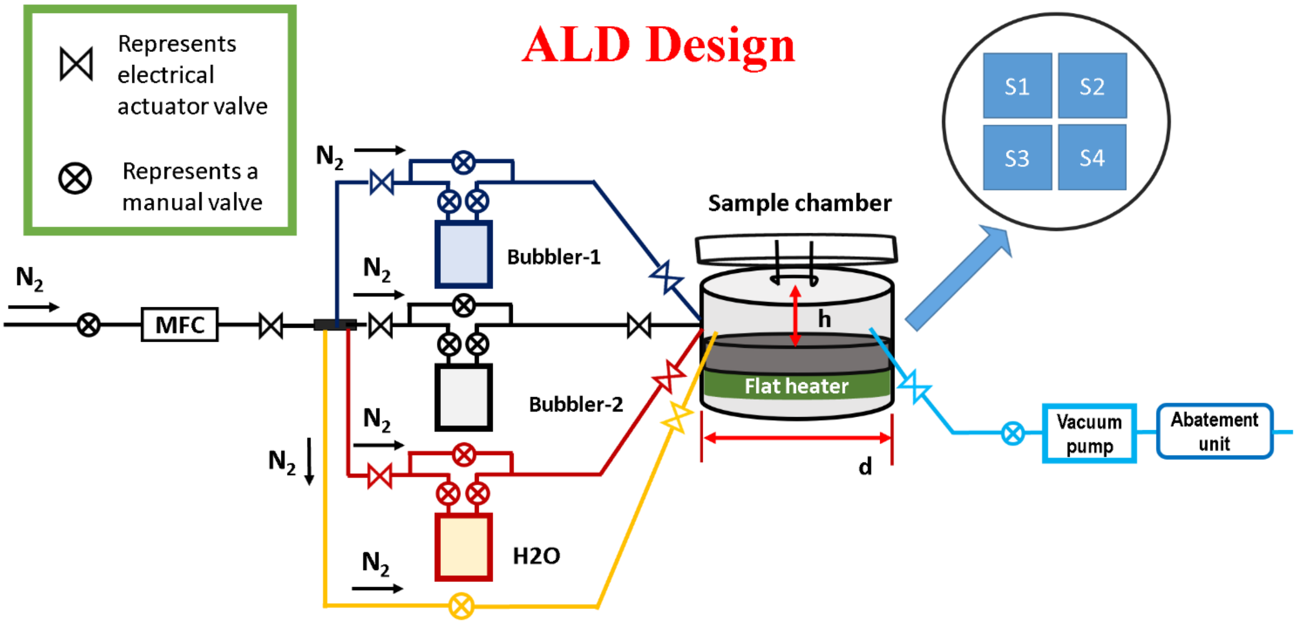


Figure: Schematic of the homemade atomic layer deposition (ALD) tool – to be used for semiconductor hybridisation

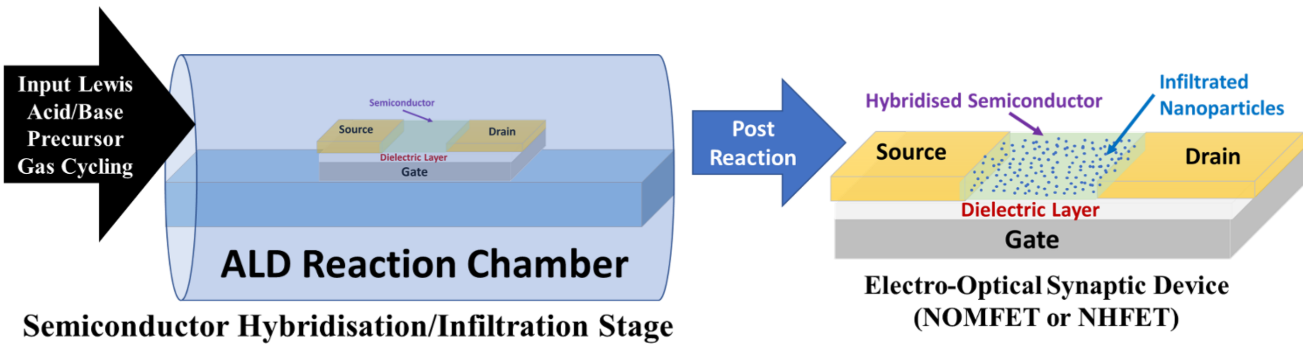


Figure: Schematic of the semiconductor hybridisation process using ALD to fabricate NOMFET or NHFET devices

Exploratory Research Projects with Support from Pratiksha Trust

Rapid, large-scale connectome estimation for mapping structure-function relationships in healthy and diseased brains

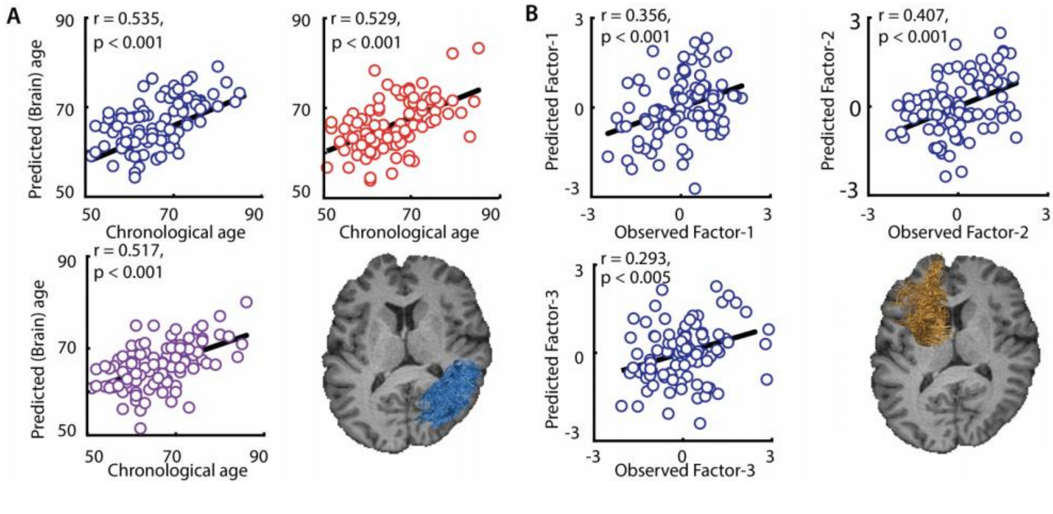
Principal Investigators:

Sridharan Devarajan
CNS & CSA, IISc

Partha Pratim Talukdar
CDS & CSA, IISc

Objectives: We seek to develop approaches for rapid connectome evaluation, building upon a state-of-the-art algorithm for connectome evaluation – Linear Fascicle Evaluation or LiFE. We seek to accelerate the LiFE algorithm to enable analysis of large-scale connectome databases, and seek to apply this algorithm for understanding the connectomic basis of healthy ageing and Alzheimer's Dementia (AD).

Progress over the last year: We have developed a GPU-accelerated technique for connectome evaluation: regularized, accelerated, LiFE algorithm ("ReAl-LiFE") (Kumar et al, 2019). We applied this algorithm for estimating neuroimaging-based biomarkers of brain health, which are necessary for early diagnosis of cognitive decline in the aging population. While many recent studies have investigated whether an individual's "brain-age" can be accurately predicted based on anatomical or functional brain biomarkers, comparatively few studies have sought to predict brain-age with structural connectivity features alone. Here, we investigated this question with data from a large cross-sectional study (TLSA - or Tata Longitudinal Study of Ageing) of elderly volunteers in India (158 participants, age-range = 51-86 yrs, 66 females). We analyzed 23 standardized cognitive test scores obtained from these participants with factor analysis. All test score variations could be explained with just three latent cognitive factors, each of which declined markedly with age. Next, using diffusion magnetic resonance imaging (dMRI) and tractography we estimated the structural brain connectome in a subset of 101 individuals. Structural connectivity features – both based on the number of fibers and based on ReAl-LiFE connection weights – robustly predicted inter-individual variations in cognitive factor scores and chronological age. Moreover, we identified critical connections in the prefrontal and parietal cortex whose strength most strongly predicted each of these variables. These findings were recently published at the NeurIPS workshop on Medical Imaging (Gurusamy et al, 2020).



We have recently submitted an extended proposal for funding for the DBT-DFG (Indo-German) grant, jointly with Dr. Kaustubh Patil, Dr. Robert Langner and Prof. Simon Eickhoff at the Institute of Systems Neuroscience, Heinrich Heine University Düsseldorf.

Fabricating Novel Micro-Electrode Cannula Arrays to Design Neuroprotective Therapies for Acute Stroke and Epilepsy

Principal Investigators:

Hardik J Pandya
ESE, IISc

Siddharth Jhunjhunwala
BSSE, IISc

Mahesh Jayachandra
BSSE, IISc

Report: Microneedles with recording electrodes in single, three, and four-shank designs were fabricated using microengineering technologies (Figure 1a and 1b). Electronic modules to hold these needles were designed and developed. The needles were attached to the electronic printed circuit boards (PCBs) using wire bonding (Figure 1c). The study on the acquisition of signals from the cortical columns is under progress through implantation in a rat's brain (Figure 1d).

To understand the surface signals, such as the electrocorticogram (ECoG), we have also fabricated flexible devices with 32-channel recording capabilities (Figure 1e and 1f). We have also developed electronic PCBs for interfacing these devices with the recording system and the rat's brain (Figure 1g). The testing of the fabricated devices is in progress (Figure 1h and 1i).

While working on flexible devices and microneedles, we collaborated with neurosurgeons from NIMHANS and the biomedical engineering faculty from IIT Gandhinagar. A research grant, "Bimodal Intraoperative Probe for Brain Tumour Resection", has been recently awarded under the BDTD program of DST.

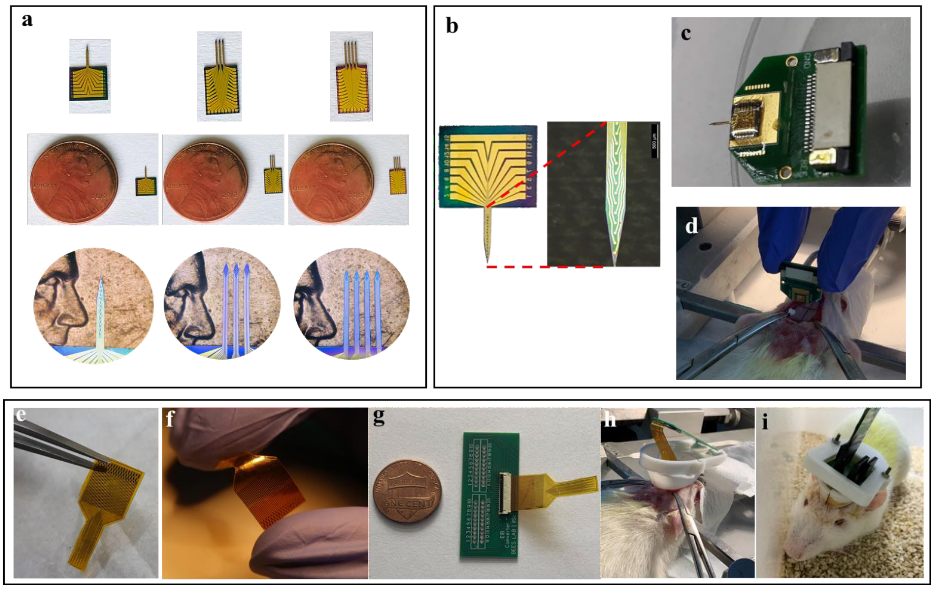


Figure 1: Microneedles and flexible devices: (a) Fabricated single, three, and four-shank microneedles, (b) Magnified view of single shank design, (c) Single shank needle wire-bonded to interface electronics printed circuit board, (d) Microneedle assembly being implanted on rat's brain for cortical recordings, (e) and (f) Show the fabricated flexible devices with recording electrodes, (g) Flexible devices attached to interface electronics printed circuit board, (h) Flexible device with protective being implanted in a rat's brain, and (i) Device attached and sealed with dental acrylic on rat's brain during live recording

Deep Neural Networks For 3D Understanding

Principal Investigators:

Venkatesh Babu
CDS, IISc

Vijay Natarajan
CSA, IISc

Unsupervised 3D reconstruction from image: In this project, we aim to reconstruct a 3D model of an object given its single-view image. This problem is more challenging than prior works, which either use 3D supervision or multi-view images. We first cluster the images according to the object pose in an unsupervised fashion. This learned prior is further exploited to assist the 3D reconstruction pipeline. We present the results in Figure 1.

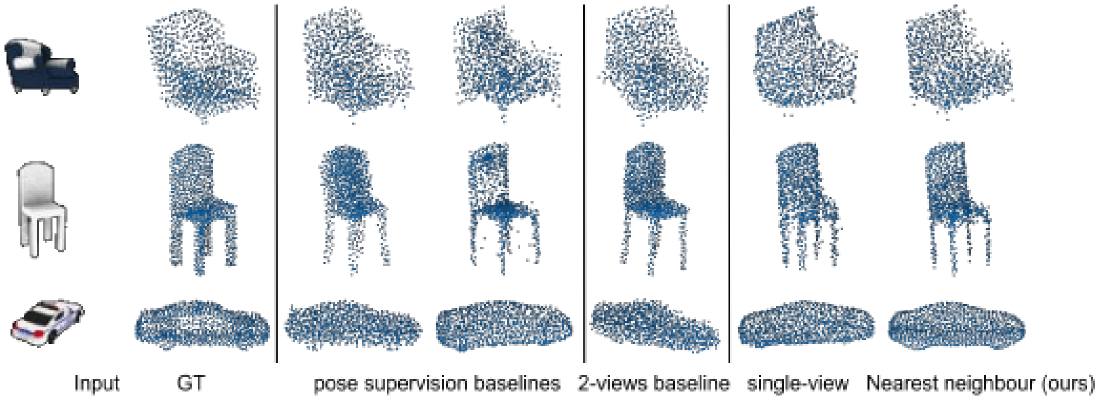


Figure 1: Point cloud reconstruction

High-fidelity 3D shape representation: Then, we observed that while a point cloud is used torepresent 3D shapes due to its memory-friendliness. But it is still a sparse representation of the surface. To describe the structural details, we need to sample more points, leading to an increase in the memory required to store it. Hence, we develop a representation that can model structural details while also bringing advantages for faster and accurate rendering of the representation. We present the reconstruction results using our method in Figure 2.

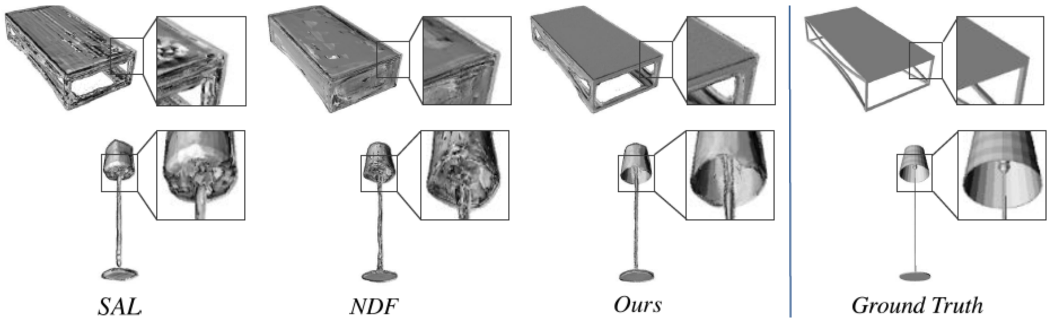


Figure 2: High-fidelity 3D reconstruction using our method

Characterizing spatiotemporal transformations between facial myoelectric signals and articulatory behavior during regular speech, silent speech and silent reading

Principal Investigators:

Prasanta Kumar Ghosh
EE, IISc

Aditya Murthy
CNS, IISc

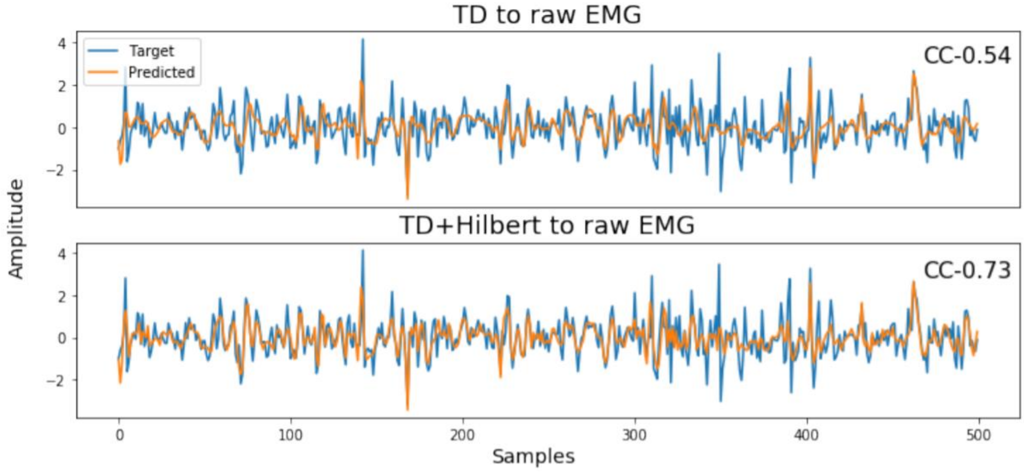
Key highlights of the work done in this project:

Can we figure out facial muscle activity from speech recording?

Learning a mapping from speech acoustic to facial myoelectrical signal captured through electromyography (EMG) is useful for a number of applications. It can be used to improve previous efforts in visualisation of facial muscle activation from speech signals. Moreover, a large number of muscles are activated while speaking; knowing the particular muscles which are activated for the enunciation of a specific speech sound can prove to be useful in improving speech synthesis and recognition. It could also help us determine the key muscles activated for each phoneme.

We have carried out a study where different features have been experimentally compared to examine their prediction capability in the acoustic to EMG inverse mapping. For this study, we use five time domain (TD) features existing in the literature. In addition to these, we have developed a Hilbert transform based envelope for broadband EMG signal.

We have used a BLSTM model for speech acoustic to EMG mapping. LSTMs have been known to be good for sequential mappings because of inherent accounting of temporal dependencies. The prediction performance is found to be significantly better for the feature extracted through the Hilbert envelope, compared to the rest of the features considered. Further, we use a CNN-BLSTM network to retrieve back the original EMG signal from these features. Since, the Hilbert features perform the best for AEI mapping, we use them with the existing TD features for recovering raw EMG. The figure shows an example of raw EMG reconstruction along with correlation coefficient values when TD and TD+Hilbert features are used. It can be seen that Hilbert features help the model to capture the finer details of the raw EMG waveform.

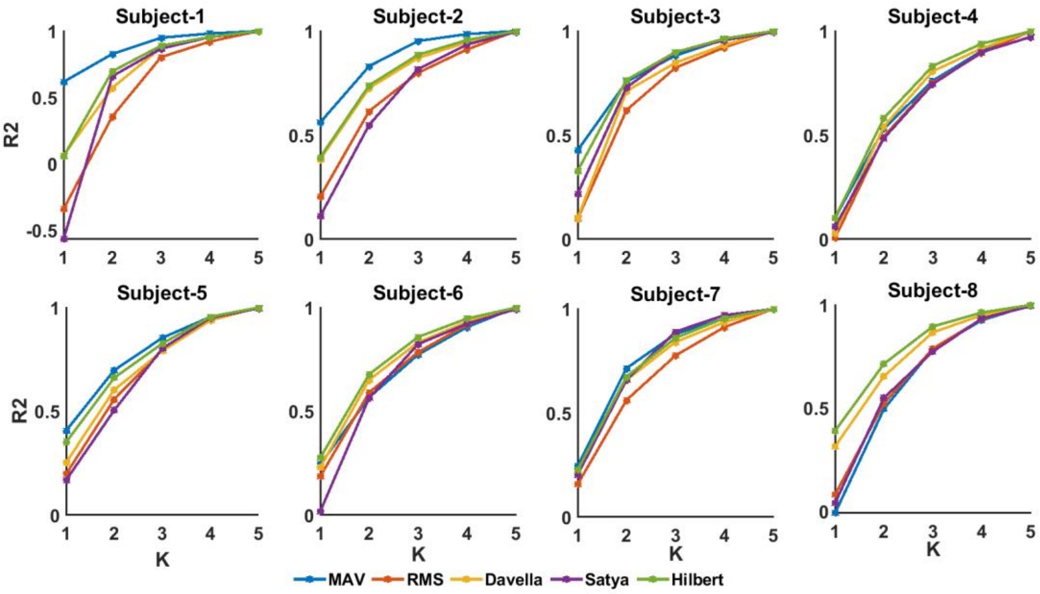


In search of synergies in facial muscle activity during speech production

In what way the central nervous system directs a large number of muscles to produce complex motor behaviors is an open question. One solution to this problem of redundancy or overabundance is the motor system organizes actions in terms of a motor "vocabulary" that is expressed in the form of motor synergies between different muscles performing an action. In the context of hand movements, studies have revealed the existence of synergies, particularly of the upper arm muscles involved in reaching movements. In the context of speech, interestingly, there has been no study attempting to test the ability of synergies to characterize speech behavior and forms the basis of our research.

For this analysis, we have used different but standard feature extraction methods for representing EMG signals such as the mean absolute value (MAV), Root mean square (RMS), a method employed by D'avilla denoted as (Davella), and low pass of modification of DAV denoted as Satya and finally, a Hilbert feature extraction method.

The raw EMG data was organized into a data matrix consisting M, which was a function of the EMG activity across time across the different muscles. For analyzing synergies, we estimated the data matrix M, from the dot product of the W and H, which were obtained from the NMF decomposition. The R2 score was used as the evaluation metric for measuring the closeness between the original data matrix and the estimated data matrix. Varying the no. of components(k) of the W vector generated different R2 scores, from which we analyze the presence of a synergy at particular K. The NMF decomposition (random initialization) was performed on 200 frames. This process was done on 10 samples from which R2 score was computed.



We have used all the features we described in the Feature Extraction Methods to test for the presence of synergies. The pattern of the R2 score with increasing k was used to test the presence of a synergy within the original data. Based on previous work, a synergy should be revealed when the R2 approaches a value of at least 0.95 in an asymptotic manner. More specifically, we tested whether a k less than the number of muscles recorded (n=5), had a value of at least 0.95, with values of k preceding and following approaching this value as an asymptote. As shown clearly in the above figure, there is no synergy detected regardless of the method used to characterize the EMG signal. We interpret these results as indicating that speech sounds are organized in a manner that allows for individual actuation of speech muscles to produce the variety of phonetic utterances that characterize speech behavior.

The following project proposal, based on the experience and analysis of this project, has been submitted to the Department of Science and Technology (DST), Govt of India.

Title: Speech reconstruction from facial myoelectric signals and articulatory motion for silent speech interface
Principal Investigators: Prof. Prasanta Kumar Ghosh, EE, IISc
Prof. Aditya Murthy, CNS, IISc

Predicting the naturalness of artificially generated videos

Principal Investigators:

Rajiv Soundararajan
ECE, IISc

S P Arun
CNS, IISc

Summary of work done: We consider the problem of naturalness assessment of predicted videos. In the first year of this project, we developed the IISc Video Naturalness Evaluation (VINE) Database and conducted initial experiments on the design of algorithms for naturalness evaluation. The main contribution during the second year was the design of features to measure the naturalness of predicted videos. In particular, we designed the motion compensated cosine similarities (MCS) of deep features across frames as well as deep features extracted from rescaled frame differences (RFD). The MCS features were designed to capture the variations in object shapes and sharpness across time with respect to the context frames. On the other hand, the RFD features help focus on the evolution of object shapes in moving regions since artifacts in predicted videos primarily were noticed in such regions. Our feature design helps achieve state of the art performance in terms of correlation with the naturalness scores provided by humans. We conducted extensive experiments to analyze these features in terms of their relevance to naturalness, complementarity, robustness to the amount of training data, and regression models. An overview of the MCS feature design is shown in the figure below:

Initiation of a larger research project: Our experience in video prediction and naturalness assessment led to a collaborative project with Qualcomm Technologies on using video prediction for frame rate upsampling in virtual reality. The first year of this project was funded at 40,000 USD. We are currently exploring funding for the second phase of this project.

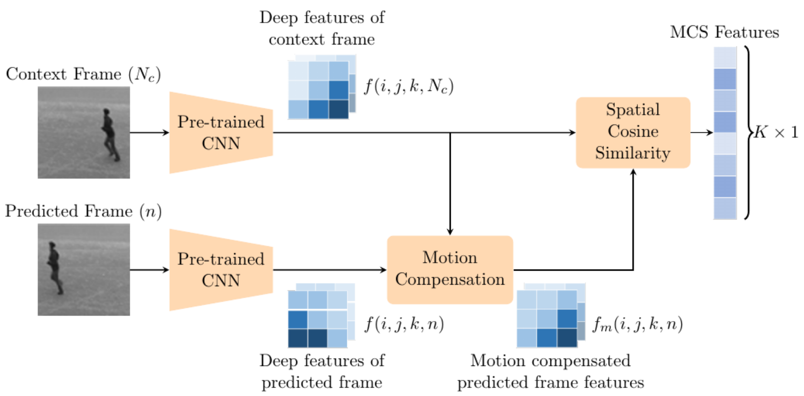


Figure 1: Motion compensated cosine features

HPC Framework for large scale study of Brain Networks

Principal Investigators:

Ambedkar Dukkipati
CSA, IISc

Sathish Vadhiyar
CDS, IISc

1. Objectives

In this project we study functional connectivity of brain networks and our work focus on the following.

- Classification task of brain functional networks obtained from rs-fMRI data.
- Which is enabled either via usage of deep learning through GCN(Graph Convolutional Networks) or via comparison of clusters or sub-networks across brain networks from different subjects(normal control/patient).
- To develop HPC frameworks to realize and implement the algorithms for above tasks.

2. Summary of work done

1. Raw fMRI data from ADNI (Alzheimer's Disease Neuroimaging Initiative) [2] with 4 groups of subjects and-ABIDE (Autism Brain Imaging Data Exchange) [1] with 2 groups of subjects have been sourced.
2. Pre-processing and standardisation using FSL tool
3. Generated functional connectivity networks from correlation matrices obtained by PCC of timeseries of each region in AAL90 atlas.
4. Used hierarchical graph convolution network (HGCN) to model the brain graph classification task on ADNI
5. Implement transfer learning using pre-trained weights from ABIDE dataset
6. Using graphs with a larger number of defined nodes, implement HPC frameworks to scale up the brain graphs classification.
7. As an additional step to verify our brain network graphs, we have used GED(Graph Edit Distance)[3] as a similarity metric.
8. We have worked on a GED algorithm to use it as a kernel for classification tasks in SVM. We have enabled the code to run for larger graphs by reducing RAM usage and runtime, by using heuristic based approach, and improving data structure.

Details are given in the following sections

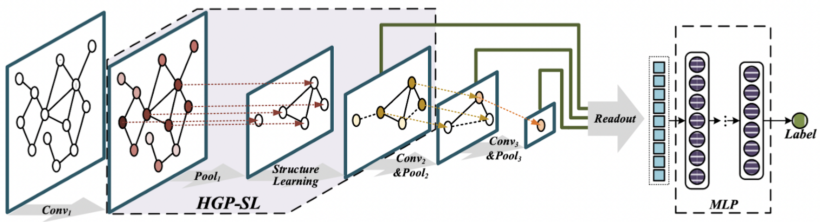


Figure 1: GCN model [6]

Various implementations on ADNI data	Accuracy scores(in %)
Subnetwork kernel using SVM [5]	82
Hi-GCN [4]	78.5
HGCN implementation	82.5
HGCN with ABIDE pre-training	83.3

Table 1: Accuracy scores from various implementations

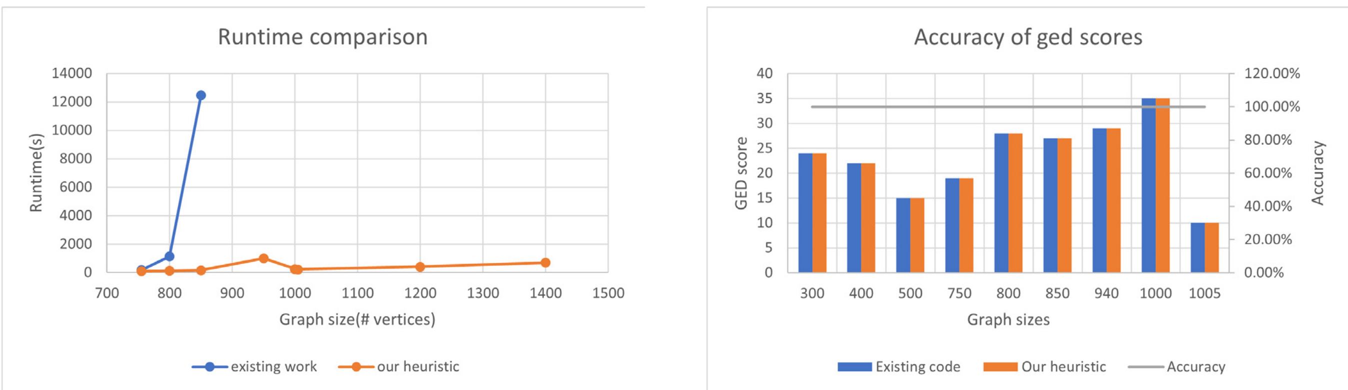
3. Dataset Preprocessing and Graph Generation

ADNI and ABIDE raw data obtained from LONI IDA have been pre-processed using the FSL tools BET (brain extraction), FEAT (fMRI analysis) and FLIRT (registration). Once standardised images have been obtained, the AAL90 brain atlas is used to identify 90 regions of interest and correlation matrices are generated from these timeseries readings. Adjacency matrix used as graph is obtained from subsequent thresholding.

4. Experiments with GCN Algorithm

Graph representations using standard GCNs are inherently "flat", since they are designed for node level representations and graph structure information is neglected during this process. So, We have used the Hierarchical Graph Convolution Network (HGCN) [6]. At each hierarchical layer, a gcn model is used to obtain embeddings of nodes and then these learned embeddings are used to cluster nodes together to obtain a coarsened graph. This whole process is repeated for L layers and we use the final output representation to classify the graph.
Figure 1 illustrates the flow of the HGCN model, while table 1 demonstrates a comparison of accuracy scores using different methods.

4.1 Transfer learning
Transfer learning is a ML method where a model developed for a task is reused as the starting point for a model on a second task, assuming both the tasks are sufficiently similar. Since the ADNI dataset has a limited size (152 subjects), we pre-trained our model on a larger dataset, called ABIDE which have around 600 columns. Once the model is trained on the ABIDE dataset, the weights are saved and the same weights are used to initialize the model while training the ADNI data. As seen from the table 1, the best result we have is by using ABIDE pre-training on ADNI data using HGCN.



(a) runtime comparison

(b) Accuracy of GED score

Figure 2: Usage of heuristic in GED computation

5. Scaling up brain networks and implementation of HPC approaches

Using k-means clustering, we have generated graphs with 270 and 900 nodes. Additionally, we have constructed graphs with 4132 nodes using the vertices defined in the AAL90 atlas.
Comparing the time-split ups of 90, 270 and 900 nodes, we have found that the processes of data storage and sending information between CPU and GPU take the most amount of time as bottlenecks. Hence we have begun to implement the following methods to reduce this time taken.

1. CUDA streams so that different processes of consecutive epochs can occur simultaneously
2. Data partitioning in order to split datasets that consume large amounts of RAM

This will also help us run the entire 4132 nodes graphs at once, which are currently limited by RAM bottlenecks and take several hours to run for a subset of the dataset. Running larger brain graphs will enable us to capture correlations at a higher spatial resolution.

As mentioned in the objective as another approach for classification, we are evaluating the usage of SVMs for classification using graph kernels. We are adopting a kernel which uses GED score as similarity metric [3]. Computing Graph edit distance involves generating and exploring search tree, which runs with exponential time complexity and hence we have resorted to parallel computing approaches. As a first step, we have worked on reducing RAM usage (by about 85%) using a combination of improved data structure and using efficient heuristic to reduce search tree space. While using the existing work for computing GED[3], we found that it is has unreasonably high runtime for apparently smaller graphs(around 3.5 hours for a 850v graph), and heavy RAM consumption(around 55GB for 850v graph). The usage of a heuristic, to reduce the number of search tree nodes generated, helped in reducing RAM usage by about 50% and large improvements in runtime. The results are shown in the graphs in figure 2. We have used artificially generated RMAT graphs for comparing GED scores. As we can infer from the plots, the speedup achieved is very promising without any compromise in accuracy.

6. Future Work

1. In order to improve accuracy scores obtained via the pre-training model, we will ascertain whether the preprocessing steps have been executed properly and consistently by comparing the GED scores as well as accuracy scores with similar papers.
2. To improve accuracy, we will also consider larger graphs while continuing to implement HPC techniques once the entire dataset with 4132 nodes can be run smoothly.
3. Using OpenMP and Cuda computing, to run the ged kernel within reasonable time on reasonably larger subgraphs/clusters(15k-20k nodes).

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Time-Based Sampling of FRI Signals

Principal Investigators:

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Chetan Singh Thakur

ESE, IISc

Introduction

Time-based sampling of continuous-time signals is an alternate sampling paradigm to conventional sampling methods such as Shannon sampling. In time-based sampling, the signal is encoded using a sequence of time instants where an event occurs. Time-based sampling methods are attractive as they output sparse measurements and are energy efficient. Our sampling and reconstruction framework extends the time-based sampling framework to classes of signals that lie in a union of subspaces.of the MCS feature design is shown in the figure below:

Problem Formulation

Let $\varphi \in L^2(\mathbb{R})$ be given. Consider the T_0-periodic function $x \in L^2([0, T_0[)$:

$$x(t) = \sum_{p\in\mathbb{Z}} \sum_{k=1}^{K} a_k \varphi(t - t_k - pT_0),$$

where $\{a_k, t_k\}_{k=1}^{K}$ parametrise the function. The function x has a rate of innovation of $\frac{2K}{T_0}$ and therefore, the minimum sampling requirement is $2K + 1$ samples in every period T_0.

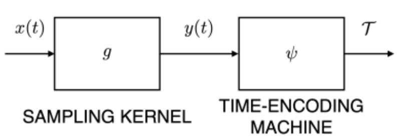
We consider kernel-based, time encoding of x, using a sampling kernel g and time-encoding machines to give the set of time instants $\mathcal{T} = \{t'_n\}_{n\in\mathbb{Z}}$. We also consider sampling a T_0-periodic FRI signal using M time-encoding machines $\psi^{(1)}, \psi^{(2)}, \cdots, \psi^{(M)}$, so as to produce M sets of time instants $\mathcal{T}^{(1)}, \mathcal{T}^{(2)}, \cdots, \mathcal{T}^{(M)}$. The input to each of the time-encoding machines is the filtered version of x.

We pose the reconstruction problem: given $\mathcal{T}$ or $(\mathcal{T}^{(1)}, \mathcal{T}^{(2)}, \cdots, \mathcal{T}^{(M)})$ and ψ (or $\psi^{(1)}, \psi^{(2)}, \cdots, \psi^{(M)}$), find x. In particular, we focus on sampling using crossing-time-encoding machines (C-TEM) and integrate-and-fire time-encoding machines (IF-TEM).

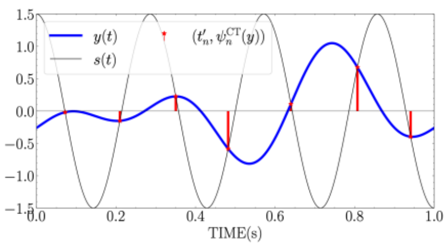
Results

Proposition 1: (Sufficient conditions for recovery of x from C-TEM measurements)

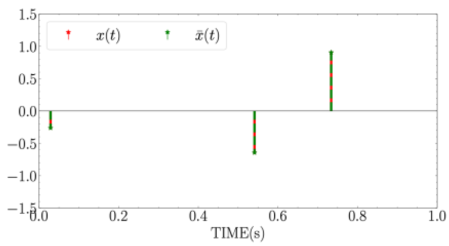
The set of time instants $\{t'_n\}_{n=1}^{N} \subset \mathcal{T}_{\text{CT}} \cap [0, T_0[$ is a sufficient representation of the T_0-periodic FRI signal x, when $N \geq 2K + 1$ and the reference $s(t) = A_s \cos(2\pi f_s t)$ be such that $A_s > \| (x * g) \|_\infty$ and $f_s \geq \frac{2K+1}{T_0}$.



(a) Single channel sampling using TEM



(b) Sampling using C-TEM



(c) Perfect Signal Recovery

We proposed equivalent sufficient conditions for signal recovery from single channel IF-TEM and, multichannel C-TEM and IF-TEM measurements.

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; Siddharth 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 is 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.

Research Publications

2021

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S. Gupta, S. Chakraborty, C.S. Thakur, "Neuromorphic Time-Multiplexed Reservoir Computing with On-the-fly Weight Generation for Edge Devices", to appear in IEEE Transactions on Neural Networks and Learning Systems, 2021.

Siddharth Barman and Paritosh Verma, "Existence and Computation of Maximin Fair Allocations Under Matroid-Rank Valuations", International Conference on Autonomous Agents and Multiagent Systems (AAMAS), 2021.

Siddharth Barman, Omar Fawzi, and Paul FerméTight, "Approximation Guarantees for Concave Coverage Problems", Symposium on Theoretical Aspects of Computer Science (STACS), 2021.

Suprovat Ghoshal and Anand Louis, "Approximation Algorithm and Hardness for Strong Unique Games", ACM-SIAM Symposium on Discrete Algorithms (SODA), 2021.

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S. Gurugubelli, and S.P. Chepuri, "Graph Learning for Clustering Multi-view Data", accepted for EUSIPCO 2021 (arXiv preprint arXiv:2010.12301).

2020

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