Pratiksha Trust Initiative on

Brain, Computation and Data Science

The Brain, Computation, and Data Science initiative, set up in June 2015, sprung out of the generous endowment provided by Mr. Kris Gopalakrishnan and Mrs. Sudha Gopalakrishnan, founders of the Pratiksha Trust, Bangalore. 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, Centre for Neuroscience, Electrical Communication Engineering, Electrical Engineering, Electronic Systems Engineering, Mathematics, and Molecular Biophysics.

The initiative was initially launched by setting up three Distinguished Visiting 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 three chairs are currently held by:

- Prof. Shihab Shamma, University of Maryland (Shri. K. Vaidyanathan Chair Professor)
- Prof. Vasant Honavar, Pennsylvania State University (Smt. Sudha Murty Chair)
- Prof. Christos Papadimitriou, Columbia University (Pratiksha Trust Chair)

The activities of the initiative have expanded to include:

- International Workshop on Brain, Computation, and Learning, a week long meeting of leading researchers from all over the world (three editions have been organized: January 2017, January 2018, and June 2019)
- Exchange of researchers leading to potential collaborative engagements between IISc and several universities (Carnegie Mellon University, Johns Hopkins University, Pennsylvania State University, University of Washington – St. Louis, Western Sydney University, University College of London, and Columbia University)
- Support of travel fellowships for international conference visits and internships
- Organization of focussed workshops and compact courses
- Support of seed grants for exploratory research projects
- Award of Pratiksha Trust Young Investigator Positions to Assistant Professors

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 salry 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)

The Pratiksha Trust Initiative in Brain, Computation, and Data Science is administered by the Division of EECS at the Institute. The scientific advisory committee comprises:

Prof. Shalabh Bhatnagar (CSA)
Prof. K.V.S. Hari (ECE)
Prof. Aditya Murthy (CNS)
Prof. M. Narasimha Murty (CSA)
Prof. Rishikesh Narayanan (MBU)
Prof. P.S. Sastry (EE) (Convener)
Prof. Rajesh Sundaresan (ECE)

About this Booklet

This booklet comprises details of the research expertise of the Young Investigators. The booklet also contains salient aspects of the eight research projects that have received a seed grant of Rs. 5 Lakhs under the Pratiksha Trust Initiative.

Pratiksha Trust Young Investigators

Sriram Ganapathy

http://leap.ee.iisc.ac.in/sriram/

Sriram Ganapathy is an Assistant Professor at the Department of Electrical Engineering, Indian Institute of Science, Bangalore. Previously, he was a research staff member at the IBM Watson Research Center from 2011-2015. He received his PhD from the Center of Language and Speech Processing, Johns Hopkins University in 2011. Currently, he serves as the subject editor for Elsevier Speech Communication journal and was the recipient of early career awards from DST and DAE. He is a member of the ISCA and a senior member of the IEEE.

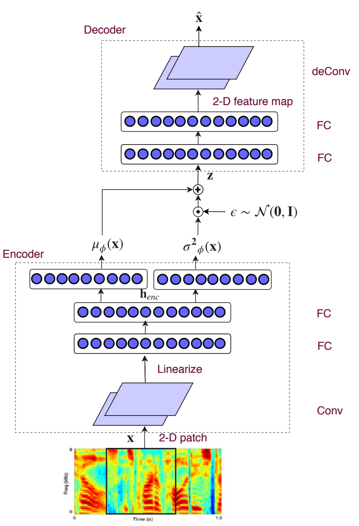
Research Highlight

Our lab, named LEAP (learning and extraction of acoustic patterns), works on the interface between signal processing, machine learning and neuroscience all within the domain of speech processing. From the neuroscience perspective, we design experiments to probe how the brain representations are evolving when new words from a foreign language are learnt. The analysis is performed with subjects engaged in a language learning task under an Electroencephalography (EEG) scanner. We are also interested in understanding the human processing of multi-talker speech where high efficiency is achieved by humans with relative ease.

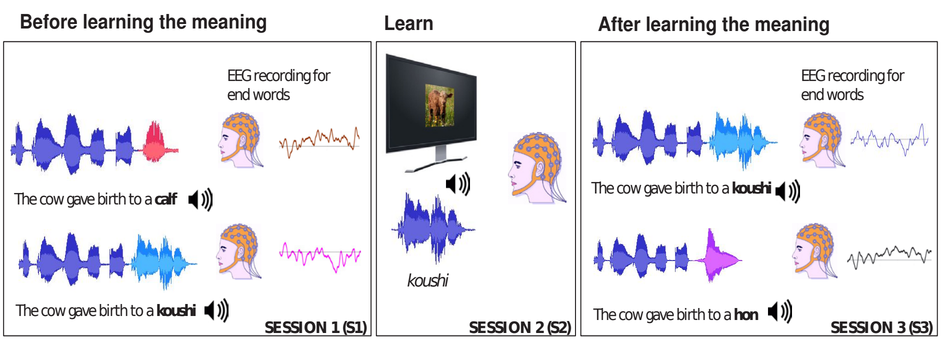
On the machine learning side, we try to develop techniques for unsupervised representation learning and data driven features from audio which are beneficial for robust speech recognition. For scenarios like low data resource languages, we are interested in active learning and other semi-supervised learning that are based on deep end-to-end models. Our interests also span into automatic speaker clustering in multi-talker speech and biometric applications of speech like speaker and language verification. We actively participate in international grand challenges in these problems and collaborate with industry and other academic institutions.

The overarching vision of the lab is to improve the current technology by understanding the human speech processing and to apply technology and big data to improve the understanding of the brain.

Unsupervised Representation Learning From Raw Audio using Variational Autoencoders.



Language learning and EEG



Prasanta Kumar Ghosh

http://www.ee.iisc.ac.in/people/faculty/prasantg/

Prasanta Kumar Ghosh received his Ph.D. in Electrical Engineering from the University of Southern California (USC), Los Angeles, USA in 2011. Prior to that he obtained his M.Sc.(Engineering) in Electrical Communication Engineering from Indian Institute of Science (IISc), Bangalore and B.E.(ETCE) in Electronics from Jadavpur University, Kolkata in 2006 and 2003 respectively. During 2011-2012 he was with IBM India Research Lab (IRL) as a researcher. He is a recipient of the INSPIRE Faculty award 2012 by the Department of Science and Technology, Govt. of India. He has also received the Young Investigator award by Pratiksha Trust in 2017 and the SERB start-up research grant for Young Scientists in Engineering Sciences in 2015. Currently, he is an assistant professor in the department of Electrical Engineering (EE) at IISc and heads the Signal Processing, Interpretation and REpresentation (SPIRE) Laboratory. The research activities in the SPIRE Laboratory have been at the intersection of speech science, engineering, and applications. Understanding & developing engineering models for various aspects in human speech production through multi-modal sensing and its applications in the area of healthcare and language learning have been the focus of the research activity. These include novel findings from basic scientific analyses of multi-modal speech production data, developing robust signal processing techniques & models that aid to meaningful interpretations of acoustic and associated gesture data, developing machine learning algorithms and tools for language tutoring as well as clinical applications including neuro-motor, respiratory & speech disorders.

Research Highlight

Human speech is produced as a result of speech articulation which involves choreographed movements of vocal folds, speech articulators including velum, epiglottis, tongue, lips, jaw. Head and facial gestures are an integral part of human speech production. For example, research using Motion Capture facility (Figure A) at SPIRE Lab shows how motion of head varies with style of speaking and the degree of synchrony between head gestures and speech. Using videostroboscopy (Figure B), SPIRE Lab researchers have analyzed the glottal vibration involved in speech production, in particular automatically segmenting the glottis for assisting in the treatment of patients with voice disorders. Signal processing techniques have been developed to convert speech from patients with voice disorder to healthy voice, which would be useful to aid to their speech based communication in everyday life. For speech production research, articulatory motion data acquisition techniques such as electromagnetic articulograph (EMA) (Figure D) and real time magnetic resonance imaging (rtMRI) (Figure C) have been used for the research work carried out in SPIRE Lab. Studies have been conducted to investigate the relation between articulatory and acoustic representations by estimating the articulatory motion from acoustics using novel inversion schemes. Research at SPIRE Lab shows how articulatory motion alters in patients with neuro-moto disease compared to a healthy individual.

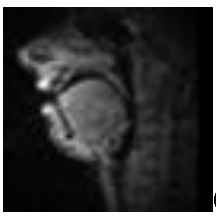
Motion Capture

A

Videostroboscopy

B

Real-time MRI



C

Electromagnetic Articulograph

D

Sridharan Devarajan

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Sridharan Devarajan received his Bachelors and Masters degrees in engineering from the Indian Institute of Technology (IIT), Madras. He completed his PhD at Stanford University where, as a Stanford Graduate Fellow, he studied the neural dynamics of attention and executive control with functional neuroimaging. In the second part of his PhD he built neuromorphic computational models of the brain in the lab of Prof. Kwabena Boahen. He completed his post-doctoral training as a Dean's Postdoctoral Fellow at Stanford's School of Medicine with Prof. Eric Knudsen, investigating neural circuit mechanisms of attention. He is now an Assistant Professor at the Centre for Neuroscience, and an Associate Faculty of the Department of Computer Science and Automation, at IISc, Bangalore. Recent awards include a Wellcome Trust-DBT India Alliance Fellowship, SERB Early Career Award, and a Pratiksha Trusts Young Investigator grant.

Research Highlight

Diffusion imaging (dMRI) is a non-invasive technique for measuring the diffusion of water molecules in the brain's white matter. Tractography algorithms are applied to dMRI data to infer structural connections between different brain regions in the living human brain. We seek to highlight here two studies involving computational approaches to diffusion imaging and tractography that were published at prestigious venues earlier this year.

First, we developed a potentially useful resource for diffusion imaging and tractography. Conventional tractography algorithms often estimate spurious connections between brain regions. Linear Fascicle Evaluation (LiFE) is a state-of-the-art approach for pruning spurious connections, but imposes heavy demands on computing time (Pestilli et al, Nature Methods, 2014). We developed a GPU-based implementation of LiFE that achieves 50-100x speedups over LiFE, and estimates sparser, more accurate, connectomes. This work was presented at the 33rd AAAI conference on Artificial Intelligence (A* conference), and was selected as one of 1,150 full-length papers from over 7,700 submissions (15% acceptance rate). (conference publication: Kumar S, Sreenivasan V, Talukdar P, Pestilli F & Sridharan D. AAAI Proceedings, 2019; https://doi.org/10.1609/aaai.v33i01.3301630).

Second, leveraging the tools described above, we sought to understand brain-behavior relationships in the context of attention. We analyzed diffusion imaging (dMRI) data from n=22 subjects at IISc (data acquired from the scanner at HCG Hospital, Bangalore) and n=60 subjects from the Human Connectome Project (HCP) database. We discovered a striking relationship between connectivity in a key midbrain region – the superior colliculus (SC) – and key metrics of attention behaviors. Taken together with our previous findings, this study showed that the SC could be a key node in an evolutionarily conserved network for controlling visuospatial attention (journal publication: Sreenivasan V & Sridharan D. Proc. Natl. Acad. Sci. USA, 2019; https://doi.org/10.1073/pnas.1902704116).

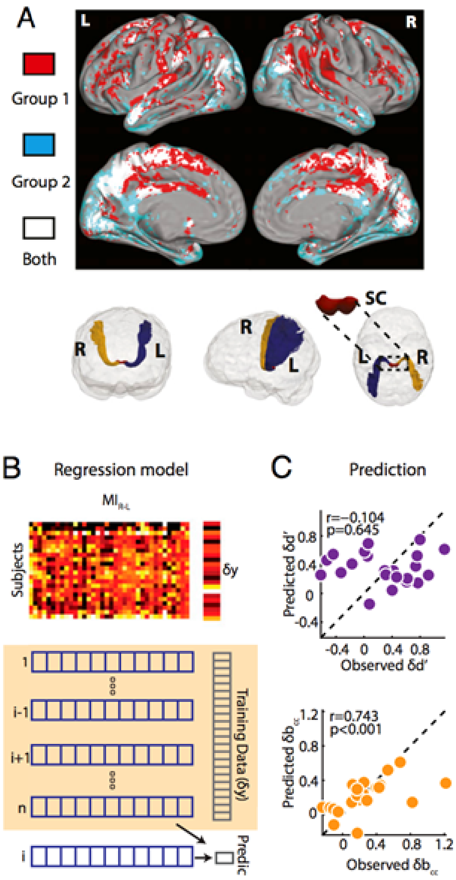

Figure. **(A)** Connectivity of the superior colliculus (SC) with other brain regions in the neocortex. **(B)** Regression model for predicting attention behavior components based on SC connectivity. **(C)** SC connectivity strongly predicts a decisional component of attention (choice bias, bcc), but not the perceptual component (sensitivity, d'). Adapted from Sreenivasan and Sridharan, PNAS, 2019.

Chetan Singh Thakur

Chetan Singh Thakur joined the Indian Institute of Science, Bangalore as an Assistant Professor in May 2017. He is also an adjunct faculty at International Center for Neuromorphic Systems, Sydney. He received his PhD in neuromorphic engineering at the MARCS Research Institute, Western Sydney University, Australia. He then worked as a research fellow for Defence Science and Technology, Australia and the Johns Hopkins University, USA. In addition, Dr. Thakur has extensive industrial experience, he worked for 6 years with Texas Instruments Singapore as a senior IC Design Engineer, designing flagship mobile processors. His research interest lies in brain-inspired computing, mixed signal VLSI systems, computational neuroscience and machine learning for edge computing. His research interest is to understand the signal processing aspects of the brain and apply those to build novel intelligent systems. He is a recipient of the Inspire Faculty Award 2016 by the Department of Science and Technology, India. He has also received the Young Investigator Award by Pratiksha Trust and "Early Career Research Award" from Science and Engineering Research Board, Government of India. He has received several research grants from Industry and Government sources including DST, SERB, Ashok Leyland, Qualcomm, WIPRO, Texas Instruments.

http://neuronics.dese.iisc.ac.in/dr-chetan-singh-thakur/

Research Highlight

Due to the proliferation of internet-of-things(IoTs) in the areas of ubiquitous sensing there has been an increased demand towards integrating intelligence directly onto the IoT hardware platform. The machine learning (ML) architecture embedded into these platforms needs to be as energy-efficient as possible. We have recently developed low-power CMOS-Memristor based neuromorphic architectures, which utilizes promising features from the neuromorphic analog architecture, memristor synaptic memory, and the hardware-friendly learning algorithm. We have also developed another novel computational framework for designing support vector machines (SVMs), which does not impose restriction on the SVM kernel to be positive-definite and allows the user to define memory constraint in terms of fixed template vectors. This makes the framework scalable and enables its implementation for low-power, high-density and memory constrained embedded application.

In another research theme, we explore neuromorphic sensors (currently, vision and auditory modalities) to build various intelligent systems that could be used for various robotics and military applications. Neuromorphic silicon retinas aim to mimic the features of biological retinas to sense and process the visual world. We have developed several Neuromorphic event-based algorithms such as for high-speed activity detection for autonomous vehicle, 3D reconstruction etc using neuromorphic sensor.

Recently, we are working on to develop fundamentally new machine learning architectures using simple computational primitives. We propose an alternate hardware-software codesign of ML and neural network architectures where instead of using matrix-vector-multiplications (MVM) operations and non-linear activation functions, the architecture only uses simple addition and thresholding operations to implement inference and learning. This will result in significant improvement in computational complexity and hence energy cost.

Siddharth Barman

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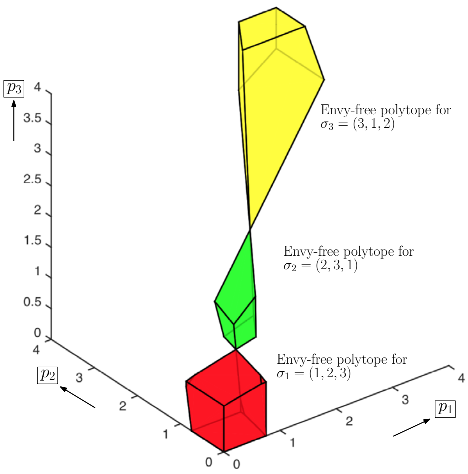
Siddharth Barman is an assistant professor in the Department of Computer Science and Automation at the Indian Institute of Science. Before joining IISc, he was a post-doctoral scholar at Caltech and obtained his Ph.D. in Computer Science at the University of Wisconsin-Madison. Siddharth is a Ramanujan 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

Fairness is a fundamental consideration in many resource-allocation settings. A substantive body of work in Economics and Mathematics is aimed at quantitatively understanding fairness and establishing existential results. Such provable guarantees, and the accompanying framework, have guided the design of (fair) allocation policies in contexts such as border disputes, course allocation, and cloud computing. However, to be useful in practice, one also requires scalable methods that explicitly find the underlying fair allocations. Motivated by this consideration, Siddharth's current research addresses algorithmic aspects of fair division.

Specifically, a recent joint work [1] of Siddharth shows that, in a relevant model, economic efficiency is not sacrificed by imposing fairness. This work is conceptually surprising since it shows that the seemingly incompatible properties of fairness and economic efficiency can be achieved together. The result has practical implications since it carries with it an algorithm for finding allocations are that both fair and (Pareto) efficient.



Another joint work Siddharth [2] is focused on fairness in settings that entail resource sharing with monetary transfers. This framework has been studied in Microeconomics for over three decades and is referred to as fair rent division, since it captures (as a stylized example) the problem of fairly dividing an apartment's rent among the roommates. The result [2] provides the first efficient algorithm for this classic problem and relies on an interesting geometric insight: in this setup, even though the underlying "feasible set" is non-convex, it is always composed of a chain of convex sets (see appended Figure). Siddharth's group is also working towards Blockchain implementations of fair-division algorithms.

[1] *Fully Polynomial-Time Approximation Schemes for Fair Rent Division*. Eshwar Arunachaleswaran, Siddharth Barman, and Nidhi Rathi. ACM-SIAM Symposium on Discrete Algorithms (SODA), 2019.

[2] *Finding Fair and Efficient Allocations.* Siddharth Barman, Sanath Krishnamurthy, and Rohit Vaish. ACM Conference on Economics and Computation (EC), 2018.

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.

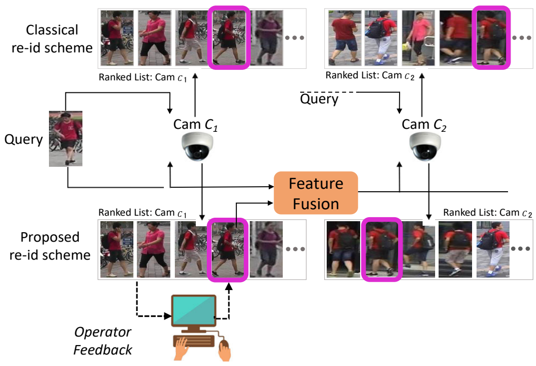
Research Highlight

Person search and retrieval from a camera network is one of the important problems in video surveillance. Often the search query comes in the form of unstructured textual description of the target of interest, and a list of candidate image observations are retrieved from different CCTV camera footages. Once the image of the target is identified in any of the cameras, the same can be used to search the rest of the network - a task popularly known as person re-identification. In a series of recent works, we have explored these problems and proposed solutions towards building a deployable video surveillance pipeline. In the text-based person search problem we aimed to create semantics-preserving embeddings by adding an additional task of attribute prediction and proposed an approach by learning an attribute-driven space along with a class-information driven space and utilized both for obtaining the retrieval results. Experiments showed that learning the attribute-space not only helps us in reporting state-of-the-art performance, but also yields humanly interpretable features.

A man wearing a pink and white stripe shirt, a pair of blue shorts and a pair of brown sandals.

The woman is wearing a gray shirt with black pants and light coloured shoes. She is carrying a light blue pures on her right shoulder. She is also carrying a light coloured umbrella.

Given a target image as query, person re-id systems retrieve a ranked list of candidate matches on a per-camera basis. In deployed re-id systems, a human operator scans these lists and labels sighted targets by touch or mouse-based selection. However, in an existing set-up, target identifications by operator in a subset of cameras cannot be utilized to improve ranking of the target in the remaining set of network cameras. To address this shortcoming, we proposed a novel sequential multi-camera re-id approach, which could accommodate human operator inputs and provide early gains via a monotonic improvement in target ranking. At the heart of our approach is a fusion function which operates on deep feature representations of query and candidate matches. Besides reporting improved results over traditional re-id baselines, we also conducted a comparative subject-based study of human operator performance. The superior operator performance enabled by our approach makes a compelling case for its integration into deployable video-surveillance systems.



Anand Louis

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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

Anand's primary focus of research has been in bridging the gap between theory and practice in the study of algorithms. For many computational problems, the best known algorithms provide a somewhat underwhelming performance guarantee, however simple heuristics perform remarkably well in practice. A possible explanation for this phenomenon could be that the instances arising in practice tend to have some inherent structure that makes them "easier" than the worst-case instances. Many attempts have been made to understand the structural properties of these instances, and to use them in designing algorithms specifically for such instances, which could perform much better than algorithms for general instances. This includes modelling real-world instances as families of random and semi-random instances, identifying certain structural properties that real-world instances typically satisfy, etc.

Sundeep Prabhakar Chepuri

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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

The main themes of my research are *sensing*, *representation*, *learning*, and *statistical inference* for high-dimensional data with applications in communications, network and data sciences, and computational imaging.

Pervasive sensors collect massive amounts of data. As a consequence, it is becoming increasingly challenging to locally store and transport the acquired data to a central location for signal/data processing (i.e., for inference). To alleviate these problems, it is evident that we need to significantly reduce the sensing (hardware) cost as well as the related memory and communications requirements by developing unconventional sensing mechanisms to extract as much information as possible yet collecting fewer data. If we had some prior knowledge about the task we want to perform on the data samples, then just a small portion of that data might be sufficient to reach a desired inference accuracy, thereby significantly reducing the amount of sampled and transported data. To this end, we have developed a data acquisition framework called *sparse sensing*, in which the goal is to optimally design a deterministic and structured sensing function to achieve a desired inference performance. The results developed in this research are applied to *environmental monitoring using sensor networks*, *indoor localization*, *medical ultrasound imaging*, and *radar systems, to name a few*.

Many science applications deal with datasets that have an underlying graph structure, e.g., datasets related to social networks, transportation networks, brain networks, sensor networks, chemical synthesis, protein-protein interactions, and meshed surfaces in computer graphics, to list a few. These datasets are complex. They are complex because of their massive volumes and because they are collected on manifolds, networks, or other irregular non-Euclidean domains. In the context of graph-data processing, we have developed mathematical tools for graph sampling and recovery, i.e., to estimate graph-structured data using observations from a few graph nodes. Having a good quality graph is central to any graph-based signal processing or machine learning. To this end, we have developed tools for graph learning, i.e., to estimate the underlying graph that best explains the available data. These mathematical and computational tools impact a wide variety of applications across multiple disciplines, ranging from classifying structured datasets to processing EEG/fMRI recordings, and from environmental monitoring to recommender systems, to list a few.

Exploratory research projects under Pratiksha Trust support

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

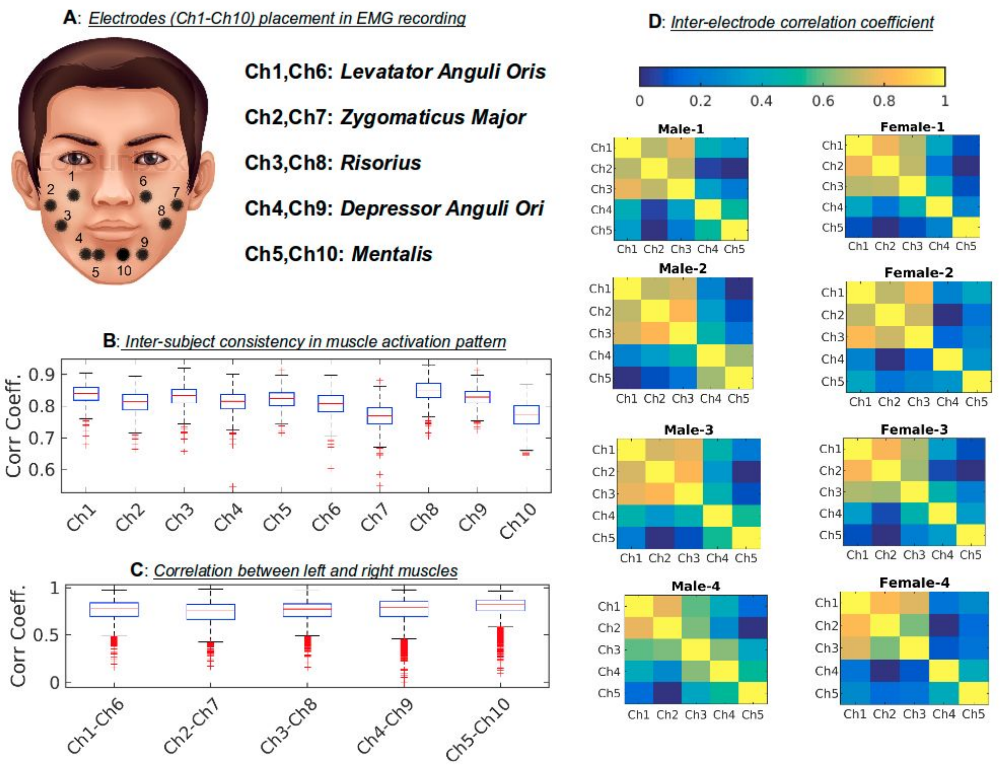
Investigators:

Dr. Prasanta Kumar Ghosh,
Department of EE, IISc (http://www.ee.iisc.ac.in/people/faculty/prasantg/)

Prof. Aditya Murthy,
Center for Neuroscience, IISc (http://www.cns.iisc.ac.in/aditya/)

The relation between muscle activation and speech articulatory behavior is not well understood. By characterizing muscle activity patterns as muscle synergies, we hope to leverage principles underlying the neural control of movements to understand the essential spatiotemporal transformations underlying speech processing. We anticipate that the successful outcome of this research will be to enable us to reconstruct speech from incomplete and highly attenuated muscle activation signals even when a subject is not speaking but rather in silent reading. This can potentially lead to novel interfaces for BCI applications when speech is compromised.

Preliminary analysis on ten electrodes (Ch1-Ch10) electro-myograph (EMG) recordings from five muscles on either side of the face (as shown in Figure A below) from eight subjects (4 Male + 4Female) show that there is a consistency in the muscle activation pattern across subjects reading the same set of 460 sentences (as indicated by high correlations in Figure B). Additionally, the same muscles on either side of the face also show highly correlated activation pattern (Figure C). However, correlation among five electrodes' activations (Figure D) show that although there is a subject specific variations, there is little correlation between depressor anguli ori (Ch4) and mentalis (Ch5) even though they are spatially very close to each other on the face. This indicates that these spatially close muscles could be involved in the production of different sounds. Factorizing all muscle activations onto functional synergies could reveal fundamental motor control patterns during speech production.



HPC Framework for large scale study of Brain networks

Investigators:

Prof. Sathish Vadhiyar,
Department of CDS, IISc (http://cds.iisc.ac.in/faculty/vss/)

Dr. Ambedkar Dukkipati,
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The work focuses on the following aspects:

a. A study and analysis of unsupervised learning algorithms to obtain brain network embeddings(from brain graphs) and using clustering algorithms (ex, k-means) on these graph embeddings, to discover clusters or groups.
b. Using the existing algorithms on community detection (ex, Louvain algorithm) on large scale brain graphs to discover communities, and comparing the two results to choose the better one for studying brain networks.
c. To develop HPC frameworks to realize and implement the above chosen algorithms for large scale brain graphs.

Planned workflow for our project:

1. Obtain fMRI data from trusted sources
2. Generate brain graphs from the obtained data
3. Develop an efficient method to obtain clusters. One can follow one of the two methods below
   a. Use existing parallel community detection methods like modularity maximization(Louvain's algorithm).
   b. Use an efficient parallel graph embedding technique to represent nodes as vectors and run a known clustering algorithm on obtained embeddings.
4. Choose the better one, to perform clustering task over all the brain graphs in the ensemble. Here
   we need to develop and employ HPC framework as we need to perform large scale computations
5. Develop tools to auto-analyse the evolution of communities in brain graphs.

Current progress:

1. Obtained fMRI data from Human Connectome Project. (https://db.humanconnectome.org)
2. Implemented a GPU code for obtaining brain graphs from brain data.
3. Considered each voxel as node (a total of 96,854)
   a. Used pearson correlation coefficient over all node pairs to generate edges
4. Investigating the use of various existing graph embedding algorithms like Node2vec[1], GraphVite[2] for generating graph embeddings.
5. Investigating the use of parallel Louvain community detection algorithm to detect communities.

References:

[1] A. Grover and J. Leskovec, "Node2vec: Scalable feature learning for networks," in Proceedings of the ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, 2016, vol. 13-17-Augu, pp. 855–864.

[2] Z. Zhu, S. Xu, M. Qu, and J. Tang, "GraphVite: A High-Performance CPU-GPU Hybrid System for Node Embedding," in The World Wide Web Conference, 2019, pp. 2494–2504.

Deep Neural Networks For Unsupervised 3D Object Reconstruction From 2D Images

Investigators:

Venkatesh Babu Radhakrishnan,
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Reconstruction of a 3D structure from a single 2D image is a crucial and significant problem. We humans can understand a scene from a 2D image easily.But for a machine, understanding an image or reconstructing 3D shape from an image is a very difficult problem. As we lose one dimension when we capture the image, reconstructing a 3D object from a 2D image is an ill-posed problem. Here we use data driven deep learning based techniques to reconstruct a 3D object from a given single image. Recent works on 3D reconstruction will either use 3D models or multiple images as supervisory signal. Whereas in our recent work, we architect a framework which uses a single RGB image to reconstruct 3D object in a self supervised manner. We briefly explain below the approach that we have taken.

Between different 3D representations such as voxel-based, mesh-based, point cloud-based representations, we used point cloud as it is information rich and efficient. We proposed a cyclic consistency based approach for reconstructing a 3D object from a single view. Our network architecture consists of a pair of encoder-decoder module. Image is fed to this encoder decoder module and a point cloud is generated as output. We have an additional pose network for predicting the camera pose from the input image. Point clouds obtained from encoder-decoder architecture is rendered to 2D image using the predicted pose by a differentiable rendering module along with silhouette loss and image loss. Further, predicted point cloud is projected to multiple random viewpoints. These images are passed through encoder decoder architecture, which predicts the point cloud. This reconstruction network is trained by the 3D cyclic consistency loss between the point clouds generated from the given image and the rendered image. Rendered images are also passed through the the pose network and we enforce a pose consistency loss between random poses used for rendering and the predicted poses for training the pose network. We have also utilized the images with similar 3D shapes as pseudo multiple viewpoints for improving the point-cloud reconstruction.

We have observed dense 3D correspondences in the reconstructed point clouds even though we didn’t enforce correspondence explicitly. We have visualized the point cloud correspondence by using UV mapping. This dense correspondence has been utilized for part segmentation by utilizing a single part segmented ground truth image.

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

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Realistic physiological models and stringent Neuro-physiological metrics are critical for developing a therapy for brain diseases. The present project is focused on design, fabrication and in vivo testing of new class of micro-electrode cannula arrays (MECA) for recording electrical signals from deep brain structures of a rat model.

Epilepsy will be induced chemically, using topical application of known convulsants and that will be suppressed by applying standard AEDs locally over the epileptic focus. The fabricated device will help us to monitor the electro-physiological changes with the application of drugs. The stroke will be induced to rat model by permanent bilateral vertebral artery occlusions, followed by transient bilateral carotid artery occlusion. We will dissect the effects of the acute stroke on different neocortical layers using fabricated electrodes for physiologically realistic therapeutic interventions of stroke.

The MECA chips with 13, 15, and 17 electrodes (linearly arranged with an inter-electrode spacing of 100µm, 50µm, 25µm respectively) are fabricated to record bio-potential from deep brain structures. The images of the fabricated devices are shown in Figure 1. The electrical signals will be recorded and analyzed at a high sampling frequency (~10 kHz).

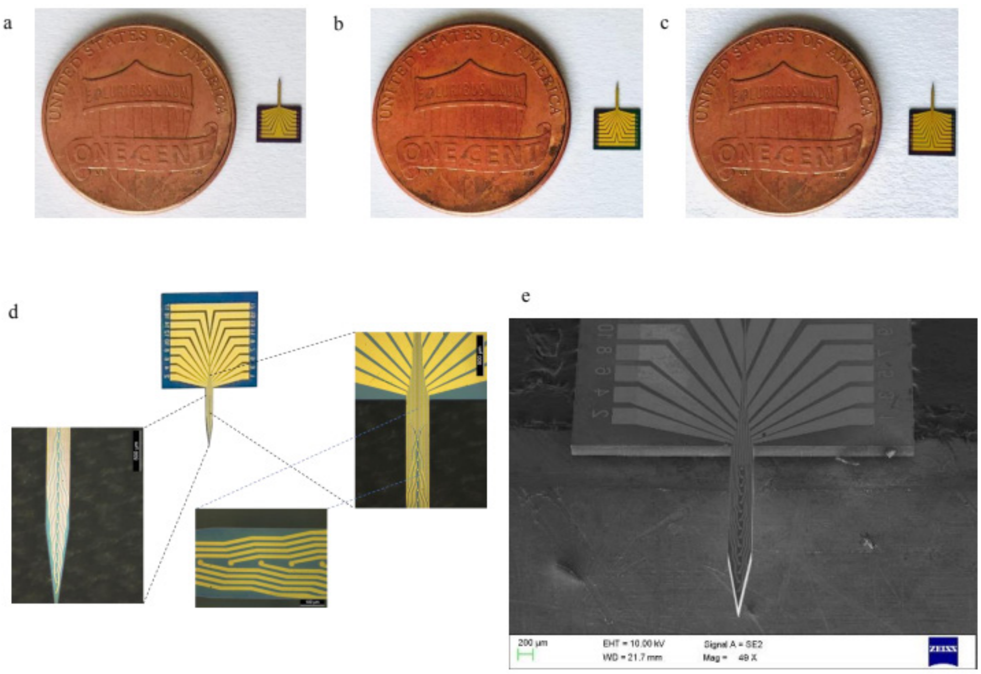

Figure 1: (a) MECA device with 13 recording electrodes; (b) MECA device with 15 recording electrodes; (c) MECA device with 17 recording electrodes; (d) Image of the MECA device with 17 recording electrodes under microscope;
(e) SEM image of MECA device with 15 recording electrodes.

Neuromorphic Fringe Projection Profilometry

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Neuromorphic cameras are vision sensors inspired by the magno-cellular pathways in human vision, which specialize in detecting high-rate transient events. This is in contrast to the parvo-cellular pathways, which are slow and are characterized by their ability to detect sustained stimuli. Neuromorphic cameras differ from frame-based ones in the same spirit as magno-cellular pathways differ from parvo-cellular pathways. In addition, neuromorphic cameras are fast and asynchronous.

We address the problem of 3-D reconstruction using neuromorphic cameras. These cameras are becoming increasingly popular for solving image processing and computer vision problems. Compared with conventional frame-based cameras, the data rates are significantly lower in neuromorphic cameras. In particular, we have developed a Neuromorphic-camera-based Fringe Projection Profilometry (NFPP) system. We use the Dynamic Vision Sensor (DVS) in the DAVIS346 neuromorphic camera for acquiring measurements. NFPP is faster than a single line-scanning method. Unlike frame-based FPP, the efficacy of the proposed method is not limited by the background while acquiring the measurement. The working principle of the DVS also allows one to efficiently handle shadows thus preventing ambiguities during 2-D phase unwrapping.

The 3-D imaging setup consists of a DAVIS346 camera and a Texas Instruments Digital Light Projector (DLP) LightCrafter 4500 projector module arranged in a stereo setup. Light projected on the DLP's micromirror array gets reflected into a lens to generate an image on the screen, from which the depth has to be estimated. The key innovations in our work are: (i) the use of neuromorphic cameras to perform 3-D scanning starting from sparse measurements; (ii) imaging with moving fringe patterns instead of static ones; and (iii) the reconstruction algorithm. The results presented in the figure below show that the exploration is indeed successful and opens up a new direction of research in 3-D scanning.

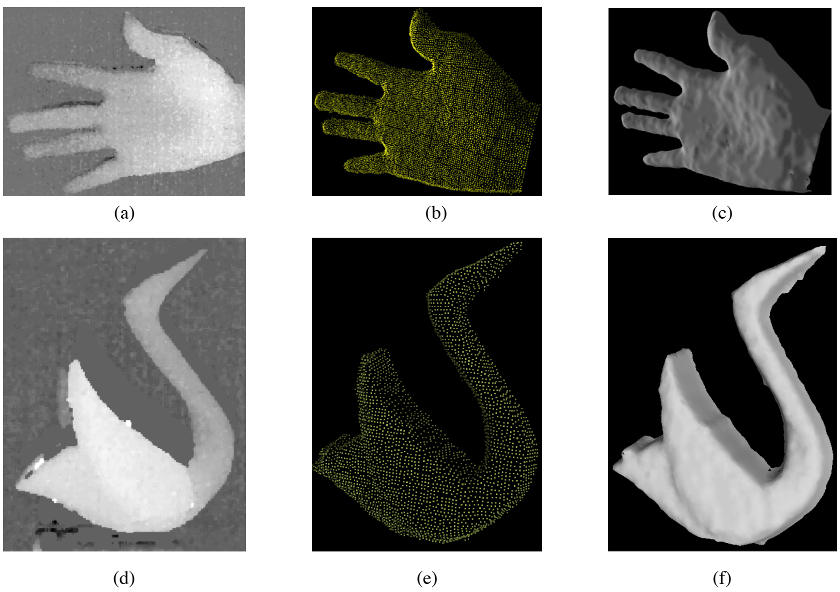

Fig. 1: Examples of scans of objects obtained using the NFPP system: (a) and (d) show the depth maps; (b) and (e) the corresponding 3-D point clouds; (c) and (f) the corresponding meshes.

Predicting the naturalness of artificially generated videos

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Problem Statement

We consider the problem of predicting the naturalness of artificially generated videos. In the first phase of this project, we particularly look at approaches in which future frames of videos are pre- dicted based on past frames popularly using convolutional neural networks (CNN). These approaches can lead to videos with several distortions. Note that when multiple future trajectories are possible given the past frames, a reference future may not be meaningful for quality comparisons. Further, we also observe inexplicable predictions such as the sudden appearance or disappearance of objects. Our main progress so far is in the design of a 'first of its kind' database of videos which are artificially generated and a subjective study to assess the perceptual naturalness of the generated videos. The database will be useful for both benchmarking current naturalness prediction algorithms and also propose new designs which correlate well with the subjective ratings.

Database and Subjective Study

We create a database of 300 artificially generated videos in which future frames are predicted based on past frames. The videos are all 5 seconds long played at a frame rate of 4 frames per second. The videos are sourced from several datasets used for video prediction including Berkeley Artificial Intelligence Research Dataset, KTH Human Action Dataset, UCF Action Recognition Dataset, and the KITTI Dataset for autonomous driving. The predicted videos are generated from several prediction algorithms including those that are designed by employing an error with respect to a given future as well those using an adversarial framework. The resulting distortions include blur, shape distortion, color changes and inexplicable appearance or disappearance of objects. Some examples of distorted frames are shown in Figure 1. We have also started conducting a subjective study to understand human responses to the generated videos. We adopt a two stimulus user study as shown in Figure 1, where a generated video is shown along with a natural video in a similar setting to remove any biases due to the video resolution. Around 40 subjects have already taken part in the study.

(a) Blurred video frame

(b) Shape distortions

(c) Subjective Study Interface

Figure 1: Database and Subjective Study

Next steps

The next steps involve benchmarking currently used cost functions for video prediction models including adversarial models. We wish to explore the relevance of video features learnt in action recognition and image recognition based features for naturalness prediction. Further we believe that a successful naturalness prediction index needs to track the shape trajectory of moving objects to capture any shape distortions. We also wish to create another database to evaluate the success of video prediction algorithms in learning the physics of the world and how humans would perceive their performance.

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

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Diffusion imaging (dMRI) is a non-invasive technique for measuring the diffusion of water molecules in the brain's white matter. Tractography algorithms are applied to dMRI data to infer structural connections between different brain regions in the living human brain. We seek to highlight here two studies involving computational approaches to diffusion imaging and tractography that were published at prestigious venues earlier this year.

First, we developed a potentially useful resource for diffusion imaging and tractography. Conventional tractography algorithms often estimate spurious connections between brain regions. Linear Fascicle Evaluation (LiFE) is a state-of-the-art approach for pruning spurious connections, but imposes heavy demands on computing time (Pestilli et al, Nature Methods, 2014). We developed a GPU-based implementation of LiFE that achieves 50-100x speedups over LiFE, and estimates sparser, more accurate, connectomes. This work was presented at the 33rd AAAI conference on Artificial Intelligence (A* conference), and was selected as one of 1,150 full-length papers from over 7,700 submissions (15% acceptance rate). (conference publication: Kumar S, Sreenivasan V, Talukdar P, Pestilli F & Sridharan D. AAAI Proceedings, 2019; https://doi.org/10.1609/aaai.v33i01.3301630).

Second, leveraging the tools described above, we sought to understand brain-behavior relationships in the context of attention. We analyzed diffusion imaging (dMRI) data from n=22 subjects at IISc (data acquired from the scanner at HCG Hospital, Bangalore) and n=60 subjects from the Human Connectome Project (HCP) database. We discovered a striking relationship between connectivity in a key midbrain region – the superior colliculus (SC) – and key metrics of attention behaviors. Taken together with our previous findings, this study showed that the SC could be a key node in an evolutionarily conserved network for controlling visuospatial attention (journal publication: Sreenivasan V & Sridharan D. Proc. Natl. Acad. Sci. USA, 2019; https://doi.org/10.1073/pnas.1902704116).

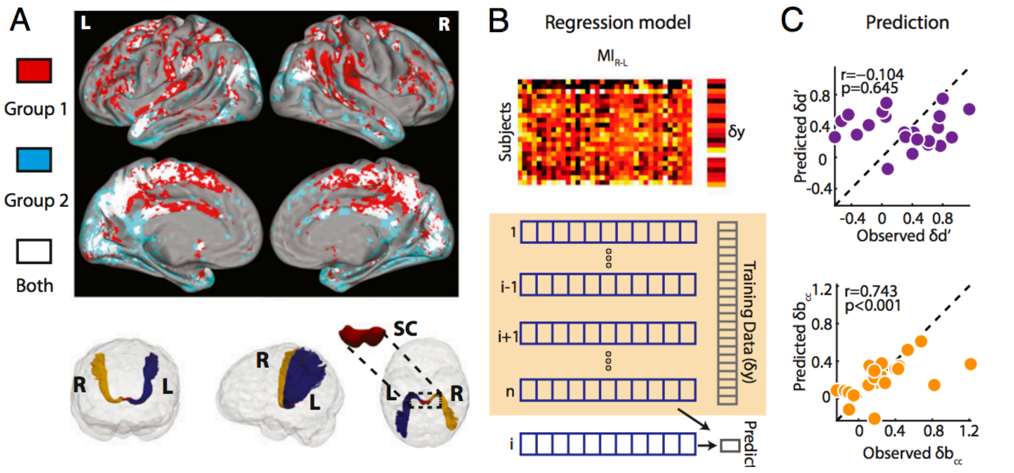

Figure. (A) Connectivity of the superior colliculus (SC) with other brain regions in the neocortex. (B) Regression model for predicting attention behavior components based on SC connectivity. (C) SC connectivity strongly predicts a decisional component of attention (choice bias, bcc), but not the perceptual component (sensitivity, d'). Adapted from Sreenivasan and Sridharan, PNAS, 2019.

Compositionality of Auditory Units in Speech Perception - An EEG Based Study

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Summary

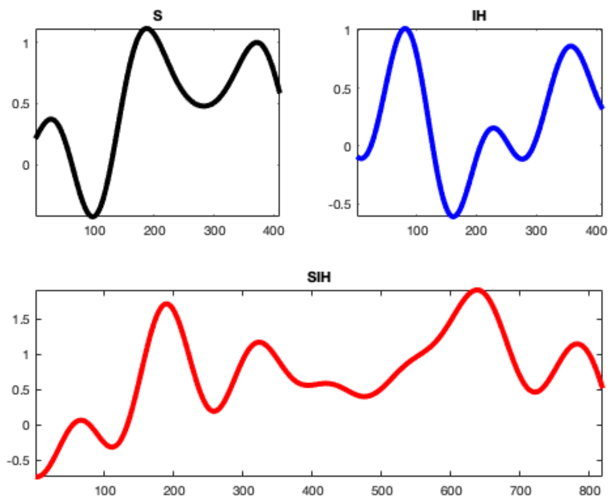
For understanding the brain processes involved in the perception of complex auditory or visual stimuli, one of the fundamental questions to answer is whether the brain performs compositional operations. This would mean that the representation in the brain for complex stimuli can be broken down into a composition of the representations for simpler basic stimuli units. In this project, we attempt to probe this question for the auditory stimuli. In automatic processing of speech, the fundamental unit of speech is a phoneme which is typically 80-100ms in duration. The main hypothesis in the proposed study is that the compositionally can be observed in EEG recordings obtained for a continuous speech listening task.

Materials and Methods

The first step in data preparation was the analysis of English phonemes to figure out 3 most / least probable consonants and vowels. From a data analysis on a speech database, the three most probable consonants were found to be (/s/,/n/,/r/) and least probable ones were (/jh/,/ ch/,/g/). Similar list for vowels were (/ih/,/iy/,/ae/) and (/ah/,/ey/,/ow/) respectively. Several words were formed using the most/least probable consonant-vowel (CV) combinations and stimuli sentences were generated that contain these words. These sentence stimuli were then read by a single speaker to generate 90 sentences from most/least probable CV set. These form the audio stimuli for the EEG experiments. Using these sentences pilot EEG data was recorded for 2 subjects, when the subjects were listening to these audio stimuli.

Preliminary Analysis

The EEG signal was pre-processed using standard EEG software. The average response to each phoneme and the EEG response to the combination is shown (from the CV /sih/ for one of the pilot subjects). The response to the CV (/sih/) is seen to be partly explained as a combination of EEG response to individual phonemes /s/ and /ih/. A time warping of the individual phoneme responses also occurs in the combination response. The next steps in the project include developing a mathematical model of the compositionality along with a larger scale data collection and analysis.



Pratiksha Trust Symposium on

Brain, Computation and Data Science

18th Oct, 2019

Golden Jubilee Hall, Department of ECE, IISc

Program

3:00pm-3:05pm	Introductory remarks by **Prof. Y. Narahari**
3:05pm-3:20pm	**Computational neuroimaging of brain connectivity in health and disease** **Dr. Sridharan Devarajan**, Centre for Neuroscience, IISc
3:20pm-3:35pm	**The curious case of Multi-talker Speech Processing in Humans and its impact on Machines** **Dr. Sriram Ganapathy**, Department of EE, IISc
3:35pm-3:50pm	**Neuromorphic In Memory Computing Architecture using Memristor as a Synaptic Device** **Dr. Chetan Singh Thakur**, Department of ESE, IISc
3:50pm-4:05pm	**Dysarthria due to Parkinson's Disease vs Amyotrophic Lateral Sclerosis** **Dr. Prasanta Kumar Ghosh**, Department of EE, IISc
4:05pm-4:20pm	**Algorithm and Economies** **Dr. Siddharth Barman**, Department of CSA, IISc
4:20pm-4:35pm	**Deep Surveillance: Person Search and Retrieval Across Cameras and Modalities** **Dr. Anirban Chakraborty**, Department of CDS, IISc
4:35pm-4:50pm	**Learning over Graphs** **Dr. Sundeep Prabhakar Chepuri**, Department of ECE, IISc
4:50pm-5:05pm	**Biologically Plausible Neural Networks** **Dr. Anand Louis**, Department of CSA, IISc
5:05pm	High Tea