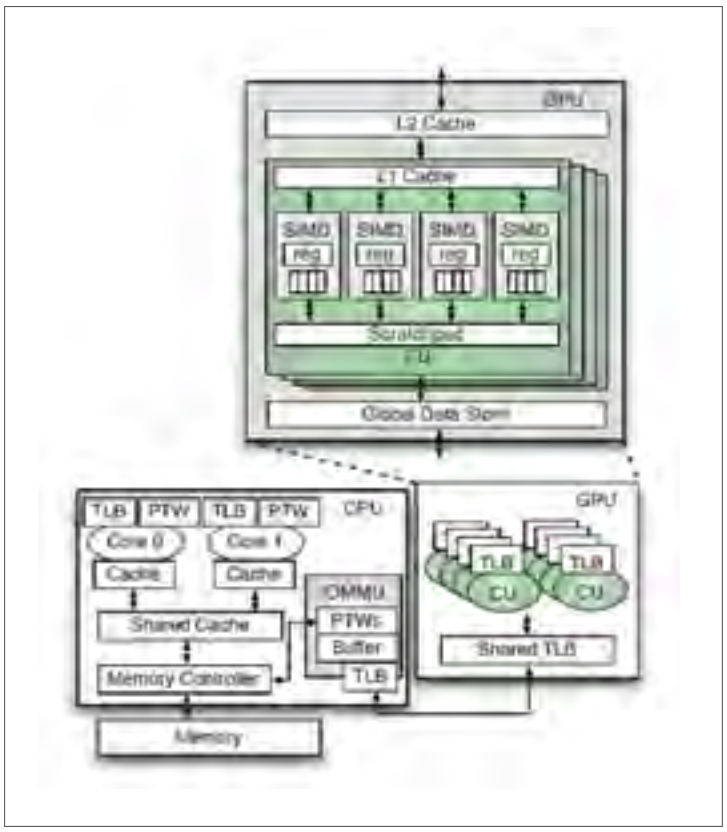
Research Snapshots 2018-19

P V Kumar (ECE)

Ensuring reliable communication with low latency, is key to next-generation applications such as interactive voice and video, multiplayer gaming, multiplayer virtual reality and telesurgery. Not surprisingly, ultra-reliable low-latency communication is one of three focus areas of 5G cellular systems.

Our group has recently come up with a class of low-complexity, packet-level forward error-correction codes, termed as streaming codes. These codes maximize the rate of information transmission while maintaining robustness against a large class of packet-erasure patterns, under a stringent decoding-delay constraint. The packet erasures could arise for example, from dropped packets due to congestion in the network, or packets that are lost on account of a wireless link that is experiencing a deep fade. Our work has received recognition in the form of a paper [2] that was one of four finalists for the 2019 IEEE Jack Wolf ISIT Student Paper Award. It was also awarded a Qualcomm Innovation Fellowship 2019, India [3].

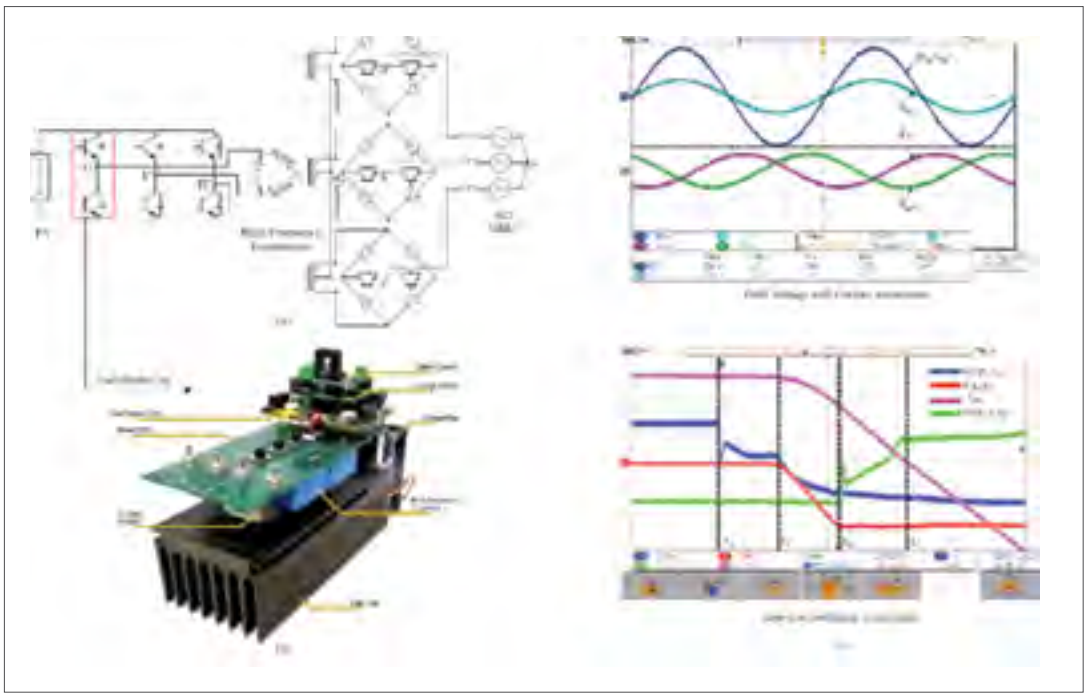


Arkaprava Basu (CSA)

Traditionally, the Central Processing Unit or CPU has been the brain of a computer. In recent times, however, Graphics Processing Unit or GPUs are emerging as a platform of choice for massively parallel computations, such as deep learning. But, writing a program for GPU is significantly harder than writing one for the CPU. Further, while a significant fraction of modern computing today happens in the public cloud computing infrastructures (e.g., Amazon's EC2), GPUs are not easy to deploy to the cloud. These present significant predicaments in fully harnessing compute capabilities of modern GPUs.
Arkaprava and his team's focus has been to make GPUs more easily programmable and deployable in the cloud platforms through co-design of the hardware and the software. More recently, they are working on how the hardware can provide feedback to the programmer to help her to write correct GPU programs.

Arkaprava Basu, Eric Van Tassell, Mark Oskin, Guilherme Cox, Gabriel Loh. "Single instruction multiple data page table walk scheduling at input output memory management unit". US Patent App. 15/852,442, 2019.

Seunghee Shin, Michael LeBeane, Yan Solihin, and Arkaprava Basu. "Neighborhood-aware address translation for irregular GPU applications". In Proceedings of the 51st Annual IEEE/ACM International Symposium on Microarchitecture (MICRO-51). Fukuoka, Japan — October 20 - 24, 2018, pp 352-363.

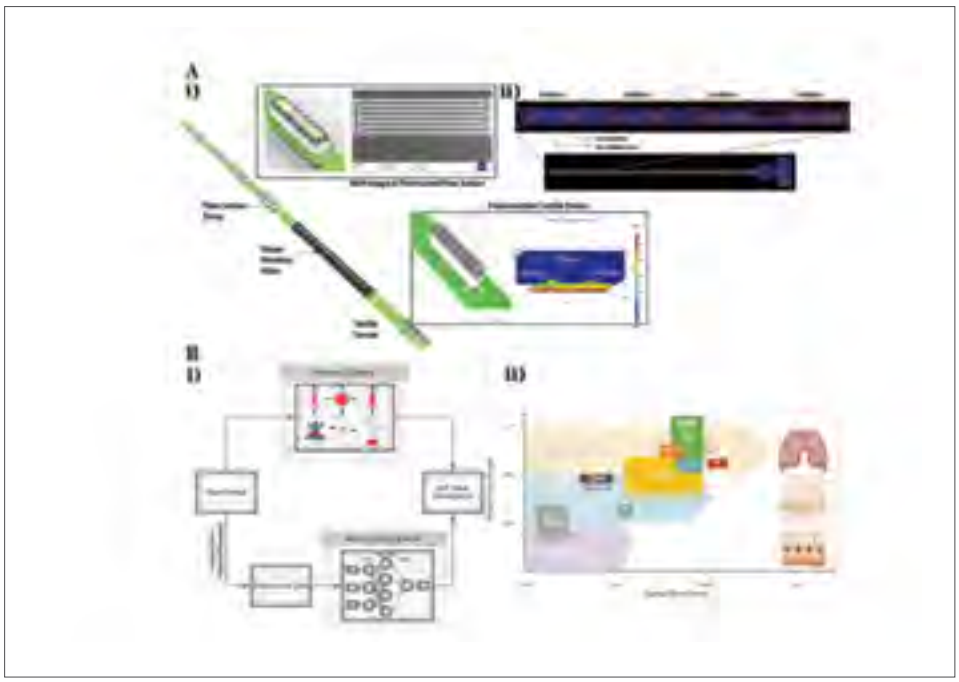


Kaushik Basu (EE)

Solar power being one of the most promising sources of renewable energy in our country, past few years witnessed rapid integration of utility scale solar into our power grid with a target of 100GW of solar capacity by 2022. A DC to AC power electronic converter, also known as an inverter, followed by a transformer is used to interface PV panels with the grid. Transformer is necessary for safety and to protect the panels from the damage due to leakage current. This transformer, operating at grid frequency of 50Hz, is one of the most expensive and heaviest components in the power conversion unit. It is well known, that size of a transformer is inversely proportional to the frequency of operation. One of the known ways to address this problem is to employ a DC-DC converter that incorporates a high frequency transformer, followed by an inverter. This so-called multi-stage solution has difficulty due to higher power loss in the semiconductor devices and presence of a large electrolytic capacitor at the interconnection of the two stages (DC-DC and DC-AC), compromising reliability. Our recent work on DC-AC converters with a high frequency transformer has shown that it possible to eliminate this capacitor through a single-stage, more silicon approach, improving reliability. Suggested, high frequency link inverter solutions practically result in minimum switching loss in power devices. As the loss is decoupled with frequency, the transformer size can be further reduced. Our target designs show that the proposed methods achieve efficiency comparable with the state-of-the-art solution, but at fraction of its size and cost.

Pal A, and Basu K, A Unidirectional Single-Stage Three-Phase Soft-Switched Isolated DC–AC Converter. *IEEE Transactions on Power Electronics,* Vol: 34, Issue: 2, Feb. 2019.

Pal A, and Basu K, A Soft-switched High Frequency link Single-Stage Three-Phase Inverter for Grid Integration of Utility Scale Renewables. *IEEE Transactions on Power Electronics,* Vol: 34, Issue: 9, Sept. 2019.



Hardik J Pandya (DESE)

The Advanced Microsystems and Biomedical Devices Facility for Clinical Research and Biomedical & Electronic (10-6-10-9) Engineering Systems Laboratory lead by Hardik J. Pandya is developing innovative healthcare technologies integrating biology/medicine with microtechnology, nanotechnology, electronic systems, and additive manufacturing to solve unmet clinical problems. Chronic inflammation of the upper airway in infants is often life-threatening and can result in a variety of diseases such as asthma, airway obstruction or hyper reactive airway diseases. Common symptoms include recurrent stridor, chronic cough, cyanotic episodes, feeding difficulties, recurrent aspiration, pneumonia often affecting the ability to breathe and swallow. Management of tracheal malformations is complex and requires an individualized approach with timely diagnosis and treatment. The small airway in infants often has the potential to worsen the impact of airway disorders. Chronic airway and soft tissue inflammation cause progressive weakening of the airway walls resulting in destruction of the tracheal cartilaginous rings.

Efficient management of difficult airway calls for newer diagnostic tools as well as development of innovative management techniques enabling a better prognosis. We present a novel, easily reproducible tool for quantitative assessment of the tissue mechanical property and simultaneously measure airflow in challenging airway- a valuable guide to surgical therapy based on precise, objective data.

This work was done in collaboration with Clinical Collaborators Dr. Sanjay Rao, Senior Consultant and Head, Department of Pediatric Surgery, Mazumdar Shaw Multispecialty Hospital.

Alekya, B., Sanjay Rao, and Hardik J. Pandya. “Engineering approaches for characterizing soft tissue mechanical properties: A review.” *Clinical Biomechanics,* vol. 69, pp. 127–140, Oct. 2019.

Vinod Ganapathy (CSA) and Chirnajib Bhattacharyya (CSA)

Commercial and end-user drones are becoming widely available. Such drones can be employed for a number of interesting and socially-beneficial use-cases, such as sensing, search and rescue, and product delivery. However, the wide availability of drones has also put a previously tightly-regulated resource, i.e., airspace, into the hands of commercial entities and end-users. We are already beginning to read about an increasing number of cases where commercial drones can pose dire risks., e.g. in the form of “near-misses” between drones and aeroplanes.

In this project, our focus is on the privacy risk posed by drones. Drones can capture pictures and video with their on-board cameras---in fact, this may be an essential part of navigating the drone. But as citizens on the ground, how do we get an assurance that these pictures and videos captured by third-party drones will not compromise our privacy? This problem is extremely challenging, primarily because the drone belongs to a third-party, e.g., it could be a delivery drone being operated by a delivery fleet operator.

At the Computer Systems Security Laboratory, we are developing techniques and tools to address this problem. We are developing the machinery by which (1) the host of a restricted space (e.g., the IISc campus, or an apartment complex), could specify a set of privacy policies that guest drones must comply, and (2) the guest drone can prove, using trusted hardware, to the host that it is in compliance. As our work matures, we hope to interact with and influence India’s emerging drone policies (e.g., Digital Sky).

Regulating Drones in Restricted Spaces, Abhishek Vijeev, Vinod Ganapathy, and Chiranjib Bhattacharyya, *Proceedings of HotMobile’19, the 20th International Workshop on Mobile Computing Systems and Applications,* Santa Cruz, California, USA, February 2019.

Vinod John (EE)

Supplying power to rural and remote regions through single-phase distribution or microgrid is a preferred choice over a three-phase system, owing to cost benefits. Though, three-phase induction machines offer better torque and power density at a low cost as compared to their single-phase counterparts. The availability of only single-phase power limits the usage of three-phase induction motors in applications such as pumps, mills, cold-storage plants in the agricultural sector and machine tool industries in small urban and rural set-ups. Inexpensive power converters are adopted to achieve cost benefits at the expense of efficiency and power quality. In this context, many active phase converters (APCs) with fewer power electronic devices are proposed to reduce the converter size and cost. These APCs have limitation such as reduced life due to low-frequency current in the dc-link, high inrush currents while starting an induction motor, impact on motor bearing life due to converter generated voltage or increased system cost due to sine-filter at the output.

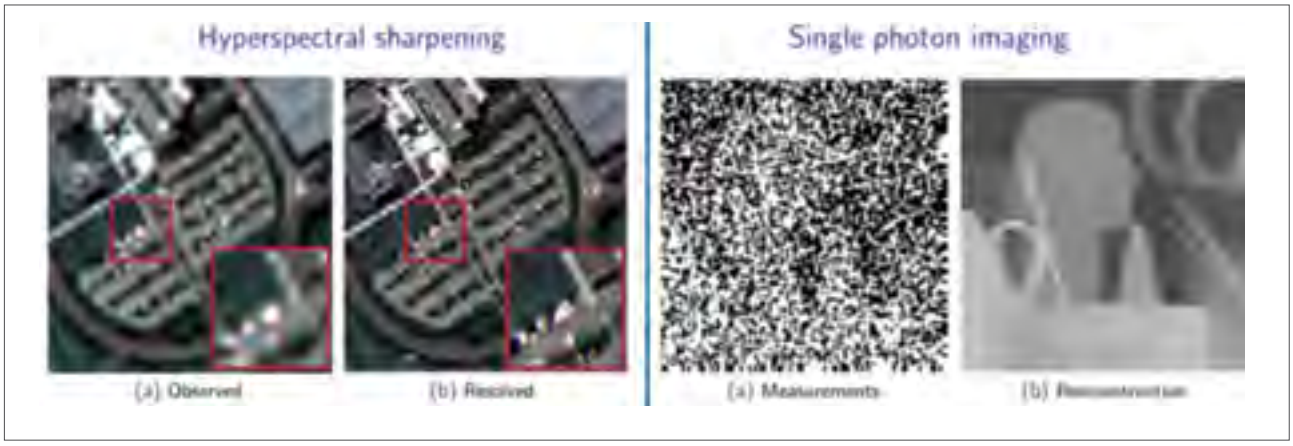
Research on an auxiliary capacitor assisted APC (AC-APC) address these challenges discussed above. The proposed AC-APC bypasses sufficient power from the grid to load, and process only a fraction of the load power, thus achieving low power converter ratings. This boosts the system efficiency and enhances the converter lifespan. The utility service provider also benefits as the AC-APC draw clean power and does not cause the harmonic distorations of a diode-bridge based converters, while having low reactive power consumption. Filtered voltages at the motor terminals enhances the motor life, which is achieved at low cost with a fewer number of filter components. This work also covers aspects such as regenerative operation which has potential use in small-scale hydel and biogas power plants, and is design to generate miminal electromagnetic noise interference.

This technology can boost the productivity of the agricultural sector. A centralized AC-APC can be used for irrigation, machinery in the agricultural fields, and compressor motors of the cold-storage plants. Typically, multiple small motors are used in a small-scale urban and rural industries, and the developed AC-APC can serve these applications as well.

Anil K Adapa and Vinod John, “An Auxiliary Capacitor Based Active Phase Converter with Reduced Device Current Stress,” IEEE Trans. on Ind. Electron., Sept. 2019.

Anil K Adapa and Vinod John, “Reduced Rating Active Phase Converter for Three Phase Induction Generator based Single Phase Grid-Tied Systems,” PEDES Conf., Dec. 2018.

“A Reduced Switch Count Active Phase Converter with Reduced Component Ratings”, Indian Patent Appl. No. 201741028910, Filed on: Aug. 2018 (Indian Institute of Science, Central Power Research Institute (CPRI) and C-DAC,).



K N Chaudhury (EE)

The quintessential computational problem in imaging modalities such as nuclear magnetic resonance imaging, x-ray tomography, microscopy, etc. is the reconstruction of high-resolution images from physical measurements. Dramatic progress has been made in the last couple of decades producing several powerful ground-truth priors that also yield fast numerical algorithms. Typically, the algorithms are based on iterative methods, where each iteration involves the inversion of the measurement model followed by enforcement of the ground-truth prior. More recently, researchers have come up with an ingenious means of enforcing priors, namely, the image after the inversion (during which artifacts are introduced) is cleaned up using a powerful image denoiser. This so-called plug-and-play paradigm involves the repeated inversion of the measurement model followed by the denoising step. Recently, we have come up with ways of speeding up plug-and-play algorithms (often by a couple of orders) using efficient image denoisers [1,2]; what would typically take minutes can now be done in few seconds. (joint work with Sanjay Ghosh, Unni VS, and Pravin Nair)

P. Nair, V. S. Unni, and K. N. Chaudhury. Hyperspectral image fusion using fast high-dimensional denoising. Proc. IEEE International Conference on Image Processing (ICIP), 2019.

V. S. Unni, S. Ghosh, and K. N. Chaudhury. Linearized ADMM and fast nonlocal denoising for efficient plug-and-play restoration. Proc. IEEE Global Conference on Signal and Information Processing (GlobalSIP), 2018.

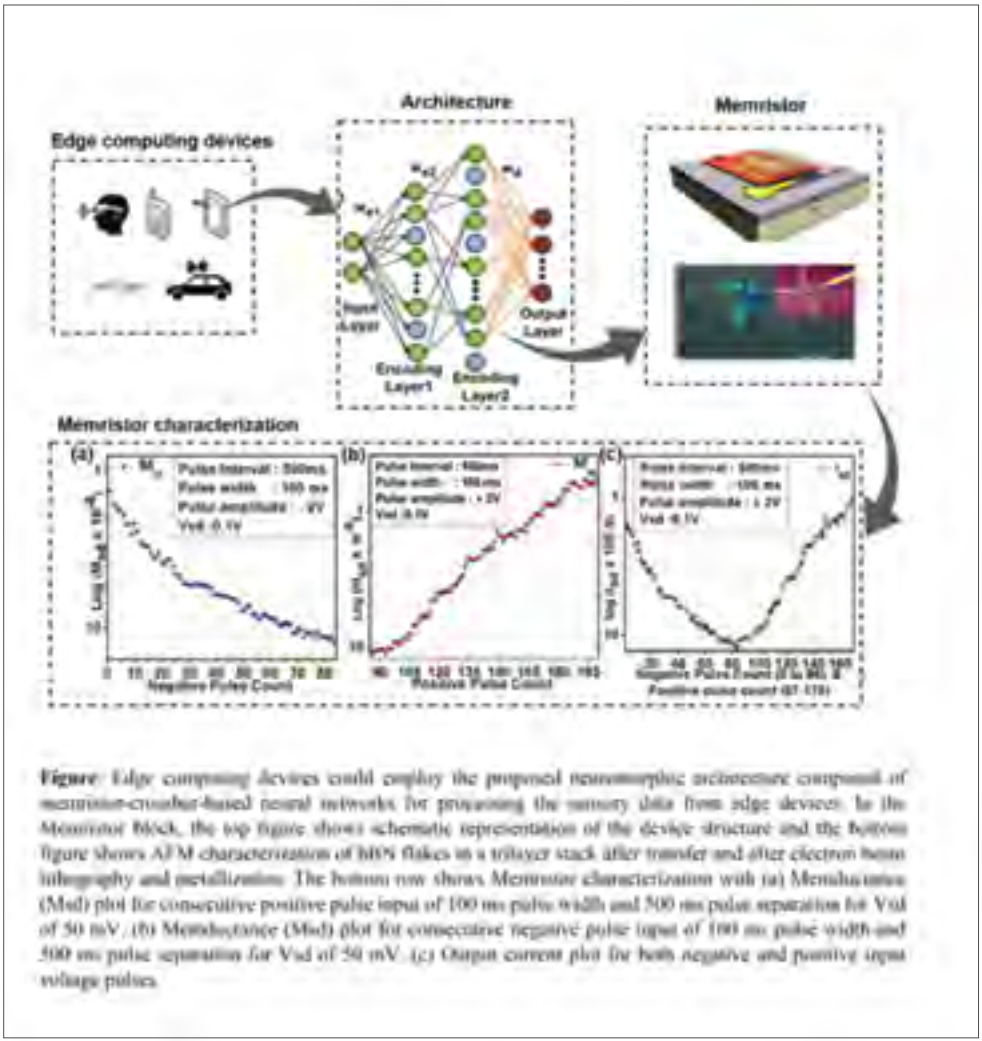


Figure: Edge computing devices could employ the proposed neuromorphic architecture composed of memristor-crossbar-based neural networks for processing the sensory data from edge devices. In the Memristor block, the top figure shows schematic representation of the device structure and the bottom figure shows AFM characterization of hBN flakes in a trilayer stack after transfer and after electron beam lithography and metallization. The bottom row shows Memristor characterization with (a) Memductance (Md) plot for consecutive positive pulse input of 100 ms pulse width and 500 ms pulse separation for Vsd of 50 mV, (b) Memductance (Md) plot for consecutive negative pulse input of 100 ms pulse width and 500 ms pulse separation for Vsd of 50 mV. (c) Output current plot for both negative and positive input voltage pulses.

C S Thakur (DESE)

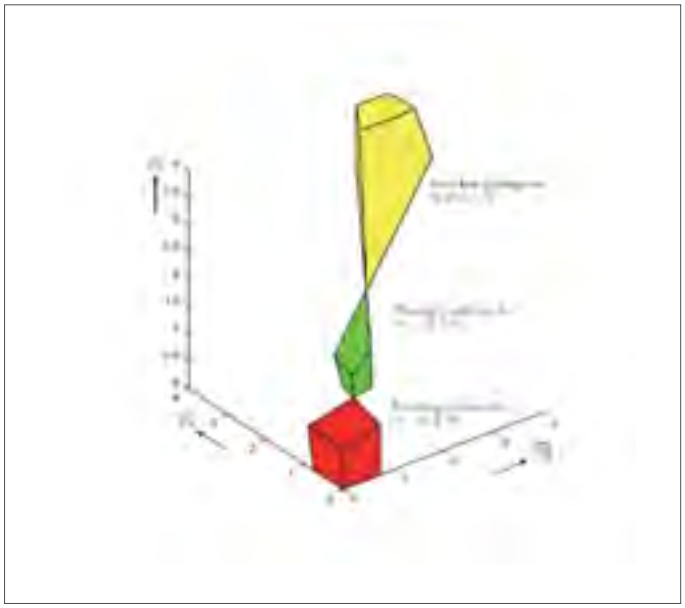
Neuromorphic systems are emerging as a promising promenade towards building the next generation of intelligent computational systems where intelligence is directly embedded onto small, low-power and computationally heavy hardware devices. Owing to the proliferation of internet-of-things (IoTs) in the areas of ubiquitous sensing, there has been an increased demand towards integrating intelligence directly onto edge devices or IoT hardware platform. The machine learning architecture embedded into these platforms needs to be as energy-efficient as possible. We developed a low-power CMOS-Memristor based hybrid architectural framework

for edge computing devices, to enable intelligent data processing directly at the sensor nodes. The basic computational block, i.e., neuron, has been implemented using CMOS analogue circuit and the synaptic connectivity between neurons has been implemented using our novel low-power memristor device as an analogue memory in our cognitive computing framework. This memristor device was fabricated (in collaboration with Prof. Arindam Ghosh, Department of Physics, IISc) using a three-layer stack comprising an ultrathin single layer molybdenum disulphide (MoS2) as the channel, hexagonal boron nitride (hBN) as the dielectric, and an extended graphite floating gate. The power consumption of the basic CMOS computational block is 3nW in the 65nm process technology, while the energy consumption per cycle was 0.3pJ for potentiation and 20pJ for depression cycles of the synaptic memristor device during the training of the machine learning algorithms. The characteristics of the proposed CMOS-Memristor hybrid framework enable it to be employed in onsite processing of data such as in IoT devices, energy- and area-constrained devices.

T. Paul, T. Ahmed, K. K. Tiwari, C. S. Thakur, A. Ghosh, (2019) “A high-performance MoS2 synaptic device with floating gate engineering for Neuromorphic Computing“. *2D Material* (IOP Science).

P. Kumar, A. R. Nair, O. Chatterjee, T. Paul, A. Ghosh, S. Chakrabartty, C. S. Thakur, “Neuromorphic In-Memory Computing Framework using Memtransistor Cross-bar based Support Vector Machines.” *IEEE Midwest Symposium on Circuits and Systems* (MWSCAS), 2019.

S. Gupta, P. Kumar, T. Paul, A. van Schaik, A. Ghosh, C. S. Thakur, “Low Power, CMOS-MoS2 Memtransistor based Neuromorphic Hybrid Architecture for Wake-Up Systems” *Nature Scientific Reports* (In Final Stage), 2019.



Siddharth Barman (CSA)

Fairness is a fundamental consideration whenever resources/goods have to be distributed among competing agents with equal entitlements, but distinct preferences. 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 several contexts, such as border disputes and cloud computing environments. However, to be useful in practice, one also requires scalable methods that explicitly find the underlying fair allocations. Motivated by this consideration, the research group of Dr. Siddharth Barman have developed results that address algorithmic aspects of fair division.

Specifically, a recent work of the group [1] shows that, in a relevant context, 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 of Dr. Barman [2] addresses fairness in settings that entail resource sharing with monetary transfers. This setting 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). Dr. Barman's group is also working towards Blockchain implementations of fair-division algorithms.

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

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

3.3.1 Computer Science and Automation

CHAIRPERSON
SHALABH BHATNAGAR

The Solid State and Structural Chemistry Unit (SSCU) was founded in November 1976. The unit has provided major thrust to frontier areas of Chemistry. Besides developing its own research and teaching programs, unit members interact closely with other departments of the institute. The unit is a premier research centre of global repute in the areas of solid state and physical chemistry. Our faculty and students work in inter-disciplinary areas at the intersection of chemistry, physics and materials science.

Current Research

THEORETICAL COMPUTER SCIENCE

Research in Theoretical Computer Science has been in areas including algorithms, graph theory, complexity theory and cryptography.

In the area of algorithms, we have developed exact and approximation algorithms for k-means clustering. We have proposed efficient algorithms for exact and approximate recovery in semi-random graphs with planted sparse vertex cuts.

We have developed a polynomial time algorithm that guarantees an absolute approximation for Strip Packing problem. We have proposed efficient scheduling

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92 MTech
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16 PhD Conferments

Core Research

Theoretical Computer Science: Algorithms and Complexity Theory, Combinatorial and Computational Geometry, Cryptography, Distributed Computing, Game Theory, and Graph Theory.

Computer Systems and Software: Programming languages, Software Engineering, High-performance computing, Compilers, Computer architecture, Operating Systems, Databases, Systems Security, Scientific Visualization.

Intelligent Systems: Machine Learning, Reinforcement Learning, Game Theory and Mechanism Design, Stochastic Optimization and Control Algorithms, Computational Biology, Data Analytics in Computer Systems.

algorithms for Smart-Grid Allocation. We have designed schemes for fair allocation of resources in various settings. We have proposed a PTAS approximation algorithm for various packing and covering problem on pseudo-disk objects. We have developed an algorithm for augmenting a contour tree and demonstrated applications to data exploration. We have proposed an efficient parallel algorithm for computing the alpha complex, a subset of the delaunay triangulation that has found significant applications in the study of biomolecules.

In the area of graphs, we have improved an upper bound for minimum spanning tree congestion using a constructive proof for a generalized version of Gyori-Lovasz Theorem. We have obtained structural and combinatorial result on Eulerian orientations of even degree hyper cubes, and very strong rainbow coloring. We have designed a tree edit distance-based approach for comparing merge trees, a topological structure that represents topological features in scientific data. The comparison measure satisfies metric properties, it can be computed efficiently, and the cost model for the edit operations is both intuitive and captures well-known properties of merge trees.

In the area of complexity theory, we have made progress on the open problem of

learning homogeneous depth three circuits. We have shed light on various structural and algorithmic aspects of an important family of polynomials, namely the design polynomial family. We have given an efficient algorithm for learning low-width algebraic branching programs.

In the area of codes and cryptography, we have done a comprehensive treatment of the private set intersection problem in the multiple client setting with common set-up. We have proposed a very efficient protocol for k-means clustering over horizontally partitioned data in the multi-server setting. We have provided a comprehensive treatment of conversion frameworks for pairing-based protocols defined over elliptic curve groups of composite order. We have settled the exact round complexity of MPC in the honest majority setting offering a range of security notions. We have designed and benchmarked practical constructions for MPC with 3 and 4 parties providing strong guarantees. We have designed the first linear running-time almost-surely terminating Byzantine Agreement protocol. We have designed efficient Non-malleable Randomness Encoders and have looked at several applications of them.

COMPUTER SYSTEMS AND SOFTWARE

Visualization: A tree edit distance-based approach for comparing merge trees, a topological structure that represents topological features in scientific data has been designed. An algorithm for augmenting a contour tree has been developed, and its applications to data exploration have been demonstrated. An efficient parallel algorithm for computing the alpha complex, a subset of the delaunay triangulation that has found significant applications in the study of biomolecules has been designed.

Privacy and security for autonomous drones: The notion of restricted spaces for drones, which are geographic zones where the activity of the drone can be restricted in ways specified by the host of the restricted space, has been developed.

Tool support for Intel SGX: Tools to assist developers to build applications securely atop the Intel SGX framework, which allows applications to compute safely in adversarial environments have been developed. The Intel SGX has some known side-channels, whose impact became clear only over the last few years. Work on OS-level techniques to close these side-channels is underway.

Computer Architecture: Work on characterizing divergences in GPGPU programs was conducted, targeting measurement of the degree of branch

divergence, memory divergence and workload divergence present in simulated program execution as well as their impact on program performance.

Operating Systems: Work on memory allocation, especially its interaction with RCU subsystem in the Linux kernel and with huge pages, and work on security of Aadhaar privacy/security have been conducted. Currently work on topics such as heap exploitation techniques and coding strategies for blockchains in the context of storage are in progress.

Software Engineering, Program Analysis, Programming Languages, Compilers, and Program Verification: Novel machine learning based solutions for program analysis and software engineering have been developed.

Research in the design of a new compiler intermediate representation for machine learning computations with an emphasis on high performance, modularity, and reusability has been conducted.

A generalized notion of typestate, called parameterized typestate (p-typestate) has been designed as a programming language feature along with a type system. This feature is expressive enough to model many non-regular program properties, and yet has a decidable and efficient decision procedure for type checking.

In the context of automating deductive verification, a decision-tree based learning framework for proving correctness of programs that require multiple invariants, like recursive and multi-threaded programs has been developed. In the area of formal verification of functional correctness, a novel technique called parametric refinement to verify template-based “generative” systems that generate a system for each input specification has been designed.

An approach for precise, scalable points-to analysis for Java programs has been implemented and evaluated. The approach is 50% faster and 30% more precise than a modern baseline approach.

An approach for automated synthesis of controllers for remote vehicles and an approach for static analysis of distributed message-passing programs are under development.

Distributed Systems and Computer Networks: Energy-efficient secure communication protocols and methods in wireless sensor networks have been developed. Symmetric key-based light weight authentication protocols for RFID Security have been designed. Julunga: A new large-scale distributed read-write file storage system for cloud computing environments, Afuronto: a six hop peer-to-peer network of zillions of nodes, 3TAAV: a three-tier architecture for pseudonym-based anonymous authentication in VANETs, and HTU: an efficient Hash-Trie data structure for URL matching for programmable web resources have been developed.

Database Systems: The concave-down behavior of query plan cost functions has been leveraged to improve the efficiency of robust query processing by orders of magnitude.

A new data encryption scheme has been proposed for Cloud repositories which is robust to active attacks by the server in collusion with compromised clients.

A new database regenerator that uses a novel region-partitioning approach has been shown to scale to large query workloads on which contemporary techniques fail to complete.

INTELLIGENT SYSTEMS

The research of faculty members associated with the intelligent systems stream has been in the areas of machine learning, deep learning, reinforcement learning, stochastic approximation algorithms, game theory, mechanism design, pattern recognition, data mining and soft computing.

In the areas of Game Theory and Mechanism Design, the state-of-the-art was advanced in multi-armed bandit based learning models to strategic scenarios where the arms are held by strategic agents. In particular, UCB (Upper Confidence Bounds) based and Thompson sampling based approaches were developed for designing multi-armed bandit mechanisms. Further, work in applying game theory for designing more robust block chain platforms was initiated.

In the areas of Stochastic Approximation Algorithms and Reinforcement Learning, detailed analyses were presented for the first time in scenarios where (a) stability of the algorithm is not guaranteed a priori and (b) the vector field is a set-valued map. Lower bounds on the probability of convergence of the algorithm to a given attractor of the underlying differential inclusion were obtained. As an application, algorithms for computing optimal policies for dynamic energy management in networks of smart grids were designed. Further, novel reinforcement learning algorithms based on cross entropy method that work for off-policy prediction and control that consistently beat the state-of-the-art algorithms over various benchmark experimental domains were also developed.

In the areas of pattern recognition and data mining, our work focused on (a) learning embeddings in social networks in the presence of outliers, (b) fusing diversity in recommendations and (c) providing a generic axiomatic characterization for measuring influence in social networks.

In the areas of machine learning and deep learning, we have contributed to proving the consistency of compressive spectral clustering where one need not compute the eigen decomposition. A deep learning based method that not only learns from the data, but also simultaneously augments its learning from structured knowledge bases like knowledge graphs has been developed as well. Further, theoretical foundations of topic modelling were investigated. Iterative algorithms were also developed for minimizing a convex function over an intersection of sets. Finally, the following topics were explored amongst the application domains: (a) autonomous navigation of small drones in GPS denied environments, (b) deep learning for NLP and machine translation, (c) classification for multiclass imbalance datasets, (d) multi-label classification, prototype selection and dimensionality reduction and (e) predicting robustness of a query plan using machine learning techniques.

Faculty & Staff

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3.3.2

Electrical Communication Engineering

CHAIRPERSON
A CHOCKALINGAM

The Solid State and Structural Chemistry Unit (SSCU) was founded in November 1976. The unit has provided major thrust to frontier areas of Chemistry. Besides developing its own research and teaching programs, unit members interact closely with other departments of the institute. The unit is a premier research centre of global repute in the areas of solid state and physical chemistry. Our faculty and students work in inter-disciplinary areas at the intersection of chemistry, physics and materials science.

Current Research

COMMUNICATION, NETWORKING, AND INFORMATION THEORY

Work on various 5G topics have commenced, such as device-to-device communications, full-duplex radios, and millimeter wave communication systems. Study on Wireless communications and networking-Low-complexity multiuser and MIMO detection, Large MIMO systems, CDMA, OFDM/OFDMA, distributed space-time codes, cooperative and opportunistic communications, energy conscious communications, wireless ad-hoc and sensor networks. A new MIMO modulation scheme, termed as media-based modulation (MBM), has been investigated. Diversity results for full-duplex spatial modulation systems in feedback-assisted MIMO systems and antenna selection for error-prone feedback systems have been developed. In 4G networks, the base stations have to be switched

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Publications 185

Information Theory, Communications, Communication Networking, Signal processing, Photonics, Electromagnetics, Nanoelectronic Devices and VLSI.

off during lean periods for energy efficiency. A well-known algorithm called max-weight algorithm has been augmented with explicit learning for wireless scheduling in a setting where base stations have switching costs. Reduced state scheduling in wireless networks was explored with application to the design of distributed, high performance medium access control. Algorithms have been proposed for deploying IEEE 802.15.4 multi-hop wireless networks, with IoT applications. Formal Specification and Description Language to specify RESTful Web Services was used and the performance was studied and tested.

Index coding for noisy broadcast channels have been studied. In particular, index coded PSK modulation for prioritized receivers and characterizing the number of optimal Index codes and their relation to error performance have been studied. A fundamental exploration of the tradeoffs between public discussion rates and secret-key generation rates in the multiterminal source model has been studied. It is shown that the secret key capacity at zero rate of public discussion equals the Gacs-Korner common information in some important special cases of the multiterminal source model. It has been demonstrated that a certain computational barrier, known to exist for single small-sized community detection problems, disappears when side information (in the form of cues) is available to the analyst. A decision-theoretic basis and a quantitative explanation have been provided for why search times by human subjects to detect an oddball target are inversely correlated with the L1 distance between firing rate vectors elicited by the associated images on macaque brains.

Work on Networks, Stochastic Control, Machine Learning, Performance Analysis and Modelling have been carried out.

SIGNAL PROCESSING, INTER OF THINGS, AND CYBER PHYSICAL SYSTEMS

Study on Digital Signal Processing, Compressed Sensing and Sparse Signal Processing, Sensor Array Signal Processing, and Neuroscience have been carried out. Development of Assisted Living Systems for Healthcare has also made good progress. Several image and video processing topics have been explored, including low light image enhancement, quality assessment of image stitching algorithms, and user experience models for rate adaption in video streaming. Fast k-space sampling techniques for Magnetic Resonance Imaging have been developed using compressed sensing and optimization tools reducing the scan time. New algorithms for distributed sparse signal recovery were developed, when compressive measurements of sparse vectors with a common support are available at the nodes. Online algorithms were also proposed for the recovery of sparse vectors under the multiple measurement vector model.

An open source middleware was developed to enable IoT data exchange and edge analytics.

The middleware is currently getting deployed in a smart city test bed in Electronics City. A key feature of the system is the ability to handle video and video analytics, along with other sensory data. The usefulness of feedback in reducing electricity consumption during a field trial in Aluva in Kerala state, covering 20,000 households has been demonstrated. It suggested methods to reduce consumption, captured usage trends, and provided comparisons with neighbors.

RF, MICROWAVE, PHOTONICS, AND MICROELECTRONICS

Various components for fully integrated radar-on-chip systems are being developed as part of the ongoing indigenous translational research. An all pass filter network-based scheme is developed and tested for potential applications in wideband radar with a low probability of interception. Research on wideband antennas was extended for designing FMCW radar operating at frequencies below 5 GHz with 300 MHz bandwidth. Work on various aspects of computational electromagnetics applicable to high speed circuit design and radio-frequency Imaging has been carried out. Research work is initiated on EMI/EMC pre-compliance simulation methodologies. A novel configuration of integrated optic photonic switch matrix is proposed and analyzed to implement quantum information functions. Laser based indoor VLC system is tested and compared of different remote phosphors.

A novel asymmetrically encapsulated ITO/MoS2/Cu2O vertical heterojunction photodetector was designed and experimentally demonstrated, achieving record high specific detectivity at a given input light power (3.2x1014 Jones @ 0.26 Wm-2) and with a capability of zero external bias operation. Also, an ultra-low operating voltage SnSe2 photodetector was demonstrated with very high responsivity. An unambiguous and novel experimental technique was devised to explain the paradox of negligible photoluminescence peak shift in two-dimensional systems embedded in different dielectric media by introducing energy state dependent varying compensation of excitonic binding energy changes and quasi-particle bandgap renormalization.

Using light and sound to study electron bubbles in helium; Superfluidity in liquid and solid helium; Chiral Spectroscopy and Optical Activity; Optical and hydrodynamic studies of chiral nanostructures and their applications in biology; Soft Condensed Matter Physics have been carried out.

Work on Computational Electromagnetics, Electronic Design Automation (EDA) for high-speed chip-package-systems, Radio-Frequency (RF) sensing and inverse solvers, Antenna analysis and design, Parallel processing for many-core CPU, GPU, FPGA and cloud computing. Microwave Antennas: Microstrip, Fractals Microwave circuits: Passive circuits, Filters; RF energy harvesting and Wireless power transfer circuits Microwave Materials: Ordered and random composites, Their use in microwave systems RF MEMS: Switches, Phase shifters, Micromachined antennas, Phased array antenna, Filters Computational Electromagnetics: FDTD and finite element methods (FEM) for EM wave propagation and antennas Millimeterwave Circuit Design is done.

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Vikram Srinivasan, Adjunct Faculty

3.3.3 Electrical Engineering

CHAIRPERSON
G NARAYANAN

The Department of Electrical Engineering was started in 1911 (then known as Department of Electro-Technics and subsequently changed to Department of Electrical Engineering in 1913), just two years after the founding of Indian Institute of Science. Initially, students were admitted for a post-graduate diploma, known as the Diploma of the Indian Institute of Science (DIISc). Subsequently, the diploma programme was replaced by ME degree programme, which is a post-BE programme, and which has been named as MTech programme recently. The doctoral programme began in the 1950s. In 1970s, the MSc (Engineering) degree, a master's programme by research was introduced to supplement the research activities which is subsequently named as MTech (Research) in the recent past.

Current Research

POWER SYSTEMS

Applicability of Multi-stage Homotopy Analysis Method for large Power System Dynamic Simulations has been shown for the first time in the literature An Online Power System Stability Monitoring System Using Convolutional Neural Networks has been developed which uses heat maps as input, demonstrated applicability of Deep networks for the problem for first time in the literature. Two widely used PLLs have been tested for

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PhD, MTech (Research), MTech (Electrical Engineering), MTech (Artificial Intelligence) jointly with EECS Division, MTech (Signal processing) jointly with ECE

IN NUMBERS

22 Academic Staff
1 Scientific Staff
102 PhD Students
77 MTech, ME
28 MTech (Res)
176 Publications
9 MTech (Res), 21 MTech and 15 PhDs Conferments

Core Research

The research work of the Department of Electrical Engineering falls in two major fields, namely i) Power and ii) Systems and Signal Processing. The area of Power includes Power Systems, Power Electronics and High Voltage Engineering. The Systems and Signal Processing research area includes Machine Learning, Real Time Systems, Multimedia, Image and video Processing, Biomedical Signal Processing and Speech and audio signal processing.

compliance with IEEE C37.118.1a-2014 Standard for Synchrophasor application. Developed a low-cost micro PMU + Power quality analyser for distribution systems. Design and Implementation of IGBT based Static Excitation System with Buck Converter for synchronous machines. In the area of power system protection, A simple linear programming algorithm running in the central Master Controller (MC) to co-ordinate the relays using three different IEEE standard curves is developed. As a part of development activities in microgrid, automated synchronization and re-synchronization is tested and verified in Synchronous Generator-Grid environment in the lab. A piece wise parallel approach to the power flow incorporating generator Q limits with an aim of reducing execution time has been proposed. The proposed algorithm is validated on 118, 300, 2383, 6515 and 9241 bus systems. Results obtained from the study show considerable speedup for larger test cases can be achieved.

POWER ELECTRONICS

Power Electronic converters that can transform single phase power to three phase power is highly beneficial in many applications. A new power converter topology that performs such a task and called Auxiliary Capacitor based Active Phase Converter (AC-APC) has been developed in the laboratory. Tests on the converter shows a significant reduction of up to 60 % in the semiconductor power rating and and more than 50% reduction in power loss in the power converter. Such a converter can be very useful in agriculture,

small industry and for rural electrification. A new method of control of power electronic converters called dual comparison one cycle control has been established based on the research carried out in the laboratory. This control is shown to be simple and can be implemented using simple analog circuits. The control exhibits superior performance, in terms of current ripple, dc offset and overall stability under a wide range of loading conditions. Novel pulse width modulation (PWM) techniques were developed for two-level and three-level inverter fed induction motor drives. These novel techniques help reduce the harmonic distortion in motor current and pulsations in the motor torque in switching-frequency-constrained inverter fed motor drives. Research was also carried out to better understand and compensate the effect of inverter dead time on the motor applied voltage. Improved rotor position sensing technique for slip-ring induction motor was also proposed and demonstrated. Significant research effort was directed towards various aspects of high-speed switched reluctance (SR) machine based generation system. A 5-kW, 10000-rpm (SR) machine was developed indigenously and tested successfully. Other highlights include silicon carbide devices based power converter for SR machine, a novel protection circuit for power devices, and control methods for motoring and generating at low and high speeds. Experimental and theoretical studies in the area of detection of buried landmines using pulsed electric field has been carried out.

HIGH VOLTAGE ENGINEERING

Theoretical studies to design a compensated pulsed alternator (compulsator) to drive an electromagnetic gun has been carried out. Work has been initiated to design and develop pulsed power sources for electromagnetic manufacturing as well as microbial inactivation of liquid food. Work is also continuing in the area of nano-dielectrics as insulating material for various high voltage power apparatus. Plasma Assisted Combustion is yet another active research area of the group. Pollution induced flashover studies on EHV/UHV transmission Insulators Condition monitoring of HV apparatus Corona, Tracking, Erosion & Multistress aging studies on Composite Insulators Studies on High temperature high current low sag (HTLS) conductors Application of power electronics to Solar PV systems, Smart-grids, Smart metering etc. Derived closed-form analytical expressions that correlate harmonic sum of squares of natural frequencies (i.e. both SCNF and OCNF) of a 1-ph, 3-ph, Y- or Delta-transformer winding to its elementary inductances and capacitances for any possible condition of the neutral terminal. Successfully reduced several gaseous pollutants using a cascade of discharge plasma treatment with ozone treatment. A relatively simplified method has been developed for determining the lightning stroke current distribution on the skin of the aircraft. 2. Several modifications have been attempted on Finite Difference Time Domain Method so as to model lightning return stroke channel

SYSTEMS AND SIGNAL PROCESSING

A novel CNN based continuous monitoring system developed for assessing transient stability of a Power System following a fault. New robustness results proved for learning multi-class and multi-label classifiers under label noise. Transfer learning method suggested for CNNs using the novel concept of bank of filter trees. Fast algorithms algorithms for high-dimensional filtering have been designed. Interesting Results on convergence analysis of nonconvex ADMM show the efficacy of the algorithm. A distributed algorithm for rigid registration of point sets has been designed and uniqueness results for rigid registration have been observed. Conducted research in the broad areas of networked control systems and networked transportation. - In the area of networked control systems, we have explored multiple problems related to resource aware online sampling for control. In particular, we have looked at the implicit timing information carried in

the online sampling instants, online sampling under sensing and actuation time delays and online sampling for control under channel blackouts. These works have reached a mature stage and we have submitted them to journals. In addition, in 2018, we had also initiated work on online sampling for control over Markov channels and other problems. - In the area of Networked transportation, we submitted a paper on hierarchical-distributed coordination of intersection traffic for autonomous and networked vehicles. In addition, we also initiated research on coordinating feeder vehicles in multi-modal transport. On the topic of Geometric Methods for Accurate 3D Registration of Depth Representations, we developed a highly efficient and accurate method for 3D registration of depth representations such as scans or depth maps. Our approach exploits the geometric (Lie group) structure of 3D motions. This method is also extended to the multiview scenario where we jointly solve the 3D registration problem for multiple scans. Our approach matches the state-of-the-art method in accuracy and outperforms it in speed.

Focus areas of research in the computer vision includes the following 1) Cross-modal matching: Given the data from one modality, the goal is to retrieve semantically meaningful data from another modality. This has several applications like matching image-text, photo-sketch, NIR-visible data, etc. We are developing algorithms to handle noisy data, unseen data, unlabeled data, etc. 2) Current classification algorithms cannot handle incoming data from unseen classes. We are working on different aspects of this challenging problem like utilizing attributes for classifying data from unseen classes (zero-shot learning), detecting data from unseen classes (novelty detection), etc. 3) We are also working on different applications related to autonomous driving, like semantic segmentation of urban scenes, object detection, etc. In the area of digital signal processing, the research work carried out includes Visual Speech Recognition, Indian Sign language recognition, Reconfigurable and scalable FPGA Architectures and implementing Image denoising in hardware. We have developed a framework for addressing and solving the problem of phase retrieval in the presence of quantization error. In the area of image processing and deep learning, the research work includes the development of new wavelet-based reconstruction strategies for unlimited sampling, which is a new sampling strategy that promises to offer an unlimited dynamic range. We have also filed a patent on realizing analog-to-digital converters that work on the principle of unlimited sampling. Novel strategies have been developed for performing shape-specific segmentation and demonstrated applications to fundus images, which greatly aided in the automated assessment of glaucoma. Approaches for acoustic source localization, new risk minimization strategies for speech signal denoising, and new and robust techniques for spectrotemporal modeling of the speech signal have been developed. It has been discovered that a new class of signals that can be reconstructed from their magnitude spectrum and established Hilbert integral relations. Advanced techniques for robust extraction of several parameters of voicebox from speech acoustics Improved understanding of articulation during different modes of speech has been developed.

In the area of biomedical imaging, the research work includes development of a novel type of regularization for MRI reconstruction that results in lower reconstruction error compared other regularizations used so far. The new regularization has power to eliminate large amount of noise without suppressing image resolution. Further, a novel type of regularization for reconstructing images from highly under-sampled non-uniform spatial point measurement with application to speeding up confocal microscopy has been developed. For this problem, the widely celebrated compressive sensing regularization fails. The regularization is adaptive to image structure and yield high quality reconstruction.

Also, expanded the research activities in a range of different directions such as pschyophysicis and neuroscience, understanding human performance on speech tasks, speech recognition and language recognition.

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Supratim Ray | PhD (Johns Hopkins), Assistant Professor

3.3.4 Electronic Systems Engineering

CHAIRPERSON
JOY KURI

Department nurtures educational research with a theme: “Atom to System”, which encompasses nanoelectronics, signal and information processing, neuromorphic integrated circuits, diagnostic and healthcare devices, communication networks and Internet on Things, and power electronic drives. It runs country’s one of the most unique and successful M.Tech. program in “Electronic Systems Engineering”.

Current Research

In nanoelectronics, atom-to-circuit modeling methodology is developed that enables systematic performance evaluation of emerging 2D materials at device and circuit levels before entering into capital-intensive manufacturing phase. A hardware-accelerator-assisted high-throughput density-functional-theory based structure-searching technique is proposed to model the reversible lithium storage capacity of 2D materials. First-of-the-kind high power devices have been developed for FinFET technology for design and manufacturing in SoCs in FinFETs and related CMOS nodes. The entire gamut of channels engineering algorithms, and related circuits, have been conceived for two-dimensional magnetic recording. Also, encoders have been developed for quantum stabilizer codes over qudits. There is development of unlimited dynamic range ADCs, and neuromorphic event-based activity recognition engines. A coprocessor implementation on Xilinx Kintex

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IN NUMBERS

16 Faculty & Staff
75 PhD
75 M.E/M.Tech
68 Publications
2 PhD conferments

Ultrascale XCKU085 based HTG-K800 FPGA board for classification and training of images using binary connect CNN is conceived. Microneedle arrays have been developed for paediatric applications. In the area of electronics for health-care, there is work on electronic-nose and non-invasive technologies for breath analysis. In the area of network security and IoTs, a network testbed is built that can be used to test various security solutions following a behaviour based approach. Further, there is design and construction of a fast loop algorithms to detect air anomaly inside airplane cabins. This includes CO2 build up, particulate matter and ozone anomalies at cruising altitudes. Also, in the area of communication networks, the problem of distributed scheduling in wireless communication networks where heterogeneously delayed queue lengths and channel states of all links are available at all the transmitters is researched. In the area of power electronics, multilevel inverters with switched capacitive filers for the suppression of low frequency harmonics for variable speed drives have been developed. Also, there is active work on active power decoupling, universal adaptable converters for grid interfaces, inter-inverter communication by means of fractional harmonics, virtual energy internet, grid emulation, traction drive for electric vehicles, self-commissioning of electric vehicle drives, high gain boost topology for ultra-capacitor interface to dc-link of electric drive or dc-link of grid interface converter.

Faculty & Staff

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TV Prabhakar | PhD (Tu Delft), Principal Research Scientist
Chandramani Singh | PhD (IISc), Assistant Professor
Shayan Garani Srinivasa | PhD (Georgia Tech), Associate Professor
Mayank Srivastava | PhD (IIT Bombay), Assistant Professor
Chetan Singh Thakur | PhD (Western Sydney), Assistant Professor
L Umanand | PhD (IISc), Professor
Kuruvilla Varghese | MTech (IISc), Principal Research Scientist
V Nagakrishna | Scientific Officer Gr II
P Ramachandran | Scientific Officer Gr II

Core Research

Nanoelectronics and power semiconductor devices, Signal and quantum information processing, Communication Networks, Internet of Things (IoT) and Embedded Systems, Very Large Scale Integration, Neuromorphic Engineering, Power electronics Drives, Energy Harvesting, Mechatronics, Microengineering of diagnostic devices

3.4 Division of Interdisciplinary Research

IN NUMBERS

- 36 FACULTY MEMBERS
- 275 PhD STUDENTS
- 119 MASTER'S STUDENTS

Interdisciplinarity is the characteristic feature of the research carried out in this Division. Specific research areas include Bioengineering, Urban infrastructure and transportation, Nanoscale materials, Nano devices and systems, Economics, Finance, Human resource management, Marketing, Optimization, Public policy, Energy, Water, Internet of things, Distributed sensing, Computer systems, Computational science, Data sciences and bioinformatics.

THEMES

Interdisciplinary research has emerged as a crucial component of the research landscape in recent years. By breaking down departmental barriers, interdisciplinary research facilitates novel breakthroughs that may not be possible within the confines of a particular discipline. The Division of Interdisciplinary Research has a wide range of Departments/Centres with the common theme of a strong interdisciplinary focus.

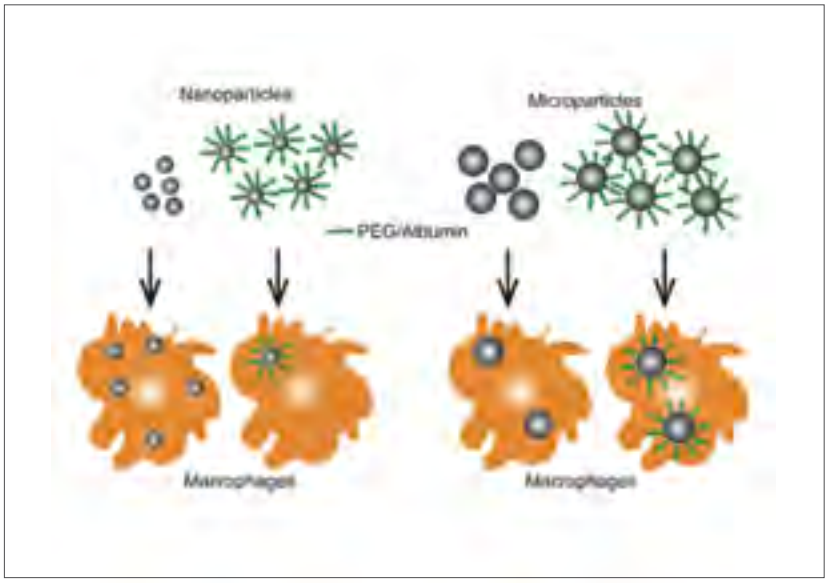
RESEARCH HIGHLIGHTS

The Division of Interdisciplinary Research consists of the Centre for BioSystems Science and Engineering, Centre for Society and Policy, Centre for Infrastructure, Sustainable Transportation and Urban Planning, Centre for Nano Science and Engineering, Department of Computational and Data Sciences, Department of Management Studies, Interdisciplinary Centre for Energy Research, Interdisciplinary Centre for Water Research, Robert Bosch Centre for Cyber Physical Systems and Supercomputer Education & Research Centre

DEPARTMENTS | CENTRES | UNITS

- CENTRE FOR BIOSYSTEMS SCIENCE AND ENGINEERING
- CENTRE FOR SOCIETY AND POLICY
- CENTRE FOR INFRASTRUCTURE, SUSTAINABLE TRANSPORTATION AND URBAN PLANNING
- CENTRE FOR NANO SCIENCE AND ENGINEERING
- COMPUTATIONAL AND DATA SCIENCES
- MANAGEMENT STUDIES
- INTERDISCIPLINARY CENTRE FOR ENERGY RESEARCH
- INTERDISCIPLINARY CENTRE FOR WATER RESEARCH
- ROBERT BOSCH CENTRE FOR CYBER PHYSICAL SYSTEMS
- SUPERCOMPUTER EDUCATION AND RESEARCH CENTRE

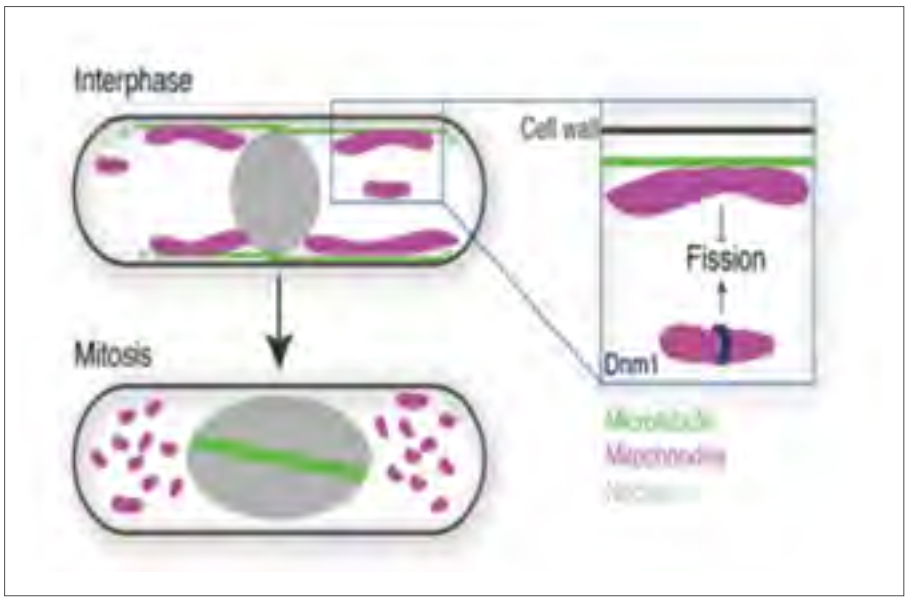
Research Snapshots 2018-19



Siddharth Jhunjhunwala (BSSE)

A number of nano- and micro-particulate formulations are either currently in use or are being developed for a variety of biomedical applications. These particulates are primarily cleared from the body by phagocytes, and preventing this process is necessary to improve circulation or retention times. A common strategy to prevent phagocytic uptake of nano-particulates is to coat their surface with polyethylene glycol or albumin. However, it remains unclear if this strategy works for particulates of all sizes. In this study, Siddharth Jhunjhunwala's team show that the aforementioned surface modification strategies that help nano-particulates evade phagocytic uptake do not work for micro-particulates. Further, it highlights the need to reassess the importance of particulate size in clearance from the body.

Preeti Sharma, Devashish Sen, Varsha Neelakantan, Vinidhra Shankar, Siddharth Jhunjhunwala*. Disparate effects of PEG or albumin based surface modification on uptake of nano-and micro-particles. *Biomaterials Science, 2019.* Vol. 7, Pg. 1411-1421. DOI: 10.1039/C8BM01545G



Vaishnavi Ananthanarayanan (BSSE)

Most of us remember from our early years of learning biology that mitochondria are the ‘power house of the cell’. The textbook representation of mitochondria that we are familiar with is not entirely accurate. Within a cell, mitochondria are actually present in the form of an intricate network of tubes that are constantly moving about, bumping into each other and tearing apart. This dynamic nature of mitochondria is characteristic to any healthy, living eukaryotic cell. To enable these dynamics, separate players - molecular scissors which cut the mitochondria, and molecular glues which enable fusion of mitochondria – are essential. All these players come together to maintain a perfect balance of fission and fusion for the proper functioning of the cell.

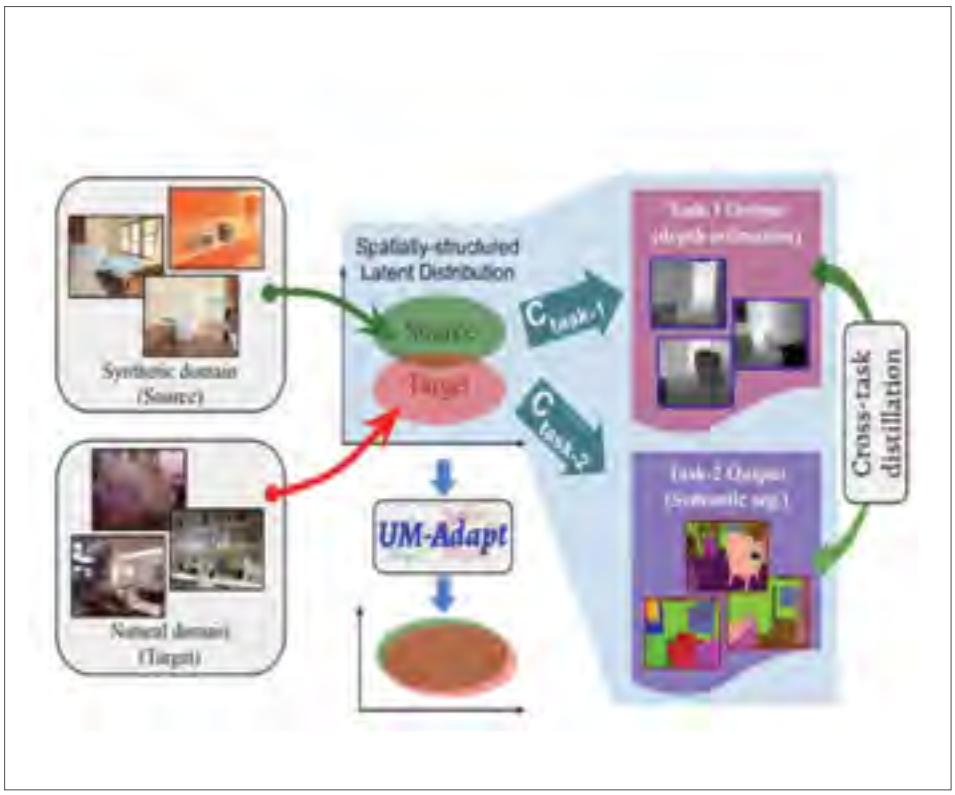
Recent work from our lab has shown that another component of cells, the cytoskeleton, which can be thought of as the skeleton inside your cells, plays an important role in controlling mitochondrial dynamics. This class of cytoskeletal structures called ‘microtubules’, are self-organizing tubes that can grow and shrink. In the model organism we used in this study, called the fission yeast, mitochondria remain bound to the microtubules. We discovered that this attachment to microtubules is essential to maintain the balance between fission and fusion of mitochondria. When microtubules shrink, mitochondria undergo fission, and conversely, when microtubules grow, mitochondrial fission is prevented. Why is this important? In several diseases including neurodegeneration, mitochondrial form, and therefore function, is affected. This work gives us insight into how we might be able to restore mitochondrial function in disease states by changing microtubule dynamics.

Mehta + , Chacko + , Chug, Jhunjhunwala and Ananthanarayanan*. (2019) Association of mitochondria with microtubules inhibits mitochondrial fission by precluding assembly of the fission protein Dnm1. (in press) (+ , equal contribution; *, corresponding author) http://www.jbc.org/content/early/2019/01/02/jbc.RA118.006799

M Sekhar (ICWaR)

Groundwater accounts for approximately half of Indian urban water use. We conducted a study to understand the sustainability and future water security of groundwater resources in Bangalore city, which is largely unknown. Moreover, very little is known about role of recharge from extreme events, which have the potential to buffer urban floods. The study revealed that in highly urbanized areas such as Bangalore we could show that the natural water cycle is altered dramatically by the effect of leaking pipes and recharge of waste water in resulting in the positive groundwater balance in core areas. However, in the rapidly growing peripheral areas, the converse was true. The excess rainfall event during August–September 2017 had resulted in a recharge of 47 Mm3 for those months when compared to 19 Mm3 for the entire year of 2016.

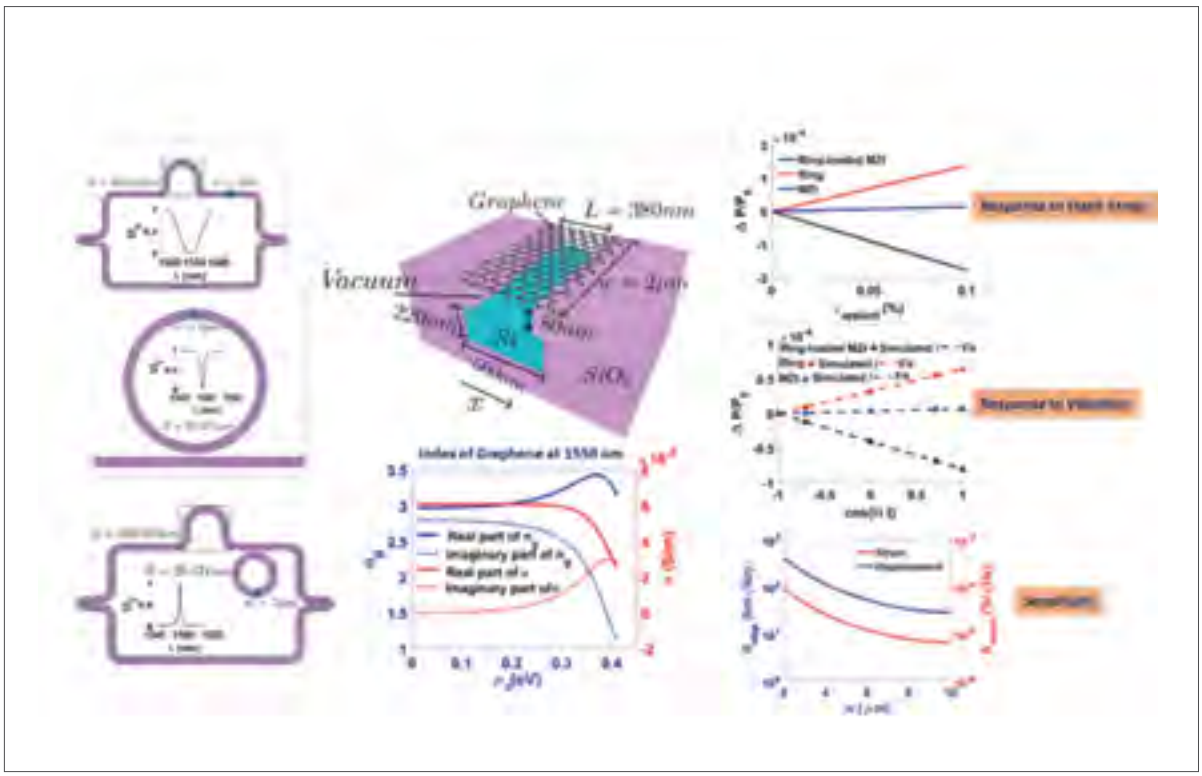
Sekhar, M., Tomer, S., Thiyaku, S., Giriraj, P., Murthy, S., & Mehta, V. (2018). Groundwater Level Dynamics in Bengaluru City, India. Sustainability, 10(1), 26.



Venkatesh Babu R (CDS)

Recent advances in deep learning heavily rely on the availability of a huge amount of clean annotated information involving substantial manual effort. Although such methods achieve near human-level performance on popular benchmarks, many recent studies show that these benchmarks only weakly test their intended purpose, because these models exhibit an alarming level of dataset-bias (or non-generalizability). Generalization refers to the intelligence, or the ability of abstraction, that enables an algorithm/model to be effective across a range of inputs and applications. Most of the existing approaches independently address task-transferability and cross-domain adaptation, resulting in limited generalization. In this research work, we have proposed a simple, yet effective unsupervised multi-task adaptation framework, that yields generic image representations with superior transferability across both tasks and domains. Such a learning approach is of immense importance for the advancement of Artificial Intelligence, as it not only reduces the data-dependency of deep models, but also provides an effective solution to adapt models trained solely on controlled synthetic environment, to unknown natural scenarios.

Jogendra Nath Kundu, Nishank Lakkakula, R. Venkatesh Babu, “UM-Adapt: Unsupervised Multi-Task Adaptation Using Adversarial Cross-Task Distillation”, accepted in IEEE International Conference on Computer Vision (ICCV) 2019.



Akshay Naik (CeNSE)

Scaling of Micro-Electro-Mechanical System (MEMS) toward highly sensitive nano-electro-mechanical systems (NEMS) requires the use of ultra-low mass structures like Graphene membrane. The fundamental question is - how would the material would behave when the size is scaled to a one or two atomic layers? Characterising mechanical property of such materials becomes extremely challenging with the current techniques. Recently, researchers at Centre for Nano Science and Engineering, IISc have proposed a novel method to measure strain and displacement of Graphene. The transduction scheme exploits Silicon Photonics; a versatile photonic integrated circuit platform developed for optical interconnect application. The scheme uses overlap between a guided wave and Graphene to interrogate the changes in the mechanical property which is demonstrated to detect the strain and displacement of graphene based nanoelectromechanical system. The scheme, if implemented using ring loaded Mach-Zehnder interferometer with modest optical quality factors of about 2500, should be able to achieve displacement sensitivity of about 30fm/√Hz and strain sensitivity of 6x10-6 %/√Hz. This is the first time such an integrated photonics-based transduction proposal is made and accepted by the community as a viable option for probing materials at such extreme scale.

Ref: Aneesh Dash, S. K. Selvaraja, and A. K. Naik, “On-chip optical transduction scheme for graphene nano-electro-mechanical systems in silicon-photonic platform”, *Optics Letters, 2018.* DOI: 10.1364/OL.43.000659

3.4.1

Centre For Biosystems Science And Engineering

CHAIRPERSON
G K ANANTHASURESH

The Centre for BioSystems Science and Engineering (BSSE) at the Indian Institute of Science (IISc) was founded on June 4th, 2015. BSSE undertakes research and training in the broad multi-disciplinary area of biological systems with equal emphasis on science and engineering by bringing together biologists, engineering, and those who are trained as bioengineers

Current Research

SYSTEMS BIOLOGY OF CANCER

The aim of this work is to understand the dynamics of Epithelial-Mesenchymal Transition (EMT) and Cancer Stem Cells (CSCs) – the two key drivers of cancer metastasis and therapy resistance. We offered novel insights into different subsets of CSCs/EMT cells can organize themselves at different locations within a tumor and identified a potential therapeutic target to alleviate tumor progression.

QUANTITATIVE CYTOSKELETAL BIOLOGY

The objective of this work was to identify the relationship between microtubules and mitochondria and the effect of microtubule attachment on mitochondrial dynamics. In fission yeast, mitochondria associate with microtubules during interphase. We observed that in mutants of microtubule dynamics that result in cells with long and short microtubule bundles, mitochondria exhibit long but few, and short but several mitochondria respectively.

FACT FILE

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Degree Programs offered PhD

IN NUMBERS

4 Academic Staff
32 PhD students
27 Publications

We discovered that the correlation between microtubule and mitochondrial lengths was a consequence of increased fission of unbound mitochondria. During mitosis, cells employed this property of increased mitochondrial fission upon reorganization of the cytoplasmic microtubules into the spindle, to partition mitochondria stochastically between daughter cells with low partition error (bioRxiv 2018).

DRUG DELIVERY

Polymeric systems, particularly, micro- and nano-carriers have emerged as a promising solution for the targeted delivery of active drugs. Use of particles for delivery offers several advantages. Biologics are protected from the harsh external environment present (immune clearance and enzymatic degradation) during their voyage and increases their bioavailability at the target site. Particles can be designed to target specific sites including organ, cells and intra-cellular targets. For this part of the research, we are particularly interested in applying biomaterial and nano- and microcarrier-based research to bridge the gap between basic biology and clinical therapies by designing polymeric particle-based vehicles to effectively deliver cargo to their target sites. The major focus is to utilize particle technologies to develop engineering platforms for targeted and efficient delivery of therapeutics for treatment of chronic inflammatory diseases such as osteoarthritis and persistent antibiotic resistant bacterial infections such as in case of tuberculosis.

IMMUNOENGINEERING

Research in this area is directed towards the development of drug delivery systems and biomedical implants that have the capacity to modulate inflammatory immune responses with the ultimate goal of treating specific diseases. Our current focus is on developing strategies to treat complications that arise from type-2 diabetes and characterizing the immune micro-environment associated with tumours.

Faculty & Staff

Rachit Agarwal | PhD (Texas), Assistant Professor
Vaishnavi Ananthanarayanan | PhD (Max Planck Institute, Dresden), Assistant Professor
Mohit Kumar Jolly | PhD (Rice), Assistant Professor
Siddharth Jhunjhunwala | PhD (Pittsburgh), Assistant Professor

Associate Faculty

GK Ananthasuresh | PhD (Michigan),
Ganapathy Ayappa | PhD (Minnesota), Professor
Bikramjit Basu | PhD (Katholieke), Professor
Dipshikha Chakravortty | PhD (NCCS), Professor
Nagasuma Chandra | PhD (Bristol), Professor
Kaushik Chatterjee | PhD (Penn State), Assistant Professor
Saumitra Das | PhD (Kolkata), Professor
Narendra Dixit | PhD (Illinois), Associate Professor
Namrata Gundiah | PhD (Berkeley), Associate Professor
Ashok M Raichur | PhD (Nevada), Professor
Annapoorni Rangarajan | PhD (NCBS), Associate Professor
Rahul Roy | PhD (Illinois), Assistant Professor
Deepak Kumar Saini | PhD (AIIMS), Assistant Professor
Sandhya S Visweswariah | PhD (IISc), Professor

Core Research

The primary research areas of BSSE include Computational Systems Biology, Mathematical Biology, Drug Delivery, Biomaterials, Quantitative Cell Biology, Biophysics and Immunoengineering.

3.4.2

Centre For Society and Policy

CHAIRPERSON

ANJULA GURTOO

The Centre for Society and Policy (CSP) is a policy research centre, established in November 2018. As an interdisciplinary centre for science and technology policy, the centre explores interactions between science, technology, society, and development. The Centre researches and initiates dialogues with the aim to expand the social compact, that is, honour the implicit agreement between science and society to work together for sustainability, and mutual benefit. The Centre organizes seminars, lectures, and outreach through workshops and training programmes. It has a vibrant visiting faculty program to attract leading scientists and researchers in the field of science and technology policy.

Current Research

The CSP today addresses several policy agendas including sustainable futures, intellectual property rights, health policy, impact assessments, urban development, genetics and society, entrepreneurship, and Crowd work and informal economic systems. The centre contributes to the knowledge on S&T policy through policy briefs and working papers. The centre has several eminent visiting professors and scholars. The centre is committed to policy engagement and impacting policy at all stages of S&T research.

FACT FILE

Established: November 2018

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Core Research

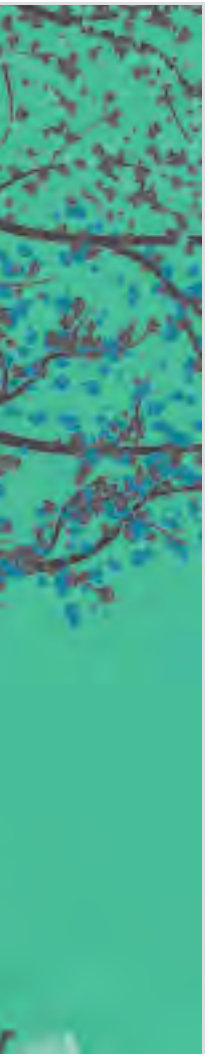
The primary research areas of BSSE include Computational Systems Biology, Mathematical Biology, Drug Delivery, Biomaterials, Quantitative Cell Biology, Biophysics and Immunoengineering.

Faculty & Staff

Anjula Gurtoo | PhD (IIM Ahmedabad), Professor
TA Abinandanan | PhD (Carnegie Mellon), Professor
Bitasta Das | PhD (Manipal), Instructor – Humanities

3.4.3 Computational and Data Sciences

CHAIRPERSON
SASHI KUMAAR GANESAN



The department focusses on inter-disciplinary programs driven by computation and data- intensive methods, systems and applications. The research is aligned along computational science and computer and data systems. The former explores computational methods and applications to scientific domains, while the latter into design, implementation and evaluation of high performance hardware and software systems.

Current Research

In the domain of Computer and Data Systems, several advancements were achieved this year. In the area of database systems, a workload-dependent database regenerator, named HYDRA, was designed that materially improves on the prior art by adding scale, dynamism and functionality. Additionally, novel encryption schemes were designed for cloud-resident databases, along with some new robust query-processing algorithms. On high performance/parallel computing side, a multi-node multi-device algorithm was proposed for finding the minimum spanning-tree that increased efficiency in processing large-scale graph applications on heterogeneous CPU-GPU systems. In large-scale distributed systems research, the highlights were a novel interval-centric computational model for performing analytics on large dynamic, temporal graphs as well as an energy and latency-aware scheduling heuristics for stream and task processing on edge plus cloud and elastic cloud

FACT FILE

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Degree Programs offered MTech and PhD

IN NUMBERS

14 Academic Staff
6 Scientific Staff
40 PhD students
2 MSc (Engg.) students
41 MTech students
25 MTech (Res) students
72 Publications
7 MSc (Engg.), 1 MTech (Res) and 6 PhD conferment

Core Research

- Computational methods for Compressed Domains, Dynamical Systems, Finite elements, Natural language processing, Numerical analysis, Signal processing, Statistics etc.
- Computational Science research aims to design architectures and platforms for Big Data, Cloud computing, Databases, Accelerators, Reconfigurable Architectures, hybrid CPU-GPU graph processing, middleware strategies for supercomputer systems, etc.
- Computer and Data systems research find application in Climate modelling, Electromagnetics, Fluid mechanics, Internet of Things, Knowledge Harvesting, Medical imaging, Video Analytics, Photonics, Structural biology, Systems Biology, etc.

resources. In the area of data science, deep neural network based novel algorithms and learning frameworks have been the focus. The major research contributions spanned the areas of representation learning, document-dating, distantly supervised neural relation extraction, inductive framework for multi-aspect tensor completion to name a few. Major successes have been achieved in evaluating the robustness of deep neural nets under adversarial attacks and probable remedies were proposed using adversarial training. Besides these, works on domain adaptation from synthetic to natural images and improving person re-identification systems via incorporating human-operator feedback have also reported very promising results. In computational sciences too, some very important research successes were observed in 2018. Novel regularization methods have been proposed towards improving reconstructed photoacoustic images. Additionally, computationally efficient image-guided filtering based fusion approach has been developed towards improving photoacoustic imaging. An algorithm based on direct data-assimilation to dynamical system was also designed, which is being used in ISRO's NAVIC-IRNSS precision satellite orbital estimation. Another major research milestone was achieved with the successful completion of a theoretical, computational and experimental study on discovering quantum effects of matter on photon when an emitter is near a limiting small absorbing/metallic nanoparticle or when placed at limiting small distances from an absorbing/metallic structure. In computational biology and bio informatics, progress was achieved in the areas of drug discovery, development of algorithms for accelerated secondary analysis of genomes, structural modelling of several different proteins explaining their molecular properties and modelling of metabolic diabetes.

Faculty & Staff

Deepak N Subramani | PhD (MIT), Assistant Professor
Anirban Chakraborty | PhD (UC Riverside), Assistant Professor
R Venkatesh Babu | PhD (IISc), Associate Professor
Sashikumaar Ganesan | PhD (Otto-Von-Guericke), Associate Professor
Jayant R Haritsa | PhD (Wisconsin-Madison) Professor
SK Nandy | PhD (IISc), Professor
Debnath Pal | PhD (Jadavpur), Professor
Soumyendu Raha | PhD (Minnesota), Professor
K Sekar | PhD (Madras), Professor
Yogesh Simmhan | PhD (Indiana), Assistant Professor
Partha Pratim Talukdar | PhD (Penn), Assistant Professor
Sathish S Vadhiyar | PhD (Tennessee), Associate Professor
Murugesan Venkatapathi | PhD (Purdue), Associate Professor
Phaneendra Yalavarthy | PhD (Dartmouth College), Associate Professor

3.4.4

Centre for Nano Science and Engineering

CHAIRPERSON
NAVAKANTA BHAT

CeNSE is an interdisciplinary research centre with a focus on nanoscale systems. The research facilities include national nanofabrication facility (14,000 square feet clean room) and characterization labs that cater to material, electronic, mechanical, chemical and optical characterization. At present, the centre has 12 faculty members, 144 PhD and 10 MTech students.

Current Research

An on-chip optical transduction scheme is demonstrated to detect the strain and displacement of graphene based nanoelectromechanical system. The scheme, if implemented using ring loaded Mach-Zehnder interferometer with modest optical quality factors of about 2500, should be able to achieve displacement sensitivity of about 30fm/√Hz and strain sensitivity of 6x10-6 %. It was highlighted as Editor's pick article in Optics Letters.

Novel devices have been developed and demonstrated in silicon photonics for high-speed communication. For the first time, a passive bandwidth of 15GHz in crystalline Si for all-optical signal distribution is demonstrated. An aggregate data rate of 48 Gbps over four channels is shown. Using silicon photonics platform, on-chip highly sensitive simultaneous measurement of absorption and density of fluids is developed and an on-chip theoretical

FACT FILE

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Degree Programs offered: MTech, PhD

IN NUMBERS

12 Academic Staff
144 PhD students (regular)
10 PhD students (ERP)
10 MTech students
174 publications

limit of 340 nm/RIU has been achieved for the proposed configuration. The platform would be used for chemical and bio sensing.

Million-fold reduction in UV detector dark current has been achieved. Of importance to ultra-violet detector applications, a million-fold reduction in dark current was linked to the presence of microscopic defects called screw dislocations in GaN. This result in expected to have a significant impact not just on GaN opto-electronics (such as UV detectors for strategic applications) but also for GaN power electronics. A UV detector is supposed to generate current only in the presence of UV illumination. Dark current is a current that flows across the detector even in the absence of UV illumination. Thus, a reduction in this dark current is essential to enable sensitive detectors.

A simple, wafer-scale and low-cost liquid phase epitaxy (LPE) technique is developed to grow high-quality epitaxial germanium on silicon. The method is orientation agnostic; it works well for Ge (100), Ge (111) and Ge (110). Hall mobility in these films is the highest ever reported for polycrystalline Ge on silicon. Ozone-treatment for aluminum-doped ZnO surface has been developed that reduces recombination at AZO/perovskite interface, improving device performance. $BaBiO_3$ and Ag_2CrO_4 are developed as possible absorbers for thin-film all-oxide solar cells.

Energy loss mechanisms such as Akhieser effect, Thermoelastic dissipation, Clamping loss, Resistive Loss and Air Damping in MEMS and NEMS are being studied as a function of material properties and geometry and its relationship with phase noise. A Fluctuation-Dissipation lab is being set up with state-of-the-art equipment needed for engaging in the proposed research. Research efforts have also begun toward study of internal fluid flow in MEMS resonators. Packaging of MEMS and NEMS devices is undertaken for enabling fabrication of reliable sensors. Work has started toward an advanced packaging technology called Epi-seal. Development of sensor systems and systems for fabrication technology is also being undertaken.

Effort is being initiated towards emerging gallium oxide materials and devices for next-generation power electronics and deep-UV devices, including setting up an indigenous materials growth platform. In parallel, GaN transistors for RF and power electronics are being developed as technology deliverables. High performance buried channel normally-off MOS HEMT has been developed by optimizing Mg doped GaN layer.

Highly sensitive Hydrogen sulphide sensors are developed using nano-disc decorated suspended W-WOx core-shell nanostructure. NO_2 gas sensing in ppb level is demonstrated using thickness and microstructure optimized WO_3 films. Microwave synthesized NiO films are developed for room temperature NO_2 gas sensing. Joule heating has been demonstrated in O_2 ambience as a novel technique to create metal-metal oxide core-shell structures. Superparamagnetic, nanocrystalline Cobalt ferrite thin films have been developed using low temperature microwave synthesis for RF CMOS applications. Application of point-of-care diagnostics for the monitoring and management of diabetic kidney disease is undertaken. Creatinine electrochemical sensor is demonstrated using $FeCl_3$ based dry chemistry. Hydrophobic mediated growth of galvanic-nanobuds from germanium nanowires has been demonstrated for a highly tunable SERS substrate in biosensing.

Fundamental studies pertaining to microscale droplet impact on nanostructured meshes has led to the development of a low-cost micro-droplet printing technique. A fabrication process has been developed for demonstration of large-area nanostructured flexible surfaces for antimicrobial applications. An air-

liquid interface-based device for cell capture and manipulation in microchannels has been developed. This provides a mechanical element (like robotic arm) for complex manipulations in a microchannel. A device capable of estimating cell's mechanical properties from the time information in electrical impedance data has been demonstrated. Research in Heterogeneous Integration and System Scaling lab has led to demonstration of a new 3D integration scheme for ultra-thin devices. 3D Stacks of various functional devices have been demonstrated. Extended functionality tests have demonstrated their long-term reliability

Magnetic dipole resonances in chiral and achiral dielectric metamaterials are being engineered. Sensitive UV photodetection in graphene-silver hybrid devices has been demonstrated. Manoeuvrability of magnetic nanoswimmers within living cells and their application as mobile viscometers have been demonstrated. A therapeutic and stable suspension of ferrite coated magnetic nanoswimmers is demonstrated. Plasmonic nanoparticles are integrated with magnetic nanoswimmers to develop a system of mobile nanotweezers. Studies are undertaken toward understanding the collapse of vapor bubbles in liquid helium.

Piezo-MEMS devices are developed that include ultrasound transducers (PMUTs) and piezo actuators. This work has necessitated research in material development for MEMS-suitable thin film piezoelectric materials and appropriate stacks with electrodes on passive structural substrates. Thin film PZT is incorporated as the active material in the MEMS device architectures; nanostructured ZnO and AlN are also developed as alternative piezoelectric materials. MEMS devices based on each of these piezoelectric materials have been experimented with, and functioning devices are demonstrated as sensors and actuators. Fabrication processes are developed with these materials compatible with MEMS processing that promises to provide the scalability required for mass production.

A widely tunable, high power fiber laser is developed, spanning from the 1 μm to the 1.6 μm. Near-complete Raman conversion of high power fiber lasers has been demonstrated using a novel mechanism. A high-power supercontinuum fiber laser source has been demonstrated with output power of 70W, the highest power in this class reported till date. An on-chip, high repetition rate frequency comb has been developed with widely tunable center frequency and repetition rate for applications in optical communications and metrology.

Detection of 5 nm nanoparticles and single protein molecules has been demonstrated using a hybrid nanopore system consisting of a DNA nanostructure integrated with a solid-state nanopore. Our work (in collaboration with Dr. Varsha Singh, MRDG) on swarming motility in the bacterial species Psuedomonas aeruginosa has revealed a clear picture of the interplay between active behaviour of the bacteria, involving sensing and decision making, and the passive flow physics resulting from surfactant driven fingering phenomenon. This work suggests purely physical methods to control motility of this bacteria. This work on swimming motility of Psuedomonas aeruginosa has revealed a previously unidentified connection between the torque-speed characteristics of the bacterial flagellar motor and the geometry of the flagella. Specifically, a tuning condition is identified for the flagellar motor which results in more than 4x enhancement of swimming speeds for use in bacteria-based microrobots.

Faculty & Staff

Sushobhan Avasthi | PhD (Princeton), Assistant Professor
Navakanta Bhat | PhD (Stanford), Professor
Ambarish Ghosh | PhD (Brown), Associate Professor
Akshay Naik | PhD (Maryland), Associate Professor
Digbijoy N Nath | PhD (Ohio State), Assistant Professor
Rudra Pratap | PhD (Cornell), Professor
Srinivasan Raghavan | PhD (Penn State), Professor
Shankar Kumar Selvaraja | PhD (Ghent), Assistant Professor
Prosenjit Sen | PhD (UCLA), Associate Professor
VR Supradeepa | PhD (Purdue), Assistant Professor
Manoj Varma | PhD (Purdue), Associate Professor
Saurabh Chandorkar | PhD (Stanford), Assistant Professor

Associate Faculty

Gaurab Banerjee | PhD (Washington), Associate Professor
Arindam Ghosh | PhD (IISc), Professor
PS Anil Kumar | PhD (Pune), Associate Professor
C Ramamurthy Praveen | PhD (Clemson), Associate Professor
Sujit Kumar Sikdar | Dr. Med. Sci. (Kyushu), Professor
V Venkataraman | PhD (Princeton), Professor
KJ Vinoy | PhD (Penn State), Professor
Bharadwaj Amrutur | PhD (Stanford), Professor
GK Ananthasuresh | PhD (Michigan), Professor
N Ravishankar | PhD (IISc), Professor

Core Research

Core research topics include, but are not limited to, nanoelectronics, MEMS/NEMS, nanomaterials including pervoskites and 2D materials, nanophotonics using silicon and other materials, lasers, nanobiotechnology, electrochemical and nanopore biosensors, microfluidics, GaN and Gallium Oxide RF, power and opto-electronics, oxide/ chalcogenide electronics, 3D systems scaling, photovoltaics and energy harvesting devices, sensors for agriculture, food and environment, autonomous microrobots, quantum fluids and materials, computational nanoengineering

3.4.5

Centre For Infrastructure, Sustainable Transportation And Urban Planning

CHAIRPERSON
ABDUL RAWOOF PINJARI

Centre for Infrastructure, Sustainable Transportation and Urban Planning (CiSTUP) conducts interdisciplinary research on understanding, planning, design, operation, and control of transportation systems. Development of state-of-the-art transportation modelling and analysis tools for safe, efficient, and sustainable mobility and city planning is a focus area. CiSTUP advises transportation agencies, civic authorities, and policy makers on scientific approaches to designing, planning, and operation of transportation systems.

Current Research

Research under the theme of “Predict and pre-empt traffic congestion”, such as multiscale mobility sensing, modeling, inference and simulation tools for multimodal transport planning and traffic control.

Emerging mobility systems – on-demand last mile connectivity for public transit systems, shared mobility as a service (e.g., bike sharing systems; Vehicle allocation and routing problems), electric vehicles, etc.

Understanding and modelling traveler choices in complex travel environments. For example, analytical and learning models for driving behaviour in heterogeneous and undisciplined traffic streams

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Core Research

Transportation planning, Transportation Engineering, Travel demand modelling, Traffic operations and control, Transportation networks, Operations research in transportation, Travel behaviour, Integrated and multimodal transportation systems, Public transportation operations and planning, Shared mobility, Smart mobility, Intelligent transportation systems (ITS), Emerging transportation technologies (electric, connected, automated vehicles), Sustainable transportation and urban planning, Transportation infrastructure, Pavement engineering.

Decision-support tools for public transit agencies, including ridership forecasting models and bus-bunching avoidance solutions

Development of integrated driving and traffic simulators

Associate Faculty

Bharadwaj Amrutur | PhD (Stanford), Professor
P Anbazhagan | PhD (IISc), Assistant Professor
Gurtoo Anjula | PhD (IIM Ahmedabad), Professor
Gl Sivakumar Babu | PhD (IISc), Professor
MH Balasubramanya | PhD (ISEC), Professor
Ipsita Banerjee | PhD (Univ. Of California), Research Scientist
Shalabh Bhatnagar | PhD (IISc), Professor

HN Chanakya | PhD (UAS), Chief Research Scientist
B Gurumoorthy | PhD (Carnegie Mellon), Professor
JM Chandra Kishen | PhD (Colorado), Professor
MS Mohan Kumar | PhD (IISc), Professor
Monto Mani | PhD (IIT Madras), Professor
Caleb Ronald Munigety | PhD (IIT Bombay), Research Scientist
Abdul R Pinjari | PhD (Texas), Associate Professor
TV Ramachandra | PhD (IISc)Scientific Officer
Parthasarathy Ramachandran | PhD (Oklahoma State), Professor
Ananth Ramaswamy | PhD (Louisiana State), Professor
Tarun Rambha | PhD (Texas), Assistant Professor
K S Nanjunda Rao | PhD (IISc), Principal Research Scientist
M Sekhar | PhD (IISc), Professor
TG Sitharam | PhD (Texas), Professor
M Sudhakar Rao | PhD (Pune), Professor
L Umanand | PhD (IISc), Associate Professor
Ashish Verma | PhD (IIT Bombay), Assistant Professor

3.4.6

Interdisciplinary Centre for Energy Research

CHAIRPERSON
S DASAPPA

As part of post-Centenary vision of IISc to take up challenging socially relevant research pursued in various departments brought under one roof. Further, there are several National level missions announced by the Government of India directly make a difference to the people of the nation and the world. With this background, the Interdisciplinary Centre for Energy Research (ICER) at IISc launched in 2012 with a major thrust on renewable energy along with other research in the broad area of energy.

Although research on energy science and related technologies has a long tradition in the Institute, this was the first time that an interdisciplinary approach was undertaken to bring together core expertise from various disciplines under one roof. Augmenting the ongoing research at IISc, specific focus on solar power and associated technologies was considered. The group on biomass conversion processes and technologies had paved way in the industry and societal relevant intervention. Further identifying the energy, in general, is an interdisciplinary and to provide an environment to pool the expertise from various disciplines that cover the basics through to application and development, was ICER's focus.

FACT FILE

The centre offers PhD programs in the area of Energy.
Established 2012
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Under this new initiative, research on various fields such as biofuels, combustion, concentrated solar power (CSP), next-generation solar photovoltaic (PV), novel energy storage technologies, green buildings, and sustainable technologies are undertaken.
To nurture fundamental research and promote technological development, ICER has a student research PhD degree program in all the broad areas of energy with the involvement of over 30 faculty members from various departments. Currently, the Centre has 13 Associate faculty member and about 30 participating faculty members either through student research or projects.

Current Research

With sustainable energy in the focus, utilization of all resource for efficient conversion is the focus. ICER provides a platform to integrate expertise from various disciplines such as Mechanical, Electrical, Physical and Chemical Sciences towards addressing the energy needs, with major focus on renewable energy. Advancement of the on the ongoing R and D areas of solar energy, biomass, hydro, combustion and utilization of a range of fuels, clean coal and also prime movers like new cycle using supercritical CO2, gas turbines, IC engines for alternative fuels, energy storage, smart grids, cold and thermal plasma etc would be of interest.

Apart from the above areas, other areas of national and international importance for collaborative research are efficient conversion of municipal solid wastes with focus on distributed approach meeting the emissions norms, electrical and electronic waste to value-added products and recovery — efficient conversion of solid, liquid and gaseous meeting the emission norms.

Solar research on PV as well as thermal conversion through material research and process optimization, new cycle development for a range of thermal energy would be of interest.

The following are the major R&D projects at the centre.

National Centre for Clean Coal Technologies: Supported by DST, for Supercritical CO2 and Steam based Power Systems, clean coal combustion, coal gasification, high-temperature materials research [Funding of Rs. 30 crores approx. (US $ 4 million) for the period 2018-2023].

Two Stage Adsorption based Solar Cooling cum Desalination: Supported by DST.

Chemisorption based Thermal Storage using Metal Hydrides: Supported by DST

High-Efficiency Solar Receiver for s-CO2 integrated with Static focus Solar Dish: Supported by MNRE

Development of metal hydride based high temperature thermal energy storage systems for waste heat utilization: Supported by GAIL

A multi-institutional (IISc, USC, RMIT, Lanza Tech) project with IISc as a lead “Advanced biofuels generation from thermo-chemical conversion of biomass – Research, Demonstration, and Analysis,”, in principle sanction under Mission Innovation IC#4.

UKICERI: UK-India Clean Energy Research Institute is an Indo-UK collaborative project jointly funded by Department of Science and Technology (DST), Govt. of India and Engineering and Physical Sciences Research Council (EPSRC), UK. IISc is part of a major consortium on smart grid and photovoltaics led by IIT Kharagpur from India side and Loughborough University from UK side.

Research Centre for Solar Power in Challakere Campus: Under this project, which is supported by Karnataka Government, IISc has set up research test beds in PV as well as small scale CSP for cutting edge solar power technologies which include activities such as data generation, controls and monitoring of performance.

MAJOR COMPLETED PROJECTS

Solar Energy Research Institute for India and the United States (SERIIUS): Co-led by IISc on the India side and National Renewable Energy Laboratory (NREL) on the US side, SERIIUS is a major India-US consortium in engaged in solar energy research, under the US.-India Joint Clean Energy Research and Development Center (JCERDC) programme. Altogether, the consortium has 34 partners from both India and US sides, comprising of academic institutions, R&D laboratories, and industries. The consortium received a funding of US$25 million from US and Indian governments, along with matching funding from industry and other partners. The first phase of SERIIUS was for the period 2012-2018, and as a continuation of India-US collaboration in energy, a new clean energy initiative is under consideration under the JCERDC programme.

National Centre for Combustion Research & Development (NCCRD): Indian Institute of Science and IIT Madras were the two institutions selected to host the National Centre for Combustion Research & Development (NCCRD) funded by DST. Under this programme, IISc received a total funding of Rs.36 crore (US$ 5 million) over five years starting from 2012. Several advanced and state-of-the-art facilities in combustion research have been established, to address grand challenges in the area of combustion.

NOVEL FINDINGS

• Developed India's first closed loop supercritical carbon dioxide based Brayton cycle power block, which is more efficient and compact, and has potential to replace steam-based power plants in various applications such as nuclear, solar and waste heat based plants.

• To meet the hydrogen economy sustainably, IISc has developed thermo-chemical conversion process to generate pure hydrogen from biomass, which can be upgraded for PEM fuel application (99.97 % pure).

• Advanced biofuels like methanol and ethanol from thermo-chemical conversion of biomass

• In photovoltaic research, IISc has developed large area test bed and dash-board for reliability and suitability of various PV technologies for unique Indian atmospheric conditions. Also, novel encapsulated organic PV was developed on flexible glass substrates, for extended life and stability of the cells.

• IISc has pioneered development of Cu-based intermetallic alloy coatings for high-temperature solar reflector in solar thermal applications.

• IISc has developed a two-Stage Silica gel + Water Adsorption based Solar Cooling cum Desalination System

• Syngas and natural gas-fired ultralow emission combustor technology for hybrid solar thermal energy systems in the 100-kW range.

Faculty & Staff

S Dasappa | PhD (IISc), Professor
R V Ravikrishna | PhD (Purdue), Professor
Praveen C Ramamurthy | PhD (Clemson), Professor
Pradip Dutta | PhD (Columbia), Professor
Saptarshi Basu | PhD (Connecticut), Associate Professor
Pramod Kumar | PhD (IISc), Associate Professor
Joy Kuri | PhD (IISc), Professor
Bikramjit Basu | PhD (Katholieke), Professor
Anindya Deb | PhD (New York), Professor
Gopalan Jagadeesh | PhD (IISc), FNAE, Professor
Satyam Suwas | PhD (IIT Kanpur), Professor

3.4.7 Interdisciplinary Centre for Water Research

CHAIRPERSON
P P MUJUMDAR

Reaching across traditional disciplinary boundaries ICWAR aims to provide a comprehensive understanding of impact of complex environmental factors on areas related to water science and technology and offer efficient and effective engineering solutions to environmental problems. Students in ICWAR receive a broad education and carry out research addressing some of the grand science and engineering challenges of modern society.

Current Research

Current research in the ICWAR program is focused on (i) assessment of hydrologic impacts of climate change on local and regional hydrological regimes, ecological, social and economic systems, (ii) development of effective methodologies for sustainable water management at local and basin scales; (iii) development of smart water solutions for agriculture sector (irrigation and water management) by integration of observations of sensors and satellite and ICT tools, (iv) development of methodologies for intelligent water supply network monitoring and control for equitable distribution of water in mega cities; and (v) understanding interactions, synergies, and feedbacks that link the land surfaces, freshwater, oceans, and atmosphere systems.

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IN NUMBERS

7 PhD students
1 Publications

Core Research

Urban water systems; Urban hydrology/ hydrogeology; Watershed and river basin hydrology; Floods and droughts; water management; Agrohydrology; Satellite hydrology; Wetland Science; Land-atmosphere interactions; Lake ecosystems; Aquatic geochemistry; Geothermal reservoir modelling; Global water cycle and impacts of climate change; Isotope hydrology; Applications of sensor and satellite technologies; Domestic and industrial wastewater treatment; Climate change impact on hydrology of Indian rivers; Urban Floods and lake ecosystem; Hydrologic flux; Glacier Hydrology; Nanotechnology based solutions for water purification

Faculty

Chairman

P. P. Mujumdar | PhD (IISc), Professor

Associate Faculty

Govindasamy Bala | PhD (McGill University), Professor
Mohan Kumar MS | PhD (IISc), Professor
Nagesh Kumar D | PhD (IISc), Professor
Sekhar M | PhD (IISc), Professor
Srinivas VV | PhD (IIT Madras), Professor
Subramanian S | PhD (Mysore), Professor
Prosenjit Ghosh | PhD (PRL), Associate Professor
Ramananda Chakrabarti | PhD (Rochester), Associate Professor

3.4.8 Management Studies

CHAIRPERSON
PARTHASARATHY RAMACHANDRAN

The oldest management education department in the country, tracing its origin back to 1947, currently has a masters and a doctoral program. The department faculty and students engage in research in a wide array management topics and seek to set standards of excellence in management research and education.

Current Research

Explored new venture incubation framework as promoted by academic institutions, companies and individuals through Technology Business Incubators, Accelerators and Co-working spaces. Analyzed the performance of TBIs located in Bangalore, Chennai and Hyderabad.

Research has been carried out on development of financial econometric methods, to assess the effect on stock prices on firm-specific, market, or economy wide events. Development of Likelihood Ratio Tests for testing the hypotheses arising in this “Event Study”, is a notable contribution.

Monte Carlo methods for computing sensitivities (derivative with respect to underlying and model parameters): Developed a scheme known as rolling adjoints that can use Monte

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IN NUMBERS

42 PhD
31 M Mgt
25 Publications
12 PhD. Conferments
16 M. Mgt. Conferments

Carlo methods to compute price sensitivities along simulated scenarios.

Small satellites are becoming increasingly important due to their promise of providing more flexibility in launch and operation. Developed valuation techniques to compare the added flexibility advantage of small satellites with respect to large communication satellites.

Research in energy, environment and technology management & policy has focused on sustainability assessment of various sub-systems of the Indian economy. The subsystems included for assessment are megacities, urban mobility, national and rural energy systems, corporate sector and urban waste.

Core Research

Industrial Economics, Innovation & Startups, Technology Management, Operations Management, Supply Chain Management, Empirical Finance, Statistics, Operations Research, Demand Management, Quantitative finance, Real Options, Financial risk management, Energy and Environment Policy, Sustainability Transitions, Informal urban systems, IP and patents, Language Studies.

Faculty & Staff

KB Akhilesh | PhD (IISc), Professor
Anjula Gurtoo | Fellow (IIM Ahmedabad), Professor
MH Bala Subrahmanya | PhD (ISEC), Professor
P Balachandra | PhD (IISc), Principal Research Scientist
Chiranjit Mukhopadhyay | PhD (Missouri), Professor
M Mathirajan, Ph. D. (IISc) | Chief Research Scientist
Parthasarathy Ramachandran | PhD (Oklahoma State), Professor
Shashi Jain | PhD (TU Delft), Assistant Professor
Yadnyvalkya | MS (Engg.) (Moscow), MA (CIEFL), Principal Research Scientist

3.4.9

Robert Bosch Centre for Cyber Physical Systems

CHAIRPERSON
BHARADWAJ AMRUTUR

RBCCPS was established in 2011 as a research and academic centre under the Division of Interdisciplinary Research, to promote research in cyber-physical systems (CPS). The Centre brings together expertise from various departments and, together with in-house research staff, focuses on foundational and applied research to solve cutting edge problems in Robotics involving advanced machine learning techniques, Connected Autonomous Systems like drones and 5G-enabled autonomous vehicles, and Socio-Technical Systems like urban transportation systems and Smart Cities.

Current Research

Under the theme of IoT enabled Socio-Technical Systems, the centre is leading an effort to create a nationwide data exchange for smart cities, called the India Urban Data Exchange (PI: Bharadwaj Amrutur), and studying how people can be incentivized to make better choices to choose greener mobility options (PI: Rajesh Sundaresan). Under the theme of robotics & autonomous systems, the centre is exploring cooperative algorithms for autonomous drones, Cognitive team theory, Non-linear control for drones, Security framework for drones, Learning based control for quadrupeds, Nano-Robotics, Switched reluctance motors for robotics and electric vehicles. More information on the current research projects is available at http://www.rbccps.org/projects/on-going- projects/.

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IN NUMBERS

291 Publications
27 PhD Students

Associate Faculty

Bharadwaj Amrutur | PhD (Stanford), FNAE, Professor & Chairman
GK Ananthasuresh | PhD, (Michigan), Professor
R Venkatesh Babu | PhD (IMSc), Assistant Professor
Arkaprava Basu | PhD (Wisconsin), Assistant Professor
Kaushik Basu | PhD (Minnesota), Assistant Professor
Shalabh Bhatnagar | PhD (IISc), FNAE, Professor
Chiranjib Bhattacharyya | PhD (IISc), FNAE, Professor
Deepak D'Souza | PhD (CMI), Professor
Vinod Ganapathy | PhD (Wisconsin), Assistant Professor
Debasish Ghose | PhD (IISc), FNAE, Professor
Prasanta Kumar Ghosh | PhD (USC), Assistant Professor
Ambarish Ghosh | PhD (Brown), Associate Professor
Ashitava Ghosal | PhD (Stanford), Professor
Aditya Gopalan | PhD (Texas), Assistant Professor
Gurunath Gurrala | PhD (IISc), Assistant Professor
M S Mohan Kumar | PhD (IISc), Professor
Chandra R Murthy | PhD (UC San Diego), Associate Professor
G Narayanan | PhD (IISc), Professor
S N Omkar | PhD (IISc), Chief Research Scientist
Radhakant Padhi | PhD (Missouri), Professor
Parimal Parag | PhD (Texas A&M), Assistant Professor
Arpita Patra | PhD (IIT Madras), Assistant Professor
T V Prabhakar | PhD (TU Delft), Principal Research Scientist
Chandra Sekhar Seelamantula | PhD (IISc), Associate Professor
Yogesh Simmhan | PhD (Indiana), Assistant Professor
Rajiv Soundararajan | PhD (Texas), Professor
Rajesh Sundaresan | PhD (Princeton), Professor
Suresh Sundaram | PhD (IISc), Associate Professor
Pavan Tallapragada | PhD (Maryland), Assistant Professor
Himanshu Tyagi | PhD (Maryland), Assistant Professor
Manoj Varma | PhD (Purdue), Associate Professor
Ashish Verma | PhD (IIT Bombay), Associate Professor

Technical Staff

Arun Babu | PhD (Homi Baba National Institute), Member of Technical Staff
Josephine Selvarani Ruth D | PhD (NIT Tiruchirapalli), INSPIRE Faculty
Ashish Joglekar | PhD (IISc), Member of Technical Staff
Shishir N Y Kolathaya | PhD (Georgia Institute of Technology), INSPIRE Faculty
Raghu Krishnapuram | PhD (Carnegie Mellon University), Distinguished Member of Technical Staff
Alexandre Reiffers | PhD (National Research Institute In Computer Science And Control), PostDoc
Abhay Sharma | PhD (IISc), Member of Technical Staff
S Sridhar | PhD (Institute Of Mathematical Sciences), Member of Technical Staff

3.4.10

Supercomputer Education & Research Centre

CHAIRPERSON
SATHISH VADHIYAR

The Supercomputing Education and Research Centre (SERC), at IISc provides the state-of-the-art computing environment, which compares well with the top Computing Centres anywhere in the world, catering to the ever-increasing demands of high performance computing for scientific and engineering research. The Centre hosts 24/7 supercomputing facilities and services including supercomputers of Petaflop capacities for traditional HPC (High performance computing), deep learning and AI based applications, HPC software and about 2 Petabytes of storage. The centre also provides periodic HPC training courses to both the Institute community and personnel from outside the Institute and offers HPC consulting services. In addition, the Centre leads several national initiatives.

In 2018, our supercomputer systems have served about 40 departments, 90 research groups and 350 users of the Institute various fields including aerospace, brain research, chemistry, climate modelling, computational and data sciences, computer science, earth sciences, electronics system engineering, materials research, mechanical engineering, microbiology and cell biology, molecular biophysics etc. About 248 million CPU core hours have been provided for research in these areas. The supercomputing usage resulted in a total of about 75 publications across the Institute.

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URL www.serc.iisc.ac.in

IN NUMBERS

HPC services to 40 departments, 90 research groups and 350 students of the Institute
75 publications across the Institute based on supercomputing usage
250 million CPU core hours of usage
More than 95% utilization

Current Research

Faculty conducted research on cloud systems with research students from CDS in the "Cloud Systems Lab". For the year 2018, key areas of the research focus have been on "Software Defined Networks (SDN) and Services", "Micro-service realizations for serverless architectures and scaling considerations" and "Resource Disaggregation Frameworks in Cloud Setups". The SDN initial proposal won a runner up prize in the Engineer's Day competition at Nokia Networks, India. The research on resource disaggregation was supported by Ericsson Global Services, India. by way of summer internships and mentoring. As a consequence of this, the student has been offered a job in the organisation. Further, initial investigations on storage and cloud service resilience has been started by two PhD students in the lab. The initial exploration on the storage resilience was accepted for fasttrack research presentation in the DSN-2019 conference.

Faculty & Staff

Filbert Minj | MTech (JNU), Principal Research Scientist
J Lakshmi | PhD (IISc), Principal Research Scientist
Sathish Vadhiyar | PhD (Univ. Of Tennessee), Associate Faculty And Chair
Yogendra Kumar Negi | MTech (Delhi), Scientific Officer

Associate Faculty

N Balakrishnan | PhD (IISc), Professor
R Govindarajan | PhD (IISc), Professor

Honorary Professors

N Balakrishnan | PhD (IISc), Honorary Professor

Core Research

Supercomputing systems, applications and statistics, Cloud Systems, networking, digital library, information security, computational electromagnetics

3.5 Division of Mechanical Sciences

IN NUMBERS

- 105 FACULTY MEMBERS
- 478 PhD STUDENTS
- 174 MASTER'S STUDENTS

Geotechnical Engineering, Civil & Aerospace Structures, Transportation, Water Resources, Environmental Engineering and Sustainable Habitat, Climate, Structural and Functional Materials, Manufacturing, Design Theory and Methodology, Geochemistry, Tectonics, Planetary Evolution, Remote Sensing and GIS Applications, Aerodynamics, Combustion, Navigation and Guidance, Solid Mechanics, Fluid Mechanics, Thermal Sciences, Acoustics, Robotics, Dynamics, Biomolecular Engineering, Catalysis, Colloids and Interfacial Science, Nanotechnology, Thermodynamics and Simulations across length scales.

THEMES

Research work in the Division encompasses diverse areas. Seismology and climate change -- modelling as well as paleo studies -- are focus areas, which lead naturally to work on environmentally sustainable materials and design and on waste management. The work on materials includes study and modelling of biomaterials, polymers and photovoltaics. Fluid dynamics, including shock waves and other phenomena at hypersonic speeds, is another key area of study that cuts across the various departments in this Division. Researchers in this Division also work on identifying novel drug and vaccine targets for viral infections such as HIV, hepatitis C and dengue.

RESEARCH HIGHLIGHTS

The Division consists of departments of Aerospace Engineering (which includes DRDL-IISc Joint Advanced Technology Programme and ISRO-IISc Space Technology Cell), Civil Engineering, Chemical Engineering, Materials Engineering, Mechanical Engineering, Centre for Atmospheric & Oceanic Sciences, Centre for Earth Sciences, Centre for Product Design and Manufacturing, Centre for Sustainable Technologies and Divecha Centre for Climate Change

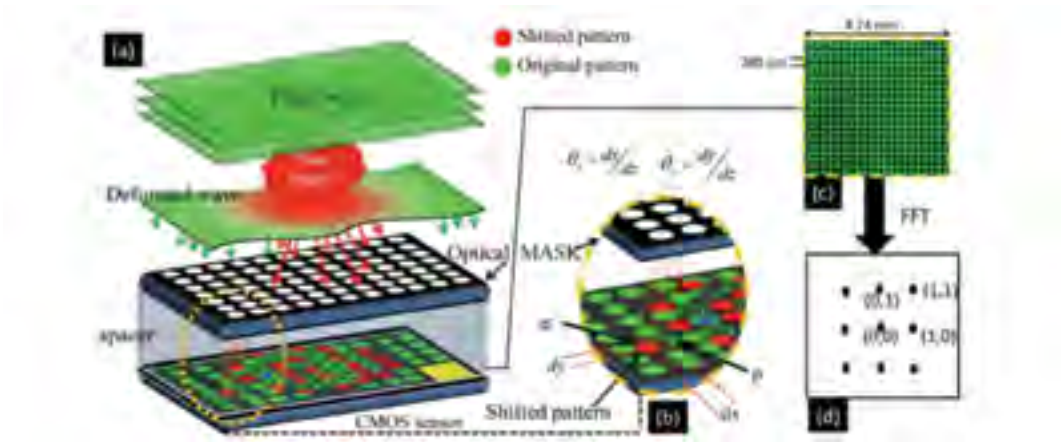
DEPARTMENTS | CENTRES | UNITS

- AEROSPACE ENGINEERING
- CENTRE FOR PRODUCT DESIGN AND MANUFACTURING
- CHEMICAL ENGINEERING
- MATERIALS ENGINEERING
- MECHANICAL ENGINEERING
- CIVIL ENGINEERING
- CENTRE FOR EARTH SCIENCES
- CENTRE FOR ATMOSPHERIC AND OCEANIC SCIENCES
- CENTRE FOR SUSTAINABLE TECHNOLOGIES
- DIVECHA CENTRE FOR CLIMATE CHANGE

Research Snapshots 2018-19

S N Omkar (AE)

This drone surveillance system has been mainly developed to identify violent activities by individuals in large public areas. The system does so by first spotting each human in the image frame. Next, the body posture of each human is estimated which is then used to make a determination if two people are involved in violent activity.



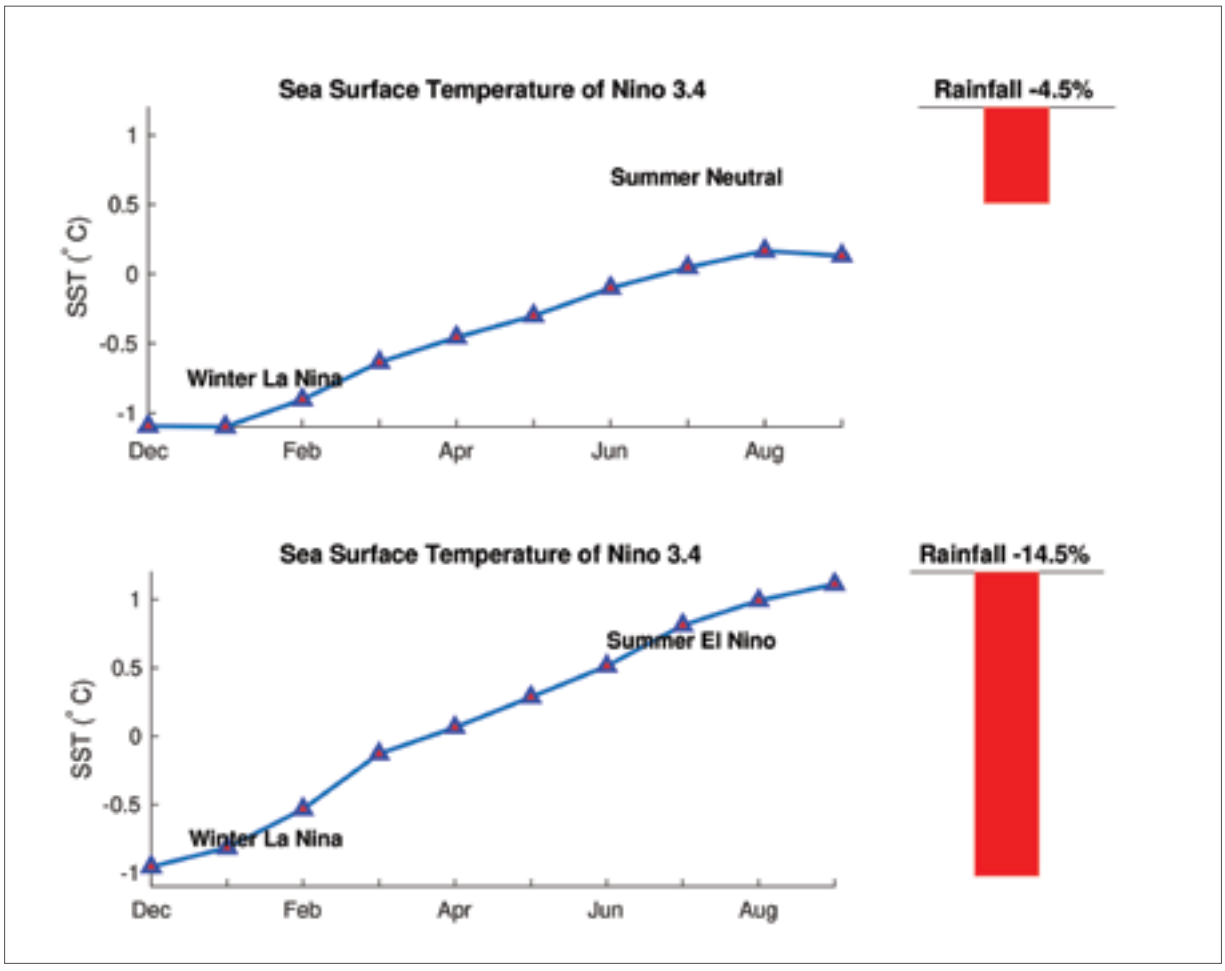
G Hegde (BSSE), KPJ Reddy (AE), D Roy (CiE), R Vasu (IAP)

A major requirement in optical flow visualization for quantitative aerodynamic studies of hypersonic flows is a high speed camera, capable of capturing a few million frames per second

of the flow fields. The IISc team of researchers have designed a low cost wavefront measuring camera that can detect both the amplitude and phase of the captured light wave simultaneously.

(a) Captured I image of the flow field using the developed wavefront camera. Cropped ROI image is processed for vertical density gradients. (c) recovered wavefront d) Recovered 3D-density distribution

Biswajit Medhi, Gopalkrishna Hegde, K.P.J Reddy, Debasish Roy, and R. Vasu, “A novel wavefront measuring camera for quantitative measurement of density in high-speed gas flows”. *Rev. Sci. Inst. 89,* 085122 (2018).



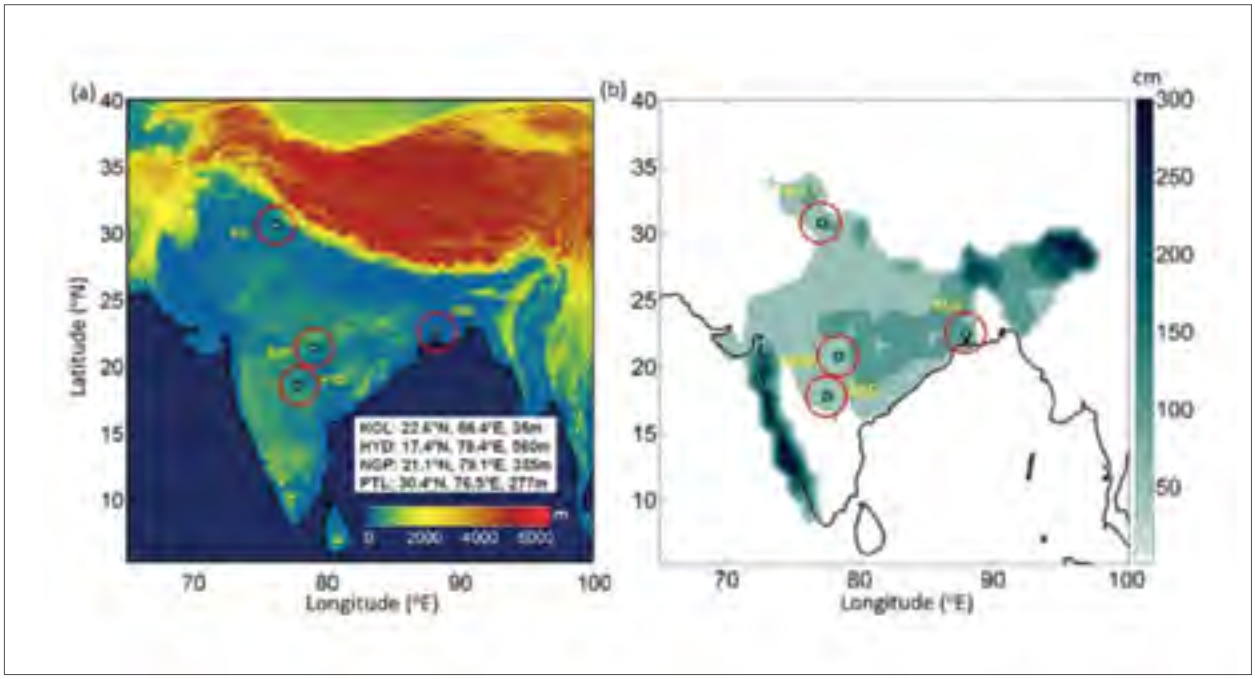
Arindam Chakraborty (CAOS)

The impact of El Nino Southern Oscillation (ENSO) on the Indian summer monsoon has been widely studied for many decades. The warm phase of ENSO, i.e., El Niño, is known to be associated with deficient summer monsoon rainfall. Here it is shown that a La Nina event, i.e., the cold phase of ENSO in the preceding winter leads to below normal seasonal rainfall. Further, when ENSO changes phase from La Niña (winter) to El Niño (summer), the effect on Indian rainfall is severe, foreshadowing drought-like conditions. Our results highlight a fundamental

asymmetry between the two phases of ENSO, and provide a path towards the hitherto elusive seasonal prediction of Indian summer monsoon rainfall.

The evolution of sea surface temperature in the Nino3.4 region in the central and eastern equatorial Pacific ocean (an indicator of El Nino and La Nina). When the northern summer is ENSO neutral (top) following a winter La Nina, rainfall over India is about 4.5% below its long-term mean. On the other hand, if ENSO changes phase from winter La Nina to summer El Nino (bottom), the chances that Indian monsoon will be below normal are high (14.5% below its long-term mean on average).

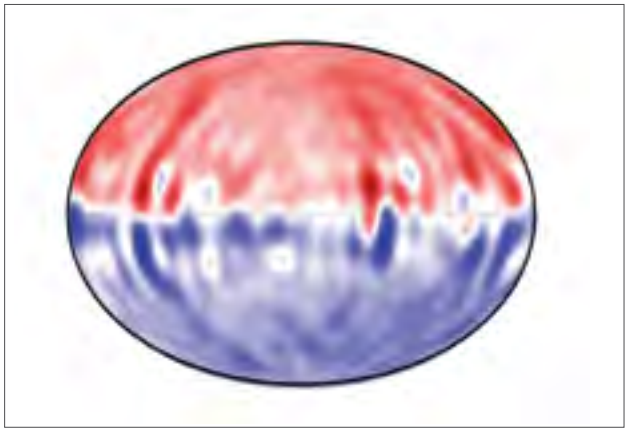
A. Chakraborty, Preceding winter La Niña reduces Indian summer monsoon rainfall, *Environmental Research Letters, 10*.1088/1748-9326/aabdd5, 2018.



GS Bhat (CAOS)

Mesoscale systems (MCS) are cloud clusters that extend to tens to hundreds of kilometres. Embedded within the mesoscale, there are groups of cumulonimbus clouds, or storms, with typical sizes of the order of 10 kms. This study establishes the interconnection between MCS's and storms over India during the 2013 monsoon season. The authors used Doppler Weather Radar (DWR) data of summer monsoon low pressure systems.

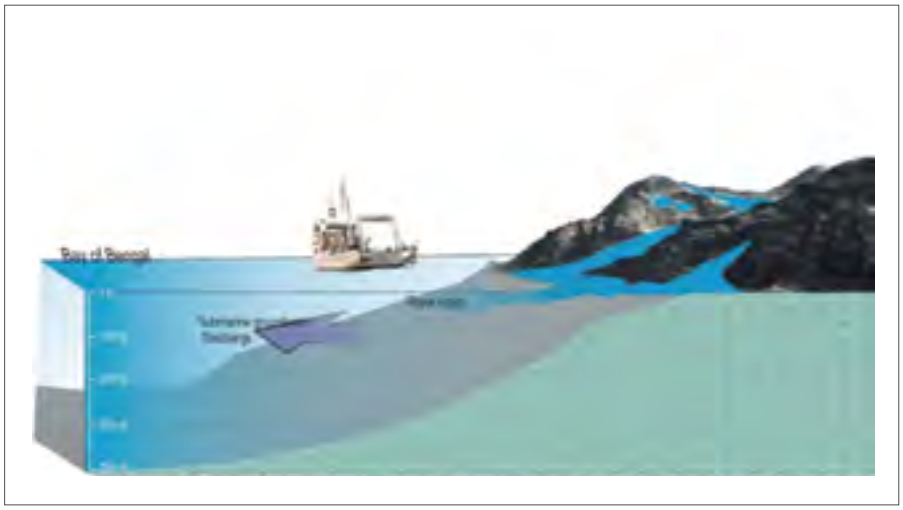
Sindhu K.D. and Bhat G.S. (2018): Characteristics of monsoonal precipitating cloud systems over the Indian subcontinent derived from weather radar data. *Q. J. R. Meteorol. Soc;* 1–19.



B Sreenivasan (CEaS)

The magnetic fields of many planets are approximately axial dipoles. To understand why the dipole is preferred, the evolution in time of a seed magnetic field is studied using a rotating dynamo model. It is shown that the growing magnetic field by itself excites helical convection over a range of length scales within the dynamo region [figure (a)]. The time scale for the growth in convection intensity roughly coincides with the time scale for the formation of the dipole [figure (b)]. It is also shown that the dipole forms from a chaotic state well before the eventual saturation of the magnetic field, implying that a planetary dynamo would have chosen its dominant polarity during its growth phase, i.e. during the early life of the planet.

B. Sreenivasan& S. Kar, Scale dependence of kinetic helicity and selection of the axial dipole in rapidly rotating dynamos, *Phys. Rev. Fluids,* 3, 093801, 2018.



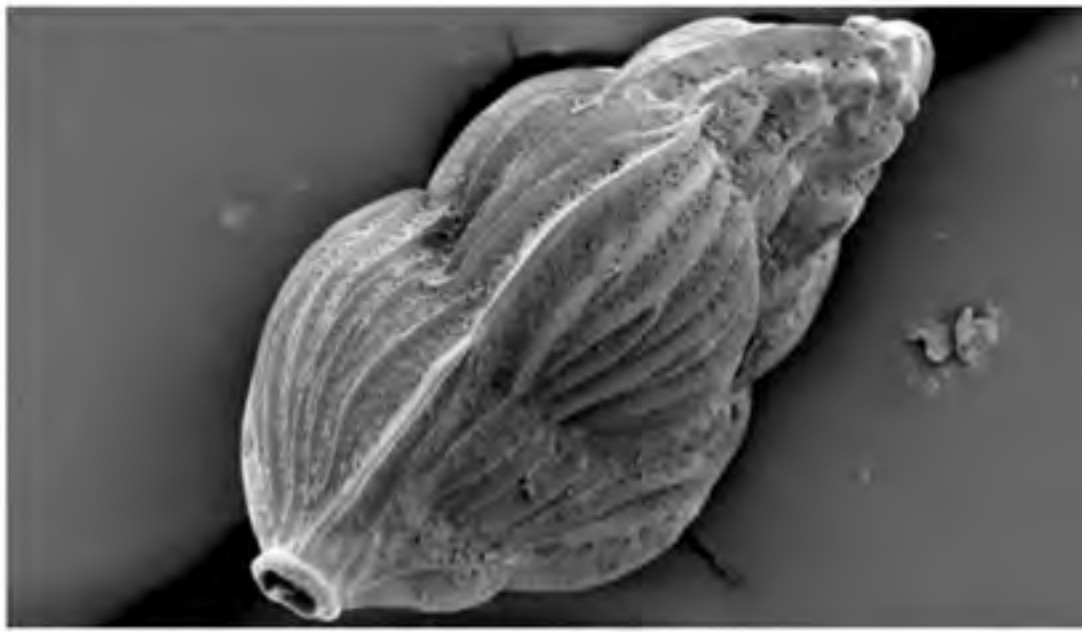
Ramananda Chakrabarti (CEaS)

Large fluxes of dissolved cations and anions, generated by the weathering of rocks, are transported by rivers to the oceans. In addition to rivers, groundwater also carries these ions to the oceans. However, the contribution of the submarine groundwater discharge (SGD) to the

dissolved ion concentrations of the oceans is debated as it is not easily traceable in seawater due to mixing.

In a study published in the journal Scientific Reports of the Nature Publishing Group, Dr.Ramananda Chakrabarti, Surajit Mondal, and Dr. Shiba Shankar Acharya from the Centre for Earth Sciences along with J. SreeLekha and Prof. Debasis Sengupta from the Centre for Atmospheric and Oceanic Science, IISc, have provided a direct evidence of the SGD-driven flux of Strontium (Sr) to the Bay of Bengal (BoB).

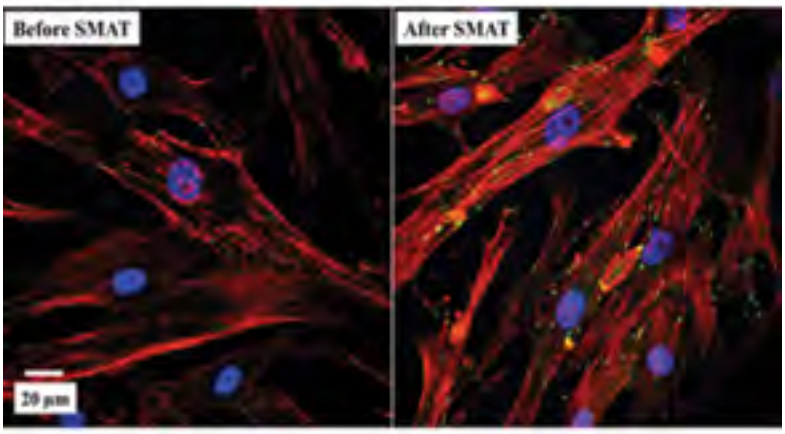
Reference: Chakrabarti, R., Mondal, S., Acharya, S. S., Lekha, J. S., & Sengupta, D. (2018). Submarine groundwater discharge derived strontium from the Bengal Basin traced in Bay of Bengal water samples. *Scientific reports,* 8(1), 4383.



Sambuddha Misra (CEaS)

Nearly 40% of the total CO2 emitted from burning of fossil fuel is absorbed by seawater and the deep-ocean contains nine times more dissolved CO2 than the atmosphere. Microscopic carbonate-secreting organisms living in seawater, like coccoliths and foraminifera (shown in the figure), incorporates trace quantities of dissolved elements from seawater into their calcium carbonate shells. This research discovered that the isotopic composition of lithium, ratio of 7Li to 6Li, trapped within the calcium carbonate lattice is strongly correlated with pH of the organism's growth environment. This result can be used as a new proxy for seawater pH to accurately determine the timing, rate, and extent of natural and anthropogenic alteration of the CO2 budget of the ocean-atmosphere system.

Bohlin, M.S., Misra, S., Lloyd, N., Elderfield, H. and Bickle, M.J., 2018. High-precision determination of lithium and magnesium isotopes utilising single column separation and multi-collector inductively coupled plasma mass spectrometry. *Rapid Communications in Mass Spectrometry,* 32(2), pp.93-104.

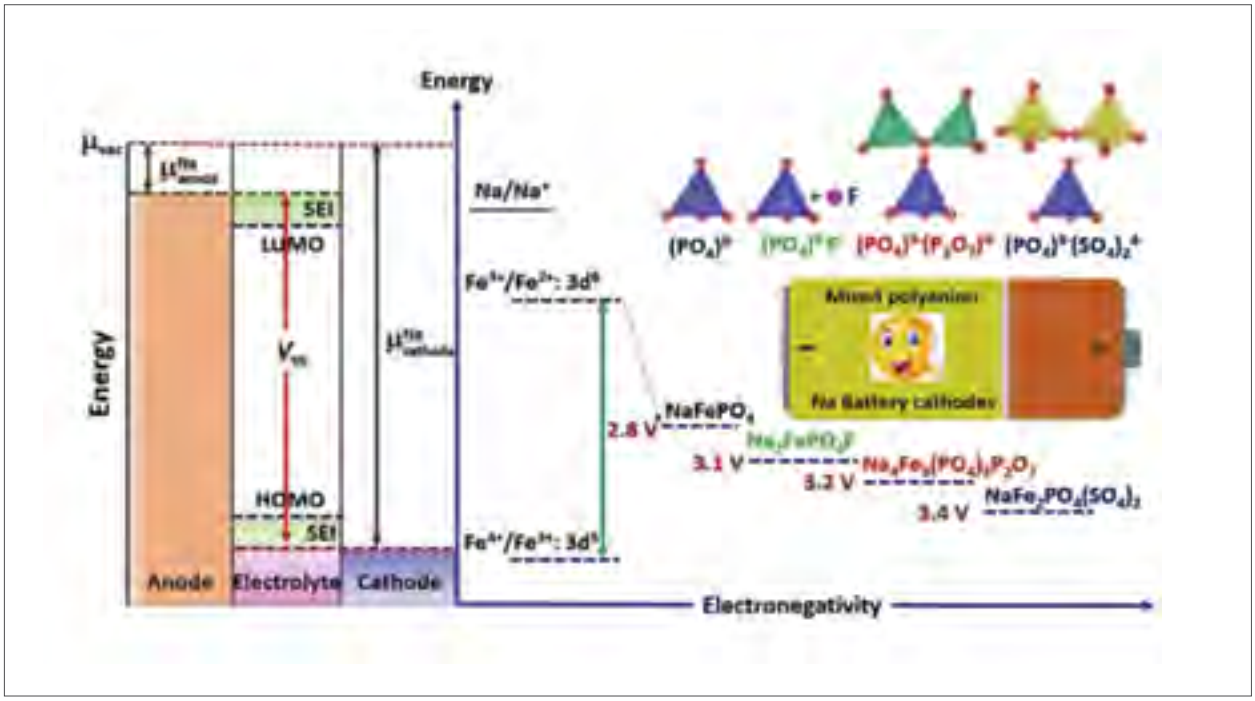


Kaushik Chatterjee (ME)

Metallic implants are used to replace dysfunctional bone joints (hip and knee) in patients suffering from osteoarthritis. The alloys used at present (316L, Ti-6Al-4V, Co-Cr-Mo), are stiffer compared to human bone and contain elements such as Al, V, Ni that have potential cytotoxic effects. Furthermore, they lack the necessary ability to bond with the surrounding bone (termed as osseointegration) or in other words are not bioactive. This has led to the development of new alloys that are less stiff, non-toxic and bioactive compared to existing alloys. In our work, we have developed a new high strength low modulus (less stiff) nontoxic β Ti-Nb-Sn alloy for joint applications. Subsequently, we have employed a facile yet innovative approach to improve the ability of the alloy to bond with the bone.

In this approach, the surface of the alloy is severely deformed by impact of hardened steel balls moving randomly in space at high speed. This process that is used to deform the alloy surface is known as surface mechanical attrition treatment (SMAT).

S. Bahl, S.R.K. Meka, S. Suwas, K. Chatterjee, Surface Severe Plastic Deformation of an OrthopedicTi–Nb–Sn Alloy Induces Unusual Precipitate Remodeling and Supports Stem Cell Osteogenesis through AktSignaling, *ACS Biomaterials Science & Engineering* 4(9) (2018) 3132-3142.

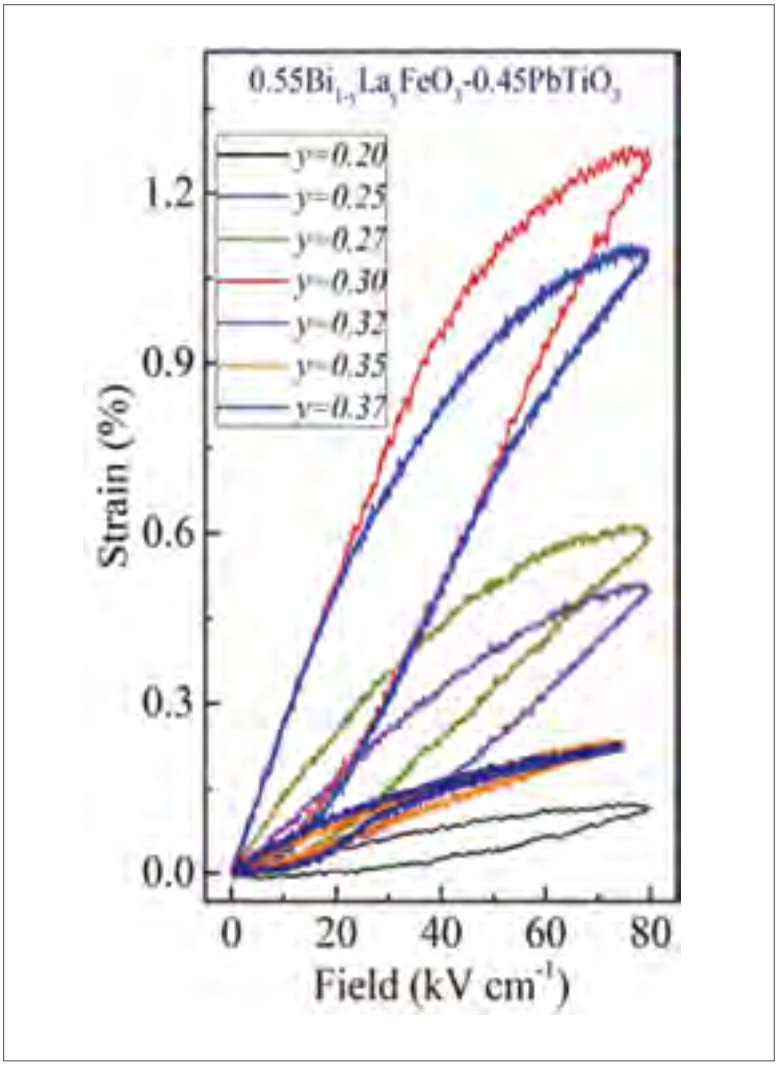


Prabeer Barpanda (MRC)

'Building better batteries' remains an ongoing process to cater diverse energy demands starting from small-scale consumer electronics to large-scale automobiles and grid-storage. While Li-ion batteries have carried this burden over the last three decades, the ever-growing and highly diverse applications (based on size, energy-density and stationary vs. mobile usages) have led to an era of 'beyond lithium-ion batteries'. In this post-lithium-battery genre, sodium-ion batteries (NIBs) have emerged as a pragmatic option particularly for large-scale applications.

Our current work focuses on the world of mixed polyanionic cathode materials to realize the next generation sodium-ion batteries with high energy density.

Reference:
P. Barpanda et al, Adv. Energy Mater, 8(27), 1703055, 2018.



Rajeev Ranjan (ME)

The interesting properties of the class of ceramic materials called “ferroelectric -perovskites” have been used in wide ranging applications such as SONAR, ultrasound imaging, focusing of mirrors in space telescopes, heath monitoring of structures, automobile industry, etc. These materials produce voltage on being stressed and can change shape on application of electric-field. The latter phenomenon is known as electrostrain. The larger the electrostrain, the better the material can perform. Most piezoelectric ceramics exhibits electrostrain in the range ~ 0.2 -0.3 %.

For the first time, we demonstrate that ceramic, which is very easy to make, less time and energy consuming than that required for making of a single crystal, can show electrostrain greater than 1 %. We achieved an electrostrain of 1.3 % by compositional design of the material system BiFeO3-PbTiO3-LaFeO3.

Narayan et. al., Nature Materials, 17, (2018) 427-431

3.5.1 Aerospace Engineering

CHAIRPERSON
JOSEPH MATHEW

Founded in the year 1942 as the Department of Aeronautical Engineering, it was renamed as the Department of Aerospace Engineering in the year 1982 to reflect the growing activities in space research and education. The department offers PhD, MTech and MTech (Res) programs and currently has 33 faculty and 248 research students. The academic and research activities are in four major areas, namely, Aerodynamics, Structures, Propulsion, and Guidance & Control.

Current Research

AERODYNAMICS

A strong experimental program spanning low-speed to hypersonic flows is has been enabled by the availability of several wind tunnels and shock tunnels, fitted with instrumentation for classical measurements and modern diagnostics and flow visualization. Computational studies cover external aerodynamics of wings and full aircraft, DNS and LES of turbulent and transitional flows, aeroacoustics and new algorithms. An extensive numerical study of a new form of vortex breakdown (conical) was completed. Significant short-time transient growth found in rapidly swirling jets that exhibit bubble breakdown. Global thermoacoustic oscillations in pulse tubes have a different type of instability wave which govern their overall heat transfer and thermoacoustic efficiencies. Proper orthogonal decomposition analysis to understand bypass transition in boundary

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Degree Programs offered: PhD, MTech (Res), MTech

IN NUMBERS

25 Academic Staff
10 Scientific Staff
136 PhD Students
15 MTech (Res)
38 MTech
2 MSc (Engg)
201 Publications
12 MSc (Engg), 16 MTech, 2 MTech (Res), 25 PhD Conferments

Core Research

Aerodynamics: Low speed flows – transition & turbulence, Supersonic & hypersonic flows – mixing, drag, heat transfer, Computational Fluid Dynamics, LES, Aeroacoustics, Stability, Aeroelasticity.

Aerospace Structures: Composite structures, nanocomposites, functionally-graded materials, vibrations, wave propagation, structural health monitoring, finite element analysis, non-destructive evaluation.

Propulsion: Atomisation & sprays, scramjet propulsion, electric propulsion, combustion instability, flame evolution.
Guidance & Control: Optimal control, path planning, image processing, obstacle avoidance, multi-agent systems

layers due to freestream turbulence has been completed and experiments for roughness-induced transition initiated. Chromium coating for reducing wave drag in hypersonic flight was investigated by measuring static temperature enhancement in shock layer using two-temperature ratio pyrometry. Studies of critical mode operation of supersonic ejectors were completed. High compression ratio inlet tests, carried out in the Hypersonic Wind Tunnel, yielded unstart data. A new cold flow DCR experimental test rig was designed, fabricated and installed. A new supersonic mixing layer facility was established. CFD algorithms being developed include meshless solvers, higher-order accurate staggered updating, Implicit gradient reconstruction for wave-by-wave dissipation modelling. Applications include design of a serpentine intake, highly curved diffusers, high-lift flows, and aerodynamic configuration optimization. Study of a new approach for shocks in large eddy simulation of turbulent flows was completed and applied to the launch configuration of supersonic jets impinging on wedge deflectors. A new type of crackle noise was observed to develop in the quiescent surrounding by nonlinear steepening. A study of transitional and turbulent flow in turbomachinery (compressor) cascades was completed, showing bypass transition with and without spot pre-cursors. Exposure of shock waves to open wounds in animal model showed promotion of angiogenesis, suggesting a new technique for wound healing.

STRUCTURES

Isospectral Rayleigh beams and discrete system models were investigated. An exact solution of the Bresse-Timoshenko beam with slope inertia model was found. Effect of uncertainty on failure enveloped of composite structures was quantified. Meshfree Galerkin method and quadratic spline based finite element methods for rotating beams was proposed. Optimal designs for piezoelectric benders were proposed. Other problems include dynamics of woodpecker beak pecking, bio-inspired structures for blast mitigation, computational techniques (Cellular Automata, Phase field modeling and X-FEM modeling) for corrosion pits in metallic structures, structural health modeling of adhesively bonded joints in composites, and wave propagation in structural waveguides using Peridynamics modelling. Quantification of the effect of manufacturing processes on the structural in the area of fatigue induced transverse matrix cracking of laminated composites done. Explicit accounting of spatial variations in the microstructure, that changes the resin flow within a single glass tow during resin infusion, has been done. Single and dual adhesive bond strength analysis of single lap joint between dissimilar adherends was done. An FEM multiscale model has been developed for predicting fracture initiation and fatigue damage behaviour of alloys. A new theoretical correlation for effective mechanical properties of fibre reinforced composite with high concentration regime of particle/fibre dispersion was obtained. Mechanism of enhancement in stiffness and strength due to nano-material dispersion has been established. Molecular dynamics simulation have shown mechanisms of subsurface deformation in aluminium under high strain rate shear and formation of nanoscale molecular structures of aluminium and graphene due to friction stir welding. NDE of effect of porosity and moisture content on polymer composite structures, and also NDE of adhesively bonded joints in composite structures investigated. Piezoceramics (PZT) for active and passive vibration and noise control, and for aircraft de-icing was developed. Stability parameters were estimated directly from flight flutter-test time response data using an autoregressive (AR) model, which in turn was used to estimate the frequency and damping.

PROPULSION

Resaerch led to the discovery of generation and evolution mechanisms of premixed flames in turbulence; commissioned the scramjet combustion facility; successfully stabilized and visualized hydrogen-air flame in the scramjet combustor at flight relevant conditions. Two types of coupling of acoustic and hydrodynamic modes considered in a

backward facing step combustor using experimental data and explained with stability analysis. Weakly-nonlinear analysis of swirling jets showed cause-effect relationship of vortex breakdown and PVC. We showed scaling to 23,000+ cores of our explicit filtering based LES solver for complex geometries using the overset mesh method. A new numerical scheme for handling stiff source terms arising in simulations of MPD thrusters was developed. Role of atomizer geometry and flow conditions on drop size distribution aircraft engine injectors and other gas-centered swirl coaxial atomizers. Impact dynamics of hydropcarbon fuel drops on heated solid surfaces encountered in engine combustors studied. Established licensing for technology transfers (post patent) - one for Silica from RHA (a Waste -to-Wealth approach), and another for H2S removal from biogas from industrial effluent treatment plants (a Waste-to-Energy approach).

GUIDANCE & CONTROL

Developed an optimal guidance strategy for autonomous soft-landing of a spacecraft on lunar surface, guidance for engaging high-speed ballistic targets, a state-constrained adaptive control technique for Euler-Lagrange systems, a state-constrained robust adaptive cruise control design approach for air-breathing hypersonic vehicles, and identified parameters for a minimal model for Type-1 diabetic patients from clinical data. Guidance law for mimicking short range ballistic trajectories was obtained. Parallel parking maneuvers for autonomous ground vehicles were proposed. Vertical landing guidance and autonomous road navigation by unmanned aerial vehicles flying at very low altitudes was achieved. Imitation learning from an expert pilot using deep convolutional neural network was implemented. Low Altitude Remote Sensing (LARS) for agriculture, and analysis of LARS imagery using deep learning. Deep learning algorithms for semantic segmentation, object detection, crop and disease mapping, yield estimation, violence activity detection etc., Biomechanics of yogic postures were investigated. New, cooperative algorithms for multi-UAV system and UAV-UGV coordination to handle forest fire fighting, employing multi-level search with formation flying were developed.

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Sourabh Suhas Diwan | PhD (IISc), Assistant Professor
Ranjan Ganguli | PhD (Maryland), FNAE, Professor
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3.5.2

Centre for Atmospheric And Oceanic Sciences

CHAIRPERSON
DEBASIS SENGUPTA

The Centre for Atmospheric Sciences was established in 1982 and renamed Centre for Atmospheric and Oceanic Sciences in 1996. Known for pioneering work on monsoon physics and variability, its activities now span a broad range of topics in atmosphere, ocean and climate science.

Current Research

We highlight a few results to convey a flavour of research at CAOS. Analysis of IMD radar observations have revealed distinct convective cells ("storms") buried within the widespread cloud cover of the monsoon. Each storm comprises of clusters of cumulonimbus clouds, tens to hundreds of square kilometres in area and lifespan of 30 minutes to 3 hours. Very heavy rainfall is associated with storms, and the outflow from the storms merge in the upper troposphere to produce extensive cloud cover.

The Bay of Bengal plays a fundamental role in the birth of monsoon weather systems. The BoB Boundary Layer Experiment (BoBBLE) was undertaken by India and the United Kingdom in June-July 2016. Physical and biogeochemical observations showed the time evolution of the Sri Lanka dome and the summer monsoon current. It also showed two freshening events when upper ocean salinity decreased, leading to thick barrier layers. These observations, made during a suppressed phase of the monsoon intraseasonal oscillation, captured ocean warming and preconditioning of the atmosphere to convection.

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IN NUMBERS

9 Academic Staff
22 PhD Students
36 Publications
4 MTech
7 PhD Conferments

Remote forcings ("teleconnections") have important implications for seasonal prediction of rainfall over India. It has been shown how these forcings can affect monsoon rainfall. For example, if the previous winter was a La Nina, the rainfall during the current summer over India would decrease slightly. Furthermore, if the present summer is El Nino, last winter's La Nina increases the probability of drought. These remote effects on the monsoon are manifest slowly, due to the slow propagation of surface pressure anomalies in subtropics as ENSO changes its state with season.

The atmospheric concentration of methane (CH4) has increased by almost 150 % since the pre-industrial period, contributing ~20% to the total anthropogenic greenhouse gas radiative forcing. Recent work in the centre has investigated the effectiveness of CH4 in global warming per unit of radiative forcing. Idealized model simulations indicate that the effectiveness of CH4 is nearly ~80% of the role of CO2, and this is related to shortwave absorption bands of CH4.

Black carbon (BC) in the atmosphere does not only exert a warming effect, it also influences Free-Space Optical communication links. Atmospheric warming by an elevated BC-layer at altitude of around 4.5 km enhances atmospheric stability, leading to large reductions in the atmospheric refractive index structure parameter. This alleviates the attenuation of the signal by BC, leading to fewer link outages. The net effect is improvement in wavelength transmission and thus fewer adaptive optics units are required to manage communication systems.

We estimate spatial averages from point observations all the time, but this is not straightforward. With the possibility of missing data, the spatial average is a ratio between random variables. We have extended optimal averaging theory to situations where individual observations might be missing, by deriving convergent series approximations for the bias and variance. We have applied this theory to understand uncertainty in spatial averages of rain-gauge derived precipitation estimates over India, for e.g. Indian Summer Monsoon Rainfall.

In the area of geophysical fluid dynamics, observational data of sea-surface height has been used to understand midlatitude surface ocean dynamics at scales near the local deformation radius, i.e., 200 km to 100 km, where Earth's rotational effects become important. Calculations of energy and enstrophy fluxes and kinetic energy spectra, from estimated geostrophic currents, compare favourably with corresponding results from a comprehensive Earth system model. These calculations appear to reveal a rotationally dominated portion of a surface oceanic counterpart of the Nastrom-Gage spectrum that describes upper-tropospheric energy and enstrophy cascades in the atmosphere.

In the area of physical oceanography, we have understood the mechanisms of movement and dispersal of river water in the Bay of Bengal with the help of satellite-derived sea surface salinity and surface currents.

Faculty & Staff

G Bala | PhD (McGill), Professor
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Arindam Chakraborty | PhD (IISc), Associate Professor
Ravi S Nanjundiah | PhD (IISc), Professor
SK Satheesh | PhD (Kerala), FASc, FNASc, FNA, Professor
Debasis Sengupta | PhD (Bombay), Professor
PN Vinayachandran | PhD (IISc), FASc, FNA, Professor

Core Research

CAOS faculty and students study the monsoons and tropical climate variability, cloud physics and tropical convection, space-time variations of rainfall and extreme rain events, the hydrological cycle, physical oceanography and air-sea interaction, nonlinear climate dynamics, the planetary boundary layer, aerosol physics and chemistry, radiation and climate, large-scale waves and geophysical turbulence, climate change, the carbon cycle and geoengineering. In addition to ocean and climate modelling, data analysis and theoretical work, the Centre has a long tradition of field campaigns to study physical processes from in situ measurements on land and in the atmosphere and ocean.

Jai Sukhatme | PhD (Chicago), Associate Professor
Venugopal Vuruputur | PhD (Minnesota), Associate Professor
Ashwin K Seshadri | PhD (CMU), Assistant Professor

Associate Faculty

Prosenjit Ghosh | PhD (Devi Ahiliya Vishwa Vidhyalaya, Indore), Associate Professor

3.5.3

Centre for Earth Sciences

CHAIRPERSON
D NAGESH KUMAR

The faculty members are involved in innovative, multidisciplinary research using geological, geophysical and geochemical tools to understand Earth processes. Equipped with state-of-the-art analytical facilities and wide-ranging expertise, they are working on diverse problems in earthquake geology, global tectonics, core dynamics, ocean-atmosphere interaction, climate change and paleoclimate studies, petrology and geochemistry of igneous, sedimentary and metamorphic rocks, chemical weathering of the continents.

Current Research

Advances were made in understanding the mechanism of earthquakes along the India-Eurasia plate boundary- the Himalaya-Andaman-Sumatra and the oceanic intraplate activity in the Indian Ocean plate.

Also investigated were mechanisms that support topography such as those in the India-Eurasia collision zone, investigating the stability of continental cratons; identification of the possible source of the Indian Ocean geoid low.

Insights obtained on tectonic correlation of India and Madagascar; CO2 migration during charnockites genesis modeled; evidence of crustal-scale subduction in Neo-Archean from

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IN NUMBERS

7 Academic Staff
29 PhD and 7 MTech Students
32 Publications
4 MTech and 3 PhD Conferments

Core Research

Dynamo theory, Planetary magnetism, Magnetohydrodynamics, Climate Change (Past and Present), Geobiology, Isotope Hydrology, Climate-Tectonics Interaction, Chemical Oceanography, Environmental Tracers, Microchronology, Petrology, Metamorphism, Isotope geochemistry, Origin and evolution of the Solar System, Crust-mantle processes, Paleoclimate reconstruction, Early life signatures, Solid Earth Geophysics, Lithosphere dynamics, Mantle convection, Mechanics of Faulting, Intraplate Seismicity, Seismic Hazard, Chemical weathering and planetary thermostat, Chemical Oceanography, Advanced Chemical Oceanography.

high P-T granulites of Scotland and from chromite-silicate chemistry of the Sittampundi complex of southern India.

The first results on tangent cylinder convection obtained from the Little Earth Experiment. New insight on core-mantle interaction obtained from computational and experimental models developed in CEaS. A new constraint is proposed for the strength of Earth's toroidal magnetic field.

Estimating temperature of oil and gas formation in sedimentary strata; retrievals of seasonality from fossil record of Phanerozoic age; reconstruction of climate during Harappan civilization, were other topics of interst thatw dere pursued.

Geochemical and isotopic study melt droplets (spherules) from the Lonar crater, India, reveal the nature of the extra-terrestrial impactor, evaporation-condensation effects and melting

of the Precambrian basement; Geochemical and isotopic studies reveal the origin of lamprophyre dykes from Wajrakarur, India from a modified sub-continental lithospheric mantle; Economically viable REE deposits from the beach placers of Andhra Pradesh were identified.

Seasonal variation in light stable isotope geochemistry of Godavari River: An attempt to quantify the role of chemical weathering of continental silicate rocks in controlling atmospheric CO2 concentrations.

Reconstruction of past climate utilizing the marine sedimentary archive is my primary research. Members of my group involved in paleoclimate studies apply non-traditional stable isotopes like lithium, boron, and magnesium do study the changes in seawater pH, composition, and alkalinity. Additionally, my group is also working on the spatio-temporal variability of major Indian rivers with a focus on anthropogenic impact transition metal budget of fluvial systems.

Faculty & Staff

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3.5.4 Chemical Engineering

CHAIRPERSON
GANAPATHY K AYAPPA

The Department of Chemical Engineering is a center of excellence in chemical engineering research and education. It has 12 full-time faculty, 1 Ramalingaswami fellow, 1 DST-INSPIRE faculty fellow, and 54 students carrying out research in both fundamental and applied areas with a strong synergy with industry.

Current Research

We have developed a network-theoretic approach to understand the transmission of stress in disordered materials (such as grains, suspensions, emulsions and foams) by seemingly ordered “force-chains”. In continuation of our previous study, we have showed that a novel dilation-driven vortex in sheared granular materials is generic, and arises whenever the gravity and shear directions are non-colinear. We have carried out rheometry of dense suspensions to study and understand the phenomenon of Discontinuous Shear Thickening (DST) in dense particle-liquid suspensions. We have developed a tool for characterizing the flowability of cohesive powders, which is of value to the pharmaceutical and foods industries.

Our work has focused on improving treatments for HIV and hepatitis C virus infections. A key problem with treating HIV infection is the ability of the virus to establish latent infection, which escapes drugs and immune responses. Efforts are ongoing to reverse viral latency. Using a detailed stochastic model of the viral latency genetic circuit, we showed that drugs that can reverse latency suffer a trade-off between their efficacy and synergy. The choice of

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IN NUMBERS

12 Academic Staff
41 PhD Students
2 MTech (Res), 2 MTech
57 Publications
5 MTech
6 PhD Conferments

optimal drug combinations must contend with this trade-off. With hepatitis C, we developed a comprehensive model to explain the unexpected observation that individuals who have strong immune responses tend to respond better to treatments that directly target the virus. The model is built on the hypothesis that the immune response prevents viral replication and hence restricts the ability to develop resistance to drugs. The model described data from over 50 clinical trials quantitatively.

Process development to fabricate nanostructured thin films on flexible substrates using low-cost additive patterning techniques such as inkjet printing, and product development to fabricate low-cost sensors for chemical/ mechanical sensing were pursued.

Developed a technique for rigorously computing free-energies of molecular solids which can be easily implemented in popular packages such as LAMMPS and GROMACS Developed a technique for rigorously solute-solvent interfacial free-energies of molecular solids which can be easily implemented in popular packages such as LAMMPS and GROMACS Developed insights into the molecular mechanisms of retardation of ice growth by anti-freeze proteins Computed the effect of surfactant layers of nanoparticle on inter-particle interactions Computed phase diagrams of semi-clathrates

Work in the lab focuses on developing low-cost point-of-care diagnostics approaches for infectious diseases. A paper-and-plastic chip was developed for nucleic acid detection of TB DNA. A new device for collection and stabilization of sputum from remote locations was developed. Mathematical models were developed to describe the imbibition of fluid into porous membranes.

The theme of research activities in our group is the development of a process engineering toolkit that will enable the use of metallic nanostructures as building blocks for applications in the fields of sensing, energy conversion, and nanoelectronics. We have developed a scalable process for the formation of self-assembled arrays of metal nanoparticles on any desired substrate. This has aided in the fabrication of several devices such as floating gate memory devices, flexible SERS (Surface Enhanced Raman Scattering) substrates and PEMFC (Proton Exchange Membrane Fuel Cell) catalyst layers.

A low-cost disposable dual-layer (PDMS) polymer co-planar electrodes device for microfluidic impedance cytometry was fabricated. The bottom layer forms the channels for the microelectrodes fabricated by flowing in molten Field's metal. The top layer serves as the sample channel for cell suspensions or microdroplets. The impedance change (spikes) due to the transit of single cell/droplet over the in-contact microchannel electrodes is detectable above the noise by lock-in detection and can be further processed to sample cells at high rates in label free format.

We have been pursuing studies of 2D assembly of bacterial pore forming toxins. We find that the first set of conformational changes that ensure protein insertion into bilayer membranes and toxin oligomerization is enhanced by the presence of cholesterol. Cholesterol is a key mammalian cell membrane constituent that is absent in bacterial membranes that can explain how these proteins selectively puncture across such cells.

The kinetics of nanopore assembly by pore forming toxins was studied using single molecule imaging. Cholesterol was found to be a critical component for effective pore formation. Molecular dynamics simulations were used to study the interaction of pore forming toxins on lipid bilayer membranes. Dye leakage experiments and kinetic modelling studies reveal oliogomeric protein arcs cause leakge. Super-resolution STED microscopy shows complex nanoscale domain formation.

Core Research

Biomolecular and Biomedical Engineering, Catalysis and Reaction Engineering, Colloids and Interface Science, Complex Fluids and Transport Processes, Nanotechnology, Energy Science and Engineering, Environmental Engineering, Thermodynamics, Statistical Mechanics and Molecular Simulations

Photocatalysis is an advanced oxidation process, which has shown to possess an enhanced capability to remove a wide range of contaminants from aqueous effluents. We used novel photocatalysts for inactivation of microorganisms as well as exploring the potential of photocatalysis in reduction reactions. In other work, the Pichia N-glycosylation pathway was re-engineered to mimic the human type N-glycosylation. These modifications resulted in the conversion of the yeast Man9−20GlcNAc2 glycan structure to a more human like GlcNAc2Man3GlcNAc2 form.

Laminar-turbulent transition in soft-walled channels and tubes, Soft-wall turbulence and ultra-fast mixing in microchannels, Kinetic models for dense granular flows, Turbulence collapse due to particle loading in a particle-gas-suspension, Multiscale modeling of lamellar mesophases from molecular properties to rheology.

Our research interests are in the field of colloids and interfaces, specifically in energy storage systems, nanoparticles, agitated dispersions, foams, and emulsions. We combine experimental investigations and process/phenomenological/CFD/ population balance modelling in our research efforts. Discrete simulations and solution of population balance equations are allied interests.

A microkinetic model for CO oxidation over palladium-substituted ceria was developed. Platinum and ruthenium substituted titania catalysts were synthesized using the sonochemical method and used for reforming and partial oxidation. Photocatalysts using AgBr and Ag3PO4 with ceria nanoflakes as a substrate, and graphene oxide foams showed a high degradation of dyes and antimicrobial activity.

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3.5.5 Civil Engineering

CHAIRPERSON
ANANTH RAMASWAMY

The department spans four major areas: Structural, Geotechnical, Water Resources and Environmental, and Transportation Engineering. A wide spectrum of research activities - analytical, numerical, and experimental -- are pursued. In addition to the doctoral and masters research, a unique MTech program is offered where a student can opt for a major and a minor.

Current Research

A reliability-based approach for stability analysis of jointed rock slopes has been developed. This approach considers the effect of strain rate on the constitutive behaviour of jointed rocks, which is very important parameter to consider in estimating the stability of rock slopes. Different strain conditions that prevail in during excavations, blasting and earthquakes can be accounted for, by using an appropriate strength applicable to the strain range of the loading condition. A huge data base of rocks belonging to velocity softening and velocity hardening ranges of stress-strain behaviour is generated. Further, laboratory triaxial compression tests are carried out on jointed rock samples at different strain rates to fill the gaps in the database. A reliability-based slope stability analysis approach is then developed in a probabilistic framework based on finite element numerical simulations to obtain the reliability index for rock slopes. This method is extremely useful for designing optimal rock support systems for slopes. Formulation to solve the geomechanics problems in rocks by using finite elements limit analysis and semi-definite programming has been developed. Methods to solve the bearing capacity problems in rocks using the method of

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IN NUMBERS

22 Academic Staff
4 Scientific Staff
98 PhD Students
6 MTech (Res), 40 MTech
120 Journal Publications
2 MSc (Engg), 29 MTech
17 PhD Conferments

characteristics have been evolved. Method introduced to determine the stability of tunnels have been proposed.

Geotechnical earthquake engineering in particular, considering local site effects to ascertain the influence of local soils on the buildings during an earthquake and its response to shaking has been investigated. Micro-zonation of Bangalore, Lucknow (in Indo-Gangetic belt) have been undertaken. Strain-dependent nonlinearity effects on soils, liquefaction and post-liquefaction behaviour of sandy soils have been considered in the studies. Acceleration time history at the ground surface and the response spectra has been generated. New ground motion prediction equation has been developed for the first time and are applicable from 4 to 9 magnitude and up to distance of 750 km. Integrated subsurface investigation with advanced geophysical methods have been used to identify cavity formation in the lateritic soil of western ghats. Amplification and liquefaction of shallow bedrock sites has been investigated and new empirical model has been developed using recorded earthquake data.

Transformation of ammonium to nitrate upon sewage discharge to sub-surface environment exposes about 65 million households in rural and urban India to risks of drinking nitrate contaminated groundwater. Building on earlier research, a twin pit is modified in Mulbagal town, Karnataka, to remove nitrate in pit toilet sewage and is functional for nearly one year. The first pit serves as an anaerobic chamber, while the second pit facilitates aerobic reactions in the upper half and is equipped with a bio-barrier in its lower half. Quality of treated sewage is monitored by soil water samplers installed adjacent to the pit. After anaerobic digestion in pit 1, sewage flows into the aerobic chamber (upper half of pit 2), where, COD/N ratio of 1.49 to 1.73 facilitates aerobic conversion of ammonium to nitrite and nitrate ions. Annamox reactions in a bio-barrier chamber reduce ammonium and nitrite concentrations, while, denitrification reactions in the bio-barrier remove nitrate.

Climate change impacts on water balance of river basin using ArcSWAT and ensemble of GCMs are studied. Daily rainfall and evaporation are downscaled using MMM-KDE and k-nearest neighbour approach. Future projections show an increase in the water stress, Increase in irrigation demand and reduction in groundwater recharge. Assessment of surface water storage trends for increasing groundwater areas in India are studied in peninsular river basins using GRACE satellites data. Recovery from 2002 major drought is observed as one of the causes of Increasing trends in surface water observed in all the river basins studied. A new approach for Spectral-spatial classification of hyperspectral data with mutual information based segmented stacked autoencoder approach is developed.

Dependence on structure and uncertainty in spatial return levels of urban precipitation extremes are modelled with Bayesian Hierarchical Models. A significant variation in spatial return levels of extreme precipitation is observed over Bangalore city; quantification of dependence structure among the extremes is useful in modelling spatial precipitation extremes. Partition of uncertainty in streamflow projections and simulating extreme rainfall events over Upper Ganga basin is carried out using high-resolution climate and hydrologic models. This study segregates sources of uncertainty in model simulations to provide a better understanding of basin hydrology; reconstruction of historical floods is possible with such model integration. The team has also contributed to the understanding of persistence of river flows and how it is impacted by rainfall and catchment characteristics. Persistence of streamflow is shown to be a function of catchment characteristics alone rather than rainfall.

Advancement in hydrological research to resolve critical gaps in the functioning of groundwater systems in tropical semi-arid hard rock aquifers through theoretical,

Core Research

Some major research thrust areas are predictive science, theoretical and applied mechanics, large scale testing, water resources and environmental engineering, and transportation engineering. While the analytical and computational research spans from theoretical development to high performance computing, the experimental research spans from laboratory based to field studies

experimental and computational research studies aimed towards applications of water resources and water quality. Advances in multidisciplinary catchment hydrology science in forested and agriculture dominated systems pioneered through installation of experimental watersheds (e.g. Kabini Critical Zone Observatory). Notable contributions from the study are deciphering vegetation/ human controls on water and elemental budgets in contrasted systems. Other significant contributions include concomitant algorithm development for retrieval of hydrological variables from satellite remote sensing towards providing finer scale hydrological projections demanded by farmers, urban planners & policy makers in addition to resource estimation under climate & anthropogenic stresses, and incorporating uncertainty analysis.

A systematic study of variety of methods based on Kalman Filter techniques to predict the state as well as the parameters in water distribution systems (WDS) has been investigated; Application of the developed models on field data; Identification of type of Kalman Filter based techniques to be used under what conditions; Application of the developed models to estimate both source strength as well as wall reaction parameters; Development of models to predict both state as well as parameters in WDS; Estimating leaks in WDS using Kalman filter based approach along with localization; Development of Controller based model such as DI-PID and MPC to estimate equity of supply in local as well as in large urban network with establishment of hybrid techniques. Modelling of Coastal aquifers to address the issues concerning heterogeneity and anisotropy has been done. Estimation of system parameters addressing these issues with geophysical constraints being imposed through ERT data has been done on the 85 Sq Km area Surathkal aquifer.

A new methodology was developed in fuzzy framework for regionalization of reference evapotranspiration (ET0) and its effectiveness is demonstrated through case study on India. Sensitivity of ET0 and surface runoff to different predictor variables is investigated for eighteen homogeneous ET0 regions delineated in peninsular India using the approach. Further, a new methodology is developed for assessing adequacy and planning expansion of hydrometric networks.

Development of robust reduced order models for uncertainty quantification, development of domain decomposition-based methods for modeling and analysing localized damage with uncertainty. We developed new error bounds for linear and nonlinear dynamical systems which are found to be better than the state-of-the-art. Subsequently, these error bounds were used to optimally train reduced order models for failure prediction in a probabilistic language. The process of developing parallel solvers is in progress. Figuring out potential approaches to solve domain decomposition-based methods, and developing related algorithms is underway. We also explored tensor decomposition-based representation of random fields, using experimental data such as images to construct random field models for materials modelling, and multiscale mechanics of nanocomposite materials.

Understanding of the microscale phenomena in granular materials and its manifestation at the ensemble scale formed another line of research. The studies developed were based on utilization of the technique of x-ray computed tomography in understanding granular materials. It also led to understanding the packing of cohesive frictional materials. In this endeavour, we attempted to discern the structure and fabric of these cohesive granular ensembles. Through a combination of x-ray computed tomography and concomitant image analysis, made progress into quantifying the structure of these granular ensembles. In addition to quantification of the structure, investigating initiation and propagation of regions of localization such as shear bands and fractures. The platform of cutting to impose severe plastic deformation on a range of materials, including model granular systems, was used to study the interparticle interaction.

Hygro-thermo-chemo-mechanical modelling of concrete has been developed. Effects of moisture migration in concrete, the hydration process and strength gain, and influence of mineral admixtures in the process were studied. These effects under sustained loading conditions contributed to the creep and shrinkage in concrete. Effect of high temperature on concrete resulting in the dehydration and degradation was another aspect studied in this program.

Non-classical continuum mechanics of solids, wherein the aim is to describe the defect structure (micro-cracks, dislocations, disclinations to wit) using such homogenized tensorial quantities as curvature, torsion and non-metricity. Within this framework, to understand the consequences of defect motion and other constraints geometrical (e.g., gauge symmetries) or thermodynamic (e.g., the entropy inequality) in modifying the balance laws and material constitution that describe a component journey to failure through brittle or ductile damage. The question to which to seek an answer is if such a non-classical model could be a macro-continuum extension to what molecular dynamic simulations accomplish in the nanoscale. A related curiosity is to explore if defects could be so engineered as to control damage and failure in components according to certain design criteria. New stochastic search techniques on Riemannian manifolds.

Micromechanics based characterization of cementitious materials - the size effect observed due to the heterogeneity is addressed and the fracture and fatigue behaviour is studied. Acoustic emission-based characterization of damage in concrete - the evolution of damage due to microcracking is quantified. Fatigue behaviour of concrete - models are

proposed to compute the rate of fatigue crack propagation and the factors on which it depends. Studies on acoustic emission characteristics of cementitious materials during early age hydration were carried out.

Development of computational and experimental methods for efficient estimation of time variant structural reliability was undertaken. Application of model distance measures in modelling global response sensitivity indices in uncertain structural systems. Development of Rao-Blackwellized particle filters for combined state and parameter estimation in nonlinear systems.

Development of a program to model and simulate the cutting of polycrystalline aggregates beyond the incipient chip formation stage. Program to study the mechanics of indentation with extreme deformation (deep indentation by punches, narrow-angle wedge) was undertaken.

Methods for the identification of linear structural system parameters in time, frequency and modal domains have been developed. Algorithms so developed have been verified on simple structures such as beams, frames, etc. using synthetic data. Experiments have been conducted on the structural models, signatures from test data have been obtained and the algorithms developed have successfully been applied on the experimental data. Methods for the identification of non-linear structural parameters (of systems with geometric non-linearity) combining static and dynamic test data are currently underway.

Developed an isogeometric based formulation for bending analysis of laminated composite plates with various boundary conditions. Developed an isogeometric variational asymptotic method for

bending analysis of laminated composite beams with various boundary conditions. Experimental studies to understand in-plane shear behaviour of cement stabilized rammed earth. Experimental studies to understand the influence of FRP as external reinforcement to improve in-plane shear behaviour of masonry assemblage.

The increased focus on demand centric approaches has resulted in emergence of traffic engineering and management, demand management, travel behaviour, transportation planning and policy as key research areas of transportation engineering today. The problem solving in demand centric approaches of transportation engineering is heavily derived from modelling, optimization, and data sciences with a clear emphasis on sustainability issues in transportation. Develop and evaluate sustainable transport measures that improves the liveability of Indian cities. Kumbh Mela Experiment project, which focuses on understanding crowd dynamics in mass religious gatherings and develop crowd management solution particularly focusing on crowd risk.

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Venkatarama Reddy BV | PhD (IISc), Professor
Venkatesha S | MSc (Engg) (IISc), Senior Scientific Officer
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3.5.6

Centre for Product Design and Manufacturing

CHAIRPERSON
AMARESH CHAKRABARTI

Centre for Product Design and Manufacturing (CPDM) is among the most research and technology intensive design and manufacturing schools in India, steeped in the ambience of Indian Institute of Science (IISc). CPDM is the design and manufacturing face of IISc.

Current Research

Product Development Process, Informatics, Innovation: Measures have been developed for novelty and usefulness that can be used to assess creativity of design outcomes during the design process, which was hitherto impossible. To assist designers in problem-solving, a web-based tool called Idea-Inspire 4.0 is developed to support analogical design. A representation has been developed that combines instances of SAPPhIRE model for representing complex systems and provide a more comprehensive explanation of a complex system than currently possible, with which analogues are presented in order to maximize their utility in inspiring ideation. Computation of Minkowski sum has diverse applications but its exact computation is complex; using novel slice-representation, a space partitioning scheme for polyhedrons, both exact convex decomposition and computation of non-regularized Boolean of thousands of components robustly and efficiently, has been achieved. A marching sphere algorithm is developed to compare data sets measured off two configurations of a surface where the surface is highly deformable.

FACT FILE

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IN NUMBERS

7 Academic Staff
1 Scientific Staff
40 PhD Students
48 MDes, 1 MSc (Engg), 1 MTech (Res)
25 MDes Conferments
36 Publications
4 PhD Conferments

HUMAN FACTORS

Natural behaviour simulation using digital human models through balanced postures, autonomous bracing for performance enhancement without over-stressing itself has been achieved. Development of PURAK, affordable, functional, trans-radial prosthetic device, funded by the Wellcome Trust UK, is completed with conduction of pan-India user trials on 45 subjects, leading to a startup. Methodology and tools are being developed for Early detection of neuromotor developmental delay/defects in infants such as using User-friendly Heart rate monitor based on PPG signals, wireless communication via Bluetooth with Firebase authentication for custom authentication, Video image processing for eyeball movement detection, IMU sensor performance analysis for segmental movement analysis, etc. Data processing has been conducted for heart rate variability analysis delay and restriction in infants. An eye gaze-controlled heads up display for cars has been invented. Data processing on heart rate variability analysis during manual material lifting is underway.

MATERIALS AND MANUFACTURING

A novel approach for tracking body segments of workers in real-time and for analysing the tracked data to identify distinct events in an assembly process has been developed; this paves way for automated, real-time assessment of assembly difficulty and its sources. To support reuse of legacy knowledge in appropriate manufacturing scenarios, automated identification of the context of diagnostic knowledge from documents is needed; a method for understanding the context of issues in documents is proposed. Setting up of a common engineering facility centre for a smart factory research platform has been initiated.

SUSTAINABILITY

An uncertainty category called 'solution-variant definition' has been proposed to assess the uncertainty involved in assessing environmental impacts of design concepts, thereby allowing design for sustainability to be applied earlier in product development, with profound impact on the product with respect to its environmental-benignity. A web-based tool called InDeaTe for knowledge-driven, sustainable design process support is developed for improving sustainability considerations in design. The tool has been tested in six case studies in India and the USA, with significant improvements in design of sustainable systems.

TECHNOLOGY INTEGRATION

Work has been initiated in developing a next generation tele-ultrasound system for fetal phonocardiography. Development of functional Mark-1 functional prototype of an indigenous insulin pump has been completed. Based on Image processing, process for real time lane detection for driver assistance are being developed for different environmental and road condition. A Technology Business Incubator in area of geriatric care and MedTech has been initiated.

Faculty & Staff

Amaresh Chakrabarti | PhD (Cambridge), Professor
Anindya Deb | PhD (SUNY), Professor
B Gurumoorthy | PhD (Carnegie Mellon), Professor
Dibakar Sen | PhD (IISc), Professor
Rina Maiti | PhD (IIT Bombay), Assistant Professor

Core Research

Product Development Process, Informatics, Innovation, Entrepreneurship, Creativity, Biomimetics, KBS, PLM, Human Factors, Digital Anthropometry and Modelling, HMI, OHAS, Technology Integration, Medical Devices, Human factors Engineering and clinical engineering research, CAD/CAE, Sustainability, Green Buildings, Sustainable Materials, Design for BoP, Materials and Manufacturing, Computational Metrology, Metal Foams, Bio-composites, Smart Factory, Additive Manufacturing.

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