EECS RESEARCH STUDENTS SYMPOSIUM

April 4 and 5, 2024
Indian Institute of Science, Bengaluru

Book of Abstracts

This report was published on April 4 and 5, 2024
Indian Institute of Science, Bengaluru .

Preface

The EECS Research Students Symposium 2024 is the fifteenth in the series of annual research students symposia initiated in 2010. The symposium is organized by six departments, following the best traditions of collaboration: **Computational and Data Sciences (CDS), Computer Science and Automation (CSA), Electrical Communication Engineering (ECE), Electrical Engineering (EE), Electronic Systems Engineering (ESE), and Cyber Physical Systems (CPS)**.

For the EECS 2024 symposium, a team of six faculty members coordinated by **Viveka Konandur Rajanna (ESE)** and consisting of **Pandarasamy Arjunan (CPS), Ratikanta Behera (CDS), Samir Hazra (EE), Sumit K. Mandal (CSA)**, and **Velpula Balaswamy (ECE)**, and an energetic team of student and staff volunteers, has put in a spectacular effort to organize the event.

As you know, the primary purpose of this event is to showcase the work of our senior research students who are on the threshold of wrapping up their work. These students will present their work in 11 research cluster sessions: **Artificial Intelligence and Machine Learning; Brain, Computation and Data Sciences; Cyber Physical Systems; Microelectronics, RF and Photonics; Computer Systems, Networking and IoT; Power Engineering; Security and Privacy; Signal Processing and Communications; Theoretical Computer Science; and Visual Analytics**. All these sessions also have keynote talks by leading researchers, including industry experts. We are felicitous to get some of the best experts in the world delivering talks in these sessions.

We are fortunate to have a great lineup of plenary speakers: **Prof. Kaushik Roy (Purdue University), Prof. Kavitha Telikepalli (TIFR Mumbai)** and **Prof. Faruk Kazi (VJTI Mumbai)**. Another highlight of the symposium is a series of talks by some faculty members who have recently joined IISc. This year, we will have talks by **Ravi Prakash (CPS), Debayan Das (DESE), Danish Pruthi (CDS), Kiran Kumari (EE), Chaya Ganesh (CSA)**, and **Sudhan Majhi (ECE)**.

The organizing committee has assembled a splendid technical program for this event – congratulations to them on a superlative effort. We are excited by the excellent response received in registrations for this event. We thank our alumni, industry collaborators, faculty members, and students for registering in such large numbers. We sincerely hope the symposium will facilitate lively interactions among the participants and inspire everyone to attempt and solve intellectually-challenging research problems in EECS and beyond.

Our thanks go out to the sponsors **Qualcomm India (Diamond), Kotak IISc AI-ML Centre (Gold) Google (Gold), Advanced Micro Devices (AMD) (Gold), ARTPARK IISc (Gold), Bharat Electronics Limited (BEL) (Gold), Tejas Networks(Gold), British Telecom India Research Centre (BTIRC), IISc (Silver), Centre for Brain Research IISc (Silver), and Centre for Networked Intelligence (Silver)** for their generous sponsorship for this event (as on 27 March 2024). Their support is very much appreciated. Please interact with them at their outreach posts (ECE) and get to know more about the opportunities available.

Please join us for this year's in-person symposium and make this a successful event. I urge all of you to exercise caution and care, and follow the norms, while participating in the symposium.

I wish all of you a fruitful symposium.

Rajesh Sundaresan
Dean, Division of EECS, IISc, Bengaluru.

Contents

1. Organising Committee and Schedule

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1.4 Program at a Glance

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(ECE Hut)
[11:15 AM – 11:45 AM]

Lunch Break
(Main Guest House)
[1:30 PM – 2:30 PM]

High Tea
ECE Hut
[3:30 PM – 4:00 PM]</td></tr>
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<tr><td>2</td><td>Brain Computation and Data Science, AI + ML</td><td>(MP 30 ECE)</td></tr>
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<tr><td colspan="4">Faculty Talks (ECE Golden Jubilee Hall) [2:30 PM – 5:00 PM]</td></tr>
<tr><td colspan="2">Dr. Ravi Prakash, CPS</td><td>Dr. Chaya Ganesh, CSA</td><td>Dr. Danish Pruthi, CDS</td></tr>
<tr><td colspan="2">Dr. Kiran Kumari, EE</td><td>Dr. Sudhan Majhi, ECE</td><td>Dr. Debayan Das, DESE</td></tr>
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[11:00 AM – 11:30 AM]

Lunch Break
(Main Guest House)
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(Purdue University)
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2. Day 1: 4^{th} April 2024 (Thursday)

2.1 Research Cluster Talks

Location: ECE Building

2.1.1 Session 1: Artificial Intelligence & Machine Learning

Session Chair: Prathosh A P (ECE), Shirish Shevade (CSA)
Faculty Organizer: Pandarasamy Arjunan (RBCCPS)
Student Organizer: Rankit Kachroo (CSA), Nibedita Roy (CSA), Gopinath (CSA)
Location: MP 20, ECE Department

Invited Talk 1: Risk-sensitive Learning in a Human-based Decision Making System

Speaker: Prashanth L A, Associate Professor, IIT Madras

Abstract
We consider a human decision making system, where an algorithm produces outcomes that are maximally aligned with the preferences of one or possibly multiple humans. It is well-known that expected value cannot capture human preferences. In this talk, we will use cumulative prospect theory (CPT), which is known to model human decisions well, with substantial empirical evidence. We bring this idea to risk-sensitive bandit and reinforcement learning settings, where the aim is to develop CPT-value optimization algorithms that are online, model-free and easy to implement in complex real-world systems. We present preliminary results from two applications in the transportation domain geared towards improving the traveler's experience.

Bio Prashanth L.A. is an Associate Professor in the Department of Computer Science and Engineering at Indian Institute of Technology Madras. Prior to this, he was a postdoctoral researcher at the Institute for Systems Research, University of Maryland - College Park from 2015 to 2017 and at INRIA Lille - Team SequeL from 2012 to 2014. From 2002 to 2009, he was with Texas Instruments (India) Pvt Ltd, Bangalore, India. He received his Masters and Ph.D degrees in Computer Science and Automation from Indian Institute of Science, in 2008 and 2013, respectively. He was awarded the third prize for his Ph.D. dissertation, by the IEEE Intelligent Transportation Systems Society (ITSS). He is a coauthor of two books: 'Stochastic Recursive Algorithms for Optimization: Simultaneous Perturbation Methods', and 'Risk-Sensitive Reinforcement Learning via Policy Gradient Search'. His research interests are in reinforcement learning, simulation optimization and multi-armed bandits.

Student Talk 1: Learning Low Rank Latent Spaces With Simple Deterministic Autoencoders

Speaker: Alokendu Mazumder, Robert Bosch Centre for Cyber-Physical Systems.

Abstract

The autoencoder is an unsupervised learning paradigm that aims to create a compact latent representation of data by minimizing the reconstruction loss. However, it tends to overlook the fact that the high dimensional latent vectors lies in some low dimensional manifold, which is crucial for effective data representation. To address this limitation, we propose a novel approach called Low-Rank Autoencoder (Lo-RAE). In LoRAE, we incorporated a low-rank regularizer to adaptively learn a low-dimensional latent space while pre-serving the basic objective of an autoencoder. This helps embed the latent vector in a lower-dimensional latent space while preserving important information. It is a simple autoencoder extension that learns low-rank latent space. Theoretically, we establish a tighter error bound for our model. Empirically, our model's superiority shines through various tasks such as image generation and downstream classification. Both theoretical and practical outcomes highlight the importance of acquiring low-dimensional embeddings.

Student Talk 2: Global Variance based Classifier Alignment for Long-Tail Class Incremental Learning

Speaker: Jayateja Kalla, Department of Electrical Engineering.

Abstract: In this symposium talk, we discuss the designed two-stage framework to enhance long-tail class incremental learning, enabling the model to learn new classes progressively while mitigating catastrophic forgetting in the context of long-tailed data distributions. Addressing the challenge posed by the under representation of tail classes in long-tail class incremental learning, our approach achieves classifier alignment by leveraging global variance as an informative measure and class prototypes in the second stage. This process effectively captures class properties and eliminates the need for data balancing or additional layer tuning. Alongside traditional class incremental learning losses in the first stage, the proposed approach incorporates mixup classes to learn robust feature representations, ensuring smoother boundaries. The proposed framework can seamlessly integrate as a module with any class incremental learning method to handle long-tail class incremental learning scenarios effectively.

Student Talk 3: Freenets: Learning Layerfree Neural Network Topologies

Speaker: Rahul Madhavan, Department of Computer Science and Automation.

Abstract

We propose a novel data driven approach to neural architectures based on information flows in a Neural Connectivity Graph (NCG). This technique gives rise to a category of neural networks that we call "Free Networks", characterized entirely by the edges of an acyclic uni-directional graph. Furthermore, we design a unique, data-informed methodology to systematically prune and augment connections in the proposed architecture during training. We show that any layered feed forward architecture is a subset of the class of Free Networks. Therefore, we propose that our method can produce a class of neural graphs that is a superset of any existing feed-forward networks. Additionally, we demonstrate the existence of certain classes of data, which are expressible through FreeNets, but not through any other feedforward architecture over the same number of neurons. We perform extensive experiments on this new architecture, to visualize the evolution of the neural topology over real world datasets, and showcase its performance alongside comparable baselines.

Student Talk 4: FastVPINNs-TensorBased Robust Variational Physics Informed Neural Networks for Complex Geometries

Speaker: Thivin Anandh, Department of Computational and Data Science.

Abstract

Variational physics-informed neural networks (VPINNs) offer a powerful approach for solving partial differential equations by minimizing a loss function based on the variational form of the partial differential equation similar to Finite element methods. While hp-VPINNs, which employ domain decomposition with hierarchical polynomial bases, excel in tackling high-frequency problems, their computational cost scales linearly with the number of element, hindering their applicability to complex geometries. This work introduces a novel, tensor-based implementation of hp-VPINNs that significantly reduces training time and expands its reach to complex domains with many elements. Our framework leverages efficient tensor operations to dramatically accelerate computations, achieving over 100x speedup in median time per epoch compared to standard hp-VPINNs on a 20x20 grid. Furthermore, with strategic hyperparameter selection and refinement strategies, our approach can surpass both the accuracy and speed of conventional PINNs, particularly for high-frequency solutions. The potential of this method is further demonstrated by solving inverse problems on complex domains. This scalable and efficient implementation paves the way for broad application of hp-VPINNs to real-world problems, opening exciting avenues in various scientific and engineering disciplines.

Student Talk 5: Diarization of Speaker and Language in Conversational Environments (DISPLACE)

Speaker: Shareef Babu, Department of Electrical Engineering.

Abstract

In multilingual cultures, social interactions frequently comprise code-mixed or code-switched speech. The code-mixed or code-switched instances pose significant challenges for speech-based systems, such as speaker and language identification or automatic speech recognition (ASR). Minimal resources have labeled data as well as unlabeled data in multilingual multi-speaker conversational

environments. In multi-speaker and multilingual scenarios, the task of identifying "who spoke when" and "which language was spoken when", termed as speaker diarization (SD) and language diarization (LD) respectively, are significantly challenging. There is a need to effectively address these issues and develop multilingual multi-speaker multilingual diarization solutions. Having labelled data is difficult to address these problems.
To address the above challenging task, we collected the data in a conversational setting with code-mixing/switching, natural overlaps, reverberant, and noise environments. We recorded both close-field and far-field recordings (close-field recordings for annotation purposes and far-field recordings for addressing the diarization problems). Manually annotated the speaker segments, language details, and content, for the better quality of rich annotations we use close-field recordings. We conducted the second Diarization of Speaker and Language in Conversational Environments (DISPLACE) challenge in line with the theme of Interspeech 2024. We opened the call for participation in this challenge with three tracks 1) speaker diarization 2) language diarization 3) automatic speech recognition, which grabbed the attention of academia and industry participants. A leader-board platform is deployed for all 3 tracks for participants to monitor their progress in system development. As part of the challenge, we released updated baseline systems for the SD and LD tracks which provided improved performance over the first DISPLACE challenge benchmarks. The wide participation for the second DISPLACE challenge across the globe resulted in significant improvements over the baseline system for both the SD and LD tracks. The ASR track using close-field recordings was observed to be significantly challenging.

2.1.2 Coffee break

Invited Talk 2: Building LLMs in India – Learnings and Opportunities

Speaker: Ashok Jagannathan, Krutrim
Abstract
Krutrim is India's first LLM-based chat application that has been developed on top of a fully trained and fine-tuned LLM to align with the Indian context. In this talk, I will discuss some of the problems we had to solve to reach the current state of the model. As we continue to improve our model, I will also talk about some of the future looking challenges and opportunities in building a fully self-sufficient AI ecosystem in India.

Bio
Ashok Jagannathan is currently a Vice President at Krutrim where he is looking into optimizing inference deployment at scale. Previously, he was a Senior Principal Engineer with Intel where he worked for around 20 years building various processors that cover client, server, graphics, and AI usages. His technical expertise spans the areas of silicon development, computer system architecture, system software and performance optimization. He holds a Ph.D. in CS from UCLA and an undergraduate degree from NIT, Trichy.

Student Talk 6: DeiT-LT: Distillation Strikes Back for Vision Transformer Training on Long-Tailed Datasets

Speaker: Harsh Rangwani, Department of Computational and Data Sciences.

Abstract

Vision Transformer (ViT) has emerged as a prominent architecture for various computer vision tasks. In ViT, we divide the input image into patch tokens and process them through a stack of self-attention layers. However, unlike Convolutional Neural Networks (CNNs), ViT's simple architecture has no informative inductive bias (e.g., locality). This causes ViTs to require a large amount of data for pre-training. Various data-efficient approaches (DeiT) have been proposed to train a ViT on balanced data effectively. However, limited literature discusses the use of ViT for datasets with long-tailed imbalances. In this work, we introduce DeiT-LT for tackling the problem of training ViTs from scratch on long-tailed datasets. In DeiT-LT, we introduce an efficient and effective way of distillation from CNN via distillation DIST token, by using out-of-distribution images and re-weighting the distillation loss to enhance focus on tail classes. This leads to learning of local CNN-like features in early ViT layers, improving generalization for tail classes. Further, to mitigate overfitting, we propose distilling from flat CNN teachers, which leads to learning low-rank generalizable features for DIST tokens across all ViT layers. With the proposed DeiT-LT scheme, the distillation `DIST` token becomes an expert on the tail classes and the classifier CLS token becomes an expert on the head classes. The experts help to effectively learn features related to both the majority and minority classes using a distinct set of tokens within the same ViT architecture. We show the effectiveness of DeiT-LT for training ViT from scratch on datasets ranging from small-scale CIFAR-10 LT to large-scale iNaturalist-2018.

Student Talk 7: Dame: A Distillation Based Approach For Model-Agnostic Local Explainability

Speaker: Debarpan Bhattacharya, Department of Electrical Engineering.

Abstract

The frameworks for explaining the functional space learned by deep neural networks, also known as eXplainable AI (XAI) models, are majorly based on the notion of the locality. Most of the approaches for local model-agnostic explainability employ linear models. Driven by the fact that a linear model is inherently interpretable, they are used to approximate the nonlinear function locally. In this paper, we argue that local linear assumption may be inept as the black box models under investigation are often highly non-linear. We present a novel perturbation-based approach for local explainability, called the Distillation Approach for Modelagnostic Explainability (DAME). It separates the two tasks - local decision boundary approximation and finding saliency-based explanation. DAME performs a joint optimization over these tasks to generate the explanations, while directly operating on the high dimensional input space. The DAME framework is a learnable, saliency-based, post-hoc, model-agnostic explainability model and requires only the query access to the black box. A comprehensive set of evaluations, consisting of visualizations, proxy-task based measures (deletion and overlap) and end-user utility study with subjective evaluations, presented on diverse object and sound classification tasks, demonstrate that DAME provides more accurate and precise explanations compared to several other XAI methods.

Student Talk 8: Bad Values but Good Behavior: Learning Highly Misspecified Bandits and MDPs

Speaker: Debangshu Banerjee, Department of Electrical Communication Engineering.

Abstract

Parametric, feature-based reward models are employed by a variety of algorithms in decision-making settings such as bandits and Markov decision processes (MDPs). The typical assumption under which the algorithms are analysed is realizability, i.e., that the true values of actions are perfectly explained by some parametric model in the class. We are, however, interested in the situation where the true values are (significantly) misspecified with respect to the model class. For parameterized bandits, contextual bandits and MDPs, we identify structural conditions, depending on the problem instance and model class, under which basic algorithms such as ε-greedy, LinUCB and fitted Q-learning provably learn optimal policies under even highly misspecified models. This is in contrast to existing worst-case results for, say misspecified bandits, which show regret bounds that scale linearly with time, and shows that there can be a nontrivially large set of bandit instances that are robust to misspecification.

Student Talk 9: Adding Explainability to Visual Clustering Tendency Assessment (VAT) Methods Through Feature Importance

Speaker: B Srinath Achary, Department of Computer Science and Automation.

Abstract

Clustering is an important unsupervised learning approach to discover interesting patterns from the dataset. A preliminary problem in clustering involves determining whether and how many clusters exist in input data – also known as the clustering tendency assessment problem. Recently, a family of algorithms called Visual Assessment of Clustering Tendency (VAT) has gained popularity among researchers from various domains to visually estimate the number of clusters from a reordered dissimilarity matrix image (RDI) of the input data. However, knowing the number of clusters and the assignment of data points to these clusters is insufficient from an end-user perspective. In this paper, to enhance the interpretability and explainability of VAT methods, we introduce a novel methodology, called FIM-VAT, to identify the importance of individual features in a dataset concerning the corresponding VAT output (RDI) by leveraging the concept of Spearman rank correlation. Experimental validation on ten real and synthetic datasets demonstrates our proposed technique's performance in identifying feature importances in VAT for cluster structure assessment.

2.1.3 Session 2: Brain, Computation and Data Science

Session Chair: Prasanta Kumar Ghosh (EE)
Faculty Organizer: Ratikanta Behera (CDS)
Student Organizer: Nidhi Patidar (CSA), Harsh Gupta (CSA), Sridhar Bajpai (CSA)
Location: MP 30, ECE

Invited Talk 1: Understanding Mild Cognitive Impairment using Resting state fMRI

Speaker: Neelam Sinha, Professor, Center for Brain Research, IISc.

Abstract: Mild Cognitive Impairment (MCI) is characterized by subtle changes in cognitive functions, linked to disruptions in brain networks. In this talk, we will see the utility of Resting state functional Magnetic Resonance Image (RS-fMRI) time series, in understanding these changes.

Bio

Neelam Sinha is a faculty at CBR, working on neuroimaging.She obtained PhD at IISc for her work on strategies for rapid MR imaging, in 2008. She worked in the MR Imaging group at GE Healthcare for a year, and then joined IIIT-Bangalore. At IIIT-Bangalore, her research focus was on problems in healthcare, which included surgical video, fundal image and neuro-data analysis. She executed a DST-funded project on resting state fMRI for brain characterization. She has worked on problems such as age-estimation using Diffusion MR, analysis of atypical PD variants, chromosomal mutation detection in Low Grade Glioma using structural MR images, in collaboration with NIMHANS. As part of an industry-sponsored project, she has worked on visual functioning networks in the brain, utilizing fMRI time series. She was part of a state-funded centre (MINRO) with projects on EEG analysis for quantifying abstract notions, such as creativity. She joined CBR in July 2024.

Student Talk 1: Reinforcement Learning with Quasi-Hyperbolic Discounting

Speaker: Eshwar S R, Department of Computer Science and Automation.

Abstract

Reinforcement learning has traditionally been studied with exponential discounting or the average rewards setup, mainly due to their mathematical tractability. However, such frameworks fall short of accurately capturing human behavior, which often has a bias towards immediate gratification. Quasi-Hyperbolic (QH) discounting is a simple alternative for modeling this bias. Unlike in traditional discounting, though, the optimal QH-policy, starting from some time t_1, can be different to the one starting from t_2. Hence, the future self of an agent, if it is naive or impatient, can deviate from the policy that is optimal at the start, leading to sub-optimal overall returns. To prevent this behavior, an alternative is to work with a policy anchored in a Markov Perfect Equilibrium (MPE). In this work, we propose the first model-free algorithm for finding an MPE. Using a brief two-timescale analysis, we provide evidence that our algorithm converges to invariant sets of a suitable Differential Inclusion (DI). We then formally show that any MPE would be an invariant set of our identified DI. Finally, we validate our findings numerically for the standard inventory system with stochastic demands.

Student Talk 2:Transfer in Sequential Multi-armed Bandits via Reward Samples

Speaker: Rahul NR, Department of Electrical Communication Engineering.

Abstract

Transfer learning in multi-armed bandits and reinforcement learning involves leveraging knowledge from one task in improving the learning and decision making in the other related task. In this talk, we consider a sequential stochastic multi-armed bandit problem where the agent interacts with bandit over multiple episodes. The reward distribution of the arms remain constant throughout an episode but can change over different episodes. We propose an algorithm based on UCB to transfer the reward samples from the previous episodes and improve the cumulative regret performance over all the episodes. We provide regret analysis and empirical results for our algorithm, which show significant improvement over the standard UCB algorithm without transfer.

Student Talk 3: Bridging Technology and Neurosurgery: A Multimodal Approach to Brain Tumour Delineation

Speaker: Arjun B S, Department of Electronic System Engineering.

Abstract

Brain tumours are a significant health issue globally, and the ability to accurately identify tumour margins during surgery is critical for successful patient outcomes. Despite the availability of fluorescence and image guidance methods, improving accuracy and resolution in identifying tumour margins is still challenging. The talk discusses the technological progress toward developing an intraoperative probe designed for accurate brain tumor delineation, emphasizing the indigenous design and fabrication of multimodal sensors, robotic systems, and imaging tools. In India, where brain tumors represent a significant health challenge with an estimated 30,000 new cases annually, including a disproportionately high number among children, the probe offers the potential for improving surgical outcomes through precise tumor delineation. Extensive ex vivo studies found that simultaneous electromechanical characterization is a robust biomarker for tumor delineation, grading, and heterogeneity assessment. The electrical impedance of gliomas (462±56Ω) was found to be significantly lower than corresponding normal (1267±515Ω) regions at 100kHz. It was seen that the higher-grade gliomas relaxed only by 30% in comparison to 55% in the case of low-grade gliomas in 60 seconds. Building on these insights, a novel imaging approach was developed that leverages electrical impedance tomography for brain tissue imaging.

The electrical impedance tomography approach hence developed demarcated white and grey matter boundaries and between tumor and necrotic boundaries within the samples suggesting the potential for margin delineation. The subsequent design of a handheld robotic probe, utilizing parametric modeling and 3D printing for customizable continuum robotic tips (CCR) significantly reduced the time required for CCR design from hours to a few minutes, and manufacturing time, from days or weeks to a few hours. The viscoelastic response of the solid tumor samples characterized using the handheld probe was significantly different from that of the other tumor samples and normal tissues. The probe will potentially benefit thousands of patients and their families, improving quality of life and reducing healthcare costs associated with repeated surgeries.

Student Talk 4:Design and Development of a Bimodal, Auditory event-related Potential Extractor System for Neonatal Hearing Screening.

Speaker: Rathin K Joshi, Department of Electronic System Engineering.

Abstract

Stimuli-induced EEGs, known as Event-Related Potentials (ERPs), reflect the real-time health status of underlying neurophysiological phenomena and are often used for scanning sensory pathways. Neonatal deafness is one of the prevalent chronic deficiencies present at birth, ranging from 1.59 to 8.8 per 1000 live births for normal babies, whereas 7 to 49 per 1000 live births for NICU babies. If not detected on time, adverse consequences of hearing impairment lead to challenges in speech sound interpretation, delays in language acquisition, economic and educational disadvantage, social isolation, and mental health stigma. Therefore, early identification and subsequent intervention play a vital role in saving a child from permanent disability. Auditory Brainstem response (ABR) is the current gold standard for hearing screening, which checks a limited portion of the auditory pathway from the outer ear to the brainstem. There is no current system that checks the complete auditory pathway at birth. Additionally, the need for more clinicians, expensive equipment, specialized hospitals with audiometry tools, and patient follow-up are the challenges for neonatal hearing screening, especially in resource-constrained countries, including India.

The presented research work bridges the mentioned gaps by developing an affordable, easy-to-operate, portable bimodal auditory ERP extractor system to check the complete auditory pathway for neonatal hearing screening. The main subsystems of the developed neonatal hearing screening headband include auditory stimuli generation, biopotential acquisition, wearable system design, and evoked response extractor and interpretation. In the developed headband, the existing neonatal hearing screening strategy is enhanced by adding a novel cortical signature–mismatch negativity (MMN). MMN is the earliest ERP, present at birth. Before acquiring evoked brainwaves from n=3 neonates, the system was validated against commercial systems used in clinical practice for five adults. Auditory-evoked brainstem (ABR) and cortical (MMN) responses were obtained from three neonates. Extracted brainstem responses from neonates were validated with the reference system. Validation results showed that the peak latencies matched, and more characteristic ABR peaks were evident in the response extracted from the developed system. Additionally, the ERP imaging depicted inter-trial variabilities, suggesting possible habituation between presented oddball stimuli for MMN. We envisage replicating the experiment on a large neonatal cohort to understand subjective variabilities and enhance the robustness of the developed system. In a nutshell, the presented research is an attempt to develop a novel, affordable indigenous system development for newborn hearing screening, not only by replicating the current gold standard (ABR) but also by enhancing the neonatal hearing screening protocol by adding an enhanced measure (MMN).

2.1.4 Coffee Break

Student Talk 5: Tackling Computational Challenges In Genome Assembly

Speaker: Sudhanva S Kamath, Department of Computational and Data Sciences.

Abstract

Automated telomere-to-telomere (T2T) de novo assembly of diploid and polyploid genomes is a formidable task. A string graph is a commonly used data structure to represent overlap information between reads, which are substrings of a genome inferred using a sequencing instrument. The string

graph formulation employs graph simplification heuristics, which drastically reduce the number of vertices and edges. One of these heuristics involves an unsafe procedure - removing the reads contained in longer reads. In practice, this simplification can introduce gaps in the assembly by removing all reads that cover one or more genome intervals. The factors contributing to such gaps remain poorly understood. In this work, we mathematically derived the frequency of observing a gap near a germline and a somatic heterozygous variant locus. Our analysis shows that (i) an assembly gap due to contained read deletion is an order of magnitude more frequent in Oxford Nanopore reads than PacBio HiFi reads due to differences in their read-length distributions, and (ii) this frequency decreases with an increase in the sequencing depth. Drawing cues from these observations, we addressed the weakness of the string graph formulation by developing the RAFT assembly algorithm. RAFT addresses the issue of contained reads by fragmenting reads and producing a more uniform read-length distribution. The algorithm retains spanned repeats in the reads during the fragmentation. We empirically demonstrate that RAFT significantly reduces the number of gaps using simulated datasets. Using real Oxford Nanopore and PacBio HiFi datasets of the HG002 human genome, we achieved a twofold increase in the contig NG50 and the number of haplotype-resolved T2T contigs compared to Hifiasm.

Student Talk 6: Scalable Algorithms for Genome-aware Sequence-to-Graph Alignment

Speaker: Ghanshyam Chandra, Department of Computational and Data Sciences.

Abstract

Genomes are conventionally represented as a string in the alphabet A, C, G, T. This mode of representation makes it difficult to capture the genetic diversity within the population. Pangenome graphs are an alternative representation built from a collection of genomes to overcome this issue. Standard pangenome graph generation methods involve computationally intensive techniques like multiple sequence alignment (MSA) or partial order alignment heuristics. However, these methods face challenges due to MSA formulations being NP-hard and quadratic-time complexity in sequence-to-graph alignment using partial order alignment. A scalable alternative is a seed-chain-extend heuristic, which clusters short exact matches (seeds) and extends them with base-to-base alignment. Constructing a Pangenome graph requires incremental sequence-to-graph alignment, where the input order impacts the resulting graph. The scale and availability of high-quality human genome data demand a robust and scalable sequence-to-graph alignment algorithm, which will be used for pangenome graph generation and application. This talk will introduce novel formulations for the sequence-to-graph alignment problem, along with provably good algorithms. These algorithms are designed to scale efficiently to handle trillions of DNA bases, catering to tasks such as pangenome graph generation and read alignment. The talk will commence by presenting a new formulation that leverages graph topology to identify good pattern matches of DNA sequences within pangenome graphs. Subsequently, these pattern matches will be utilized to generate the pangenome graphs. The discussion will then extend the formulations to encompass general pangenome graphs, followed by genome-aware pattern matching of genomic sequences to the pangenome graphs.

2.1.5 Session 3: Theoretical Computer Science

Session Chair: Arindam Khan (CSA)
Faculty Organizer: Sumit K. Mandal (CSA)
Student Organizer: Atharv Desai (CSA), Siddhartha Sarkar (CSA)
Location: ECE 1.07, ECE Department.

Invited Talk 1: Testing Correctness of Samplers using Property Testing: from Theory to Practice and back again.

Speaker: Sourav Chakrabarti, Professor, ISI Calcutta.

Abstract
How can one test the correctness of a program that is supposed to output an element from a large universe according to a certain distribution? These kinds of programs are heavily used in real life but are rarely tested for correctness. This problem can be framed as a problem in property testing. Property testing is a subject that deals with these challenges. It tries to design sub-linear algorithms for testing various properties of inputs. The key lies in the way the data is accessed by the algorithm. One of the central problems in property testing and many other related subjects is testing if a distribution has a certain property - say whether a distribution on a finite set is uniform. The conventional way of accessing the distributions is by drawing samples according to the distributions. Unfortunately, in this setting the number of samples that are necessary for testing properties of distribution (for most natural properties) is polynomial in the size of support of the distribution. Thus when the support is relatively big the algorithms become impractical in real life applications.

We introduced a new way of accessing the distribution using “conditional-sampling oracle". This oracle can be used to design much faster algorithms for testing properties of distribution and thus makes the algorithm useful in practical scenarios. We show that the conditional oracle can be implemented in many real life problems and we have been able to show the usefulness of this model and our algorithms in practical purposes and in other areas of research - like testing of probabilistic verification. This model also throws a number of interesting theoretical questions. The talk will be based on the following works:

1. On the Power of Conditional Samples in Distribution Testing with Eldar Fischer, Arie MAtsliah and Yonatan Goldhrish (SICOMP 2016)
2. Property Testing of Joint Distributions using Conditional Samples with Rishiraj Bhattacharyya (ToCT 2018)
3. On Testing of Uniform Samplers with Kuldeep Meel (AAAI2019)
4. On Testing of Samplers with Kuldeep Meel and Yash Pote (NeuRIPS 2020)
5. Designing Samplers is Easy: The Boon of Testers with Kuldeep Meel, Priyanka Golia and Mate Soos (FMCAD22)
6. On Quantitative Testing of Samplers with Kuldeep Meel, Priyanka Golia and Mate Soos (CP22)
7. Testing of Horn Samplers with Ansuman Banerjee, Shayak Chakraborty, Sayantan Sen, Uddalok Sarkar and Kuldeep Meel (AISTAT 2023)
8. Tight Lower Bound on Equivalence Testing in Conditional Sampling Model with Diptarka Chakraborty and Gunjan Kumar (SODA 2024)
9. Testing Self-Reducible Samplers with Rishiraj Bhattacharyya, Yash Pote, Uddalok Sarkar and Sayantan Sen (AAAI 2024)

Bio

Sourav Chakraborty is a Professor in Computer Science at the Indian Statistical Institute, Kolkata, India. He finished his bachelors in Mathematics from Chennai Mathematical Institute in 2003 and then went on to do his Master's (in 2005) and Ph.D. (in 2008) in Computer Science from the University of Chicago under the guidance of Prof. Laszlo Babai. After doing one year of postdoc at Technion, Israel, and one year of postdoc at CWI Amsterdam, he joined Chennai Mathematical Institute in 2010. He joined the Indian Statistical Institute in 2018. His main area of interest is Theoretical Computer Science with a particular focus on query complexity, property testing, Fourier Analysis of Boolean functions, streaming algorithms, and graph algorithms. Recently he has been using property testing techniques in other more applied areas.

Student Talk 1: Bin Packing under Random Order: Breaking the Barrier of 3/2

Speaker: KVN Sreenivas, Department of Computer Science and Automation.

Abstract

Best-Fit is one of the most prominent and practically used algorithms for the bin packing problem, where a set of items with associated sizes needs to be packed in the minimum number of unit-capacity bins. Kenyon [SODA '96] studied online bin packing under random-order arrival, where the adversary chooses the list of items, but the items arrive one by one according to an arrival order drawn uniformly at random from the set of all permutations of the items. Kenyon's seminal result established an upper bound of 1.5 and a lower bound of 1.08 on the performance of Best-Fit in the random-order model, and it was conjectured that the true ratio is close to 1.15. The conjecture, if true, will also imply that Best-Fit (on randomly permuted input) has the best performance guarantee among all the widely-used simple algorithms for (offline) bin packing. This conjecture has remained one of the major open problems in the area, as highlighted in the recent survey on random-order models by Gupta and Singla [Beyond the Worst-Case Analysis of Algorithms '20]. There have been some improvements for certain special cases; however, the upper bound of 3/2 for the general case, however, has remained unimproved. In this paper, we make the first progress towards the conjecture, by showing that Best-Fit achieves a random-order ratio of at most 1.5-epsilon, for a small constant epsilon>0. Furthermore, we establish an improved lower bound of 1.144 on the random-order ratio of Best-Fit, nearly reaching the conjectured ratio.

Student Talk 2: No Distributed Quantum Advantage for Approximate Graph Coloring

Speaker: Rishikesh Gajjala, Department of Computer Science and Automation.

Abstract

We give an almost complete characterization of the hardness of c-coloring x-chromatic graphs with distributed algorithms for a wide range of models of distributed computing (deterministic, randomised and quantum). In particular, we show that these problems do not admit any distributed quantum advantage!

Student Talk 3: The Exchange Problem

Speaker: Mohit Garg, Department of Computer Science and Automation.

Abstract
Auctions are widely used in exchanges to match buy and sell requests. Once the buyers and sellers place their requests, the exchange determines how these requests are to be matched. The two most popular objectives used while determining the matching are maximizing volume at a uniform price and maximizing volume with dynamic pricing. In this talk, we will focus on the algorithmic complexity of the problems arising from these matching tasks.

2.1.6 Coffee break

Invited Talk 2: Random Walks and Graph Property Testing

Speaker: Akash Kumar, Assistant Professor, IIT Bombay.

Abstract
Random Walks on graphs reveal lots of interesting information about a graph and this information has been used to get a lot of algorithmic mileage in the classical literature on algorithms. It is perhaps not surprising that this primitive continues to be relevant even in the big data era as we deal with larger and larger graphs. In this talk, I will describe how random walks were put to use by algorithm designers even in the setting of sublinear time algorithms. The talk will cover how you can use random walks to gain insights about planar graphs and how you can use random walks to also obtain insights about expanding graphs and clusterable graphs. The talk will assume minimal background and it will attempt to present a standalone narrative which should be of interest to students and researchers in Spectral Methods. Based on joint works with C. Seshadhri, Andrew Stolman, and Agastya Jha.

Bio
Akash Kumar is a James R Isaac Chair Assistant Professor in the Computer Science Department at IIT Bombay. His research interests lie in the areas of Property Testing and Spectral Graph Theory. He did his PhD from Purdue in 2020. He followed this with a postdoc from 2020 to 2022 (which was at EPFL) after which he joined IIT Bombay.

Student Talk 4: On Approximation Schemes for Stabbing Rectilinear Polygons

Speaker: Aditya Subramanian, Department of Computer Science and Automation.

Abstract
We study the problem of stabbing rectilinear polygons, where we are given n rectilinear polygons in the plane that we want to stab, i.e., we want to select horizontal line segments such that for each given rectilinear polygon there is a line segment that intersects two opposite (parallel) edges of it. Our goal is to find a set of line segments of minimum total length such that all polygons are stabbed. For the special case of rectangles, there is a O(1)-approximation algorithm and the problem is NP-hard

[Chan et al.]. Also, the problem admits a QPTAS [Eisenbrand et al.] and even a PTAS [Khan et al.]. However, the approximability for the setting of more general polygons, e.g., L-shapes or T-shapes, is completely open. In this paper, we characterize the conditions under which the problem admits a $(1+\varepsilon)$-approximation algorithm. We assume that each input polygon is composed of rectangles that are placed on top of each other such that, for each pair of adjacent edges between rectangles, one edge contains the other. We show that if all input polygons satisfy the hourglass condition, then the problem admits a QPTAS. In particular, it is thus unlikely that this case is APX-hard. Furthermore, we show that there exists a PTAS if each input polygon is composed out of rectangles with a bounded range of widths. On the other hand, if the input polygons do not satisfy these conditions, we prove that the problem is APX-hard, already if all input polygons have only eight edges. We remark that all polygons with fewer edges automatically satisfy the hourglass condition. On the other hand, for arbitrary rectilinear polygons we even show a lower bound of $\Omega(\log n)$ for the possible approximation ratio, which implies that the best possible ratio is in $\theta(\log n)$ since the problem is a special case of Set Cover.

Student Talk 5: Random-Order Online Independent Set of Intervals and Hyper rectangles.

Speaker: Debajyoti Kar, Department of Computer Science and Automation.

Abstract

Given a collection of geometric objects, the maximum independent set problem aims to find the maximum cardinality subset of pairwise disjoint objects. When the objects are intervals, the problem is popularly known as interval scheduling, and a simple greedy algorithm returns an optimal solution. For d-dimensional hyperrectangles, polynomial-time $(logn)^{O(d)}$-approximation algorithms are known [Chalermsook and Chuzhoy, '09]. However, the problem becomes formidable in the online setting where the input objects appear one by one in an adversarial order and on the arrival of an object, the algorithm needs to make an immediate and irrevocable decision whether or not to select the object while maintaining feasibility. Even for interval scheduling, nothing better than the trivial O(n)-approximation is possible. Random-order models were introduced to mitigate excessively pessimistic results in the adversarial-order arrival model, presenting a more realistic representation in many scenarios. In this model, the input set of items is chosen by the adversary; however, the arrival order of the items is determined by a permutation selected uniformly at random from the set of all permutations. We study the maximum independent set problem on d-dimensional hyperrectangles in the random-order model and present a simple $\tilde{O}((logn)^d)$-competitive algorithm, which runs in $\tilde{O}(n)$ time. This matches the best-known offline approximation guarantees upto polylogarithmic factors. Our approach also yields $(logn)^{O(d)}$-competitive algorithms in the random-order model for more general objects such as d-dimensional fat objects and ellipsoids.

2.1.7 Session 4: Power Engineering

Session Chair: Vishnu Mahadeva Iyer (EE), Gopalaratnam Narayanan (EE)
Faculty Organizer: Samir Hazra (EE)
Student Organizer: Chetan Sharma (EE),Pratyush Poudel (EE), Govind Rai (EE)
Location: Golden Jubilee Hall, ECE

Invited Talk 1: A Single-Stage Bidirectional Three-phase AC to DC Converter Employing Reduced Switching State PWM with Step-Voltage Switching for Elimination of Device Voltage Overshoot

Speaker: Souvik Chattopadhyay, Assistant Professor, IIT Kharagpur.

Abstract
This work introduces a new single-stage bidirectional power converter topology with a two-state PWM strategy for a three-phase AC to DC high-frequency isolated converter. It is designed to eliminate voltage spikes on the AC side (current-fed side) without resorting to traditional clamp circuits. The proposed converter incorporates two split full bridges on the DC side (voltage-fed side), to produce a two-step voltage waveform across the transformer secondary. It also employs a reduced switching state SPWM strategy on the AC side devices. The step-voltage switching combined with the PWM strategy eliminates transient overshoots across the AC side devices. The proposed converter has reduced current and voltage stress on the devices and achieves soft-switching in most devices, contributing to an overall increase in efficiency. It can be used as a high-power-density battery charger topology.

Bio
Souvik Chattopadhyay (Member, IEEE) received the B.E. degree from the Bengal Engineering College, Howrah, India, in 1988, and the M.Sc. and Ph.D. degrees from the Indian Institute of Science, Bangalore, India, in 1990 and 2002, respectively, all in electrical engineering. He is currently an Assistant Professor with the Department of Electrical Engineering, IIT Kharagpur, Kharagpur, India. From 1991 to 1995, he was with Crompton Greaves, Ltd., Bombay, India, from 1996 to 1998, he was with Cegelec India, Ltd., Noida, India. From 2002 to 2003, he was an Assistant Professor at the Department of Electronics and Communication Engineering, Jalpaiguri Government Engineering College, Jalpaiguri, India. From 2003 to 2004, he was an Assistant Professor with the Department of Electrical Engineering, IIT Madras, Chennai, India. His research interests are designing, analyzing, controlling, and modeling switched-mode power converters.

Student Talk 1: Asymmetrical Phase-shifted Full-bridge Converters in Input-parallel Output-parallel Configuration

Speaker: Roja Peri, Department of Electrical Engineering.

Abstract
Power-electronic converters are essential components in high-power and high-current applications, including grid-integrated renewable energy, uninterruptible power supply systems and storage systems. Modular architectures are preferred in this domain due to their scalability and reconfigurability.

This talk introduces asymmetrical modular phase-shifted full-bridge (PSFB) converters in input parallel output-parallel (IPOP) configuration. The performance of these converters under varying levels of parametric mismatches for different control schemes is investigated, examining their impact on power sharing among the modules. Departing from the traditional symmetrical modules with symmetrical loading, a Lagrangian loss optimal load (L2OL) sharing control method, enhancing system efficiency across the entire load range by appropriately dispatching and loading the modules, is proposed. Additionally, optimal pre-design strategies for unit asymmetrical PSFB modules and a method for increasing the number of modules while minimizing asymmetry are discussed. This study endeavours to enhance the efficiency and adaptability of power-electronic systems, particularly for integration with energy storage systems such as ultracapacitors and/or batteries.

Student Talk 2: Non-Permanent Magnet-Based Electric Drives for Electric Mobility

Speaker: Syam Sundar Nair, Department of Electrical Engineering.

Abstract

An electromagnet rotor-based switched reluctance machine (ERSRM) is proposed for electric vehicle (EV) applications. The proposed machine is realized with the winding on the rotor, with an objective of gaining higher torque density (Nm/kg), reduced input current, and wider torque-speed characteristics. This is done by establishing rotor excitation through inductive power transfer from stator to rotor. In the approach of rotor excitation through a wireless power transfer (WPT) system, the stator has a transmitting coil fed by a resonant converter, and the rotor has a receiving coil that has a high pass filter to allow high-frequency signals necessary for rotor excitation. A 50kW ESRM has been modelled and validated in FEM (Finite Element Method) simulation tools like FEMM and JMAG. A modulating and carrier-based dodecagonal space vector pulse width modulation (DSV-PWM) technique for split-phase open-end induction motor (OEIM) has been proposed here. The advantage of the DSV-PWM technique is that the fifth and seventh order (6n±1; n=1,3,5,...) harmonics are eliminated from the phase voltage of the split-phase OEIM. The modulating waveform is generated with a simple algorithm and compared to the triangular carrier signal for producing DSV-PWM for the 2-level inverter and multilevel inverters of the OEIM drive. The PWM for the inverter connected to the second end of the OEIM is produced by performing a small logical operation using the PWM of the inverter connected to the first end of the OEIM. The DC voltage relation between inverter-1 and inverter-2 is 1:0.366. The PWM timing of the space vectors of the dodecagonal space vector structure (DSVS) of a conventional split-phase induction motor (with shorted neutral of respective phase groups) is the same as the PWM timing of DSVS of the split-phase OEIM. So, mapping the space vectors of the DSVS of conventional split-phase to that of the OEIM is simple. This can be achieved using a logical operator like XOR. The proposed algorithm is 3 times faster than the conventional sector-based algorithm for DSV-PWM signal generation. A detailed analysis of the modulating waveform generation and the experimental verification of the proposed drive has been carried out.

Student Talk 3: A Multilevel Converter Testbench for High-Frequency Power Magnetics Characterization

Speaker: Neha Rajput, Department of Electrical Engineering.

Abstract

The talk will present a new multilevel magnetic component tester circuit and testbench to characterize high-frequency magnetics for power electronics applications. The proposed circuit topology is

reconfigurable and enables the testing of magnetics under various excitation conditions: triangular flux, trapezoidal flux, the presence of DC bias, and a combination of low-frequency and high-frequency excitations. Furthermore, the proposed topology enables the popular two-winding-based measurement approach to quantify the core losses. A SiC- MOSFET-based hardware prototype of the multilevel converter is developed in the laboratory to enable higher operating frequencies. Experimental results from the hardware testbench will be presented to validate the multilevel and multifrequency operational capabilities of the magnetic tester circuit.

Student Talk 4: A relook at Zero Voltage Switching in power converters.

Speaker: Aabid Ahmad Dar, Department of Electrical Engineering.

Abstract

Recently, power electronic converters have seen a significant improvement in switching performance and efficiency with the advent of wide-bandgap semiconductor devices. However, switching losses still limit the performance at higher frequencies. Soft-switching techniques are preferred to curb switching losses and improve converter performance. Some popular soft-switched topologies, such as synchronous buck converter, phase-shifted full-bridge (PSFB) converter, and dual active bridge (DAB) converter involve one or more half-bridge legs with an inductive impedance network connected to the mid-point. During the dead time interval between the complimentary MOSFET switchings in a half-bridge leg, the energy stored in the inductive element should be sufficient to discharge the parasitic output capacitance, Coss, completely of the incoming MOSFET, to achieve soft switching or Zero Voltage Switching (ZVS). The device parasitic output capacitance, Coss, exhibits a non-linear dependence on the applied drain–source voltage, VDS. Traditionally, the ZVS analysis is simplified, and an equivalent fixed capacitance is used to study the ZVS transitions. The traditional approaches of approximating the non-linear capacitance with a charge equivalent or energy equivalent capacitance can lead to erroneous ZVS analysis.

In this work, the device output capacitance, Coss, is modeled as a function of the applied drain–source voltage, VDS, to analyze the ZVS transitions. The proposed model only relies on datasheet information. The non-linear voltage-dependent capacitor-based analytical model is linearized, and numerical approaches are used for studying ZVS transitions. The proposed analytical model can be easily implemented in a circuit simulation platform to study the ZVS transitions. Finally, the proposed model is compared with the traditional equivalent capacitor-based approaches for ZVS analysis.

Student Talk 5: A Wide Output Range Soft-switched Single-stage Dual Active Bridge Type AC-DC Boost PFC Converter

Speaker: Himanshu Bhusan Sandhibigraha, Department of Electrical Engineering.

Abstract

This work proposes a wide output range single-stage soft-switched AC-DC power factor correction (PFC) converter topology. The converter is an isolated active-clamp boost PFC converter with active switches on the secondary side. The active switches of the secondary side are used to control the voltage and current at the output port. The operation of the proposed converter topology and a control strategy suited for battery charging is elaborated. The steady-state analysis of the proposed topology is presented, which is used to determine current stresses and soft-switching boundaries and perform power flow analysis. Switching circuit simulation results and experimental results from a 1 kW rated

hardware prototype have been shown to validate the topology and converter operation. Further, an extended circuit topology to integrate multiple DC ports with an AC grid with galvanic isolation is presented.

2.1.8 Coffee break

Invited Talk 2: Power Engineering – Renewable Integration, digital technologies – Challenges and Opportunities

Speaker: Shanthakumar MS, Hitachi Energy.

Abstract

Hitachi Energy as the pioneering technology leader, we collaborate with customers and partners to enable a sustainable energy future – for today's generations and those to come. Hitachi Energy is co-creating global and local solutions to solve the global challenge of an inclusive and equitable carbon-neutral future. Considering above, we believe Power Engineering and associated technologies & solutions play a major role in green energy transition.

Bio

Shanthakumar M S, M.Tech. in Drives & Power Electronics, working in Hitachi Energy as HVDC Market Product Manager, India & South Asia. Area of expertise Power electronics converters, high power Machines, HVDC transmission & FACTS technologies.

Invited Talk 3: Wireless Charging & Multiport USB PD adapters

Speaker: Milind Dighrasker, Infineon Technologies.

Abstract

The first part of talk would focus on wireless charging and associated challenges related to in-band communication & foreign object detection. The second part of it would describe multiport PD adapter and requirement of new single stage power converter topology for this application.

Bio

Milind Dighrasker is M.Tech in Power electronics from IIT Kanpur has got 20 years of industrial experience across various product and semiconductor companies. He also has entrepreneurship experience, where he was running a start-up, in the area of power converter design for four years. He has got 13 patents to his credit.

Student Talk 6: Characterizing SiC MOSFETs: Energy-Based Method for Partial Hard Turn-on Loss Estimation and Circuit Parasitics Measurement in a 200kW Stack Magnetic Materials

Speaker: Manish Mandal, Department of Electrical Engineering.

Abstract

Converters capable of processing a few hundred of kilowatts are important for traction-based applications. With superior switching and conduction loss and thermal performance, SiC MOSFETs can enable high efficiency and high power density in power converters. However, fast switching transients of SiC MOSFETs can amplify the impact of circuit parasitics and cause various issues like prolonged oscillations, high device stress, crosstalk, EMI , etc. Estimating circuit parasitics is crucial for optimal gate and power circuit layout design, especially when the internal geometry of the power module is unknown. A systematic approach for estimating circuit parasitic inductance in a 200kW SiC based Stack is presented and validated through experimental and simulation (ANSYS) results.

To reduce switching loss, soft-switching converters are preferred. However, zero-voltage turn-on of SiC MOSFET is lost at small load currents and it incurs significant turn-on loss. This is defined as partial hard turn-on transition. Estimating partial hard turn-on loss is is crucial for predicting light load efficiency but is challenging due to circuit parasitics and difficulties in measuring waveforms of high-side devices. Although indirect, a simple and accurate energy-based method is presented is estimate the loss using experimentsl data for a 1200 V/39A SiC MOSFET.

Student Talk 7: Improved Direct-Coupled High-Bandwidth Voltage Amplifier for B-H Characterization of Magnetic Materials

Speaker: Aditya Raj, Department of Electrical Engineering.

Abstract

B-H characteristics of magnetic core materials are an essential input to the design and performance evaluation of electrical machines, electromagnetic bearings, and, magnetic components in power converters. The magnetic cores in different applications experience different types of excitations including sinusoidal, non-sinusoidal, alternating with a dc offset, pulsewidth modulated (PWM), etc. This paper reports a cost-effective direct-coupled multistage power amplifier that can provide the above types of excitations. A variant of cascode amplifier is utilized for voltage gain stage to achieve high bandwidth and low DC offset. It is challenging to directly couple the output of this stage to the input of the succeeding current-gain stage due to reasons including divergent bias current requirements of the two stages. An intermediate stage is proposed between the voltage and current gain stages which effectively decouples the DC bias circuits of the two stages and passes the signal from DC to high frequencies, without any attenuation. The developed multistage amplifier is tested for its bias current stability, frequency response, linearity, and heat sink temperature rise. The capabilities of the developed amplifier are demonstrated through characterization of M36 and ferrite cores, which are popular in electromechanical and power conversion applications respectively. M36 core is tested with excitations including sinusoids upto 1 kHz, sinusoids with DC bias as in electromagnetic bearings, and, sinusoidal PWM that are typical in motor drives. The ferrite core is excited with quasi-square wave excitations and square wave excitations with and without DC bias, as encountered in power electronic converters.

2.1.9 Session 5: Signal Processing and Communications

Session Chair: Sudhan Majhi (ECE)
Faculty Organizer: Velpula Balaswamy (ECE)
Student Organizer: Sheetanshu Singh (ECE), Rohit Kumar Shukla (ECE), Rangam Diwakar (ECE), Satyam Sahu (ECE)
Location: ECE 1.08, ECE Department

Invited Talk 1: Turbo Coded OFDM-OQAM Using Hilbert Transform

Speaker: K Vasudevan, Professor, IIT Kanpur.

Abstract
Orthogonal frequency division multiplexing (OFDM) with offset quadrature amplitude modulation (OQAM) has been widely discussed in the literature and is considered a popular waveform for 5th generation (5G) wireless telecommunications and beyond. In this work, we show that OFDM-OQAM can be generated using the Hilbert transform and is equivalent to single sideband modulation (SSB), that has roots in analog telecommunications. The transmit filter for OFDM-OQAM is complex valued whose real part is given by the pulse corresponding to the root raised cosine spectrum and the imaginary part is the Hilbert transform of the real part. The real-valued digital information (message) are passed through the transmit filter and frequency division multiplexed on orthogonal subcarriers. The message bandwidth corresponding to each subcarrier is assumed to be narrow enough so that the channel can be considered ideal. Therefore, at the receiver, a matched filter can used to recover the message. Turbo coding is used to achieve bit-error-rate (BER) as low as 10^{-5} at an average signal-to-noise ratio (SNR) per bit close to 0 db. The system has been simulated in discrete time.

Bio
K Vasudevan completed his Bachelor of Technology (Honours) from the department of Electronics and Electrical Communication Engineering, IIT Kharagpur, India, in the year 1991, and his M.S. and Ph.D. from the department of Electrical Engineering, IIT Madras, in the years 1996 and 2000 respectively. During 1991–1992, he was employed with Indian Telephone Industries Ltd, Bangalore, India. He was a Post Doctoral Fellow at the Mobile Communications Lab, EPFL, Switzerland, between Dec. 1999 and Dec. 2000, and an engineer at Texas Instruments, Bangalore, between Jan 2001 and June 2001. Since July 2001, he has been a faculty at the Electrical department at IIT Kanpur, where he is now a professor. His interests lie in the area of communications and signal processing.

Student Talk 1: Cell-free Massive MIMO for Next-Generation Wireless Communications: Potential, Challenges & Solutions

Speaker: Maria Francis, Department of Electrical Communication Engineering.

Abstract
Cell-free massive MIMO (CF-mMIMO) is an incarnation of distributed massive MIMO, where a set of geographically distributed access points (APs) coherently serve the user equipment (UEs) in the same time-frequency resources. Such a network is expected to harness all the advantages of a massive MIMO system while improving cell-edge user performance. In this work, we analyse

the potential issues in the practical implementation of such a network and explore the strategies to address them. In a CF-mMIMO system, all the activities of the APs' are coordinated by a central processing unit (CPU) connected via fronthaul links. Conventional CF-mMIMO systems are not scalable because of the huge fronthaul signaling requirements. Hence, we consider an AP-centric virtual cell network called 'selective user forwarded cell-free massive MIMO,'where each AP serves only a finite set of UEs. Such a system provides significant savings in the fronthaul signaling without much degradation in spectral efficiency (SE). We then proceed to model different impairments in the performance of CF-mMIMO systems. Channel aging refers to the changes in the wireless channel characteristics over time due to the mobility of the UEs, environmental changes, and system dynamics. Because of the channel aging scenario, the channel state information (CSI) at the CPU will be outdated compared to the channel gains at the data transmission phase. We model the channel aging effects in a selective user-forwarded CF-MIMO system and baseline its performance with conventional CF-mMIMO. Simulation results show that the selective user-forwarded CF-mMIMO is more resilient to channel aging. We further study the quantization distortion in a CF-mMIMO system uplink imposed by the finite capacity fronthaul links. We analyze the performance of a selective user-forwarded CF-mMIMO in the presence of quantization distortion and compare it with that of a conventional CF-mMIMO.

Student Talk 2: Channel Estimation and Symbol Detection in overloaded MIMO systems

Speaker: Swati Bhattacharya, Department of Electrical Communication Engineering.

Abstract

In this talk, we present a novel joint channel estimation and symbol detection scheme using Alternating Direction Method of Multipliers (ADMM) for overloaded MIMO systems. Overloaded MIMO systems refer to the scenario where the number of receive antennas is comparable to the number of transmit antennas. Standard linear techniques such as Zero Forcing (ZF) or Minimum Mean Square Error (MMSE) detectors do not perform well in such cases, leading to the requirement of new algorithms. We show that using the ADMM based approach significantly outperforms the existing algorithms in terms of BER for i.i.d Rayleigh fading and correlated channels. This work was presented at IEEE SSP 2023, Hanoi, Vietnam [1]. With the advent of 5G, there has been a shift in the spectrum to higher frequencies and bandwidth of millimeter-wave (mmWave) range where the channel structure exhibits low-rank property. Furthermore, the ADC sampling frequency also drastically increases, motivating the use of low-resolution ADCs. To that end, we propose a novel mmWave channel estimation algorithm in 1-bit quantized systems in an overloaded MIMO scenario. This work was presented at IEEE SPCOM 2022, IISc Bangalore, India [2].

Student Talk 3: Deep Learning for Tomographic Inverse Scattering with Arbitrary and Unknown Viewing Angles

Speaker: Karthik Girija Ramesan, Department of Electrical Communication Engineering.

Abstract

Inverse scattering involves retrieving information about an object by studying how waves scatter upon interacting with it. Specifically, tomographic inverse scattering refers to the process of reconstructing a cross-sectional image of the object. Typically, the object is illuminated from various angles, known as viewing angles, and waves from each illumination scatter upon interacting with the object.

The scattered field measured at the receivers is then used to create a tomographic image of the object. Different algorithms exist for inverse scattering, including non-iterative methods, iterative approaches, and those based on Deep Neural Networks (DNNs).

Traditionally, DNNs used for solving the Inverse Scattering Problem (ISP) have been trained with a fixed transceiver configuration, meaning they are tailored for a specific predetermined set of viewing angles. Consequently, any changes in the viewing angles require the network to be retrained. To overcome this constraint, we propose a DNN model designed to handle arbitrary viewing angles. However, while the viewing angles may be arbitrary, knowledge of these angles remains essential for inverse scattering. Therefore, we investigate the feasibility of DNN-based tomographic inverse scattering when the viewing angles are unknown. Using an approach that involves alignment of the intermediate estimates obtained from the model designed to handle arbitrary viewing angles, we have been able to achieve good tomographic reconstruction even when the viewing angles are unknown.

Student Talk 4: Design and Optimization of Cell-Free Systems: Channel Estimation, Duplexing Scheme, and Synchronization

Speaker: Anubhab Chowdhury, Department of Electrical Communication Engineering.

Abstract

Cell-free massive multiple-input multiple-output (CF-mMIMO) systems, where multiple access points (APs) jointly and coherently serve a large number of user-equipments (UEs) in a geographical area, offer multi-fold improvement in spectral efficiency (SE) compared to cellular mMIMO systems. However, to make CF-mMIMO systems a practically viable technology, the signal processing challenges involved need to be thoroughly understood and addressed. In this regard, we consider three crucial aspects of CF-mMIMO systems: channel estimation, dynamic time division duplexing (DTDD), and synchronization.

In the symposium, the presentation will primarily focus on channel estimation and the development of a novel pilot allocation algorithm for CF-mMIMO systems. Here, we note that the benefits of CF-mMIMO systems over traditional cellular systems critically depend on the quality of the estimated channels at the APs. However, ensuring pilot contamination-free channel estimates across all the APs requires inordinately high pilot length, which substantially reduces the time available for data transmission. To this end, we propose a novel pilot design and allocation algorithm that ensures no pilot contamination among any pair of UEs that are proximal to a common AP, and this is guaranteed at all APs. Further, our algorithm procures the pilot allocation with a minimum number of orthogonal pilots being reused across the UEs. Numerical results illustrate the superiority of the proposed technique over existing methods from the literature. Finally, the presentation will briefly highlight our key contributions and interesting findings regarding the performance of the DTDD-enabled CF-mMIMO systems and the effects of asynchronous reception on the uplink SE.

Student Talk 5: Dictionary Learning Algorithms for CSI Feedback in Massive MIMO-OFDM FDD Systems

Speaker: Pavan Kumar G V V R, Department of Electrical Communication Engineering.

Abstract

In a massive multiple-input multiple-output (MIMO) frequency division duplex (FDD) system, it is required to compress the channel state information (CSI) and feed it back to base station (BS). In

this talk, we focus on the compressive sensing (CS)-based feedback design and proposes dictionary learning (DL) algorithms. Initially, we propose a fast dictionary learning (FDL) algorithm to update the singular vectors of matrices in the K-singular value decomposition (K-SVD) algorithm in a narrowband single-user (SU) case. The proposed FDL algorithm is a variation of the existing K-SVD algorithm with low computational complexity. Next, in a massive multi-user (MU) MIMO-orthogonal frequency-division multiplexing (OFDM) system, it is required to feed back the frequency domain channel transfer function (FDCHTF) of each subcarrier at the user equipment (UE) to the BS. To reduce CSI feedback, we propose a common dictionary learning (CDL) algorithm with two methods: CDL-KSVD and CDL-orthogonal Procrustes (OP). The CD conceived for exploiting the spatial correlation of channels across all the subcarriers and UEs compresses the CSI at each UE, and upon reception reconstructs it at the BS. In both cases, we show that the proposed dictionary's estimated channel vectors exhibit lower normalized mean-squared error (NMSE) than the traditional fixed Discrete Fourier Transform (DFT) based dictionary.

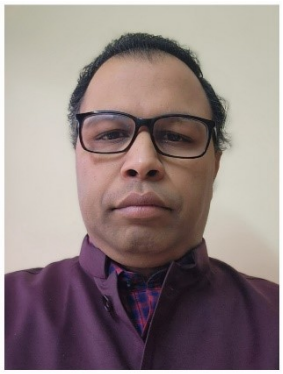
2.1.10 Coffee break

Invited Talk 2: Broadcast-Broadband Convergence

Speaker: Anindya Saha, Tejas Networks.

Abstract

The surge in real-time and Over-The-Top (OTT) content consumption via cellular networks has underscored the necessity for innovative solutions to enhance Quality of Experience (QoE) for cellular subscribers. As OTT content usage over cellular networks continues to climb, it exerts greater strain on these networks. In response to evolving bandwidth consumption patterns, this paper proposes a synergy between terrestrial broadcast and cellular technologies. By diverting a portion of cellular data traffic to non-3GPP broadcast networks, this approach alleviates the burden on cellular infrastructure. The study aims to illustrate how Broadcast Broadband Convergence fosters enhanced traffic efficiency, thus addressing the burgeoning demands on cellular networks.



Bio

Anindya Saha is VP of Wireless (CTO Office) at Tejas Networks, with approximately 28 Years of experience. He is an expert on Software Defined Radios, leading the Baseband and RF system design for 5G Products. In his earlier role as CTO at SaankhyaLabs (a wireless semiconductor startup acquired by Tejas Networks), he led the design and development of the Baseband and RF subsystems for Saankhya's products in wireless communication, spanning from Broadcast Receivers, Satellite IoT modems, and White-Space broadband modems.

He has been instrumental in developing 5G Radio, Broadcast Radio, and SDR Platforms and holds several fundamental patents (40+ approved US and India patents) and publications in this domain. He has also received the "Hall of Fame" award from the Telecommunications Standards Development Society, India (TSDSI), due to his pioneering work on "Broadcast Broadband Convergence" in 2022. He is currently the Chair of the IEEE Communication Society, Bangalore

Chapter, a Senior Member of IEEE, and participates in 3GPP, ORAN, and TSDSI standardization activities. He has authored around 10+ IEEE publications and co-authored a chapter titled "IEEE 802.22/802.22.3 Cognitive Radio Standards: Theory to Implementation" in the Handbook of Cognitive Radio, published by Springer. Anindya has a breadth of experience ranging from Semiconductor Chip Design to Wireless Communication. Before joining the core team at SaankhyaLabs, Anindya worked for multinationals like Texas Instruments and Broadcom. At TI and Broadcom, he led several award-winning SoC designs related to Broadband Gateways, DSL Modems, and Ethernet switches. Anindya has a master's degree in electrical communication Engg from IISC, Bangalore (1994-1996) and a bachelor's degree in electrical communication Engg. from IIT-BHU, Varanasi (1989-1993), where he was the recipient of the Gold Medal in Graduate Studies. His profile is available at https://in.linkedin.com/in/anindyasaha.

Student Talk 6: Optimal Time and Power Allocation for Phase-Shift Configuration and Downlink Channel Estimation in Ris-Aided Systems

Speaker: Suji N, Department of Electrical Communication Engineering.

Abstract

In a reconfigurable intelligent surface (RIS)-aided downlink, channel estimation errors due to noise during training lead to a sub-optimal RIS phase-shift configuration. This degrades the RIS beamforming gain. Furthermore, estimation errors in the effective downlink channel gain, which is also a function of errors in the RIS phase-shift configuration, degrades the data rate. We analyze this cumulative impact of channel estimation errors on the downlink data rate. We derive the rate-maximizing optimal training durations and transmit powers for pilots and data for a two-phase training scheme. In the first phase, the base station estimates the channel from the uplink pilots and configures the RIS. In the second phase, the user equipment estimates the channel from the downlink pilots and coherently demodulates the data. Our analysis uses a novel tractable approximation for the effective downlink channel gain and a novel proof that it is asymptotically Gaussian for a large number of RIS elements even in the presence of spatial correlation due to the closely-packed nature of the RIS elements. Our analysis applies to the scenario where enough pilots are sent to estimate the cascaded channels and the cascaded channel grouping scenario that uses fewer pilots. We also study two channel models that depend on the location of the RIS relative to the BS. The optimal power allocation achieves a higher rate than the conventional approach that assigns equal power to pilots and data. Cascaded channel grouping improves the rate further because of its lower training overhead.

Student Talk 7: Theory and Algorithms for Group Testing

Speaker: Sameera Bharadwaja, Department of Electrical Communication Engineering.

Abstract

Identifying a set of k defectives from a population of n items is an interesting problem. A naive solution is to test the items individually, which requires n tests. This approach is inefficient when n is large and k is small, there are constraints on the time-to-test, cost budget, or testing hardware and resource constraints. An alternative is to pool items together and run m < n tests in parallel, with each test pooling random subsets of the items together. The outcomes of these tests and the information on which subsets of items are pooled in each test are then used to decode the defective/non-defective state of all the n items. This approach is called group testing (or pool testing).

The first part of this talk presents a Probably Approximately Correct (PAC) formulation of the group testing problem. This enables one to analyze the group testing algorithms when certain approximation error tolerance and recovery confidence are allowed. Specifically, we derive novel achievability bounds on the number of tests for three binary group testing algorithms, namely Column Matching (CoMa), Combinatorial Basis Pursuit (CBP), and Definite Defectives (DD) under the PAC formulation. In a particular case where we set the approximation error tolerance to zero, the derived bounds match the existing bounds in the literature. We further analyze the order-wise behavior of the derived bounds. We conclude this part of the talk by highlighting the practical importance of PAC formulation-based analysis.

The second part of the talk presents iterative recovery algorithms in the context of COVID-19 detection using pooled RT-qPCR procedure. In contrast to the classical group testing formulation, the system model used here involves quantitative measurements from a non-linear setting. We show that the performance of our recovery algorithms is superior to that of classical algorithms, namely, CoMa and DD, which use binary measurement models. Further, we show that our algorithms perform better than the classical compressed sensing methods under practical considerations, namely, measurement noise, and are robust to incorrect RT-qPCR system-parameter configuration choices.

Student Talk 8: Waveform Design to Improve the Performance of Dual Function Radar Communication Systems

Speaker: Satwika Bhogavalli, Department of Electrical Communication Engineering.

Abstract

The dual-function Radar and communication systems (DFRC) integrate Radar and communication functionalities by sharing resources and using the same waveform. A few objectives of the DFRC systems include accurate estimation of the target parameters (like direction of arrival (DOA), range and velocity) and achieving high data transmission rates. Leveraging multiple input multiple output (MIMO) architecture with orthogonal frequency division multiplexing (OFDM) as a waveform is a common strategy to meet these requirements. In this talk, we explore the performance of different estimation methods like Fourier transform and subspace methods, and their required assumptions on the waveform, which may impact the data rate. To address the trade-off between the accuracy in the target parameter estimation and the data rate, a waveform design is required. Additionally, incorporating index modulation in both spatial and frequency domains in MIMO OFDM DFRC systems can enhance performance. In these systems, we present a method for codebook selection by optimizing different performance metrics using the Pareto-front optimization technique.

2.2 Faculty Talks

Opening Address: Rajesh Sundaresan (Dean, EECS)
Location: ECE Golden Jubilee Hall

2.2.1 Session 1: Faculty Talks

Faculty Talk 1: Generalization of Task Parameterized Interactive Imitation Learning

Speaker: Ravi Prakash, RBCCPS, IISc.

Abstract
One of the main appeals of robot learning from demonstrations is that it enables humans with different levels of robotic expertise to transfer their knowledge and experience about skills and tasks to the robot. This alleviates the need to program such skills by hand, which is tedious, error-prone, and requires an expert. However, one of the long-term challenges of this approach is generalizing the learned behavior to novel situations. In this talk, I will present a task parameterized approach for policy generalization in wide variety of tasks. Thus promoting scalability and data efficiency in robot learning, allowing robots to learn faster and adapt to new scenarios. For instance, a robot can be trained to clean surfaces with a reduced set of shapes, to dress an arm in a certain configuration, or to pick objects with a certain shape and place them on the right shelf.

Bio
Ravi Prakash is an Assistant Professor at the Robert Bosch Centre for Cyber- Physical Systems in the Indian Institute of Science Bengaluru. Before this, he was a Postdoctoral Researcher in the Learning and Autonomous Control group at the department of Cognitive Robotics, TU Delft. He earned his Ph.D. in Control and Automation, from the Indian Institute of Technology Kanpur. His research has contributed to leveraging human prior knowledge and dynamical analysis to design robot learning and control strategies for intelligent robots. He is the recipient of the DAAD Postdoc networking fellowship for AI and Robotics, with funded research visits to the German Aerospace Center (DLR), Munich. His current research interests include learning complex manipulation policies from human demonstration/corrections, bimanual robot manipulation, task generalization in a novel environment, and human-friendly safe compliant control.

Faculty Talk 2: Dodging Bullets: SNARK Impossibilities and How to Avoid Them

Speaker: Chaya Ganesh, CSA, IISc.

Abstract
The celebrated result by Gentry and Wichs established a theoretical barrier for succinct non-interactive arguments (SNARGs), showing that for (expressive enough) hard-on-average languages, we must rely on non-falsifiable assumptions. There are other impossibility results for SNARGs and NIZKs in literature, existing constructions that seemingly bypass these impossibilities. The talk will investigate these barriers and make the separations more clear. We then show new negative and positive results related to the proof size. We formalize a folklore lower bound for the proof size of black-box extractable arguments based on the hardness of the language. We identify a class of non-trivial

languages, which we dub ""trapdoor languages", that can bypass these impossibility results.

Bio

Chaya Ganesh is an Assistant Professor in the Department of Computer Science and Automation at Indian Institute of Science . Before joining IISc, she was a post-doctoral researcher in Aarhus University, and prior to that she received her PhD from NYU's Courant Institute of Mathematical Sciences. Her research interests are broadly in Cryptography and Security. More recently, she is exploring efficient zero-knowledge proofs and rational cryptography. She has won the IBM global university award, Google and Protocol labs research grants, Infosys Young investigator award and Intel Rising Star award.

Faculty Talk 3: Can ChatGPT Challenge False Assumptions?

Speaker: Danish Pruthi, CDS, IISc.

Abstract

Despite all the excitement associated with large language models (of the likes of ChatGPT), our understanding of such models is quite limited. However, fueled by economic interests and competition, claims about their capabilities abound. This talk would focus on one such claim from OpenAI which postulates that ChatGPT can challenge false assumptions. I will present new evidence that questions the veracity of this claim, highlighting the need for scientific rigor amidst a myopic rush towards development and adoption of larger language models.

Bio

Danish Pruthi is an Assistant Professor at the Indian Institute of Science (IISc), Bangalore. He received his Ph.D. from the School of Computer Science at Carnegie Mellon University. He is broadly interested in the areas of natural language processing and deep learning, with a focus towards inclusive development and evaluation of AI models. He completed his bachelors degree in computer science from BITS Pilani, Pilani. He is also a recipient of the Schmidt Sciences AI2050 Early Career Fellowship, Siebel Scholarship, CMU Presidential Fellowship and industry awards from Google and Adobe Inc. Until recently, his legal name was only Danish—an "edge case" for many deployed NLP systems, leading to airport quagmires and, in equal parts, funny anecdotes.

2.2.2 High Tea

2.2.3 Session 2: Faculty Talks

Faculty Talk 4: Sliding Mode Control for Quadcopter in Presence of Disturbances

Speaker: Kiran Kumari, EE, IISc.

Abstract

This talk will discuss the development of a super-twisting sliding mode controller for the application of attitude and altitude tracking control of a quadrotor in the presence of disturbances. For this, the mechanics of a quadrotor will be introduced, followed by the design of the super-twisting-based sliding mode controller. The validation of the designed controller by MATLAB simulations and Software-In-The-Loop (SITL) simulations for the PX4 flight-controller stack in a ROS-Gazebo-based environment will also be presented. The SITL simulations also demonstrate the robustness of the proposed controller in the presence of different wind disturbances.

Bio

Dr. Kiran Kumari is an Assistant Professor in the Department of Electrical Engineering at IISc, Bengaluru, India. Before joining IISc, she was a Post-Doctoral Fellow at the Control Engineering Department of Technical University Ilmenau, Germany. She completed her Ph.D. in Systems and Control Engineering at IIT Bombay in 2021. She received the B.Tech. degree in Electronics and Communication Engineering from Guru Gobind Singh Indraprastha University, Delhi, in 2013 and the M.Tech. Degree in Control and Automation from IIT Delhi, India, in 2015. Her current research interests include event-triggered control, multi-agent systems, sliding mode control, nonlinear systems and control, and control of quadrotors.

Faculty Talk 5: Channel Estimator and Symbol Detector for OTFS Systems Impaired by Impulsive Noise

Speaker: Sudhan Majhi, ECE, IISc.

Abstract: In this talk, first, we will discuss how the orthogonal time frequency space (OTFS) system compensates for both the frequency-selective and time-selective fading channels. We will discuss the conventional message-passing detector (MPD) algorithm, which is used for OTFS estimates channel state information but delivers suboptimal performance in the presence of impulsive noise (IN). To circumvent this limitation, we will talk about a novel l0 -norm constrained maximum Versoria criterion (l0 -MVC) based channel estimator for the OTFS systems in the presence of IN. Then we will move to OTFS symbol detectors based on the maximum Versoria criterion (MP-MVC). Then the performance of channel state information will be discussed for OTFS channel estimation and signal detector.

Bio

Sudhan Majhi received an M.Tech degree in computer science and data processing (CSDP) from Indian Institute of Technology (IIT) Kharagpur, India and a Ph.D. degree from Nanyang Technological University (NTU), Singapore. He has post-doctoral experience with the University of Michigan, Dearborn, USA, the Institute of Electronics and Telecommunications Rennes (IETR), France, and Nanyang Technological University, Singapore. He was an Assistant

professor jointly with the Mathematics and Electrical Engineering department at IIT Patna. He was also an associate professor in the Department of Electrical Engineering at IIT Patna. Currently, he is an associate professor in Electrical Communication Engineering (ECE) at Indian Institute of Science, Bangalore. He is a fellow of Sir Visvesvaraya Young Faculty Research. He has received SERB-TETRA and SERB- STAR awards in 2022 and 2023, respectively. He was an Editor of IEEE Transactions on Vehicular Technology Journal, IEEE Communications Letters, IEEE Wireless Communications Letters and Circuits, Systems and Signal processing (CSSP) – Springer. His research interest is signal processing for 6G wireless communications.

Faculty Talk 6: Overview of Hardware Security and Internet of Bodies

Speaker: Debayan Das, DESE, IISc.

Abstract

This talk will overview the hardware security landscape, focusing on side-channel analysis (SCA) on embedded electronic devices. Advanced machine-learning-based attacks and white-box-inspired countermeasures to protect cryptographic devices against these SCA attacks will be discussed. In the latter part of the talk, we will focus on the growing number of wearables and implantable devices around us, leading to the Internet of Bodies (IoB). We will look into the different biomedical circuits/systems applications and discuss some of the ongoing works and future directions.

Bio

Dr. Debayan Das received his PhD and MS in Electrical and Computer Engineering from Purdue University, USA, in 2021 and his Bachelor of Electronics and Telecommunication Engineering degree from Jadavpur University, India, in 2015. He is an Assistant Professor with the Department of Electronic Systems Engineering (DESE) at the Indian Institute of Science (IISc), Bangalore. He has worked as a Security Researcher at Intel, USA, during 2021-22 and as a Research Scientist in the Intel Labs, USA, during 2022-23. Before his Ph.D., he worked as an Analog Design Engineer at a startup based in India. He has interned with the Security Research Lab, Intel Labs, USA, over the summers of 2018 and 2020. His research interests include mixed-signal IC design, biomedical circuits, and hardware security. Dr. Das received the Pratiksha Trust Young Investigator Award in 2023, IEEE HOST Best Student Paper Award in 2017 and 2019, IEEE CICC Best Student Paper Award in 2021, the Third Best Poster Award in IEEE HOST 2018, and the 2nd Best Demo Award in HOST 2020. In 2019, one of his papers was recognized as a Top Pick in Hardware and Embedded Security. He was recognized as the winner (third place) of the ACM ICCAD 2020 Student Research Competition (SRC). During his Ph.D., he was awarded the ECE Fellowship during 2016–2018, the Bilsland Dissertation Fellowship in 2020–2021, the SSCS Pre-doctoral Achievement Award in 2021, and the Outstanding Graduate Student Research Award by the College of Engineering, Purdue University, in 2021 for his outstanding overall achievements. He has authored/coauthored more than 55 peer-reviewed conferences and journals, including 2 book chapters and primary reviewer for multiple reputed journals and conferences, including TCAS-I, TVLSI, TCAD, Design & Test, TODAES, JETCAS, TBME, IEEE Access, IoTJ, DAC, GLSVLSI, IMS, VLSI Design.

3. Day 2: 5th April 2024 (Friday)

3.1 Research Cluster Talks

Location: ECE Building

3.1.1 Session 6: Cyber Physical Systems

Session Chair: Ravi Prakash (RBCCPS), Kiran Kumari (EE)
Faculty Organizer: Pandarasamy Arjunan (RBCCPS)
Student Organizer: Sudarshan Bandyopadhyay (RBCCPS), GVS Mothish (RBCCPS), Ahan Basu (RBCCPS), Shreyansh Sharma (RBCCPS)
Location: MP 30, ECE

Invited Talk 1: Multi-Agent Coordination for Persistent Monitoring with Sensing, Communication, and Localization Constraints

Speaker: P. B. Sujit, Professor, IISER Bhopal.

Abstract

Persistent monitoring is performed in various applications like search and rescue, border patrol, wildlife monitoring, etc. Typically, these applications are large scale, and hence using a multi-robot system helps achieve the mission objectives effectively. Often, the robots are subject to limited sensing range and communication range, and they may need to operate in GPS-denied areas. In such scenarios, developing motion planning policies for the robots is difficult. Due to the lack of GPS, alternative localization mechanisms, like SLAM, high-accurate INS, UWB radio etc. are essential. Having SLAM or a highly accurate INS system is expensive, and hence we use agents having a combination of expensive, accurate localization systems (anchor agents) and low-cost INS systems (auxiliary agents) whose localization can be made accurate using cooperative localization techniques. To determine efficient motion policies, we use a multi-agent deep reinforcement learning technique (GALOPP) that takes the heterogeneity in the vehicle localization capability, limited sensing, and communication constraints into account. GALOPP is evaluated using simulations and compared

with baselines like random search, random search with ensured communication, greedy search, and area partitioning. The results show that GALOPP outperforms the baselines. The GALOPP approach offers a generic solution that be adopted with various other applications.

Bio

P.B. Sujit is Professor in the Department of Electrical Engg and Computer Science at Indian Institute of Science Education and Research Bhopal. Before joining IISER Bhopal, he was with IIIT-Delhi, University of Porto and Brighan Young University, Utah. He obtained PhD in Aerospace Engineering from IISc Bangalore in 2006, MTech in 2002 and B.E in 1998. His primary research interests are in building autonomy for autonomous air-ground-sea vehicles and multi-robot systems.

Student Talk 1: Modelling On-street Parking Search Process of Car Drivers

Speaker: Helen Thomas, Department of Cyber Physical Systems.

Abstract

This study attempts to understand the behaviour of human four-wheeler drivers specifically in the context of parking in any public parking spots within an urban area. Specifically, we collect data from human test subjects to understand factors that affect the decisions of a human while searching for and parking in public spaces in urban areas. These independent factors that will be used for predicting the parking choice of a drivers include the time elasped since search for parking space has begun, traffic congestion levcel faced by the driver, age, gender, type of parking space available, distance to final destination etc. A Driving simulator built using CARLA and Python Pygame platforms is used to collect data. Behavioural models in the domain of discrete choice theory and machine learning wll be used to fit the data, and infer insights on parking choice behaviour.

Student Talk 2: A Visual Analytic Approach for Automatic Detection of Cyclonic Events in Satellite Observations

Speaker: Akash Agrawal, Department of Cyber Physical Systems.

Abstract

The increasing frequency and intensity of cyclonic events demand more accurate and timely predictions to enhance disaster management efforts. This comprehensive research project is aimed at leveraging deep learning techniques to enhance cyclone detection and intensity estimation to improve disaster management in the fields of geological and climate sciences. The project will involve the development of advanced Scientific Machine Learning models, and collaboration with the Indian Space Research Organisation (ISRO) to analyse meteorological data. The ultimate goal is to provide real time accurate predictions, enable effective decision-making, and contribute to scientific advancements in cyclone analysis and disaster mitigation over the North Indian Ocean Region. Framework development will involve training the ML models using the prepared datasets and validating the models using cross-validation techniques, benchmarking against existing methods. Collaboration with ISRO experts will provide access to rich meteorological data for analysis and validation and ensure domain-specific accuracy and reliability.

Student Talk 3: Approximate Stability Radius in Linear Systems: Analysis and Design

Speaker: Ananta Kant Rai, Department of Electrical Communication Engineering.

Abstract

The robustness of the stability properties of dynamical systems in the presence of unknown/adversarial perturbations to system parameters is a desirable property. In this work, we present methods to efficiently compute and improve the approximate stability radius of linear time-invariant systems. We propose two methods to derive closed-form expressions of approximate stability radius. We also propose to compute this metric of resilience using the input-output data generated by the discrete time LTI system.

Student Talk 4: Intelligent Onboard Routing Using Decision Transformers

Speaker: Rohit Chowdhury, Department of Computational and Data Sciences.

Abstract

We develop a novel, deep learning method based on the decision transformer (decoder-only model) for onboard routing of autonomous marine agents. Training data is obtained from aforementioned level-set PDE or MDP solvers, which is further processed to sequences of states, actions and returns. The model is autoregressively trained on these sequences and then tested in different environment settings. We demonstrate that (i) a trained agent learns to infer the surrounding flow and perform optimal onboard routing when the agent's state estimation is accurate,(ii) specifying the target locations (in case of multiple targets) as a part of the state enables a trained agent to route itself to the correct destination, and (iii) a trained agent is robust to limited noise in state transitions and is capable of reaching target locations in completely new flow scenarios. We extensively showcase end-to-end planning and onboard routing in various canonical and idealised ocean flow scenarios.

3.1.2 Coffee break

Invited Talk 2: Driving into the Future: Strategies for Autonomous Driving Development

Speaker: Srikanth Vidapanakal, Ola Electric.

Abstract

In this talk, we will be discussing the evolution of Autonomous driving approaches. We will discuss the limitations of modular approach and how we can overcome these limitations. We will examine various end to end variants of autonomous driving and what are some good representations for motion planning. Finally we will discuss how multimodal machine learning is impacting the Autonomous Driving landscape and the way forward.

Bio

Srikanth Vidapanakal is a seasoned technologist with over 24 years of experience spanning System Software, Cloud Computing, Big Data, and Machine Learning. He has led multiple Data Science projects in insurance, retail, EdTech, E-commerce and Marketing domains. At Ola, he has spearheaded multiple AI initiatives and built AI teams focused on AV/ADAS, Smart Mobility, CCTV Video Analytics and Voice Recognition. He has filed over 12+ patents with 2 granted patents in the US and published in conferences such as ICRA and NeurIPS. Currently, he leads the Autonomous Driving

and Robotics team, tackling the unique challenges of developing autonomous driving technologies for India. He has keen interest in Computer Vision, Deep Learning and Reinforcement Learning and applications to Robotics and Autonomous Driving.

Student Talk 5: Scheduling DNN Inferencing on Edge and Cloud for Personalized UAV Fleets

Speaker: Suman Raj, Department of Computational and Data Sciences.

Abstract

Drone fleets with onboard cameras coupled with DNN inferencing models can support diverse applications, from infrastructure monitoring to package deliveries. Here, we propose to use one or more "buddy" drones to help Visually Impaired People (VIPs) lead an active lifestyle. Video inferencing tasks from such drones are used to navigate the drone and alert the VIP to threats, and hence have strict execution deadlines. They have a choice to execute either on an accelerated edge like Nvidia Jetson linked to the drone, or on a cloud INFerencing-as-a-Service (INFaaS). However, making this decision is a challenge given the latency and cost trade-offs, and network variability in outdoor environments. We propose a deadline-driven heuristic to schedule a stream of diverse DNN inferencing tasks executing over video segments generated by multiple drones linked to an edge, with the option to execute on the cloud. We use strategies like task dropping, work stealing and migration, and dynamic adaptation to cloud variability, to fully utilize the captive edge with intelligent offloading to the cloud, to maximize the utility and the number of tasks completed. We evaluate our strategies using a setup that emulates a fleet of > 50 drones within city conditions supporting > 25 VIPs, with real DNN models executing on drone video streams, using Jetson Nano edges and AWS Lambda cloud functions.

Student Talk 6: Signal Temporal Logic Compliant Co-design of Planning and Control

Speaker: Vaishnavi J, Department of Cyber Physical Systems.

Abstract

This work proposes a novel approach for motion planning in autonomous ground robots, focusing on handling signal temporal logic (STL) tasks. The approach is structured into two phases: (i) learning spatio-temporal motion primitives to encapsulate the inherent robot-specific constraints and (ii) constructing STL-compliant motion plan using learned spatio-temporal motion primitives. Initially, we employ reinforcement learning to construct a library of motion primitives. Then, Gaussian process regression is used to map motion primitives to spatio-temporal characteristics. Subsequently, we present a sampling-based STL-compliant motion planning strategy tailored to meet the STL specification. We demonstrate the effectiveness and adaptability of our framework through experiments conducted on 'Differential-drive robot' and 'Quadruped' for multiple STL specifications and environments. The proposed framework is entirely model-free and capable of generating feasible STL-compliant motion plans across diverse environments.

Student Talk 7: Towards Mitigating Sim2Real Gaps: A Formal Quantitative Approach

Speaker: Sangeerth P, Deaprtment of Cyber Physical Systems.

Abstract

We introduce the notion of simulation-gap functions to formally quantify the potential gap between an approximate nominal mathematical model and the high-fidelity simulator representation of a real system. Given a nominal mathematical model alongside a quantified simulation gap, the system can

be conceptualized as one characterized by bounded states and input-dependent disturbances. This allows us to leverage the existing powerful model-based control algorithms effectively, ensuring the enforcement of desired specifications while guaranteeing a seamless transition from simulation to real-world application. To provide a formal guarantee for quantifying the simulation gap, we develop a data-driven approach. In particular, we collect data using high-fidelity simulators, leveraging recent advancements in Real-to-Sim transfer to ensure close alignment with reality. We demonstrate the effectiveness of the proposed method through experiments conducted on a nonlinear pendulum system and a nonlinear Turtlebot model in simulators.

Student Talk 8: Verification of Camera-Based Autonomous Systems

Speaker: Habeeb P, Deaprtment of Computer Science and Automation.

Abstract

Autonomous technologies are becoming increasingly prevalent in the automotive industry due to the numerous benefits they offer, including improved safety and security, enhanced accessibility for the mobility challenged, and the ability to navigate in hazardous environments. Autonomous vehicles rely on various inputs, including camera images, lidar readings, and infrared signals, which are processed by advanced neural network-based controllers. These controllers play a critical role in determining the vehicle's trajectory, making it imperative that the closed-loop control system and perception modules are highly reliable and accurate.

Testing the autonomous vehicle in real-world terrains or test tracks provides valuable information for debugging and giving an assurance about the system's reliability. However, these evaluations are often expensive and afford very limited coverage. A promising alternative is to reason about a model of the vehicle in simulated (or synthetic) environments. Both safe and unsafe trajectories from a simulated environment are known to transfer well to real environments. Thus, analysis in a simulated environment can give us an effective way to debug and gain confidence in our system.

In this work, we consider the problem of verifying the safety of the trajectories of a camera-based autonomous vehicle in a given 3D scene, with a specified initial and target region within the scene. We give a baseline procedure and an abstraction-refinement-based algorithm to verify that all trajectories starting from a given initial region safely reach a specified target region without colliding with obstacles. We also present a prioritization-based falsification procedure whose objective is to find a large number of spatially distinct unsafe trajectories, that could be used to re-train/re-design the neural network/controller. Both these techniques are based on the notion of invariant regions which are volumes within which the camera records the same image of the 3D scene.

3.1.3 Session 7: Computer Systems, Security & Privacy

Session Chair: K V Raghavan (CSA), Chaya Ganesh (CSA)
Faculty Organizer: Sumit K. Mandal (CSA)
Student Organizer: Bhargava Imandi (CSA), Shubham Bhawsar (CSA)
Location: MP 20, ECE

Invited talk 1: Almost-Surely Terminating Asynchronous Byzantine Agreement Against General Adversaries

Speaker: Ashish Choudhury, Associate Professor, IIIT Bangalore.

Abstract
In this work, we study almost-surely terminating asynchronous Byzantine agreement (ABA) for n parties tolerating a computationally unbounded adversary. While the existing works in this domain have primarily considered a threshold adversarial model where the adversary can corrupt any subset of up to t parties, very little attention has been paid to the non-threshold adversarial model. In the latter model, the corruption capacity of the adversary is characterized by an adversary structure, which enumerates all possible subsets of potentially corrupt parties and where the adversary can select any one subset from the adversary structure for corruption. While the optimal resilience for ABA against threshold adversaries is t < n/3, against non-threshold adversaries one can design an ABA protocol, provided the adversary structure satisfies the $Q^{(3)}$ condition meaning that the union of no three subsets from the adversary structure covers all the n parties. We present the first almost-surely terminating ABA protocol against $Q^{(3)}$ adversary structures. Previously, almost-surely terminating ABA protocol is known with non-optimal resilience where the adversary structure satisfies the $Q^{(4)}$ condition; i.e. if the union of no four subsets from the adversary structure covers all the n parties. To design our protocol, we present a shunning asynchronous verifiable secret-sharing (SAVSS) scheme for $Q^(3)$ adversary structures, which is of independent interest.

Bio
Ashish Choudhury is currently an associate professor at IIIT Bangalore where he previously held the Infosys Foundations career development chair professor position. He received his MS (by research) and PhD degrees from IIT Madras and did his postdoc at ISI Kolkata and the University of Bristol. His research interests include secure multiparty computation and classical consensus protocols. His works have appeared in reputed journals like the Journal of ACM, Journal of Cryptology, Theoretical Computer Science, Distributed Computing, IEEE Transactions of Information Theory and flagship conferences like CRYPTO, ASIACRYPT, PODC, DISC and TCC. He has been teaching multiple courses on cryptography and Discrete Maths on NPTEL. Recently he published a research monogram on Secure Multiparty Computation with Arpita Patra as part of the Synthesis Lecture series on Distributed Computing.

Student Talk 1: Asterisk: Super-fast MPC with a Friend

Speaker: Protik Kumar Paul, Department of Computer Science and Automation.

Abstract

Secure multiparty computation (MPC) enables privacy-preserving collaborative computation over sensitive data held by multiple mutually distrusting parties. Unfortunately, in the most natural setting, where a majority of the parties are maliciously corrupt (also called the dishonest majority setting), traditional MPC protocols incur high overheads and offer weaker security guarantees than are desirable for practical applications. In this paper, we explore the possibility of circumventing these drawbacks and achieving practically efficient dishonest majority MPC protocols with strong security guarantees by assuming an additional semi-honest, non-colluding helper party HP. We believe that this is a more realistic alternative to assuming an honest majority, since many real-world applications of MPC involving potentially large numbers of parties (such as dark pools) are typically enabled by a central governing entity that can be modeled as the HP.

In the above model, we are the first to design, implement and benchmark a practically efficient and general multi-party framework, Asterisk. Our framework requires invoking HP only a constant number of times, achieves the strong security guarantee of fairness (either all parties learn the output or none do), scales to hundreds of parties, outperforms all existing dishonest majority MPC protocols, and is, in fact, competitive with state-of-the-art honest majority MPC protocols. Our experiments show that Asterisk achieves 228 - 288x speedup in preprocessing as compared to the best dishonest majority MPC protocol. With respect to online time, Asterisk supports 100-party evaluation of a circuit with 10^6 multiplication gates in approximately 20 seconds. We also implement and benchmark practically efficient and highly scalable dark pool instances using Asterisk. The corresponding run times showcase the effectiveness of Asterisk in enabling efficient realizations of real-world privacy-preserving applications with strong security guarantees.

Student Talk 2: Designing Virtual Memory System of MCM GPUs

Speaker: Pratheek B, Department of Computer Science and Automation.

Abstract

Multi-Chip Module (MCM) designs have emerged as a key technique to scale up a GPU's compute capabilities in the face of slowing transistor technology. However, the dis- aggregated nature of MCM GPUs with many chiplets connected via in-package interconnects leads to non-uniformity. We explore the implications of MCM's non-uniformity on the GPU's virtual memory. We quantitatively demonstrate that an MCM-aware virtual memory system should aim to 1 leverage aggregate TLB capacity across chiplets while limiting accesses to L2 TLB on remote chiplets, 2 reduce accesses to page table entries resident on a remote chiplet's memory during page walks. We propose MCM-aware GPU virtual memory (MGvm) that leverages static analysis techniques, previously used for thread and data placement, to map virtual addresses to chiplets and to place the page tables. At runtime, MGvm balances its objective of limiting the number of remote L2 TLB lookups with that of reducing the number of remote page table accesses to achieve good speedups (52%, on average) across diverse application behaviors.

Student Talk 3: Reduce, Reuse and Adapt: Accelerating Graph Processing on GPUs

Speaker: Ullas A, Department of Computer Science and Automation.

Abstract

Designing parallel graph algorithms on GPUs has been challenging. We observe three limitations with the existing work. First, algorithms often rely on only one of the strategies to propagate information: push or pull. We observe that neither is an optimal choice in many cases. Second, the cost of updating the underlying data structures per iteration is high. This results in a significant performance overhead. Third, considering the inherent irregularity of graph processing, one-size-fits-all approach is too rigid for different types of graphs. In this work, we address these shortcomings by improving the processing of an existing graph framework, Subway. In particular, we propose a novel technique in terms of amalgamating the two propagation strategies (push and pull) into a hybrid traversal strategy. In this, the vertices of the graph propagate their information by pulling the information from the neighbours, performing a local computation, and subsequently pushing the result to all the neighbours, all within an iteration. We propose to reuse the SubCSR structure in Subway across a few iterations to significantly reduce the computational overhead, but without compromising the correctness or efficiency of the algorithm. Furthermore, we explore heuristics on when to use push, pull, or hybrid traversal strategies. We illustrate the effectiveness of our three-pronged approach by applying it to four popular graph algorithms: Connected Components (CC), Single-Source Shortest Path (SSSP), Breadth First Search (BFS) and Page Rank (PR) on an NVIDIA GeForce RTX 3060 GPU. Our extensive experimental evaluation on GeForce RTX 3060 GPU reveals that the proposed hybrid approach with adaptive heuristics and approximate subCSR computation is effective in reducing the execution time of CC, SSSP, and PR by 31%, 7.56%, and 6.43% respectively, compared to the minimum of push or pull algorithm that uses subCSR structure.

Student Talk 4: Succinct Verification of Compressed Sigma Protocols in the Updatable SRS setting

Speaker: Moumita Dutta, Department of Computer Science and Automation.

Abstract

We propose protocols in the Compressed Sigma Protocol framework that achieve a succinct verifier. Towards this, we construct a new inner product argument and cast it in the Compressed Sigma Protocol (CSP) framework as a protocol for opening a committed linear form, achieving logarithmic verification. We then use our succinct-verifier CSP to construct a zero-knowledge argument for circuit satisfiability (under the discrete logarithm assumption in bilinear groups) in the updatable Structured Reference String (SRS) setting that achieves O(log n) proof size and O(log n) verification complexity. Our circuit zero-knowledge protocol has concretely better proof/prover/verifier complexity compared to the the state-of-the-art protocol in the updatable setting under the same assumption. Our techniques of achieving verifier-succinctness in the compression framework is of independent interest. We then show a commitment scheme for committing to group elements using a structured commitment key. We construct protocols to open a committed homomorphism on a committed vector with verifier succinctness in the designated verifier setting. This has applications in making the verifier in compressed sigma protocols for bilinear group arithmetic circuits, succinct.

3.1.4 Coffee break

Invited talk 2: Distributed Trust: A Case for Separating Data and Computation

Speaker: John Augustine, IIT Madras.

Abstract

From the time it was first posed by Lamport, Pease, and Shostak, the Byzantine agreement problem has played a pivotal role in distributed computing contexts where participants cannot trust each other as some of them are Byzantine (i.e., malicious and capable of deviating arbitrarily from the protocol). In the classical framing of the Byzantine agreement problem, each individual node has a private input and the participants must agree on an output based on those inputs. Clearly, dealing with such private inputs is imperative in many application contexts. In this talk, however, we make the case for application settings where Byzantine resilient computation is natural when the data is publicly known. Consider, for example, the case where data is available in a public blockchain and participants in a distributed computing system are required to perform some data analytics on it. Surprisingly, such distributed computing on public data – though widely applicable in practice – has not been formally explored until quite recently. We will present a theoretical framework to study such problems and present some recent results.

Bio

John Augustine is a professor in the Department of Computer Science and Engineering (CSE) at the Indian Institute of Technology Madras. He holds a PhD from the Donald Bren School of Information and Computer Sciences at UC Irvine. His research interests are in distributed algorithms specifically focusing on distributed trust issues that emerge in settings where participants may behave maliciously. He has co-authored many refereed articles that have appeared in highly reputed conferences (SODA, FOCS, PODC, NEURIPS, DISC, SPAA, IPDPS, etc.) and journals (Algorithmica, SICOMP, TCS, JPDC, TPDS, etc). He was the chair of the distributed computing track at ICDCN 2022 and is currently serving as an associate editor at the Journal of Parallel and Distributed Computing. At IIT Madras, he is a founding member of the Cryptography, Cybersecurity, and Distributed Trust group as well as the Blockchain Research Lab and currently co-heads the CAMS-IITM Fintech Innovation Lab (CIFIL). He is also affiliated with the Theory group in CSE.

Student Talk 5: Systems Optimizations for Deep Learning Training on Accelerated Edge Devices

Speaker: Prashanthi S. K, Department of Computational and Data Sciences.

Abstract

Deep Neural Networks have had a significant impact on a wide variety of domains such as Autonomous Vehicles, Smart Cities, and Healthcare through low-latency inferencing on edge computing devices close to the data source. Recently, there has also been a push towards training DNN models on the edge. This is driven by edge devices becoming more powerful, and a heightened emphasis on privacy by retaining data on the edge. However, DNN training on the edge is poorly explored. This talk will introduce edge devices, motivate why they are competitive candidates for DNN training, and propose systems optimizations that impact power and performance in various deployment scenarios.

Student Talk 6: Tile Size and Loop Order Selection using Machine Learning for Multi-/Many-Core Architectures

Speaker: Shilpa Babalad, Department of Computer Science and Automation.

Abstract
Loop tiling and loop interchange (or permutation) are techniques that can expose task and data-level parallelisms and can exploit data locality available in multi-dimensional loop nests. Choosing the appropriate tile size and loop order is important to achieve significant performance improvement. However, the effect of these transformations on the performance of the loop nest is not straightforward due to the complex interplay of several architectural features in multi-/many-core architectures. In this work, we propose using a supervised learning technique and develop a Support Vector Machine (SVM) based hierarchical classifier to identify the best-performing tile size and loop order for a given loop nest. Our approach results in identifying tile sizes and loop orders whose performance, on average, is within 18% and 9% of the optimal performance for two sets of loop nests on Intel Xeon Cascadelake architecture. Further, our method outperforms state-of-the-art techniques, Pluto and Polly, with a geometric mean speedup of 1.35x to 1.58x.

Student Talk 7: UNMASQUE: A Hidden SQL Query Extractor

Speaker: Dr Ahana Pradhan, Department of Computational and Data Sciences.

Abstract
Hidden Query Extraction (HQE) is a novel research challenge introduced at IISc, with the goal of uncovering declarative (SQL) queries concealed within opaque enterprise applications, whether explicitly or implicitly. HQE has diverse practical applications ranging from reviving legacy code to enhancing database security, optimizing query performance through rewriting, and facilitating imperative to declarative code transformations.

UNMASQUE, an extraction algorithm developed at IISc based on active learning, serves as an initial solution to this complex problem. Remarkably, it achieves a fully non-invasive extraction approach by analyzing only the outcomes of repeated executions of the hidden query on meticulously crafted databases, employing a blend of data mutation and generation techniques. Moreover, it integrates potent optimizations to minimize the overhead associated with extraction.

Over the past few years, research efforts have matured UNMASQUE, enabling it to proficiently extract intricate SQL constructs such as Negation Predicates, Algebraic Predicates, and Set Union operators, in addition to its established capability in SPJGAOL-class query extraction. Comprehensive evaluations conducted using the TPCH-benchmark showcase UNMASQUE's ability to accurately and efficiently extract these diverse query types.

Student Talk 8: Whole program control-flow path attestation

Speaker: Nikita Yadav, Department of Computer Science and Automation.

Abstract
Path attestation is an approach to remotely attest the execution of a program P. In path attestation, a prover platform, which executes P, convinces a remote verifier V of the integrity of P by recording the path that P takes as it executes a particular input. While a number of prior techniques have been developed for path attestation, they have generally been applied to record paths only for parts of P's

execution. In our work, we consider the problem of whole program control-flow path attestation, i.e., to attest the execution of the entire program path in P. We show that prior approaches for path attestation use sub-optimal techniques that fundamentally fail to scale to whole program paths, and impose a large runtime overhead on the execution of P. We then develop Blast, an approach that reduces these overheads using a number of novel approaches inspired by prior work from the program profiling literature. Our experiments show that Blast makes path attestation more practical for use on a wide variety of embedded programs.

3.1.5 Session 8: Visual Analytics

Session Chair: Soma Biswas (EE)
Faculty Organizer: Samir Hazra (EE)
Student Organizer: Chirayata Bhattacharyya (EE), Akash Mondal (ECE), Chetan Sharma (EE), Masoud Thajudeen Tholan (EE)
Location: ECE 1.08, ECE Department

Invited Talk 1: Learning to Retain while Acquiring: Combating Distribution-shift in Adversarial Data-free Knowledge Distillation

Speaker: Konda Reddy, Assistant Professor, IIT Hyderabad.

Abstract
Data-free Knowledge Distillation (DFKD) has gained popularity recently, with the fundamental idea of carrying out knowledge transfer from a Teacher neural network to a Student neural network in the absence of training data. However, in the Adversarial DFKD framework, the student network's accuracy, suffers due to the non-stationary distribution of the pseudo-samples under multiple generator updates. To this end, at every generator update, we aim to maintain the student's performance on previously encountered examples while acquiring knowledge from samples of the current distribution. Thus, we propose a meta-learning inspired framework by treating the task of Knowledge-Acquisition (learning from newly generated samples) and Knowledge-Retention (retaining knowledge on previously met samples) as meta-train and meta-test, respectively. Hence, we dub our method as Learning to Retain while Acquiring. Moreover, we identify an implicit aligning factor between the Knowledge-Retention and Knowledge-Acquisition tasks indicating that the proposed student update strategy enforces a common gradient direction for both tasks, alleviating interference between the two objectives.

Bio
Dr. Konda Reddy Mopuri is currently an Assistant Professor in the Department of Artificial Intelligence, IIT Hyderabad. Before joining IIT Hyderabad, Dr. Mopuri was a postdoctoral fellow at the School of Informatics, University of Edinburgh, UK. He briefly served at IIT Guwahati before moving to Hyderabad. He obtained his Ph.D. in Deep Learning and Computer Vision from IISc Bangalore. His thesis won the IUPRAI Best Doctoral Dissertation Award and the SPCOM Best Doctoral Dissertation Award for the year 2018. He was awarded the Young Alumni Achiever Award for 2022, by his Alma mater, the Dept. of CDS, IISc Bengaluru. His research interests are broadly in the fields of Artificial Intelligence, Machine learning (specifically Deep Learning), Data Science and Engineering, and Computer Vision. His work has been published in top-tier venues such as ICLR, ICML, CVPR, ECCV, UAI, WACV, BMVC, Trans. on PAMI, Tran. on Image processing, and Frontiers in Robotics and AI.

Student Talk 1: Geographical Representativeness of Images of Text-to-Image Models

Speaker: Abhipsa Basu, Department of Computational and Data Sciences.

Abstract
Recent progress in generative models has resulted in models that produce both realistic as well as relevant images for most textual inputs. These models are being used to generate millions of images everyday, and hold the potential to drastically impact areas such as generative art, digital marketing and data augmentation. Given their outsized impact, it is important to ensure that the generated content reflects the artifacts and surroundings across the globe, rather than over-representing certain parts of the world. In this paper, we measure the geographical representativeness of common nouns (e.g., a house) generated through DALL.E 2 and Stable Diffusion models using a crowdsourced study comprising 540 participants across 27 countries. For deliberately underspecified inputs without country names, the generated images most reflect the surroundings of the United States followed by India, and the top generations rarely reflect surroundings from all other countries (average score less than 3 out of 5). Specifying the country names in the input increases the representativeness by 1.44 points on average for DALL.E 2 and 0.75 for Stable Diffusion, however, the overall scores for many countries still remain low, highlighting the need for future models to be more geographically inclusive. Lastly, we examine the feasibility of quantifying the geographical representativeness of generated images without conducting user studies.

Student Talk 2: Leveraging Camera Triplets in Structure-from-Motion

Speaker: Lalit Manam, Department of Electrical Engineering.

Abstract
Structure-from-motion has been a long-standing problem in 3D computer vision, which aims to reconstruct a 3D model of a scene given a collection of images. In this talk, I will focus on how leveraging the properties of camera triplets has helped develop fast algorithms to improve accuracy and efficiency in the structure-from-motion pipelines.

Student Talk 3: Novel and Efficient Model-Based and Deep Learning based Models for Medical Imaging

Speaker: Venkatesh Vadaddi, Department of Computational and Data Sciences.

Abstract
Efficient deep-learning techniques and model-based approaches have been developed to address the challenges posed by medical imaging, particularly in scenarios where data availability is limited or there is a necessity for rapid inference.

In the first work, we focused on enhancing the performance of model-based deep learning in situations with limited training data. For this, a framework was developed, which is an effective p-norm regularization enforced CNN-based model-based deep learning.

As an extension to this, the effective parameters of model-based deep learning were explored, such as unrolling and sampling parameters for iteration, as well as weight sharing/unsharing. Both of these works primarily targeted solving inverse problems within a model-based framework, with demonstrated results on the Quantitative Susceptibility Mapping (QSM) problem, which is a common inverse problem encountered in MRI post-processing.

In the second work, a novel deep-learning model was introduced to facilitate real-time segmentation, specifically for ultrasound-based median nerve segmentation. The primary objective here was to develop an end-to-end deep learning solution for clinical use aimed at aiding medical professionals in their diagnostic processes.

Student Talk 4: Personalizing text-to-image diffusion models with fine-grained attribute control

Speaker: Rishubh Parihar, Department of Computational and Data Sciences.

Abstract

Personalization of large-scale text-to-image (T2I) diffusion models aims to learn a concept from a few of its images, to generate its customizations with text prompts. When used in the context of faces, existing personalization methods show a skewed trade-off between preserving the identity or its faithful editability through T2I model. Further, these methods primarily rely on text-prompts to edit the embedded face, which is unsuitable for fine-grained attribute control. On the contrary StyleGAN models learn a rich prior over faces and enable fine-grained control over attributes with latent manipulation. In this work, we condition the T2I model on the disentangled $\mathscr{W}+$ space of StyleGANs to obtain fine-grained control over facial attributes (for e.g., smoothly adding a smile to the face), without affecting the coarse text-based control that is already present in the T2I models. To condition the T2I model on the $\mathscr{W}+$ space, we train a mapper that maps the latent codes from $\mathscr{W}+$ to the token embedding space of the T2I model. The proposed framework can accurately invert face images, with its attributes, and enables continuous control over them allowing for granular control over their edits. Our method is easily extensible for multi-person composition and individual attribute editing. Extensive evaluation results showcase the superiority of our method in identity preservation and fine-grained attribute editing.

3.1.6 Coffee break

Student Talk 5: Regularizing Neural Radiance Fields (NeRF) to Learn with Sparse Input Views

Speaker: Nagabhushan S N, Department of Electrical Communication Engineering.

Abstract
Given a few images from different viewpoints of a scene, synthesizing novel or unseen viewpoints of the scene is a classical problem in computer vision. Recently, Neural Radiance Fields (NeRF) showed impressive performance in novel view synthesis by employing a small neural network to learn the radiance field representing the scene. However, NeRFs require dense sampling of viewpoints (50-100) per scene to achieve photo-realistic synthesis quality, and their performance degrades significantly when very few input viewpoints are available. In this work, we analyze the cause for the drop in performance and design regularizations to significantly improve the quality of the reconstruction. In the first part of the talk, we will look at hand-crafting priors based on the relative depth of objects in the scene. In the second part, we will look at learning the depth priors that do not suffer from generalization issues and without the need for training on large datasets. I will conclude the talk by discussing our recent work on extending the above to explicit radiance field models and dynamic scenes.

Student Talk 6: Semi-supervised Learning for Perceptual Quality Assessment of User-Generated Videos.

Speaker: Shankhanil Mitra, Department of Electrical Communication Engineering.

Abstract
Perceptual quality assessment (QA) of user-generated content (UGC) videos is challenging due to the requirement of large-scale human annotated videos for training. In this work, we present semi-supervised learning (SSL) methods exploiting many unlabelled and limited labelled number of user-generated videos. In the first work, we leverage the benefits of consistency regularization and pseudo-labelling by generating pairwise pseudo-ranks for the unlabelled videos using a student-teacher model on strong-weak quality-invariant augmented videos. The generated pseudo-ranks are used along with the limited labels to train our SSL model. In the second work, we first design a self-supervised Spatio-Temporal Visual Quality Representation Learning (ST-VQRL) framework to generate robust quality aware features for videos. Then, we propose a dual-model based SSL method specifically designed for the video QA task, through a novel knowledge transfer of quality predictions between the two models. Finally, we present the extension of the above work on modelling both quality and semantic perspective of UGC videos with limited labelled videos.

Student Talk 7: Tracking an analysis of scalar fields in Ocean Data

Speaker: Upkar Singh, Department of Computer Science and Automation.

Abstract
The Bay of Bengal (BoB) has maintained its salinity distribution over the years despite a continuous flow of fresh water entering it through rivers on the northern coast, which is capable of diluting the salinity. This can be attributed to the cyclic flow of high salinity water, coming from Arabian sea and entering BoB from the south, which moves northward and mixes with this fresh water. In our work, we present two methods for tracking and analysis of salinity which is represented as a 3D scalar field in ocean data. Although, we study the movement of salinity in BoB and discuss our findings, the methods are not restricted to BoB region or salinity field and can be used to study and analyse other scalar fields.

Student Talk 8: Tight-frame-like Analysis-Sparse Recovery Using Non-tight Sensing Matrices

Speaker: Nareddy Kartheek Kumar Reddy, Department of Electrical Engineering.

Abstract

The choice of the sensing matrix is crucial in compressed sensing. Random Gaussian sensing matrices satisfy the restricted isometry property, which is crucial for solving the sparse recovery problem using convex optimization techniques. However, tight-frame sensing matrices result in minimum mean-squared-error recovery given oracle knowledge of the support of the sparse vector. If the sensing matrix is not tight, could one achieve the recovery performance assured by a tight frame by suitably designing the recovery strategy? — This is the key question addressed in this paper. We consider the analysis-sparse $l1$-minimization problem with a generalized $l2$-norm-based data-fidelity and show that it effectively corresponds to using a tight-frame sensing matrix. The new formulation offers improved performance bounds when the number of non-zeros is large. One could develop a tight-frame variant of a known sparse recovery algorithm using the proposed formalism. We solve the analysis-sparse recovery problem in an unconstrained setting using proximal methods. Within the tight-frame sensing framework, we rescale the gradients of the data-fidelity loss in the iterative up dates to further improve the accuracy of analysis-sparse recovery. Experimental results show that the proposed algorithms offer superior analysis-sparse recovery performance. Proceeding further, we also develop deep-unfolded variants, with a convolutional neural network as the sparsifying operator. On the application front, we consider compressed sensing image recovery. Experimental results on Set11, BSD68, Urban100, and DIV2K datasets show that the proposed techniques outperform the state-of-the-art techniques, with performance measured in terms of peak signal-to-noise ratio and structural similarity index metric.

3.1.7 Session 9: Networking and IoT

Session Chair: Rahul Singh (ECE), Chandramani (DESE)
Faculty Organizer: Ratikanta Behera (CDS)
Student Organizer: Tanisha Koshti (ECE), Akhilesh Kumar Richhariya (ECE)
Location: EC1.07, ECE Department

Invited Talk 1: On the Optimal Deployment of Reconfigurable Intelligent Surfaces in mmWave Networks

Speaker: Abhishek Gupta, Assistant Professor, IIT Kanpur.

Abstract
Wireless communications aided by reconfigurable intelligent surfaces (RISs) is a promising way to improve the coverage for cellular users. The controlled reflection of signals from RISs is especially useful in mm-wave/THz networks when the direct link between a cellular user and its serving base station (BS) is weak or unavailable due to blockages. However, the joint blockage of the user-RIS and the user-BS links may significantly degrade the performance of RIS-aided transmissions. In this talk, I will discuss the impact of joint blockages on RIS performance and its role in determining the optimal placements of RISs. The talk will introduce a few concepts of stochastic geometry which is a tractable tool to analyze wireless networks. I will discuss how to model mmWave networks with RISs when RIS locations are coupled with BS locations. I will discuss the optimal placement of RISs to minimize the joint blockage probability of the user-RIS and the user-BS links and maximize the downlink coverage probability. The results show that installing RISs near the cell edge of BSs usually provides optimal coverage. Moreover, deploying RISs on street intersections improves the coverage probability. For users associated with BSs that are deployed sufficiently close to intersections, the intersection-mounted RISs offer a better coverage performance as compared to BS-coupled RISs.

Bio
Dr. Abhishek K. Gupta received his B.Tech.- M.Tech dual degree in Electrical Engineering from IIT Kanpur in 2010 and Ph.D. degree in the Department of Electrical and Computer Engineering at the University of Texas at Austin in 2016. He is currently working as an assistant professor in the Department of Electrical Engineering at Indian Institute of Technology Kanpur. He heads the modern wireless networks group at IITK. His research is in the area of stochastic geometry and modern communication systems, including 5G, mmWave, THz, vehicular, VLC, broadcast, quantum and molecular communication, and cyber-physical systems. He was recipient of IEI young engineer award (electronics and telecommunication discipline) by Institute of Engineers (India) in 2021, Class of 1986 young faculty fellowship by IIT Kanpur in 2022, IEEE wireless communication letters exemplary reviewer award in 2016, GE-FS leadership award by General Electric Foundation and Institute of International Education in 2009 and IITK academic excellence award for four consecutive years (2006-2009). He is the author of the books, An introduction to stochastic geometry (Springer Morgan-Claypool, 2023), Numerical methods using MATLAB (Springer Apress, 2014), and MATLAB by examples (Finch, 2010). Before joining IITK, he was working as Sr. standards engineer at Samsung Research America

in Dallas, TX, USA. In the past, he has worked in Applied Microelectronics Circuit Corporation (Pune), Futurewei Technologies (NJ), and Nokia Networks (IL). He serves as an associate Editor for IEEE Transactions on Wireless Communications.

Student Talk 1: Bayesian Learning-based Rate Adaptation in IEEE 802.11ax WLANs

Speaker: Sheela Shivaramu, Department of Electronic System Engineering.

Abstract

Rate adaptation in a wireless channel relies on periodically reported channel quality indicator (CQI) values to select the optimal modulation and coding scheme (MCS). The latest 802.11ax, with a HE-sounding protocol, supports an explicit feedback mechanism where the client sends back a transformed estimate of the channel state information (CSI) in the HE CQI Report field. These reports can be expensive when generated more frequently as it introduce unnecessary computational and protocol overhead. Also, the CSI feedback information is quantized, delayed, and noisy. In our work, we obtain CSI statistically at the transmitter through Bayesian Learning to reduce the frequent CSI feedback overhead. Further, we propose a Bayesian Learning-based Rate Adaptation (BLbRA) scheme at the transmitter. BLbRA is inspired by the Thompson Sampling approach, which is widely used for online learning, efficiently learns the channel SNR probability distribution based on previous knowledge of channel measurements.

Student Talk 2: Design of TSN infrastructure for TCPS

Speaker: Joydeep Pal, Department of Electronic System Engineering.

Abstract

Remote robotic telesurgery applications across cities are a class of Tactile Internet applications which impose strict requirements in terms of low bounded latency, low jitter and high packet reliability. Enabling such applications over a shared network such as the Internet is challenging due to unpredictable congestion on the switches and routers in the network, primarily due to queueing policies and associated queueing delays. We propose and design P4TSN, a Time-Sensitive Networking (TSN) switch developed as a module on a P4-programmable SmartNIC. Specifically, this paper presents the design and implementation of TSN components i.e, a programmable Time-Aware Shaper (TAS) for bounding latency of critical application data classified as Scheduled Traffic (ST), along with a time synchronisation (required by TAS) mechanism on the SmartNIC. We evaluate the performance of a teleoperation on a testbed with four such switches in the presence of high data-rate non-critical data classified as Best Effort (BE) traffic. Further, when we enable TSN on the two edges separated by 400kms, we demonstrate their impact when the intercity connection is over traditional MPLS-enabled routers.

Student Talk 3: Integrated taxiing and TLOF pad scheduling using different surface directions

Speaker: Ravi Raj Saxena, Department of Electronic System Engineering.

Abstract

Vertical Take-Off and Landing (VTOL) vehicles have gained immense popularity in the delivery drone market and are now being developed for passenger transportation in urban areas to efficiently enable Urban Air Mobility (UAM). UAM aims to utilize the urban airspace to address the problem of

heavy road congestion in dense urban cities. VTOL vehicles require vertiport terminals for landing, take-off, refuelling (or charging), and maintenance. An efficient scheduling algorithm is essential to maximize the throughput of the vertiport terminal (vertiminal) while maintaining safety protocols to handle the UAM traffic. While traditional departure and taxiing operations can be applied in the context of vertiminal, specific algorithms are required for take-off and landing schedules. Unlike fixed-wing aircraft that require a runway to take off and climb in a single direction, VTOL vehicles can approach and climb in several directions. We propose a Mixed Integer Linear Program (MILP) formulation to schedule flights for taxiing, climbing (or approaching) using multiple directions after take-off (before landing) and turnaround on gates. We have also proposed a method to thoroughly analyze the throughput capacity of a vertiminal considering all its elements, and our MILP can achieve the maximum throughput obtained through the method. Given the parameters, our analysis can be used to analyze the capacity of a vertiport terminal without running any simulation, while our MILP can be used to get the most efficient schedule.

Student Talk 4: Low Complexity Optimal Policies for Networked Control Systems

Speaker: Manali Dutta, Department of Electrical Communication Engineering.

Abstract

We consider the problem of optimally scheduling transmissions for remote estimation of a discrete-time autoregressive Markov process that is driven by white Gaussian noise. A sensor observes this process, and then decides to either encode the current state of this process into a data packet and attempts to transmit it to the estimator over an unreliable wireless channel modeled as a Gilbert-Elliott channel [1] - [3], or does not send any update. Each transmission attempt consumes λ units of transmission power, and the remote estimator is assumed to be linear. The channel state is revealed only via the feedback (ACK/NACK) of a transmission, and hence the channel state is not revealed if no transmission occurs. The goal of the scheduler is to minimize the expected value of an infinite-horizon cumulative discounted cost, in which the instantaneous cost is composed of the following two quantities: (i) squared estimation error, (ii) transmission power. We posed this problem as a partially observable Markov decision process (POMDP), in which the scheduler maintains a belief about the current state of the channel, and makes decisions on the basis of the current value of the error e(t) (defined in (6)), and the belief state. To aid its analysis, we introduce an easier-to-analyze “folded POMDP" We then analyze this folded POMDP and show that there is an optimal scheduling policy that has threshold structure, i.e. for each value of the error e, there is a threshold $b^*(e)$ such that when the error is equal to e, this policy transmits only when the current belief state is greater than $b^*(e)$.

3.1.8 Coffee Break

Invited Talk 2 : Network Evolution towards 6G : Perspectives and way forward

Speaker: Sreenath Ramanath, Lekha Wireless Solutions Pvt. Ltd.

Bio

Sreenath obtained his M.Tech from Indian Institute of Science (IISc), Bangalore and PhD from INRIA, Sophia Antipolis, France. He has close to three decades of Research and Development experience in the wireless industry working on GPS, CDMA, Wireless LAN, WIMAX, LTE, 5G, etc., He has held various technical and managerial positions at Accord, Ittiam, Philips and Beceem (acquired by Broadcom). Currently, he is a Senior Director, Systems R& D at Lekha Wireless Solutions, Bangalore, overseeing the design and development of next generation wireless networks, algorithm design, IP and Standardization. He is a senior member of the IEEE. In the past, he has served as an Adjunct Professor with the EE Dept., IIT Bombay, Associate Researcher with the Alcatel-Lucent chair on Flexible-Radio & the Large Networks and Systems Group at Supelec, Paris, France. He was also an associate member of the INRIA-Bell Labs joint research lab on Self Organizing Networks & Efficient Co-operating Small Cell Networks, He represents Lekha contributing to India initiatives in 3GPP and ITU standardization via TSDSI, Bharat 6G Alliance and other Industry forums. He is a co-inventor in multiple patents and has authored numerous research publications in reputed international journals and conferences. His research interests span wireless communications, signal processing, networking, optimization, and game theory.

Student Talk 5: I - Detect: Life Detection under Debris in Disaster Zones

Speaker: Lakshmi Poola, Department of Electronic System Engineering.

Abstract

The recent spate of natural disasters such as earthquakes and floods have destroyed buildings and caused loss of lives. In such scenarios, the number of deaths in the aftermath of a disaster can be significantly reduced if information about survivors under debris is available to first responders and rescue workers. Large-scale destruction of roads and other communication infrastructure makes it hard to deploy advanced technologies for life detection. We explore the possibility of using low-cost, low-power sensing technologies to assist rescue personnel in locating life under debris. We have designed and prototyped a thermopile-based sensor and communication device that provides information about the presence of survivors. The system weighs under 20 gm and costs US $30 per unit. The device can easily be fitted on battery-powered toy bugs and robots that can autonomously maneuver under the debris. We have proposed three simple algorithms, which together detect humans with 100% to 88% accuracy for 0.5 to 4.5 m range with fewer false alarms. Our evaluation shows that the detection is robust enough under several harsh ambient conditions, temperature ranges, as well as partial exposure of the human body.

Student Talk 6: Q_pay Protocol Bitcoin Micropayment Transactions

Speaker: Prerna Arote, Department of Electronic System Engineering.

Abstract

Bitcoin is the most popular cryptocurrency used on permissionless blockchain. Its popularity and the number of Bitcoin transactions happening every day are increasing rapidly. However, Bitcoin suffers from high confirmation latency. On average, a Bitcoin block takes ten minutes to get mined, and the customer needs to wait for six block confirmations to avail of the service. Such high confirmation latency becomes an overhead for users making Bitcoin micropayment transactions, which require a much shorter waiting time. Some of the layer2 solutions tried to reduce this latency by performing transactions off-chain. Although these solutions help in making Bitcoin scalable, they require users to deposit collateral to the mainchain apriori. Therefore, we propose a protocol named "Q_pay" that accelerates Bitcoin payment validation without locking customers collateral. We show that a seller who follows the Q_pay protocol gets guaranteed payment and provides quick service to the customer once a "committee" has approved the Q_pay transaction. Our solution is meant for micropayments such that the service or good that the customer is seeking becomes available in a matter of seconds. We evaluate Q_pay with 600 Bitcoin nodes running on an emulated network. Results show that the Q_pay protocol is efficient as the approval latency for a committee size between 16 and 512 remains <1 second.

3.1.9 Session 10: Microelectronics, RF, and Photonics

Session Chair: Varun Ragunathan (ECE) and Debdeep Sarkar (ECE)
Faculty Organizer: Velpula Balaswamy (ECE)
Student Organizer: Tarun kumar (DESE), Indrasish Mandal (DESE), Mokshika (DESE), Siddharth Sahu (DESE)
Location: Golden Jubilee Hall, ECE

Invited Talk 1: Silicon Photonics Enabled Quantum Integrated Circuits

Speaker: Bijoy Krishna Das, Professor, IIT Madras.

Abstract
Photonic Integrated Circuits or Integrated Photonics has been evolving very fast, thanks to the CMOS fabrication process compatibility of Silicon Photonics Technology. As the silicon photonics-based transceiver modules are occupying data center and communication market space, many other potential areas of applications are being explored to reap the full benefits of semiconductor foundry infrastructures. In recent years, there have been intense attention and investment observed from both academic and industry players for the development of quantum information processor chip by exploiting silicon photonics based low-loss optical interconnect solutions. In this talk, I shall discuss about the pros and cons of silicon photonics technology focusing on quantum photonic solutions. Recent progress on silicon photonics technology developments at our CoE-CPPICS, IIT Madras will be also highlighted. .

Bio
Prof. Bijoy Krishna Das obtained his master's degree in solid-state physics from Vidyasagar University, Midnapore, India (in 1996) and Ph.D. degree (Dr.rer.nat) in integrated optics from the University of Paderborn, Germany (in April 2003). Prior to his Ph.D. research in Germany, Dr. Das started his research career in the area of integrated optics at the Microelectronics Centre, IIT Kharagpur for three years (January 1996 – December 1998). His postdoctoral research was carried out in three different countries First, he was an FRC Postdoctoral Fellow in the Graduate School of Engineering, Osaka University, Osaka, Japan (2004-2005). Later, he joined as a postdoctoral researcher in the Center for Optical Technologies, Lehigh University, Bethlehem, PA, USA. In April 2005, he re-joined the Integrated Optics Group at the University of Paderborn as Wissenschaftlicher Mitarbeiter and continued his research on integrated nonear optical devices. He also worked for a while at Laboratoire Aime Cotton, CNRS, Orsay, France. Since August 2006, Dr. Das has been associated with the Dept. of Electrical Engineering, IIT Madras, where he is presently holding a full Professor position. At IIT Madras, Prof. Das has been dedicated to the development of in-house silicon photonics device technology starting from scratch. He has graduated six Ph.D. research scholars and as many as 15 MS research scholars to date all contributing towards the establishment of CoE-CPPICS starting from 1st January 2021.

Student Talk 1: Bias and Process Scalable Analog CMOS Circuit for Low Power LDPC decoding

Speaker: Ankita Nandi, Department of Electronic System Engineering.

Abstract

Analog computation presents a compelling alternative to digital methods, leveraging physical properties to tackle computational tasks. Unlike digital systems, which rely on discrete states, analog computation like the human brain, exploits continuous variables, enabling nuanced and efficient processing. When conceptualized as an optimization function, analog computing architectures mimic dynamical systems akin to biological counterparts, thereby exhibiting remarkable energy efficiency. In this work, we design a Low Density Parity Check decoder by formulating it as an optimization function, and then follow it by the circuit design.

LDPC decoding can be viewed as a special case of XOR-SAT problems, for which low-computational complexity bit-flipping algorithms have been proposed in the literature. We propose an XOR-SAT solver algorithm using the Margin Propagation formulation to attain a low-complexity LDPC decoder that can explore the nearest valid solution based on an initial vector (channel output) within the code space. The proposed algorithm, christened MP-XOR-SAT, uses soft information to decide the bit-flips that maximize the number of parity check constraints satisfied over an optimization function. MP-XOR-SAT, can achieve results that are within 0.1dB of the Sum-Product Algorithm for the same number of code iterations.

Our proposed circuit design for the MP-XOR-SAT algorithm uses analog Margin Propagation circuits that leverage the physical properties of the transistor. The design is under simulation and the preliminary results show promising power and performance benefits. The MP-XOR-SAT circuit design is bias and process technology scalable, paving the way for low-power analog decoding solutions, offering benefits across various domains, including portable devices, IoT (Internet of Things) applications, and embedded systems.

Student Talk 2 : Efficient Quantum Transport Modeling Technique for High-throughput Screening of 2D Transistor Materials

Speaker: Sirsha Guha, Department of Electronic System Engineering.

Abstract

The downscaling of silicon technology will reach its bottleneck within the next few years. Exploration of 2D (two-dimensional) materials as silicon alternatives, has become necessary in semiconductor industry since they are predicted to offer the ultimate electrostatic integrity for nano-scale transistors. Yet, the process integration of any new material is time intensive and expensive. First-principles-based device models, which enable systematic evaluation of new materials at the device and circuit level at the very early stage of technology development and thus reduce the design-technology co-optimization time, are in great demand. Moreover, it has been reported that the typical return on investment for such commercially available models is approximately a 5:1 ratio.

However, the 2D material space is infinite, and experimental efforts can cover only a small fraction of it. Commercially available software (QuantumATK, NanoDCAL, etc.), that uses atomistic-NEGF (Non-equilibrium Green's function)-based formalism is time-consuming, demands extensive computing infrastructure, typically unsuitable for high-throughput screening of this vast material space. We aim to develop first-principles-based computationally efficient quantum transport modeling scheme to fit this purpose. We have explored parallelization techniques in the

Poisson-NEGF coupled system and associated GPU implementation schemes to make the formalism efficient for discovering appropriate transistor channel materials by screening thousands of materials from open-source databases. Moreover, we have developed ballistic as well as dissipative transport model that includes electron-phonon scattering through deformation-potential formalism.

Student Talk 3: Exploring ultra-high index Van der Waal material for nonlinear Nanophotonics

Speaker: Rabindra Biswas, Department of Electrical Communication Engineering.

Abstract

Layered materials, such as transition metal dichalcogenides (TMDCs), have recently garnered a lot of attention for their ultra-high refractive index, making them promising candidates for building next-generation resonant photonic devices. The high refractive index of TMDCs facilitates efficient trapping of light at nanoscale volumes, enabling strong light-matter interactions. This results in the tight confinement of local electromagnetic fields and, hence, significant enhancement of electric and magnetic fields, which can amplify the nonlinear optical effects. In this study, we report enhanced second harmonic generation from a subwavelength optical resonator based on TMDCs by leveraging non - radiating anapole resonance. The nonlinear photonic device consists of thick MoS2 nanodisks on top of a SiO2-silicon substrate. Comprehensive 3D linear and nonlinear electromagnetic simulations were performed to optimize the dimensions of the MoS2 nanodisk to ensure anapole modes lie within the desired wavelength range of 1400-1700nm. Subsequent detailed linear and nonlinear optical measurements of the fabricated MoS2 resonator reveal that anapole modes can be further enhanced by tuning the oxide thickness to compensate for the substrate leakage. The optimal device shows a maximum experimental enhancement of 160 times at 1440nm when compared with the un-patterned MoS2 flake region, which is an order of magnitude higher than what was previously reported. Such emerging high-quality factor nonlinear optical devices based on Van der Waal material have potential uses as wavelength converters, frequency mixing, miniaturized sensing devices, nanoscale lasers, THz and quantum sources.

Student Talk 4: Fiber-Based Higher Dimensional Quantum Key Distribution Implementation using Time-bin Qudits

Speaker: Gokul A, Department of Electrical Communication Engineering.

Abstract

Higher Dimensional Quantum Key Distribution (HD-QKD) improves information capacity and security compared to binary QKD systems. Previous HD-QKD implementations have required d+1 (d refers to encoding dimension) single-photon detectors, limiting large-scale implementation. In contrast, another HD-QKD implementation using coherent one-way (COW) protocol hardware with two detectors achieved a secret key rate (SKR) of 155 kbps for an 8-D system and 2.7% QBER tolerance for a 16-D system with qubit scrambling across a time window. In this paper, we theoretically simulate and experimentally demonstrate time-bin encoded HD-QKD using COW protocol hardware with two single-photon detectors operating at standard telecom wavelengths, achieving a remarkable maximum encoding of 6 bits per photon (i.e., 56-d system). Our HD-QKD system incorporates a practical decoy-state technique to counter the photon number splitting attack, allowing greater flexibility in choosing higher mean photon number thereby achieving higher SKR and distances. This implementation demonstrates a remarkable ninefold increase in SKR for a 16-d system (210 kbps over 25 km of standard single-mode fiber) compared to qubit-based systems, with a QBER tolerance of 13.5% for d = 16. Notably, we achieved positive key rates for emulated loss

up to 131 km of fiber length for d = 8. By optimizing detector deadtime and mean photon number using our theoretical model, we achieve enhanced key rates and security. Our findings highlight the superiority of our approach and lay the foundation for high throughput HD-QKD implementation, offering a secure and efficient method for transmitting sensitive information.

3.1.10 Coffee Break

Invited Talk 2: Exploring frontiers in metamaterials through data-driven models

Speaker: Parama Pal, TCS Research.

Abstract
Optical Metasurfaces can manipulate light matter interactions with unprecedented flexibility beyond the limitations of natural materials. I will discuss our recent efforts in the design and optimization of metasurface THz biosensors as well as our quest for developing versatile inverse models for engineered electromagnetic composites. I will discuss the opportunities and challenges of our approaches and provide an outlook on possible future directions.

Bio
Parama Pal is a Senior Scientist with TCS Research, Tata Consultancy Services. Her current interests include the development of AI-assisted design models for metamaterials and novel optical sensing paradigms applied to diverse horizontals. Prior to this, she has held positions in Robert Bosch Engineering and Business Solutions (RBEI) and the Robert Bosch Centre for Cyber Physical Systems at the Indian Institute of Science. She was a Research Fellow at the Wellman Center for Photomedicine, Harvard Medical School. She has an M.Sc. in Physics from IIT Delhi and Ph.D. in Optics from The Institute of Optics, University of Rochester, USA.

Student Talk 5: Motion of 2D exciton in momentum space leads to pseudo-spin distribution narrowing on the Bloch Sphere

Speaker: Garima Gupta, Department of Electrical Communication Engineering.

Abstract
Motional narrowing implies narrowing induced by motion; for example, in nuclear resonance, the thermally induced random motion of the nuclei in an inhomogeneous environment leads to counter-intuitive narrowing of the resonance line. Similarly, the excitons in monolayer semiconductors experience magnetic inhomogeneity: the electron-hole spin-exchange interaction manifests as an in-plane pseudo-magnetic field with a periodically varying orientation inside the exciton band. The excitons undergo random momentum scattering and pseudospin precession repeatedly in this inhomogeneous magnetic environment – typically resulting in fast exciton depolarization. On the contrary, we show that such magnetic inhomogeneity averages out at high scattering rate due to motional narrowing. Physically, a faster exciton scattering leads to a narrower pseudospin distribution on the Bloch sphere, implying a nontrivial improvement in exciton polarization. The in-plane nature of the pseudo-magnetic field enforces a contrasting scattering dependence between the circularly and linearly polarized excitons – providing a spectroscopic way to gauge the sample quality.

Student Talk 6: Space-Time Engineered Metamaterials: Design and Analysis

Speaker: Anand Kumar, Department of Electrical Communication Engineering.

Abstract

Metamaterials are artificially engineered materials with unusual electromagnetic properties not found in naturally occurring materials (""Meta"" =beyond). Space-time engineered metamaterials (STEMs) are structures whose constitutive parameters (e.g., permittivity, permeability or conductivity) modulate in space and time. Space-time modulation of electrical circuit components of electromagnetic (EM) systems provides a unique potential to model the systems' response in unusual ways, both in the time and frequency domains. EM wave-engineering through STEMs can be applied for various purposes like frequency multiplication and mixing, matching and filtering, nonreciprocity and absorption, electromagnetic cloaking, electromagnetic processing, radiation, etc.

Student Talk 7: Ultra bright single photon emission from atomically thin materials: A step closer to quantum future

Speaker: Mayank Chhaperwal, Department of Electrical Engineering.

Abstract

Single photon emitters (SPEs) provide a scalable approach to on-chip quantum technologies. The applications span the field covering quantum metrology, quantum cryptography, quantum computation, and others. TMDC monolayer-based SPEs are incredibly lucrative because of their inherent 2-dimensional nature, making them suitable for integration into photonic cavities, waveguides, and existing optical communication infrastructure. Two important figures of merit of SPEs are their emission rate and single photon purity. While high single photon purity has been achieved in these systems, the emission rate is still relatively low when compared to both the competing technologies and the projected required rates for optimal use in the mentioned technologies. Improving the emission rate often results in the degradation of the single photon purity, which makes optimizing both figures challenging. In this work, we analyze the bottlenecks currently limiting the performance of TMDC-based SPEs and provide the necessary design considerations for overcoming this bottleneck. Using the results from this analysis, we designed and fabricated our SPE device, which showed a maximum collected pure single photon rate of 10.53 MHz (7 times higher than the highest reported rate in the category) while also maintaining a high single photon purity with $g^{(2)}(0) = 0.113$. The emission wavelength is around 800 nm, meaning these SPEs can be implemented in existing satellite communication infrastructure. The results from the fabricated device not only verify our analysis but also provide a pathway for further improvements in the field.

3.2 Plenary Speaker Talks

Session Chair: Chaya Ganesh (CSA), Gurunath Gurrala (EE), Rajesh Sundaresan (ECE)
Location: Faculty Hall, Main Building

3.2.1 Plenary Talk 1: Matchings and Popularity

Speaker: Kavitha Telikepalli, Professor, IIT Madras.

Abstract

The problem of computing a stable matching in a graph is an old and well-studied problem. Gale and Shapley showed in 1962 that such a matching always exists and can be efficiently computed. This is a classical result in algorithms with many applications in economics and computer science. Stability is a strong and rather restrictive notion. This talk will be on a relaxation of stability called "popularity" and we will see simple and efficient algorithms for some popular matching problems. No background in algorithms or matching theory will be assumed.

Bio

Kavitha is a member of the STCS faculty at TIFR. She did her B.Tech. in Computer Science and Engineering from IIT Madras and her PhD in Computer Science from TIFR. She worked for a few years at IISc and then moved to TIFR. Her main research interests are in efficient graph algorithms and combinatorial optimization.

3.2.2 Plenary Talk 2: Cybersecurity of Critical Infrastructures: Challenges & Way Forward

Speaker: Faruk Kazi, Professor, VJTI Mumbai.

Abstract

Last decade has seen growing cyber attacks on critical infrastructures like energy, water & waste water, transportation, manufacturing, oil & gas etc. Vanishing air-gaps are exposing industrial control systems (ICS) and SCADA systems used in such systems to hackers. This talk illustrates changing face of cyber threats and threat actors targeting critical infrastructures. It also highlights challenges in securing operational technology (OT) as compared to IT systems and ways to protect the critical infrastructure against cyber-attacks.

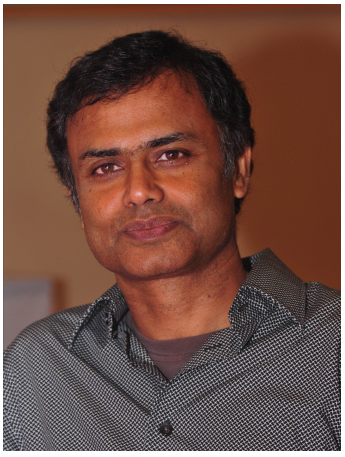
Bio

Faruk Kazi received his Ph.D. degree from Systems & Control Engineering of IIT Bombay, in 2009. He is currently a Professor and Dean of Research & Development at VJTI, Mumbai. He also works as an advisor to USAID for their SAREP program. He works in the domain of cyber-physical systems and critical infrastructure security. His research interests include SCADA security, Industrial Control System (ICS) and Operational Technology (OT) security. He is working as Chair of WG-3 (Digital Architecture and Cyber Security) of India Smart Grid Forum (ISGF). He is listed on Schneider Wall of Thanks for securing their product "ScadaPack RTU". His team has discovered more than 40 vulnerabilities in OT products of OEMs like Schneider, ABB, GE, Rockwell Automation, Mitsubishi, SEL etc. He was invited as a visiting research scholar at Swiss Federal Institute of Technology, EPFL, Switzerland and Tufts University, Boston, USA. He has delivered invited talks and presented his research work at MIT USA, SUPELEC, CNRS, Paris (France), Budapest (Hungary), Florence (Italy) and Japan. He has published more than 100 research papers in various international journals & conferences. He has received project funding from National Security Council, ISRO, BARC, DRDO and DST for his various research projects.

3.2.3 Plenary Talk 3: Rethinking Computing with Neuro-Inspired Learning

Speaker: Kaushik Roy, Professor, Purdue University.

Abstract
Advances in machine learning, notably deep learning, have led computers to match or surpass human performance in several cognitive tasks including vision, speech and natural language processing. However, implementation of neural algorithms in conventional "von-Neumann" architectures are several orders of magnitude more area and power expensive than the biological brain. Hence, we need fundamentally new approaches to sustain the exponential growth in performance at high energy-efficiency. Exploring the new paradigm of computing necessitates a multi-disciplinary approach: exploration of new learning algorithms inspired from neuroscientific principles, developing network architectures best suited for such algorithms, new hardware techniques to achieve orders of improvement in energy consumption, and nanoscale devices that can closely mimic the neuronal and synaptic operations. In this talk, I will first present our recent work on hybrid learning algorithms (using both standard deep learning combined with spike-based computing units) to achieve high energy efficiency and higher accuracy compared to standard deep-learning techniques. In particular, we focused on autonomous vision-based navigation as an application driver and developed efficient and low-complexity hybrid learning algorithms for optical flow, segmentation, object detection, tracking, and avoidance, gesture recognition with both frame based and DVS cameras as input sensors. The above algorithms for edge applications require fast and energy-efficient processing, beyond the capabilities of today's von-Neumann based commercial hardware. In the second part of the talk, I will present our work on in-memory computing-based machine learning hardware that has the potential to achieve orders of magnitude improvement in energy compared to today's deep learning hardware.



Bio
Kaushik Roy is the Edward G. Tiedemann, Jr., Distinguished Professor of Electrical and Computer Engineering at Purdue University. He received his BTech from Indian Institute of Technology, Kharagpur, PhD from University of Illinois at Urbana-Champaign in 1990 and joined the Semiconductor Process and Design Center of Texas Instruments, Dallas. His current research focuses on cognitive algorithms, circuits and architecture for energy-efficient neuromorphic computing/ machine learning, and neuro-mimetic devices. Kaushik has supervised more than 100 PhD dissertations and his students are well placed in universities and industry. He is the co-author of two books on Low Power CMOS VLSI Design (John Wiley & McGraw Hill).
Dr. Roy received the National Science Foundation Career Development Award in 1995, IBM faculty partnership award, ATT/Lucent Foundation award, 2005 SRC Technical Excellence Award, SRC Inventors Award, Purdue College of Engineering Research Excellence Award, Outstanding Mentor Award in 2021, Humboldt Research Award in 2010, 2010 IEEE Circuits and Systems Society Technical Achievement Award (Charles Desoer Award), IEEE TCVLSI Distinguished Research Award in 2021, Distinguished Alumnus Award from Indian Institute of Technology (IIT), Kharagpur,

Fulbright-Nehru Distinguished Chair, DoD Vannevar Bush Faculty Fellow (2014-2019), SRC Aristotle Award in 2015, Purdue Arden L. Bement Jr. Award in 2020, SRC Innovation Award in 2022, honorary doctorate from Aarhus University in Denmark in 2023.

3.3 Award Distribution and Closing Ceremony

Session Chair: Rajesh Sundaresan (ECE) and Viveka Konandur Rajanna (DESE)
Location: Faculty Hall, Main Building.

15th EECS Research Students Symposium

Plenary Speakers

Kaushik Roy
Professor, Purdue University

Kavitha Telikepalli
Professor, TIFR, Mumbai

Faruk Kazi
Professor, VJTI, Mumbai

Faculty Speakers

Danish Pruthi
CDS

Chaya Ganesh
CSA

Debayan Das
ESE

Ravi Prakash
CPS

Kiran Kumari
EE

Sudhan Majhi
ECE

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