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APRIL 3RD AND 4TH 2025

EECS

RESEARCH STUDENT

SYMPOSIUM

Book of Abstracts

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Indian Institute of Science, Bengaluru

भारतीय विज्ञान संस्थान

Preface

The EECS Research Students Symposium 2025 is the sixteenth 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 2025 symposium, a team of six faculty members coordinated by **Ravi Prakash (CPS)** and consisting of **Debayan Das (ESE), Danish (CDS), Tapas Roy (EE), Chaya Ganesh (CSA)**, and **Rahul Singh (ECE)**, and an energetic team of staff and student 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** which 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: **Shivkumar Kalyanaraman (CEO, ANRF), Meena Mahajan (Senior Professor, The Institute of Mathematical Sciences), Nagendra Krishnapura (Professor, IIT Madras)** and **Kyle Daigle (COO, Github)**. 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 **Debasish Ghose (CPS & AE), Pandarasamy Arjunan (CPS), C M Chandrashekar (DESE), Vaanathi Sundaresan (CDS), Kiran Kumari (EE)**, and **Shubada Agarwal (ECE)**.

The organizing committee has assembled a splendid technical program for this event – congratulations to them on the 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), Indian Institue of Science (Platinum), ARTPARK IISc (Platinum), GitHub (Gold), Tejas Networks (Gold), British Telecom India Research Centre (BTIRC), IISc (Silver), Centre for Brain Research IISc (Silver), Centre for Networked Intelligence (Silver) and Tata Consutancy Services - TCS Research (Silver)** for their generous sponsorship for this event. 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

DAY 1 : April 3 (Thursday)		
Sessions [9:30 AM-1:00 PM]	Session 1: Signal Processing and Communication, Artificial Intelligence and Machine Learning (ECE1.07, ECE) Session 2: Computer Systems, Security & Privacy (ECE1.08, ECE) Session 3: Visual Analytics and Artificial Intelligence and Machine Learning (MP 20, ECE) Session 4: Networking and IoT and Scientific Computing (IDR Seminar Hall (G22)) Session 5: Microelectronics, RF, Photonics (ECE, GJH)	Coffee Break (ECE Hut) [11:00 AM-11:30 AM] Lunch Break (Main Guest House) [1:00 PM-2:00 PM] High Tea (Faculty Hall) [4:00 PM-4:30 PM]
Address Note [Faculty Hall, Main Building [2:00 PM-2:05 PM]- Prof. Rajesh Sudaresan		
Plenary and Faculty Talks [Faculty Hall, Main Building][2:05 PM-5:20 PM]		
DAY 2: April 4 (Friday)		
Sessions [9:30 AM-1:00 PM]	Session 6: Artificial Intelligence and Machine Learning(ECE, GJH) Session 7: Brain Computation, and Data Science(ECE1.08, ECE) Session 8: Theoretical Computer Science (ECE1.07, ECE) Session 9: Power Engineering and Cyber-Physical Systems (MP 30, ECE) Session 10: Cyber-Physical Systems (IDR Seminar Hall (G22))	Coffee Break (ECE Hut) [11:00 AM-11:30 AM] Lunch Break (Main Guest House) [1:00 PM-2:00 PM] High Tea (Faculty Hall) [4:00 PM-4:30 PM]
Plenary Talks [Faculty Hall, Main Building][2:00 PM-5:00 PM]		

2. Day 1: 3rd April 2025 (Thursday)

2.1 Research Cluster Talks

Location: ECE Building

2.1.1 Session 1: Signal Processing & Communication, Artificial Intelligence and Machine Learning

Session Chair: Shubhada Agarwal (ECE)
Faculty Organizer: Rahul Singh (ECE)
Student Organizer: Lucky Gupta (EE), Yuvraj Singh (EE), Aditya Anand Gupta (EE)
Location: 1.07, ECE Department

Invited Talk 1: Opportunities for Future Automated-RAN

Speaker: Pramit Biswas , Tejas Networks

Abstract
Automation in Radio Access Networks (RAN) offers transformative potential to enhance performance and reduce operational costs. This talk examines critical challenges through three pillars: First, "simulation" addresses scalable synthetic data generation to replicate real-world dynamics. Second, "validation" ensures algorithm decisions are rigorously verified prior to live deployment. Third, "interoperability" focuses on achieving portability across heterogeneous hardware platforms through standardized interfaces and abstraction layers. These aim to empower operators to adopt automation confidently while mitigating risks of instability and vendor dependency.

Bio Pramit received his PhD from the Indian Institute of Technology Patna, India, in 2021. During his doctoral tenure, he was a visiting scholar at the G. S. Sanyal School of Telecommunications, Indian Institute of Technology Kharagpur, West Bengal, India. He is currently a Lead Engineer at Tejas Networks, India. His research interests include but are not limited to, O-RAN standardization, broadcast networks, compilers, multi-objective optimization, machine learning, cost- and energy-efficient network design and operation, wireless-optical access networks, software-defined networks, fuzzy systems, and quantum optimization. Dr Biswas has received the Visvesvaraya PhD fellowship for his doctoral research.

Student Talk 1: Inter-numerology and inter-carrier interference in mixed-numerology OFDM systems

Speaker: Venkata Satya Sreedhar Tenneti, Department of Electrical Communication Engineering.

Abstract

Mixed numerology has been adopted in the orthogonal frequency division multiplexing (OFDM)-based physical layer of 5G new radio (NR) to serve diverse use cases and services. However, when mixed-numerology OFDM systems operate over the channels envisioned for 5G, they face two kinds of interference, due to the use of the OFDM waveform. These are inter-numerology interference (INI) and inter-carrier interference (ICI). We present a unified analysis of the INI and ICI encountered by these systems. We first focus on single-input-single-output systems. We analyze INI and ICI in wideband time-varying channels in the presence of phase noise. We derive novel expressions for the fading-averaged INI and ICI powers at each subcarrier as a function of the channel's power delay profile. These lead to insightful lower and upper bounds for the bandwidth-averaged INI and ICI powers, which bring out the combined impact of Doppler spread and phase noise statistics. The bounds for ICI power are tighter than those in the literature, which employ a tractable, but less accurate, continuous-time formulation and assume infinitely many subcarriers. Our results show that INI and ICI affect high-rate modulation and coding schemes of 5G NR. To mitigate this impact, we propose a novel statistical square root power allocation scheme that exploits the variation in the INI and ICI powers across the subcarriers. It achieves a lower block error rate than the uniform power allocation, which is used in 5G NR. N ext, we turn our attention to multiple-input-multiple-output (MIMO) systems. We derive novel insightful expressions for the INI and ICI covariances for a mixed-numerology, multiuser MIMO-OFDM system in a wideband spatially correlated time-varying channel with phase noise. With this analytical foundation, we propose a joint INI and ICI mitigation technique that is based on statistical information and incorporates fairness. We derive the precoder for each user that achieves the single-user ergodic capacity. We also determine a novel power allocation that maximizes the weighted sum rate. We solve this using an iterative algorithm based on the difference of convex programming framework. The proposed approach achieves a higher weighted sum rate than several benchmarks. Our results highlight the impact of INI and ICI and the influence of various system parameters. They show that INI and ICI can lead to novel power allocations in which the stronger spatial eigenmodes are assigned less power.

Student Talk 2: Millimeter Wave Beam Selection in Time-Varying Channels with Orientation Changes and Lateral Mobility

Speaker: C Ashok Kumar Reddy Chavva , Department of Electrical Communication Engineering.

Abstract

Beamforming enables millimeter-wave (mmWave) communications to achieve high data rates in 5G and beyond systems. This requires the use of many narrow directional beams at both the transmitter and receiver to overcome the adverse propagation conditions in mmWave channels. However, accurate beam alignment incurs significant training overhead. Changes in user device orientation and mobility can quickly result in beam misalignment, reducing the data rate. They also make the beam gains a non-stationary random processes. We first present a novel modified bivariate Nakagami-m (MBN) model to tractably and accurately characterize the joint, non-stationary statistics of the channel gains seen at the times of measurement and data transmission. This model accurately captures the widely used mmWave spatial channel model (SCM), which is realistic but uses a geometry-based method to construct the channel. We use the MBN model to propose a near-optimal, practically amenable bound-based selection (PABS) rule. Our approach captures several pertinent aspects about the spatial channel model and 5G, such as transmission of periodic bursts of reference signals, feedback from the user to enable the base station to select its transmit beam, and the faster pace of updating the data rate compared to the transmit-receive beam pair. The PABS rule markedly outperforms the widely used conventional power-based selection rule and is less sensitive to user orientation changes. However, this method needs angle of arrival (AoA) at the user equipment (UE). We then propose a comprehensive and novel approach called latent Thompson sampling-based beam selection (LTBS), which combines latent Thompson sampling to track the AoA as a latent state, receive beam subset selection based on the sampled AoA in a manner compliant with the 5G new radio standard, rate adaptation, and data beam selection based on predicted throughput. We propose two variants of LTBS that trade-off between complexity and accuracy in modeling beam pair gains. The prior update and channel gain prediction in one of the variants are based on SCM. We propose variations that employ windowing to also tackle lateral user mobility, which alters the AoA and the channel statistics. Our numerical results show that the proposed methods track the AoA in a manner robust to user orientation changes and provide higher average data rates compared to conventional and state-of-the-art learning-based beam selection methods.

Student Talk 3: Design and Analysis of Low Complexity Techniques for IRS-Aided Wireless Communications

Speaker: Yashvanth L, Department of Electrical Communication Engineering.

Abstract

In this talk, we will discuss some low-complexity techniques for the design of intelligent reflecting surfaces (IRS) (also known as reconfigurable intelligent surfaces (RIS)) aided wireless communication systems and their performance. First, we address the optimization of the IRS by random tuning of IRS configurations combined with opportunistic scheduling of users. We show that, with many users in the system, multi-user diversity provides optimal IRS performance without optimizing the IRS. In the second part, we examine how an IRS, being a passive device without bandpass filters, may affect the performance of other mobile network operators when the IRS is deployed and controlled only by a single operator. We address this problem for both sub-6 GHz and mmWave bands, considering centralized and distributed IRS deployment scenarios. Finally, we discuss the issue of wideband beamforming with IRS, where the interplay of spatial wideband effects and phased array architecture

of IRSs give rise to the so-called beam-split effects, which severely degrades the array gain and achievable throughput unless treated carefully. We propose two low-complex approaches to handle the beam-split effects: the first is a distributed IRS strategy, which aims at mitigating the beam-split, and the second is an opportunistic OFDMA approach, which positively exploits the beam-split effects. Our theoretical developments and findings are supported by numerical experiments.

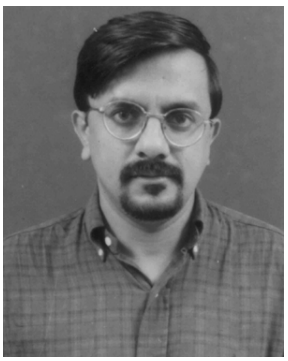
2.1.2 Coffee break

Invited Talk 2: Recommendations: Intended and Unintended Consequences

Speaker: D. Manjunath , IIT Bombay

Abstract

Recommendation algorithms mediate users' access to, and hence use of, content on the Internet. They are purportedly designed to learn user interest and make suggestions based on what is learned. Several immediate questions are rarely asked, and hence their consequence not always analyzed. In this talk, I will first provide an abstraction of the learning algorithms used in the recommendations systems. We then model how these learning algorithms interact with the user preferences that they are trying to learn. And then we present some unintended consequences on the user preferences.



Bio

D. Manjunath received his BE from Mysore University, MS from Indian Institute of Technology, Madras and PhD from Rensselaer Polytechnic Inst, Troy NY in 1986, 1989 and 1993 respectively. He has worked in the Corporate R & D center of General Electric in Scehenctady NY during the summer of 1990. He was a Visiting Faculty in the Comuter and Information Sciences Dept of the University of Delaware and a Post Doctoral Fellow in the Computer Science Dept of the University of Toronto. He was on the Electrical Engineering faculty of the Indian Inst of Technology, Kanpur during December 1994 - July 1998. He has been with the Deptt of Electrical Engineering of IIT, Bombay since July 1998.

Student Talk 4: SASHA: Sequential Attention-based Sampling for Histopathology Analysis

Speaker: Tarun Gogisetty, M.Tech in Artificial Intelligence.

Abstract

Deep neural networks are increasingly applied for histopathological image analysis. However, whole-slide images (WSIs) are acquired at gigapixel sizes, rendering it computationally infeasible to analyze them entirely at high resolution. Moreover, labels are usually available only at the slide-level, because expert annotation of images at a finer (patch) level is both laborious and expensive. In addition, regions with diagnostic information typically occupy only a small fraction of the WSI, making it inefficient to examine the entire slide at full resolution. Multiple instance learning (MIL), a weakly supervised learning paradigm, addresses these challenges by generating feature representations at the patch-level, and employing weighted aggregates of patch-level features for

WSI classification. Yet, despite their appeal, these methods are limited by the high computational cost of analyzing every image patch at high resolution. By contrast, methods that rely solely on low resolution images suffer from performance bottlenecks. Here, we propose SASHA - Sequential Attention-based Sampling for Histopathological Analysis - that combines a novel MIL method with deep reinforcement learning. First, SASHA learns informative features more efficiently than existing methods – with a hierarchical, attention-based MIL approach. Second, SASHA intelligently samples and zooms into relevant patches at low resolution, greatly limiting the number of patches that must be analyzed at high resolution. We show that SASHA performs comparably with state-of-the-art methods that analyze high resolution WSIs, and significantly outperforms competing methods that sparsely sample the WSI. Finally, we demonstrate major benefits with model size, computational overheads and inference time over these methods. We propose SASHA as an intelligent sampling model for medical imaging challenges, involving automated diagnosis with exceptionally large images containing sparsely informative features.

Student Talk 5: Approximate linear programming for decentralized policy iteration in cooperative multi-agent Markov decision processes

Speaker: Lakshmi Mandal, Department of Computer Science and Automation.

Abstract

In this work, we consider a 'cooperative' multi-agent Markov decision process (MDP) involving $m(>1)$ agents. At each decision epoch, all the m agents independently select actions in order to minimize a common long-term cost objective. In the policy iteration process of multi-agent setup, the number of actions grows exponentially with the number of agents, incurring huge computational costs. Thus, recent works consider decentralized policy improvement, where each agent improves its decisions unilaterally, assuming that the decisions of the other agents are fixed. However, exact value functions are considered in the literature, which is computationally expensive for a large number of agents with high dimensional state–action space. Thus, we propose approximate decentralized policy iteration algorithms, using approximate linear programming with function approximation to compute the approximate value function for decentralized policy improvement. Further, we consider (both) cooperative multi-agent finite and infinite horizon discounted MDPs and propose suitable algorithms in each case. Moreover, we provide theoretical guarantees for our algorithms and also demonstrate their advantages over existing state-of-the-art algorithms in the literature.

Student Talk 6: Provably Adaptive Average Reward Reinforcement Learning for Metric Spaces

Speaker: Avik Kar, Department of Electrical Communication Engineering.

Abstract

We study average-reward reinforcement learning (RL) for Lipschitz Markov Decision Processes (MDP). Adaptive discretization-based algorithms in multi-armed bandits (MABs) and in the episodic RL setting are shown to be provably efficient in the case of benign problem instances. These adaptive algorithms zoom into the better reward-yielding regions and discretize those regions of the arm/state-action space with a finer grid.

We propose two different adaptive discretization-based ideas that yield adaptivity gains in the average-reward RL setup.

1) Policy zooming: The proposed algorithms "zoom" into "promising" regions of the policy space, thereby achieving adaptivity gains. We upperbound their regret as $\tilde{O}(T^{1-d_{\text{eff}}^{-1}})$, where $d_{\text{eff}} = d_z^{\Phi} + 2$ for the model-free algorithm PZRL-MF and $d_{\text{eff}} = 2d_S + d_z^{\Phi} + 3$ for the model-based algorithm PZRL-MB. Here, d_S is the dimension of the state space, and d_z^{Φ} is the "zooming dimension given the policy class" Φ. The quantity d_z^{Φ} is problem-dependent and depends not only on the underlying MDP but also on the class Φ. This results in low regret when the agent competes against a low-complexity Φ (which has a small d_z^{Φ}).

2) Zooming in the state-action space: We develop an adaptive algorithm ZoRL with regret bounded as $\tilde{O}(T^{1-d_{\text{eff}}^{-1}})$, where $d_{\text{eff}} = 2d_S + d_z + 3$. Here, d_z is the "zooming dimension" of the problem, and we show that $d_z \leq d_S + d_A$. In contrast, algorithms with fixed discretization yield $d_{\text{eff}} = 2(d_S + d_A) + 2$, where d_A is the dimension of the action space. ZoRL achieves the improvement in the regret upper bound by discretizing the state-action space adaptively and zooming into "promising regions" of the state-action space. If an MDP is benign, then d_z is small, resulting in low regret for ZoRL.

2.1.3 Session 2: Computer Systems, Security & Privacy

Session Chair: Bhavana Kanukurthi (CSA), Sumit Kumar Mandal (CSA)
Faculty Organizer: Chaya Ganesh (CSA), Utsav Banerjee (DESE)
Student Organizer: Shweta Shukla (CSA), Pritam (CSA), Gopinath (CSA)
Location: 1.08, ECE

Invited Talk 1: FPGAs in the Computing Eco-system

Speaker: Madhura Purnaprajna, AMD.

Abstract

FPGAs are highly parallel and configurable devices that can be customized according to the application under consideration. They have become very suitable as custom hardware accelerators, across application domains. I will present a few use-cases that highlight the advantages of FPGAs as compared to CPUs and GPUs in terms of performance and energy efficiency.

Modern day FPGAs are heterogeneous. In addition to programmable logic, they are composed of processors, custom hard blocks, specialized AI Engines, etc. interacting over a programmable network on chip. This complexity introduces unique challenges for efficient mapping but simultaneously opens doors to innovative solutions. By combining FPGAs with CPUs and GPUs, these heterogeneous systems present new opportunities for achieving optimized performance and energy-efficient solutions.

Bio

I am with Xilinx AMD, where my team looks at performance projections for next-gen AMD (Xilinx) ACAP devices. My research interests are in Reconfigurable Computing and Processor Architectures. I received my PhD in Electrical Engineering from the Heinz Nixdorf Institute, University of Paderborn, Germany. I also have a Master's degree from the University of Alberta, Canada.

Student Talk 1: Proof of Execution with Control Flow Attestation

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

Abstract

Control-Flow Attestation (CFA) that can attest low-level properties of programs, in particular, the control-flow path executed by a program as it processes a particular input. CFA is particularly useful as a technology to audit program execution, which can be used to either prove that the program executed as expected, or do a post-mortem analysis of what went wrong in the execution of the program. In this talk, I will introduce the technology underlying CFA, which was introduced in 2016 and has been applied primarily in the embedded systems domain. I will quickly move on to challenges that prevent scaling up CFA to larger applications and to settings more complex than embedded systems, and describe my work which addresses these challenges.

Student Talk 2: Privacy-Preserving Graph Analysis

Speaker: Bhavish Raj Gopal, Department of Computer Science and Automation.

Abstract

Graphs are fundamental tools for modelling data in diverse real-world applications such as communication networks, traffic systems, and social networks. However, graph data is often distributed across multiple data owners and contains sensitive information, posing significant privacy concerns that impede collaborative analysis. Privacy-preserving graph analysis enables computations on graphs that store sensitive information, ensuring that all information about the topology of the graph, as well as data associated with the nodes and edges, remains hidden. In this talk, we will discuss potential solutions for privacy-preserving graph analysis, with an emphasis on using secure multiparty computation (MPC). We will review existing MPC-based approaches for privacy-preserving graph analysis, identifying their limitations in terms of efficiency, scalability, and adaptability. Furthermore, we will present our results in enhancing privacy-preserving graph analysis and highlight the remaining challenges. Specifically, we will discuss our highly scalable frameworks, Graphiti and emGraph, that can realize any message-passing graph algorithm securely.

Student Talk 3: Batching-Efficient RAM using Updatable Lookup Arguments

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

Abstract

RAM (random access memory) is an important primitive in verifiable computation. In this paper, we focus on realizing RAM with efficient batching property, i.e, proving a batch of m updates on a RAM of size while incurring a cost that is sublinear in N. Classical approaches based on Merkle-trees or address ordered transcripts to model RAM correctness are either concretely inefficient, or incur linear overhead in the size of the RAM. Recent works explore cryptographic accumulators based on unknown-order groups (RSA, class-groups) to model the RAM state. While recent RSA accumulator based approaches offer significant improvement over classical methods, they incur linear overhead in the size of the accumulated set to compute witnesses, as well as prohibitive constant overheads.

We realize a batching-efficient RAM with superior asymptotic and concrete costs as compared to existing approaches. Towards this: (i) we build on recent constructions of lookup arguments to allow efficient lookups even in presence of table updates, and (ii) we realize a variant of sub-vector relation addressed in prior works, which we call committed index lookup. We combine the two building blocks to realize batching-efficient RAM with sublinear dependence on size of the RAM. Our construction incurs an amortized proving cost of O(m log m + sqrtmN) for a batch of m updates on a RAM of size N. Our results also benefit the recent arguments for sub-vector relation, by enabling them to be efficient in presence of updates to the table. We believe that this is a contribution of independent interest.

We implement our solution to evaluate its concrete efficiency. Our experiments show that it offers significant improvement over existing works on batching-efficient accumulators/RAMs, with a substantially reduced resource barrier.

Student Talk 4: Secure Vickrey auctions for rational parties

Speaker: Girisha Shankar, Department of Computer Science and Automation.

Abstract
In this work, we construct a second price (Vickrey) auction protocol (SPA), which does not require any auctioneers and ensures total privacy in the presence of rational parties participating in auction. In particular, the confidentiality of the highest bid and the identity of the second highest bidder are protected. We model the bidders participating in the second price auction as rational, computationally bounded, and privacy-sensitive parties. These are self-interested agents who care about winning the auction more than learning about the private bids of other parties. A rational party does not deviate from the protocol arbitrarily but does so only for its own individual 'advantage' – without any consideration for others. Such an advantage is modeled using suitable utility functions.

We show that for rational and computationally bounded parties participating in our second-price auctions protocol, there exists a privacy-preserving dominant strategy equilibrium in which every party prefers to follow the protocol rather than to deviate. In addition, our work also introduces a novel way of deterring collusion for rational parties.

2.1.4 Coffee Break

Invited Talk 2: Higher-Order Lookup Table Masking against Side-Channel Attacks in Essentially Constant Memory

Speaker: Srinivas Vivek, IIIT Bangalore.

Abstract
Cryptography plays a central role in information security. It is necessary to carefully design cryptographic primitives with formal security guarantees. But it also turns out that their implementation must be performed carefully as they are prone to certain implementation-based attacks called "side-channel attacks." Such attacks are based on the fact that an adversary could exploit physical characteristics of a cryptographic implementation such as timing information, power consumption, electro-magnetic, photonic or acoustic emissions, etc., to deduce information about internal secret variables that are otherwise unavailable. Low computing-power devices such as smart cards are particularly vulnerable to such attacks. Hence, there is a need to design secure and efficient countermeasures against side-channel attacks that can be effectively deployed in such low-resource embedded devices. Masking using randomised lookup tables is a popular as well as one of the earliest countermeasures for side-channel attacks, particularly at small masking orders. An advantage of this class of countermeasures for masking cryptographic S-boxes of block ciphers compared to ISW-based masking is that it supports pre-processing and, thus, significantly reduces the amount of computation to be done after the final input shares are available. Indeed, the online computation can be as fast as just a table lookup. But the size of the randomised lookup table increases linearly with the masking order, and hence, the RAM memory required to store pre-processed tables becomes infeasible for higher masking orders. Hence, demonstrating the feasibility of full pre-processing of higher-order lookup table-based masking schemes on resource-constrained devices had remained an open problem. In this talk, we show how we solved the above open problem by implementing a higher-order lookup table-based scheme using an amount of RAM that is essentially independent of the masking order. This talk does not assume any prior knowledge of cryptography.

Bio

Dr. Srinivas Vivek holds a bachelor's degree in information technology from the National Institute of Technology Karnataka, Surathkal (IN), and a master's degree in computer science from the Indian Institute of Science, Bangalore (IN). He completed his Ph.D. in cryptography under the supervision of Prof. Jean-Sebastien Coron and Prof. David Galindo at the University of Luxembourg (LU) in 2015. Thereafter, he worked as a Research Associate in the Cryptography group at the University of Bristol (UK) under the supervision of Prof. Nigel Smart. Since January 2018, he is an Assistant Professor at the International Institute of Information Technology Bangalore (IN). He also has held the Infosys Foundation Career Development Chair Professorship between 2021 and 2024 at IIIT Bangalore. He has served as a member of the editorial board/PC of IACR Transactions on CHES, IACR Communications in Cryptology, CT-RSA, WAHC, CARDIS, AsianHOST, Indocrypt, ICISS, etc. He is a recipient of the DST INSPIRE faculty award from Govt. of India. His research is focused on the design, analysis and implementation of countermeasures against side-channel attacks, and homomorphic encryption schemes and their applications.

Student Talk 5: Pagoda: Roofline Characterization of Energy and Time for DNN Inference and Training on Edge Accelerators

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

Abstract

Edge accelerators such as Nvidia Jetsons are becoming an integral part of the computing continuum, and are often used for DNN inferencing and training workloads. Nvidia Jetson edge devices, having 2000+ CUDA cores within a 70W power envelope, also offer 1000s of power modes to customized CPU, GPU and memory frequencies. These have widely varying power and performance trade-offs that can be exploited for energy and power constrained field deployments. While data-driven methods to predict the power and latency of DNN workloads for edge devices exist, there is a lack of a methodical study on why edge accelerators and their power modes perform the way they do. We develop a time roofline and a novel energy roofline model for the Jetson Orin AGX for diverse power modes, and couple it with an analytical model of the compute (FLOP) and memory access (bytes) for DNN inference workloads to analyze them from first principles. These reveal unique, sometimes counter-intuitive, insights into the power and performance behavior of DNN workloads on edge accelerators, e.g., the default power mode MAXN is not the most energy efficient and time efficiency implies energy efficiency for all power modes. Finally, we apply these methods to modify the power mode (and hence the roofline) of the edge device to optimize the latency and energy usage for DNN inference. Our experiments show energy benefits of up to 15

Student Talk 6: Database Index Advisors on Quantum Platforms

Speaker: Manish Kesarwani, Department of Computer Science and Automation.

Abstract

Relational Database Management Systems (RDBMS) are the backbone of modern data management, enabling efficient storage, retrieval, and processing of structured data. To speed up data retrieval, databases rely on indexes—specialized data structures that help locate information quickly. Choosing the right indexes can significantly improve performance, but it is not a straightforward task. The challenge lies in balancing query speed, storage costs, and maintenance overhead, making index selection a complex combinatorial problem. Index Advisor tools settle for sub-optimal index configurations based on greedy heuristics, owing to the computational hardness of index selection. We investigate how this limitation can be addressed by leveraging the computing power offered by quantum platforms. In this talk, we will present a hybrid Quantum-Classical Index Advisor that judiciously incorporates gate-based quantum computing within a classical index selection wrapper.

Student Talk 7: Bi-directional Engineering for Hidden Query Extraction

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

Abstract

Query reverse engineering (QRE) aims to synthesize a SQL query to connect a given database and result instance. A recent variation of QRE is where an additional input, an opaque executable containing a ground-truth query, is provided, and the goal is to non-invasively extract this specific query through only input-output examples. This variant, called Hidden Query Extraction (HQE), has a spectrum of industrial use-cases including query recovery, database security, and vendor migration. The reverse engineering (RE) tools developed for HQE, which are based on database mutation and generation techniques, can only extract flat SPJGAOL queries with key-based equi-joins and conjunctive arithmetic filter predicates, making them limited wrt both query structure and query operators. In this talk, we present a HQE solution that elevates the extraction scope to realistic complex queries, such as those found in the TPC-H benchmark. A two-pronged approach is taken – on the one hand, the existing RE scope is substantially extended to incorporate union connectors, algebraic filter predicates, and disjunctions for both values and predicates. On the flip side, the predictive power of LLMs is leveraged to convert business descriptions of the opaque application into extraction guidance, representing “forward engineering" (FE). The FE module recognizes common query constructs, such as nesting of sub-queries, aggregate function coefficients, and custom non-relational functions. In essence, FE establishes the broad query contours, while RE fleshes out the fine-grained details. We have evaluated our prototype on eTPCH, a query suite comprising the complete TPCH benchmark extended with queries featuring unions, diverse join types, and sub-queries. The experimental results demonstrate that the bi-directional engineering approach correctly and efficiently extracts these complex queries, representing a significant step forward in HQE coverage.

Student Talk 8: A High-Performance Curve25519 and Curve448 Unified Elliptic Curve Cryptography Accelerator

Speaker: Aniket Banerjee, Department of Electronic Systems Engineering.

Abstract

In modern critical infrastructure such as power grids, it is crucial to ensure the security of data communications between network-connected devices while following strict latency criteria. This necessitates the use of cryptographic hardware accelerators. We propose a high-performance unified elliptic curve cryptography accelerator supporting NIST standard Montgomery curves Curve25519 and Curve448 at 128-bit and 224-bit security levels, respectively. Our accelerator implements extensive parallel processing of Karatsuba-style large-integer multiplications, restructures arithmetic operations in the Montgomery Ladder and exploits special mathematical properties of the underlying pseudo-Mersenne and Solinas prime fields for optimized performance. Our design ensures efficient resource sharing across both curve computations and also incorporates several standard side-channel countermeasures. Our ASIC implementation achieves record performance and energy of $10.38\mu s$ / $54.01\mu s$ and $0.72\mu J/3.73\mu J$, respectively, for Curve25519 / Curve448, which is significantly better than state-of-the-art.

2.1.5 Session 3: Visual Analytics, Artificial Intelligence and Machine Learning

Session Chair: Anirban Chakraborty (CDS)
Faculty Organizer: Ravi Prakash (RBCCPS)
Student Organizer: Shreeya (CSA), Avish (EE), Kartikeya (ECE), Pranav Tiwari (CPS)
Location: MP 20, ECE Department.

Invited Talk 1: From Known to Unknown: Some Novel Aspects for Open Domain Generalization and Generalized Category Discovery

Speaker: Biplab Banerjee, Associate Professor, IIT Bombay.

Abstract
Domain Generalization (DG) aims to train a classifier using data from multiple, non-overlapping distributions such that it performs well on previously unseen domains during inference. Recently, prompt learning with vision-language foundation models like CLIP has gained traction for DG. However, existing approaches often struggle under diverse domain shifts and fail to effectively handle open-set samples. Rather than treating all open-set instances as uniformly unknown, a more insightful strategy is to semantically cluster them for deeper analysis.

In this talk, I will explore prompt-based methods for open-set domain generalization in both fully supervised and low-shot settings. I will also present how the concept of class discovery can be extended to the DG scenario for improved understanding and generalization.

Bio
Biplab Banerjee is an Associate Professor in Machine Learning and Visual Computing at IIT Bombay's Centre of Studies in Resources Engineering (CSRE) and the Center of Machine Intelligence & Data Science (MInDS). He joined IIT Bombay in 2018 and has been in his current role since April 2022. He also serves as an AI engineering advisor to AWL Inc., Japan. Previously, he was an Assistant Professor at IIT Roorkee (2016–2018) and held postdoctoral positions at the Istituto Italiano di Tecnologia, Italy, and Normandy University, France. He has been a visiting professor at TU Munich, Ghent University, and Kyungpook National University.

Dr. Banerjee earned his Ph.D. in Machine Learning from IIT Bombay in 2015, receiving the "Excellence in Thesis" award, after completing his B.Tech. and M.Tech. in Computer Science from WBUT and Jadavpur University.

At IIT Bombay, he leads the Deep Learning in Remote Sensing & Computer Vision group, with over 40 members, working on deep learning for image/video analysis, including low-supervision learning, vision-language models, domain adaptation, lifelong learning, and multimodal vision tasks. He received the Young Investigator Award from IIT Bombay in 2021 and is a Senior Member of IEEE.

Invited Talk 2: Hierarchical Feature Informative Prototype with Double Angular Margin Contrast for Few-Shot Class Incremental Learning

Speaker: Sukhendu Das, Professor, IIT Madras.

Abstract

Deep learning methods provide state-of-the-art performances in many tasks, as extremely powerful approximators. However, despite their impressive advances, the conventional paradigm for training demands large amounts of data and static datasets that need to align better with the dynamic nature of real-world environments, where new classes can emerge over time, and data provided may be scarce. Humans/animals have this extraordinary ability to learn continually from past experiences, apply this freshly discovered knowledge and skills to new situations, and use them as the foundation for informed learning. Our desire is to mimic the same with machine intelligence in low data regimes. Class incremental learning (CIL) has gained significant interest due to its ability to handle ample and distinct datasets arriving in successive sessions. Moreover, the assumption of continuous access to vast amounts of data is often impractical.

Few-shot class incremental learning (FSCIL) addresses this challenge by enabling models to learn from a limited number of examples and to accommodate new classes without forgetting previously acquired knowledge. Due to the unavailability of old training samples at the incremental stages, FSCIL often suffers from catastrophic forgetting and overfitting problem to new, sparse data. We propose our innovative approach, a Hierarchical Feature Informative Prototype with Double Angular Margin Contrast, which extracts multiple feature vectors with rich semantic content from each image at various scales and abstraction levels. This is unlike the common practice of extracting a single feature vector per image, fostering superior generalization for new classes, especially with limited data samples. Double Angular margin-based contrastive learning framework ensures compact intra-class embeddings and enhances inter-class separability, preserving space for novel classes and enhancing diverse learning of feature embeddings. We utilize Contrastive Prototype Learning (CPL), in which the anchor is taken as a class prototype, encouraging the model to learn features representative of the class, making the model more robust. Instead of relying on straightforward feature averaging to create prototypes, we employ a non-parametric self-attention mechanism to obtain weighted prototypes. This approach gives prominence to the most informative and representative samples, resulting in a stronger and more reliable setup. We use Layerwise Feature Augmentation to enhance specific

types of features at each level, leading to a richer and more diverse feature representation. For inference, we use set-based distance metrics to boost confidence. The performance of the proposed work is verified using the benchmark datasets CIFAR100, CUB200, and miniImageNet, becoming a new state-of-the-art

Bio

Dr. Sukhendu Das is currently employed as a Professor in the Deptt. Of Computer Science and Engg., IIT Madras, Chennai, India. He completed his B.Tech degree from IIT Kharagpur in the Deptt. Of Electrical Engg. in 1985 and M.Tech Degree in the area of Computer Technology from IIT Delhi in 1987. He then obtained his Ph.D degree from IIT Kharagpur in 1993. His current areas of research interests are: Visual Perception, Computer Vision: Digital Image Processing and Pattern Recognition, Computer Graphics, Machine Learning and

Computational Brain modeling.

Dr. Sukhendu Das has been a faculty of the Deptt. of CS & E, IIT Madras, INDIA since 1989, and awarded the CSR changemaker award by IIT Madras in 2023. He has guided about 125 students. He has published more than 200 technical papers (with 2200 citations – src: google scholar) in international and national journals and conferences. He has completed about 25 Sponsored projects and consultancy assignments. He is a senior member of IEEE, and has received six (6) best papers and a best design contest award. Three of his MS students have recently received 5 best MS thesis awards in the Deptt. Of CS & E, IIT Madras.

Student Talk 1: A Spatiotemporal Neural Network Framework for Indian Summer Monsoon Onset Prediction

Speaker: Akanksha Rajak, Department of Computational and Data Sciences.

Abstract

This work introduces a neural network framework designed to predict the onset of the Indian Summer Monsoon with greater accuracy and longer lead times than traditional methods. The Indian Summer Monsoon delivers over 75% of the country's annual rainfall, making precise prediction of its commencement critical for agricultural planning, water resource management, and economic stability. Our approach utilizes spatiotemporal neural networks to analyze global atmospheric and oceanic variables, enabling predictions up to 60 days in advance with significantly reduced error margins compared to current operational forecasts. Through systematic evaluation of various climate indicators, we identify key predictive variables and their optimal temporal windows for monsoon onset forecasting. Our models demonstrate substantial improvements in prediction accuracy while maintaining longer forecast horizons, offering valuable lead time for stakeholders across multiple sectors. This work contributes to the growing field of climate prediction using deep learning techniques and has direct applications for enhancing resilience to climate variability in monsoon-dependent regions.

Student Talk 2: Affordance Aware Text Guided Object Placement in Images

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

Abstract

For a given scene, humans can easily reason for the locations and pose to place objects. Designing a computational model to reason about these affordances poses a significant challenge, mirroring the intuitive reasoning abilities of humans. This work tackles the problem of realistic human insertion in a given background scene termed as Semantic Human Placement. This task is extremely challenging given the diverse backgrounds, scale, and pose of the generated person and, finally, the identity preservation of the person. We divide the problem into the following two stages i) learning semantic masks using text guidance for localizing regions in the image to place humans. ii) subject-conditioned inpainting to place a given subject adhering to the scene affordance within the semantic masks. For learning semantic masks, we leverage rich object-scene priors learned from the text-to-image generative models and optimize a novel parameterization of the semantic mask, eliminating the need for large-scale training. To the best of our knowledge, we are the first ones to provide an effective solution for realistic human placements in diverse real-world scenes. The proposed method can generate highly realistic scene compositions while preserving the background and subject identity.

Further, we present results for several downstream tasks - scene hallucination from a single or multiple generated persons and text-based attribute editing. With extensive comparisons against strong baselines, we show the superiority of our method in realistic human placement.

Student Talk 3: Out-of-Distribution Detection in Long-Tailed data

Speaker: Archaism Satvikam Anudeep, Department of Computational and Data Sciences.

Abstract
The deployment of deep neural networks in safety-critical domains like healthcare remains limited due to their vulnerability to out-of-distribution (OOD) data. OOD data refers to inputs that differ significantly from the training distribution, and can lead to highly con- fident yet incorrect predictions. Existing OOD detection methods are predominantly developed and evaluated on balanced datasets that do not reflect real-world data distributions. As a result, standard OOD de- tection techniques struggle in the presence of imbalances inherent in real- world, long-tailed data. This issue is particularly pronounced in medical datasets, which exhibit distinct characteristics that make direct adap- tation of these methods non-trivial. To address these gaps, we propose Auxiliary Dataset-free Dual-Force ENforced Out-of-Distribution Detec- tion (ADD-FEND). Our method jointly applies a margin-based contrastive loss to enforce compact class clusters while introducing a latent space perturbation to expand the feature representation of minority classes. Experimental results performed on public medical datasets demonstrate that our method improves the reliability of OOD detection, leading to robust deployment of deep models

2.1.6 Coffee break

Invited Talk 2: Agent Engineering is all you need

Speaker: Rajesh Kumar S A , Phronetic AI.

Abstract
2025 is the year of AI agents. It is the year where AI agents have graduated from being assistants to workers. This has created a new type of engineering called Agent Engineering. This talk will give a brief idea of what is the role of an Agent Engineer. Further, we will mention about the new challenges and research areas that have opened up due to autonomous AI agents.

Bio
Currently, I am CEO of Phronetic AI, the AI Business Unit of Infibeam Avenues Group. Phronetic AI is a full-stack AI company specializing in multimodal AI agents, video generation, and video LLMs for enterprises. Over my 18-year career—spanning Yahoo! R& D, InMobi, and Meesho—I have built companies, invested in startups, and led exceptional machine learning teams. At Meesho, I served as Director of Machine Learning, heading a team of 30 ML scientists focused on computer vision and natural language processing. Previously, I co-founded and served as CTO at Streamoid Inc., where we developed pioneering deep learning models specialized in Fashion AI.

Student Talk 4: Zero Shot Audio to Audio Emotion Transfer with Speaker Disentanglement

Speaker: Soumya Dutta, Department Of Electrical Engineering.

Abstract
The problem of audio-to-audio (A2A) style transfer involves replacing the style features of the source audio with those from the target audio while preserving the content related attributes of the source audio. In this talk, we propose an approach, termed as Zero-shot Emotion Style Transfer (ZEST), that allows the transfer of emotional content present in the given source audio with the one embedded in the target audio while retaining the speaker and speech content from the source. The proposed system builds upon decomposing speech into semantic tokens, speaker representations and emotion embeddings. Using these factors, we propose a framework to reconstruct the pitch contour of the given speech signal and train a decoder that reconstructs the speech signal. The model is trained using a self-supervision based reconstruction loss. During conversion, the emotion embedding is alone derived from the target audio, while rest of the factors are derived from the source audio. In our experiments, we show that, even without using parallel training data or labels from the source or target audio, we illustrate zero shot emotion transfer capabilities of the proposed ZEST model using objective and subjective quality evaluations.

Student Talk 5: Benchmarking and Confidence Evaluation of LALMs For Temporal Reasoning

Speaker: Debarpan Bhattacharya, Department Of Electrical Engineering.

Abstract
The popular success of text-based large language models (LLM) has streamlined the attention of the multimodal community to combine other modalities like vision and audio along with text to achieve similar multimodal capabilities. In this quest, large audio language models (LALMs) have to be evaluated on reasoning related tasks which are different from traditional classification or generation tasks. Towards this goal, we propose a novel dataset called temporal reasoning evaluation of audio (TREA). We benchmark open-source LALMs and observe that they are consistently behind human capabilities on the tasks in the TREA dataset. While evaluating LALMs, we also propose an uncertainty metric, which computes the invariance of the model to semantically identical perturbations of the input. Our analysis shows that the accuracy and uncertainty metrics are not necessarily correlated and thus, points to a need for wholesome evaluation of LALMs for high-stakes applications.

Student Talk 6: A multimodal approach towards building Indian speech recognition systems with VAANI

Speaker: Purvi Agrawal, Department Of Electrical Engineering.

Abstract
VAANI: An IISc-ARTPARK-Google collaborative project, aims to capture the diversity of India's spoken languages for an inclusive Digital India & language AI technologies. With VAANI dataset comprising of images, and audios as the human speech captions corresponding to every image, our efforts are towards building automatic speech recognition (ASR) and multimodal systems that capture the cultural diversity of India. Out of 16000 hrs of total audio data and 1.3L total images

captured, around 790 hrs of audio data is available as transcribed (audio content labeling done by humans in form of text). In our initial ML efforts, we aim to build baseline ASR model with labeled data, metrics towards verification of quality of data, correlation between audio and image data, effective strategy to use untranscribed data for model building.

2.1.7 Session 4: Networking, IoT and Scientific Computing

Session Chair: Chandramani Singh (DESE)
Faculty Organizer: Rahul Singh (ECE)
Student Organizer: Rohit Kumar Shukla (ECE), Aditya Sharma (ECE)
Location: IDR Seminar Hall (G22)

Invited Talk 1: Internet of nano-bio-machines (IoNB) networks: Molecular communication and target detection

Speaker: Abhishek Gupta , Associate Professor, IIT Kanpur.

Abstract

Molecular communication has emerged as a promising candidate to provide communication capability to nano-networks. This talk discuss modeling and analysis of a network of nano-machines. We will discuss a molecular ad hoc network (MolAN) consisting of multiple molecular communication links in a 3D medium and its performance in terms of bit detection probability, network throughput, mean signal strength, inter-symbol-interference and co-channel interference for degradable and non-degradable molecules. We will also discuss an application of target detection under various configurations.

Bio

Dr. Abhishek K. Gupta received his B.Tech.- M.Tech dual degree in Electrical Engineering from IIT Kanpur in 2010 and PhD degree in the Department of Electrical and Computer Engineering at the University of Texas at Austin in 2016. He is currently working as an associate professor in the Department of Electrical Engineering at Indian Institute of Technology Kanpur. He serves as an Associate Editor for IEEE Transactions on Wireless Communications. He was recipient of IEI young engineer award in 2021, Class of 1986 young faculty fellowship by IIT Kanpur in 2022, IEEE-WCL exemplary reviewer award in 2016, GE-FS leadership award in 2009 and IITK academic excellence award (2006-2009). He is author of the books, An introduction to stochastic geometry (Springer Morgan-Claypool, 2022), and Numerical methods using MATLAB (Springer Apress, 2014). 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).

Student Talk 1: TSN switch using P4

Speaker: Joydeep Pal, Department of Electronic Systems Engineering.

Abstract
Programmable networking have enabled novel applications by enabling the in-network computing paradigm. In our work, a design of an IEEE802.1 TSN switch is explored on P4 targets using this paradigm to enable deterministic networking.

Student Talk 2: Dynamic Content Caching and Delivery using Restless Multi-armed Bandits

Speaker: Ankita Koley, Department of Electronic Systems Engineering.

Abstract
We consider a dynamic content caching problem wherein the contents get updated at a central server, and local copies of a subset of contents are cached at a local cache associated with a Base station (BS). When a content request arrives, based on the content's availability and age in the local cache, the BS decides whether to fetch a fresh version from the central server or serve the cached version from the local cache. Fetching a content incurs a fixed fetching cost, and serving the cached version incurs an ageing cost proportional to the age-of-version (AoV) of the content. We formulate an optimal content fetching and caching problem to minimize the average cost subject to cache capacity constraints. We frame it as a continuous time restless multi-armed bandit process (RMAB), where each arm represents a content. We prove the indexability of the single content problem and provide a Whittle index based solution to the joint problem. We subsequently allow a "wait" option for the BS whereby it can also wait for additional requests before fetching and serving a fresh content. The "wait" option introduces queue lengths to the system's state. It also substantially changes the state dynamics, the analysis and the caching policy. We again derive a Whittle index based policy. We compare the performance of the proposed policies to recent works and also show that the proposed policies are "almost" optimal via simulations.

Student Talk 3: ML-based IDS for Smart-grid Applications

Speaker: Kishan Baranwal, Department of Electronic Systems Engineering.

Abstract
IT sector has historically mitigated cyberattacks through iterative threat analysis and well-established rule-based defenses. However, Operational Technology (OT) networks, for example power grid do not have the option of evolutionary, trial-and-error security measures due to critical time sensitive nature of the service they control. Further, they do not provide any understanding of the domain specific application context. Machine Learning transcends traditional rule-based firewall by uncovering hidden patterns and complex dependencies, driving innovative solutions for grid resilience. In the last two decades adversaries have increasingly weaponized protocol-compliant attacks (for example, CrashOveride malware) that masquerade as legitimate traffic within critical infrastructure protocols, for example IEC 61850. These attacks exploit trusted communication frameworks, such as the Manufacturing Message Specification (MMS), to compromise Intelligent Electronic Devices (IEDs) and destabilize grid operations. MMS, a cornerstone of communication in a smart grid, is particularly vulnerable due to its ability to remotely execute control commands on IEDs. Recent research efforts to secure smart grids have focused on TCPIP networking related issues. However, they overlook the unique vulnerabilities inherent to MMS-specific message structures. We present MMS protocol–specific cybersecurity solutions that leverage key MMS features to detect real threats, including Industroyer-like reconnaissance and control command modification attacks.

2.1.8 Coffee break

Invited Talk 2: A Stable Parametric Model Order Reduction Algorithm

Speaker: Kapil Ahuja, Professor, IIT Indore.

Abstract

We study stability of a interpolatory model order reduction (MOR) algorithm for first-order and second-order parametric linear dynamical systems, with respect to inexact linear solves. This analysis is easily extendible to other MOR algorithms for such systems. Besides deriving the two conditions for stability, and subsequent experimentation, our most novel contribution here is achieving a backward stable algorithm.

To achieve this, we first categorize the involved orthogonality conditions into different classes. Second, we adapt the underlying linear solver (here Conjugate Gradient or CG) to satisfy these orthogonalities. Finally, and third, we implement Recycling CG in such a way that these orthogonalities can be achieved with no code changes to the linear solver (for a end user or a model reducer here) as well as cheaply (extra orthogonality cost offset by savings because of recycling).

Bio

After completing a double Master's plus a Ph.D. in Computer Science and Mathematics from Virginia Tech (USA), Prof. Kapil Ahuja did a postdoc from the Max Planck Institute in Magdeburg (Germany). Subsequently, he worked as an Assistant Professor and an Associate Professor in Computer Science and Engineering at Indian Institute of Technology Indore (IIT Indore), where he is currently holding a Full Professor position. Recently, he has also been a Visiting Professor at University of Texas at Austin (USA), IMT Atlantique (France), TU Dresden (Germany), Sandia National Labs (USA), and TU Braunschweig (Germany).

Student Talk 4: Introduction to Ollivier's Ricci curvature and its application in Community Detection

Speaker: Jayanta Pari, Department of Computational and Data Sciences.

Abstract

Many complex networks in the real world have community structures – groups of well-connected nodes with important functional roles. By considering networks as geometric objects and communities in a network as a geometric decomposition, we apply curvature and discrete Ricci flow, which have been used to decompose smooth manifolds with astonishing successes in mathematics, to break down communities in networks.

Student Talk 5: Unlocking the potential of quantum modelling of materials in the exascale era

Speaker: Kartick Ramakrishnan, Department of Computational and Data Sciences.

Abstract

Gaining ab-initio insights into complex materials problems involving larger length-scales and longer time-scales demand enormous computational resources owing to the stringent accuracy requirements of density functional theory (DFT) calculations compounded with cubic scaling complexity of DFT with number of atoms. To address this, we introduce a local real-space formulation and an efficient finite-element-based implementation methodology to incorporate projector augmented wave (PAW) formalism in the DFT-FE framework on hybrid CPU-GPU architectures. We develop efficient HPC-centric implementation methodologies combining the ideas of low-rank perturbation of identity and mixed precision arithmetic in conjunction with Chebyshev Filtered subspace iteration approaches to solve the underlying FE discretized PAW generalized eigenproblem. We show that our framework (PAW-FE) facilitates a substantial reduction in the degrees of freedom in comparison to norm-conserving pseudopotentials for achieving the required chemical accuracy while accommodating generic boundary conditions, thereby enabling faster and accurate large-scale DFT simulations than possible today. Finally, we demonstrate the usefulness of PAW-FE on large-scale problems involving tens of thousands of electrons that cannot be effectively tackled using state-of-the-art plane-wave codes in the area of catalysis and energy storage.

Student Talk 6: Accuracy and performance evaluation of scalable asynchronous compressible flow solver

Speaker: Aswin Kumar A., Department of Computational and Data Sciences.

Abstract

To address communication bottlenecks in large-scale time-dependent flow solvers, an asynchronous computing approach was developed. This method reduces communication and synchronization delays using asynchrony-tolerant (AT) schemes while maintaining high-order accuracy near processing element boundaries. Two asynchronous algorithms were explored: one that skips communication over a few time steps and another that allows communication without strict synchronization. These methods were integrated into the high-order compressible flow solver COMPSQUARE, designed for complex geometries in a multi-block framework. The performance and scalability of the algorithms were evaluated using three test cases: two-dimensional isentropic vortex advection, the Taylor-Green vortex, and flow around a NACA0012 airfoil. Results demonstrate that AT schemes can enhance scalability in established CFD solvers, offering a practical solution for extreme-scale computing in the exascale era.

2.1.9 Session 5: Microelectronics, RF and Photonics

Session Chair: Debdeep Sarkar (ECE), Arup Polley (DESE)
Faculty Organizer: Debayan Das(DESE), Chetan Singh Thakur(DESE)
Student Organizer: Chandrika (ECE), Gnanadatha (ECE), Sai Srinivas (ECE)
Location: Golden Jubilee Hall, ECE Department

Invited Talk 1: Radar Systems-on-Chips with Integrated mm-wave, Analog and Digital Processing Hardware and Software for Automotive Applications

Speaker: Karthik Subburaj, Texas Instruments .

Abstract
Radar is a key technology in automotive driver assistance and in-cabin sensing. This talk focusses on commercial mm-wave radar sensor system-on-chip architectures for such automotive applications. It starts with an introduction of FMCW radar signal chain, including its chirp synthesizers, transmitters and receivers – with their respective mm-wave, analog and digital baseband subsystems, antenna interfaces, and functional safety aspects. It then presents radar digital signal chain and processing architectures, including their configurable accelerators for FFTs, CFARs, data compression, MIMO realizations, and cybersecurity, and their programmable MCUs and DSPs for implementing customer - specific radar software. It finally presents various levels of chip-integration: with 77GHz front-end and digital processing integrated on a single chip, or on separate chips with a high-speed serial link connection, or with partial processing on both chips with an Ethernet connection, and realization of wide antenna aperture through cascading of chips.

Bio
Karthik Subburaj (M'11) was born in Tamil Nadu, India in 1980 and received B.E. degree in Electronics and Communication Engineering from College of Engineering, Guindy, Anna University in 2001. He has been with Texas Instruments, India since July 2001 and has worked on digital signal processing, PLLs, timing recovery algorithms and high speed digital design for PHY layers of GNSS receivers, FM radio transceivers and 5 Gbps serial interfaces. He is presently a systems engineer focusing on RF systems and algorithms for radar. He has authored three conference papers and holds four U.S. patents, with three more under review.

Student Talk 1: Resonant Infrared Up-Conversion using Hybrid Metasurface Supporting Quasi-BIC Resonance

Speaker: Urmila Bag, Department of Electrical Communication Engineering.

Abstract
We experimentally demonstrate resonantly enhanced sum frequency generation (SFG) from a hybrid structure consisting of multi-layer gallium selenide (GaSe) layer integrated with a silicon resonant metasurface. GaSe is a group III-VI semiconductor, with its ε-polytype exhibiting a layer-number-independent, non-centrosymmetric strong nonlinear optical response. However, the overall nonlinear optical response is still limited by the reduced interaction length. The synergistic

integration of highly nonlinear layered material with high quality (Q) resonant metasurfaces offers a promising approach for enhancing nonlinear processes efficiently. Resonant metasurfaces are 1D or 2D arrays of sub-wavelength metal or dielectric structures, enable precise control over the amplitude, phase, and polarization of incident light through frequency-selective resonances. The metasurface is designed to support a quasi-bound-state-in-continuum (BIC) resonance due to magnetic dipole mode with a high Q factor of 2037 at 3.33 μm in the mid-IR wavelength range under normal excitation of a Y-polarized incident beam by introducing subtle asymmetry in a square unit-cell. The experimentally measured linear transmission profile of the fabricated metasurface, obtained via FTIR spectroscopy, shows good agreement with simulations, yielding a Q-factor of 288 at 3.338 μm. Furthermore, we present a comparative study to optimize the GaSe layer thickness for enhancing the localized SFG field within the high-index a-Si metasurface, thereby maximizing the SFG signal from the hybrid structure. This hybrid integration enables the realization of second-order SFG processes on a centrosymmetric silicon platform, which would otherwise be inaccessible due to its intrinsic crystallographic properties. Leveraging both the high Q-factor of the quasi-BIC resonance and the large interaction volume from multilayer GaSe, we experimentally demonstrate SFG-based frequency up-conversion from 3.33μm to 793 nm, achieving a maximum normalized conversion efficiency of $3.06310^{-5}/W$. To the best of our knowledge, this work represents the first experimental demonstration of mid-infrared to near-infrared frequency up-conversion using a silicon metasurface in any configuration.

Student Talk 2: Design & Synthesis of Scalable Analog Computing Systems

Speaker: Ankita Nandi, Department of Electronic Systems Engineering.

Abstract

This thesis investigates the potential of low-power analog computing applications while simultaneously addressing key design challenges such as non-modularity, limited robustness, and lack of automated synthesis methodologies. Unlike traditional analog computing approaches that are restricted by scalability, this work introduces a systematic framework for the design of scalable Standard Analog Cells (S-ACs). These S-ACs serve as fundamental building blocks, representing various mathematical functions essential across different computing domains. These pre-characterizable and modular S-ACs bring the advantages of digital standard cells—such as reusability and automation—into the analog domain. Furthermore, a S-AC-based Field Programmable Analog Array (FPAA) was designed and fabricated to validate the feasibility of this approach in silicon. This FPAA enables programmable implementation of a wide range of algorithms, demonstrating the practical applicability of the proposed methodology. The effectiveness of the proposed S-AC framework is validated across three distinct computing. In the first domain, a communication decoding algorithm implementing XOR-SAT solvers was proposed using a software-hardware co-design approach utilizing S-AC. A Low-Density Parity Check (LDPC) decoder is designed, and a mixed-mode CMOS design is proposed to support the algorithm. The hardware implementation is demonstrated on a commercial FPGA and the in-house FPAA working in tandem for successful mixed-mode computation. Next, the framework is extended to probabilistic computing, a domain that inherently benefits from the analog representation of probabilities. A novel class of analog soft-logic gates is introduced, enabling probabilistic logic operations with potential applications in error-correction decoding, bio-inspired computing, and image processing. Conventional algorithms have been re-designed in some of these application areas to demonstrate the effectiveness of the proposed soft-logic gates.

Finally, an application in machine learning and various S-AC-based designs for mathematical functions is also presented, showcasing the natural advantages of analog computation in this field. Beyond these applications, the modularity and scalability of the proposed S-AC designs make them particularly suitable for automation and high-level synthesis. Seizing this opportunity, this thesis also proposes an automated high-level synthesis framework using factor graphs as the foundational descriptors to specify the interdependency between different analog computational primitives. This significantly reduces the time to design analog circuits and bridges the gap between analog and digital ASIC methodologies. Thus, to summarize, this thesis introduces a novel analog computing paradigm that is robust, synthesizable, and scalable across applications and operating conditions. By addressing fundamental limitations in traditional analog design, this work lays the foundation for the broader adoption of analog computing, paving the way for future advancements in energy-efficient, high-performance computation across domains such as signal processing, scientific computing, and machine learning.

Student Talk 3: Nested Ring Resonator based Device for High-Sensitivity Photonic Sensing with Multiple Fano Interferences

Speaker: Pragya Mishra, Department of Electrical Communication Engineering.

Abstract

We propose and analyze a Nested Ring Resonator (NRR) based device capable of generating multiple Fano resonances, making it a highly suitable platform for optical sensing applications. The proposed device exhibits multiple Fano resonances response with high extinction ratio demonstrating its suitability for multi-analyte sensing. The device achieves high sensitivity, making it responsive to refractive index variations, a critical requirement for biosensing applications. Additionally, the extracted Fano parameter (q), through Fano line-shape fitting, shows significant variation across different resonances, enabling tunability and broad applicability in photonic signal processing and optical filtering. With its capability to support multiple Fano resonances, high Q-factor, and strong extinction ratio, the proposed device serves as a promising candidate for high-contrast biosensing, lab-on-chip integration, and general-purpose photonic applications.

2.1.10 Coffee break

Invited Talk 2: From Light to Images: The Role of Image Processing in Sensors and Future advancements in the AI era

Speaker: Manjit Hota, Samsung Electronics.

Abstract

The journey from light to images relies heavily on sensors as a crucial component in the complete image processing chain. This process involves sensors capturing light and converting it into digital images, while addressing circuit-related issues, preparing data for application processors (APs), and enhancing image quality through techniques such as noise reduction, color correction, and resolution improvement. Additionally, the impact of AI on image processing is explored, particularly in enabling real-time analysis, object recognition, and scene understanding, alongside the challenges these innovations present from a sensor design perspective. The discussion will conclude with a look at future advancements in sensor technology and AI-driven imaging .

Bio

Manjit Hota serves as Director at Samsung Semiconductor India Research, heading the Algorithm and Image Signal Processing (ISP) pipeline team for Image Sensors. He brings nearly two decades of experience in sensor image processing and video compression to this role. At Samsung Semiconductor, Manjit focuses on advancing image sensor technology. He holds a Master's degree from IIITB and has contributed six US patents in his field of expertise.

Invited Talk 3: AI ML Air interface for 6G

Speaker: Rupali Gupta, Nokia.

Abstract

The talk "AI ML Air interface for 6G" will focus on the current progress of the topic in 3GPP mainly focus on the beam management aspects of the AI ML air interface. Also the presentation will give an idea on how this topic could proceed towards 6G. Some simulations and results will also be discussed further in this area. Other areas in the AI ML air interface will also be briefly touched, for eg: UE power control, CSI compression, UE positioning, MIMO precoding etc.

Bio

Rupali Gupta received the B.Tech. degree in electronics and communication engineering from the University Institute of Engineering and Technology, Chandigarh, India, in 2017. She received the M.Tech. research degree from the Department of Electrical Communication Engineering, Indian Institute of Science, Bengaluru, India, in 2020. From 2020 to 2022, she was at the Samsung Semiconductor Research India, Bengaluru, as a Senior Engineer. She is currently with NOKIA working as a Senior Research Specialist.

Student Talk 4: Polarization-based Optical System for Characterizing Myocardial Tissues

Speaker: Twinkle, Department of Electronic Systems Engineering.

Abstract

This work shows the development of an optical system that uses polarization-based spectroscopy to perform real-time and precise characterization of healthy and fibrotic myocardial tissues, facilitating faster and accurate diagnosis. This optical polarimetry approach can provide cardiothoracic surgeons with additional information for making better informed assessments and can help ensure precise tissue removal, minimizing the risks of incomplete resection or excessive tissue damage during surgery. Preliminary results appear promising based on the experiments conducted on left ventricle (LV) and right ventricle (RV) tissue samples from three groups: N=10 healthy controls, N=10 patients with rheumatic heart disease (RHD), and N=10 patients with myxomatous valve disease (MVD). The developed technology envisages moving from ex vivo to in vivo once the performance of the optical system is validated on a large cohort of tissue samples and conditioned to the ethical

approval for in vivo testing.

Student Talk 5: A Decoder-less Transformer with Likelihood Attention for semantic segmentation of Event Camera Data

Speaker: Lakshmi Annamalai, Department of Electronic Systems Engineering.

Abstract

Road detection is a fundamental component of autonomous driving. Conventional Camera-based road segmentations are resource-intensive and slow. A biologically- inspired sensor known as event camera offers a promising solution with advantages such as low power consumption, data sparsity, high temporal resolution etc. However, exist- ing event camera-based segmentation approaches implement computationally heavy synchronous frame-based networks with encoder-decoder architectures. To address this, we introduce EventMASK, a decoder-less transformer-based architecture with reduced computational load and latency. EventMASK operates directly on raw events, bypassing dense processing and event-to- frame conversion. However, processing raw events is challenging due to its limited contextual knowledge. To address this, we introduce an innovative likelihood-based self-attention module. In summary, EventMASK is well-suited for time-critical and resource-constrained robotic platforms.

2.2 Plenary and Faculty Talks

Opening Address: Rajesh Sundaresan (Dean, EECS)
Location: Faculty Hall, Main Building

2.2.1 Session 1: Plenary and Faculty Talks

Plenary Talk 1: Design techniques for ultra-low-distortion active filters

Speaker: Nagendra Krishnapura, Professor, IIT Madras.

Abstract
Histogram test and THD measurement of high-resolution(18 to 20 bits) ADCs require a sinusoidal source with THD -140dBc. Bench-top generators can be used, but they are bulky. The alternatives are to use a band-pass filter to clean up a medium-accuracy(-80dBc) sinusoid from a DAC or to use a sinusoidal oscillator. In either case, a very low distortion filter core is essential. This work investigates techniques for realizing ultra-low-distortion band-pass filters.

Active-RC filters have a very low distortion because nonlinearities can be suppressed using a high loop gain. The main sources of distortion in an active-RC bandpass filter are

- The nonlinearity of the output stage of the opamp used in the active filter coupled with the capacitance at the input of that stage; This is suppressed using a buffer between the first and the second stage of the opamp.
- distortion contributed by passive components(integrating capacitors) in the feedback loop that is not suppressed by the loop gain; This is mitigated using distortion cancellation.
- output conductance nonlinearity of the opamp; This is suppressed using a gain-boosted cascode output stage.

Using the principles above, low-distortion band-pass filters and sinusoidal oscillators are demonstrated in a 0.6 μm process. With a 5.6V supply, the 1kHz/10kHz band-pass filter prototype has 60dB HD2 attenuation and -143dBc/-142dBc THD for a 10Vppd output. The 1kHz/10kHz oscillator has -133dBc/-111dBc THD for a 10Vppd output.

Bio
Nagendra Krishnapura obtained his BTech from the Indian Institute of Technology, Madras, India, and his PhD from Columbia University, New York. He has worked as an analog design engineer at Celight, Multilink, and Vitesse semiconductor. He has taught analog circuit design courses at Columbia University as an adjunct faculty. He is currently a professor at the Indian Institute of Technology, Madras. His interests are analog and RF circuit design and analog signal processing.

Distinguished Faculty Talk 1: Collision Dynamics on Spherical Manifolds

Speaker: Debasish Ghose, Professor, CPS, IISc.

Abstract

Collisions between objects are often analyzed in 2D or 3D Euclidean spaces. The literature has plenty of results on this problem. However, when we talk about collisions on spherical manifolds, there is very little available. In this talk, we will discuss some new results that do not have any counterparts in the Euclidean space. We will use classical results from spherical geometry and touch upon some fundamental results in pure mathematics related to linear diophantine equations and Aryabhatta's method.

Bio

Debasish Ghose is a professor in the Robert Bosch Centre for Cyber Physical Systems and the Department of Aerospace Engineering at the Indian Institute of Science. In the past, he has held several visiting positions at many universities, such as the University of California at Los Angeles and the University of Exeter. His main areas of research interest are multi-agent and autonomous systems. He has been associated with many journals as an editorial board member and is at present with the IEEE Transactions on Control of Network Systems.

Faculty Talk 1: Cyber-Physical Systems and AI for Energy-efficient Built Environments

Speaker: Pandaraswamy Arjunan, CPS, IISc.

Abstract

The built environment encompasses human-made spaces that support various activities, from individual buildings to entire cities. Studies show that these environments account for over one-third of global energy consumption and 40% of CO2 emissions. Recent advancements in Cyber-Physical Systems and AI present new opportunities to enhance energy efficiency and occupant comfort. This talk will present challenges and opportunities of leveraging CPS and AI methods to decarbonize the built environment. Specifically, it will cover data-driven models for city-scale energy benchmarking, energy prediction, and the detection and diagnosis of anomalies and faults in critical building systems to reduce energy waste

Bio

Pandarasamy Arjunan is an Assistant Professor at the Robert Bosch Centre for Cyber-Physical Systems (RBCCPS), Indian Institute of Science, Bangalore, India. Previously, he was a postdoctoral scholar at the Berkeley Education Alliance for Research in Singapore (BEARS) Limited, a research center of the University of California, Berkeley, in Singapore. He earned his Ph.D. in Computer Science and Engineering from the Indraprastha Institute of Information Technology Delhi (IIIT-Delhi), India. During his Ph.D., he was awarded the prestigious IBM Ph.D. Fellowship for two years to support his research. He also worked as a visiting graduate researcher at the University of California, Los Angeles, USA. His research interests lie at the intersection of AI and

Cyber-Physical Systems, with applications in smart energy systems, smart buildings and cities, and smart agriculture. He leads the "AI and IoT Lab" at IISc.

Faculty Talk 2: Non-parametric sequential hypothesis testing and KL-inf

Speaker: Subhadha Agrawal, ECE, IISc.

Abstract: KL-inf, an infimum of KL-divergences between probability measures, appears naturally in the Information theoretic sample complexity lower bounds for non-parametric
delta-correct power one sequential hypothesis testing problems. In this talk, I will first introduce the classical point-vs-point hypothesis testing problem in the simple parametric setting. We will look at a lower bound on the number of samples generated before the test stops, as well as an "optimal" test for this setting. We will then generalise to non-parametric and composite vs composite hypothesis testing settings. I will conclude with some ongoing research and open directions.

Bio

Shubhada Agrawal is an Assistant Professor in the ECE Department at IISc, Bangalore. She completed her Ph.D. in Computer and Systems Science from TIFR, Mumbai, in 2022, where she received the Google PhD Fellowship in Machine Learning. She did her postdoctoral research at Georgia Tech. and Carnegie Mellon University, and received her undergraduate degree in Mathematics and Computing from IIT Delhi. Her research interests lie broadly in applied probability and sequential decision-making under uncertainty.

2.2.2 High Tea

2.2.3 Session 2: Faculty Talks

Faculty Talk 3: Artificial Intelligence for biomarker extraction in medical images

Speaker: Vaanathi Sundaresan, CDS, IISc.

Abstract: The talk will provide an overview of application of artificial intelligence (AI) for identifying imaging biomarkers for vascular abnormalities on various imaging images. The focus is specifically on development of AI models for identifying vascular signs on ultra-wide optical coherence tomography angiography images and brain MR images. Another key discussion point of the talk will be to improve the robustness of the deep learning tools by tackling one of the major practical challenges in the AI-based tool development: limited availability of manually labelled data for training in the low data regimes. The talk will focus on a technique used for synthetic lesion generation in medical imaging for efficient training of anomaly segmentation models. Future avenues of the research include for the detection of anomalies (abnormalities) using multiple diverse imaging modalities, and their classification and uncertainty quantification.

Bio

Dr. Vaanathi Sundaresan is an Assistant Professor at the Department of Computational and Data Sciences (CDS) , Indian Institute of Science (IISc), Bangalore. She is also the convenor of Biomedical image Analysis (BioMedIA) laboratory at CDS, IISc. Prior to this appointment, she was working as a postdoctoral research fellow at Athinoula A. Martinos Centre, Department of Radiology, Harvard Medical School and Massachusetts General Hospital. She received my doctorate degree at Oxford Centre for function MRI of Brain (FMRIB), Wellcome Centre for Integrative Neuroimaging (WIN), University of Oxford. Later, she continued her research at WIN as a Postdoctoral researcher, where she is currently affiliated as an Honorary Research Fellow. She has around 10 years of experience in open source tool development for medical imaging applications.

Faculty Talk 4: Trajectory Tracking using Sliding Mode Control with Obstacle Avoidance for Ground Robots

Speaker: Kiran Kumari, EE, IISc.

Abstract

This talk will overview the development of a sliding mode control based strategy for tracking a desired trajectory in the presence of static obstacles for a ground robot. A control barrier function will be presented for obstacle avoidance, utilizing a second-order barrier function. For collision avoidance, the robot is modeled by a double integrator model to optimize the control inputs, which are then mapped on a unicycle kinematic model using an approximation. The results of numerical simulations validate the performance of the proposed approach in the presence of disturbance for a desired trajectory. Experimental validation will be discussed for the proposed strategy using a four-wheeled differential drive robot and a camera-based localization system, both of which are developed in-house.

Bio

I am an Assistant Professor in the Department of Electrical Engineering at the Indian Institute of Science, Bengaluru, India.

Before joining IISc, I was a Post-Doctoral Fellow at the Control Engineering Department of Technical University Ilmenau, Germany.

3. Day 2: 4th April 2024 (Friday)

3.1 Research Cluster Talks

Location: ECE Building

3.1.1 Session 6: Artificial Intelligence and Machine Learning

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: ECE, GJH

Invited Talk 1: Teaching causal reasoning to language models

Speaker: Amit Sharma, Principal Researcher | Microsoft Research India

Abstract
Large language models (LLMs) have demonstrated remarkable accuracy in identifying cause-and-effect relationships across diverse scientific domains. However, their ability to reason over these relationships remains a challenge. To address this, I propose axiomatic training—a novel approach that enhances causal reasoning by teaching LLMs fundamental causal axioms one at a time, rather than fine-tuning them for specific tasks. By training on synthetic demonstrations of axioms such as transitivity and d-separation, I will show that models with fewer than 100 million parameters can surpass reasoning capabilities of significantly larger models such as Phi-3, Gemini Pro and GPT-4. Axiomatic training has practical applications as a tool for constructing verifiers for LLM-generated reasoning and for embedding inductive biases into LLM fine-tuning. Moreover, it provides insights into how models like GPT-4, trained solely on observational data, can exhibit advanced reasoning capabilities.

Bio

Amit Sharma is a Principal Researcher at Microsoft Research India, focusing on integrating causal inference with machine learning to enhance AI systems' generalization, explainability, and reasoning abilities. He developed the DiCE algorithm for counterfactual explanation and automated refutation methods for evaluating causal estimates, which have received over a thousand citations. The related open-source libraries, DiCE and DoWhy, are widely used across academia and industry, with millions of installations to date. Amit is also the co-founder of PyWhy, an open-source ecosystem advancing scalable causal ML tools. His work has received numerous awards, including the NASSCOM AI GameChangers award, Yahoo! Key Scientific Challenges award, and the Honda Young Engineer and Scientist award.

Student Talk 1: Knowledge Graph Guided Evaluation of Abstention Techniques

Speaker: Kinshuk Vasisht, Department of Computational and Data Sciences.

Abstract

To be deployed safely, language models must abstain from responding to inappropriate requests. Several prior studies test the safety promises of models based on their effectiveness in blocking malicious requests. Despite these efforts, there is a lack of evaluation of the underlying techniques that cause models to abstain. In this talk, I will focus on a systematic method to evaluate abstention techniques for language models, by leveraging knowledge graphs. I will cover details about SELECT, a benchmark derived from a set of benign concepts (e.g., "rivers") from a knowledge graph. The characteristics of SELECT overcome the limitations of existing benchmarks towards evaluating abstention techniques: focusing on benign concepts isolates the effect of safety training, and grounding these concepts in a knowledge graph allows us to study the generalization and specificity of abstention techniques. Using SELECT, we benchmark different abstention techniques over six open-weight and closed-source models. We find that the examined techniques indeed cause models to abstain with over 80% abstention rates. However, these techniques are not as effective for descendants of the target concepts, where abstention rates drop by 19%. We also characterize the generalization-specificity trade-offs for different techniques. Overall, no single technique is invariably better than others, and our findings can inform practitioners of the various trade-offs involved.

Student Talk 2: Adaptive Self-Distillation for Minimizing Client Drift in Heterogeneous Federated Learning

Speaker: Yashwanth M,Department of Computational and Data Sciences.

Abstract

Federated Learning (FL) is a machine learning paradigm that enables clients to jointly train a global model by aggregating the locally trained models without sharing any local training data. In practice, there can often be substantial heterogeneity (e.g., class imbalance) across the local data distributions observed by each of these clients. Under such non-iid label distributions across clients, FL suffers from the 'client-drift' problem where every client drifts to its own local optimum. This results

in slower convergence and poor performance of the aggregated model. To address this limitation, we propose a novel regularization technique based on adaptive self-distillation (ASD) for training models on the client side. Our regularization scheme adaptively adjusts to each client's training data based on the global model's prediction entropy and the client-data label distribution. We show in this paper that our proposed regularization (ASD) can be easily integrated atop existing, state-of-the-art FL algorithms, leading to a further boost in the performance of these off-the-shelf methods. We theoretically explain how incorporation of ASD regularizer leads to reduction in client-drift and empirically justify the generalization ability of the trained model. We demonstrate the efficacy of our approach through extensive experiments on multiple real-world benchmarks and show substantial gains in performance when the proposed regularizer is combined with popular FL methods.

Student Talk 3: Individual and Group Fairness in Bipartite Matching

Speaker: Atasi Panda, Department of Computer Science and Automation.

Abstract

Matching is a foundational concept in theoretical computer science, well-studied over several years. Maximum bipartite matching has diverse applications, including ad auctions, resource allocation, scheduling, school choice, and healthcare rationing. In practice, items often belong to different groups based on their attributes, necessitating fairness constraints to ensure equitable representation. These constraints are imposed using upper and lower bounds to prevent over-representation and under-representation respectively. However, enforcing only group fairness can lead to suboptimal outcomes for individuals. Moreover, deterministic matching algorithms inherently favor some individuals while assigning less preferred choices to others. This necessitates the introduction of individual fairness constraints. I will talk about probabilistic individual fairness constraints, first introduced in robust clustering. Specifically, I will present methods for generating a distribution over group-fair matchings such that, in any sampled matching, each item is assigned to one of its top choices with a probability within user-specified bounds, while maximizing the expected matching size. I will introduce efficient algorithms for computing an ex-ante probabilistic individually fair distribution over deterministic group-fair matchings.

Student Talk 4: An a-posteriori analysis of co-kurtosis PCA based dimensionality reduction using a neural ODE solver

Speaker: Tadikonda Shiva Sai, Department of Computational and Data Sciences.

Abstract

A low-dimensional representation of thermochemical scalars based on cokurtosis principal component analysis (CoK-PCA) has been shown to effectively capture stiff chemical dynamics in reacting flows relative to the widely used principal component analysis (PCA). The effectiveness of the reduced manifold was evaluated in a priori analyses using both linear and nonlinear reconstructions of thermochemical scalars from aggressively truncated principal components (PCs). In this study, we demonstrate the efficacy of a CoK-PCA-based reduced manifold using a posteriori analysis. Simulations of spontaneous ignition in a homogeneous reactor that pose a challenge in accurately capturing the ignition delay time as well as the scalar profiles within the reaction zone are considered. The governing ordinary differential equations (ODEs) in the PC space were evolved from the initial conditions using two ODE solvers. First, a standard ODE solver that uses a pre-trained artificial neural network (ANN) to estimate the source terms and integrates the solution in time. Second, a neural ODE solver that incorporates the time integration of PCs into the ANN training. The time-evolved profiles of the PCs and reconstructed thermochemical scalars demonstrate the

robustness of the CoK-PCA-based low-dimensional manifold in accurately capturing the ignition process. Furthermore, we observed that the neural ODE solver minimized propagation errors across time steps and provided more accurate results than the standard ODE solver. The results of this study demonstrate the potential of CoK-PCA-based manifolds to be implemented in massively parallel reacting flow solvers.

3.1.2 Coffee break

Student Talk 5: Identification of recirculation zones from experimental images of trapped vortex combustors using deep learning

Speaker: Priyabrat Dash, Department of Computational and Data Sciences.

Abstract
Particle image velocimetry (PIV) is a standard method for studying primary recirculation zones in trapped vortex combustors (TVCs), which can operate in an RQL configuration. However, its intrusive nature can disrupt the flow, flame, and equipment in compact combustors, leading to inaccuracies. As an alternative, we use deep learning models based on generative adversarial networks (GAN, a widely used approach) and vision transformers (ViT, a recently devised promising architecture) to estimate the position and overall structure of large-scale vortices from a non-invasively measured quantity, such as the planar laser-induced fluorescence (PLIF) of a species. These models are trained using datasets from large-eddy simulations (LES) of TVCs with information regarding all scalars constituting the state variable, with the addition of noise to mimic experimental data. Quantitative metrics such as relative errors and PDFs of velocity components and their orientation have been used to demonstrate that the ViT exhibits better performance than the GAN. Sensitivity to the type of noise added to simulation data during training is studied as well. The trained model is then used to infer velocity vectors from noisy OH-PLIF data. In the absence of ground truth for that case, qualitative observations reinforce our earlier notion of the superiority of ViT. Such models will facilitate intelligent data fusion and the development of digital twins of combustors.

Student Talk 6: Mitigating Biases in Blackbox Feature Extractors for Image Classification Tasks

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

Abstract
In image classification, it is common to utilize a pretrained model to extract meaningful features of the input images, and then to train a classifier on top of it to make predictions for any downstream task. Trained on enormous amounts of data, these models have been shown to contain harmful biases which can hurt their performance when adapted for a downstream classification task. Further, very often they may be blackbox, either due to scale, or because of unavailability of model weights or architecture. Thus, during a downstream task, we cannot debias such models by updating the weights of the feature encoder, as only the classifier can be finetuned. In this regard, we investigate the suitability of some existing debiasing techniques and thereby motivate the need for more focused research towards this problem setting. Furthermore, we propose a simple method consisting of a clustering-based adaptive margin loss with a blackbox feature encoder, with no knowledge of the bias attribute. Our experiments demonstrate the effectiveness of our method across multiple benchmarks.

Student Talk 7: Finite time logarithmic regret bounds for the minimum variance control problem with piece-wise stationary ARX model

Speaker: Madhusudanarao, ECE

Abstract

We study the adaptive control problem of non-stationary ARX systems in which the system parameters change abruptly only at certain change points, and the system parameters and change points are unknown. We call this the piecewise stationary ARX problem. We extend the finite time logarithmic regret results of stationary ARX model with PICE algorithm to non-stationary setup.

Student Talk 8: DIME: Deterministic Information Maximizing Autoencoder

Speaker:Alokendu Mazumder , RBCCPS

Abstract

Variational autoencoders (VAEs) offer a theoretically sound and popular framework for deep generative models. However, learning a VAE from data presents unresolved theoretical questions and significant practical challenges. (i) It has been observed that the learned decoder distribution tends to be the same for all points in the latent space, implying that the latent space is not dependent on data space. This results in a poor latent representation of data. (ii) Additionally, due to the stochastic nature of VAE's decoder, it tends to produce blurry images that do not align well with the real data distribution, resulting in high FID scores. In this work, we propose a deterministic approach that addresses the limitations of traditional VAEs by learning a more informative latent space. Our method leverages a von-Mises Fisher (vMF) family-based kernel to regularize hyperspherical latent spaces in simple deterministic autoencoders. This regularization can be interpreted as maximizing the mutual information between the data and the latent space, leading to a more informative representation. We investigate how this regularization can create a better and more meaningful latent space than traditional VAE. In a rigorous empirical study, we show that our proposed model can generate samples that are comparable to, or better than, those of VAEs and other state-of-the-art autoencoders when applied to images as well as other challenging data such as equations.

Invited Talk 2: Improving the Runtime-Accuracy Trade-Off during LLM Inference

Speaker: Bhuwan Dhingra, Assistant Professor of Computer Science, Duke University

Abstract

Scaling language models has led to massive improvements in benchmark performance — initially by increasing model parameters and training compute, and more recently by increasing inference-time compute. This points to a troubling trend where improving accuracy seems to necessitate adding more compute, which is already prohibitive for all but a select few organizations. However, not all user queries or generated tokens are equally difficult, suggesting techniques which combine strong and weak models for improving efficiency. In this talk, I will present two such improvements — (i) Fuzzy Speculative Decoding, which alternates token-generation between large and small models to provide a tunable runtime-accuracy trade-off; and (ii) Pairwise Self-Consistency, which estimates the confidence of long-form responses to select which queries need to be sent to a larger model.

Bio
Bhuwan Dhingra is an assistant professor of computer science at Duke University and a research scientist at Apple. He has also spent time at Google Deepmind as part of the post-training team for Gemini foundation models. His research focuses on improving the factuality, efficiency and robustness of LLMs. He received his bachelor's from IIT Kanpur and a PhD from Carnegie Mellon University. His research is supported by grants from NSF, Amazon, P&G and the Learning Engineering Virtual Institute.

3.1.3 Session 7: Brain Computation and Data Science

Session Chair: Sridharan Devarajan, Vaanathi Sundaresan
Faculty Organizer: Danish
Student Organizer: Batta Siva Sairam, Gune, Diwakar
Location: ECE 1.08

Invited Talk 1:Detecting cancer from breath by letting dogs teach AI how to smell

Speaker: Akash Kulgod,Dognosis, co-founder.

Abstract
Multiple decades of peer-reviewed studies suggest that diseases have a scent, consisting of changes in the odor-print of the volatile organic compound (VOC) profile. The past two decades have also shown that dogs, used by militaries around the world to detect explosives, can be trained to sniff out this VOC profile, allowing for the accurate detection of multiple cancers, covid-19, and infectious diseases. Yet artificial intelligence struggles with odors, which resist the simple parameterization found in other senses such as wavelength or frequency. Odor percepts arise from a combinatorial encoding of molecules by olfactory receptors, and the complexity of this relationship is exemplified by Sell's triplets, where structurally similar molecules produce dissimilar percepts, and vice versa. This challenge underpins the limitations of current machine olfaction models, such as gas sensors for cancer detection, which fail to generalize reliably. We propose a percept-first approach: trained biomedical detection dogs, wearing EEG-based BCIs, can serve as perceptual labelers, providing high-dimensional neurobehavioral data to reverse-engineer molecular patterns and transform machine olfaction.

Bio
Akash Kulgod is the co-founder of Dognosis. He studied Cognitive Science with Highest Honors at UC Berkeley, has performed research in 8 labs across 5 countries in cognitive science, and is the first author of three publications and one patent on canine cognitive neuroscience.

Dognosis is a Bangalore-based deeptech startup decoding canine cognition to reveal the hidden world of scent and unlock disease screening at scale. We currently work with wearable brain-computer interfaces (BCIs), machine learning, and highly trained biomedical detection dogs to develop a highly accurate and cost-effective multi-cancer early detection (MCED) test.

Student Talk 1: Non-Invasive Prediction of IDH1 Mutation in Glioblastoma: Radiomics-Driven Textural Analysis of Preoperative MRI

Speaker:Dr. Vaishanvi Ravi, Department of Computational and Data Science

Abstract

Glioblastoma (GBM) is an aggressive brain tumor with prognosis and treatment responses heavily influenced by genetic mutations, particularly IDH1. Traditional diagnostic approaches, including biopsies and molecular profiling, are invasive, costly, and time-consuming, necessitating non-invasive alternatives. Radiomics, an emerging field in computational oncology, enables quantitative extraction of imaging biomarkers from medical scans, potentially revealing tumor characteristics imperceptible to the human eye. In this study, we investigate the predictive power of radiomic texture features from T1-weighted and FLAIR MRI scans in distinguishing IDH1-mutant GBMs from wild-type cases with varying MGMT methylation statuses. We extract Gray-Level Co-occurrence Matrix (GLCM) and Gray-Level Dependence Matrix (GLDM) features and train a Support Vector Machine (SVM) classifier, addressing class imbalance using the Synthetic Minority Oversampling Technique (SMOTE). The model demonstrates very good sensitivity and specificity in detecting IDH1 mutations in both MGMT-unmethylated cases and MGMT-methylated wild-type tumors. T1-weighted imaging outperforms FLAIR in IDH1 classification, with GLDM features from T1 scans yielding superior results. Our findings suggest that radiomic analysis can effectively capture mutation-driven necrotic patterns; however, when multiple genetic alterations contribute to necrosis, distinguishing their individual effects remains challenging. Notably, T1-based GLDM features excel in detecting subtle necrotic changes, while T1-based GLCM performs best when necrosis is widespread. These results highlight the potential of radiomics as a non-invasive tool for glioblastoma characterization, aiding in precision oncology and personalized treatment strategies.

Student Talk 2: A Dynamic Data Driven Agent Based Model for Characterizing the Space Utilization of Asian Elephants in Response to Water Availability

Speaker: Anjali P. Department of Computational and Data Science.

Abstract

The human-wildlife conflict poses significant challenges for communities that live near wildlife habitats. In this study, we use a dynamic data-driven agent-based model (ABM) developed using DDDAS principles as a computational tool to study space-use characteristics and emergent human-elephant conflict patterns as a response to different scenarios of water availability. The ABM has individual elephant agents that dynamically make movement decisions on the basis of data-driven behavior and movement models. We simulate various scenarios involving Asian elephants (Elephas maximus) and their environment in a region in the Periyar-Agastyamalai complex in southern India. In the current application, we focus on examining how rivers, streams, and water holes influence the spatial distribution of elephant activity and crop-raiding behavior. Through simulation experiments, we explore the implications of water availability on human-elephant interaction patterns. The crucial role that water plays in determining the spatial utilization patterns of elephants is highlighted. The results of the experiments indicate that crop raiding also occurs opportunistically as elephants access human settlements in search of water sources. Furthermore, the availability of water significantly

influences spatial utilization patterns, which warrants further investigation as a potential strategy for conflict management.

Student Talk 3:Design and Development of Micro-Engineered Electrodes and Electronic Systems for Parkinsonian Rat Models

Speaker: Sreenivas Bhaskara, Department of Electronic Systems Engineering.

Abstract

Ten million people are affected by Parkinson's disease (PD) that majorly affect motor functions. The medication fails to help advanced PD patients. Deep brain stimulation (DBS) is a clinical therapy for treating PD. The current targeted brain regions (Subthalamic nucleus) for DBS is proven to be beneficial but has several side effects. The scientific community is interested in finding an effective target region for the treatment. It is an ethical practice to prove the hypothesis in animal models prior to humans. This research work is focused on developing neural interfaces for electrophysiological signal acquisition/electrical stimulation along with necessary electronic systems for conducting exploratory research to find effective brain region for rat models.

Student Talk 4:Semi-supervised deep transfer for regression without domain alignment

Speaker: Mainak Biswas,PhD, BCD program

Abstract

Deep learning models are seldom deployed widely for real-world applications (e.g., medicine), because source models do not generalize well to "domain-shifted" target data. Many successful domain adaptation approaches require full access to source data and reliably labelled target data. Yet, such requirements are unrealistic in scenarios where source data cannot be shared either because of privacy concerns or are too large, and incur prohibitive storage or computational costs. Moreover, resource constraints may limit the availability of labelled targets. We illustrate this challenge in a neuroscience setting where source data are unavailable, labelled target data are meagre, and predictions involve continuous-valued outputs. We build upon Contradistinguisher (CUDA), an efficient framework that learns a shared model across the labelled source and unlabeled target samples without intermediate alignment of representations. Yet, CUDA was designed for unsupervised DA, with full access to source data, and for classification tasks. We develop CRAFT – a CUDA-based Regularization Approach for Flexible Training – for source-free (SF), semi-supervised transfer of pretrained models in regression tasks. We showcase the efficacy of CRAFT in two neuroscience settings: gaze prediction with electroencephalography (EEG) data and "brain age" prediction with structural MRI data. For both datasets, CRAFT yielded up to 9% improvement in root-mean-squared error (RMSE) over fine-tuned models when labelled training examples were scarce. CRAFT leveraged unlabelled target data and outperformed four competing state-of-the-art source-free domain adaptation models by up to 4%. We propose CRAFT as an efficient approach for source-free, semi-supervised deep transfer for regression that is ubiquitous in biology and medicine.

3.1.4 Coffee break

Invited talk 2: Image complexity-based visual network categorization using fMRI time series

Speaker: Neelam Sinha, .

Abstract
In this talk, we will look at the utility of fMRI time series in understanding visual networks. The topological aspects that differentiate visual networks, when stimulated using images with varying levels of complexity, will be examined. The pilot work carried out on the publicly available dataset BOLD5000 will be presented.

Bio

Neelam Sinha is a faculty at Center for Brain Research, an autonomous center located in IISc. Her group works on modeling multimodal neuroimaging data. Prior to this role, she was a faculty at IIIT-Bangalore.

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 2023.

Student Talk 5: Fast Combinatorial Algorithm for Enhancing Read Sequencing Accuracy

Speaker: Parvesh Barak,Department of Computational and Data Sciences

Abstract
Third-generation, long-read sequencing technologies have transformed genomics by generating longer and sufficiently accurate DNA sequences. A single sequencing instrument can routinely generate terabases of data in an experiment. However, these instruments also introduce errors during sequencing. The average sequencing error rate ranges from 0.1%-4%, depending on the choice of instrument and protocol. These errors must be corrected while preserving the correctly sequenced bases to support downstream applications. Existing algorithmic and deep-learning solutions to this problem use ad-hoc heuristics, require substantial computational resources, and lack formal guarantees. In this work, we draw inspiration from the well-established techniques for the haplotype assembly problem and introduce a mathematical formulation for read error correction. We prove the problem to be NP-had and give a fixed-parameter tractable solution. We present a dynamic programming algorithm and its parallel implementation for multicore CPUs. Preliminary results show that our method achieves competitive accuracy compared to state-of-the-art solutions on human genome sequencing data.

Student Talk 6: Targeted sequencing of Oncogenes from WGS data

Speaker: Daanish Mahajan, IMI **Abstract**

Whole Genome Sequencing (WGS) can be both costly and time consuming when the study is focused on certain specific target regions of the genome. ONT's Read Until" technology can be used to achieve this efficiently by reversing the voltage across the pore, thereby rejecting the read if it comes from the non-target region. To achieve sufficient enrichment, the decision to accept / reject needs to be made quickly because of the speed of the read that passes through the pore. The current state of the art tool Readfish [Payne et al., 2021] works by first basecalling and then mapping the initial part of the sequenced reads to the reference. This approach relies on the need for powerful GPU for faster basecalling and hence limits its usage. There are other works [Senanayake et al., 2023] that use deep learning to solve the problem but perform poorly on intra-species classification tasks. The third line of work maps raw signals to the reference, hence eliminating the need of basecalling. Our approach leverages the tool RawHash2 [Firtina et al., 2024] to classify cancerous genes from WGS data. We achieve faster decision making at the cost of slight trade-off in accuracy w.r.t. all the signal-based mappers. The talk will highlight the ideas used and ongoing effort to make the tool in par with Readfish without the need for GPUs.

Student Talk 7:Enhancing Representations for Cluster Tendency Assessment and Partitioning of Tabular Data

Speaker: Paritosh Tiwari,RBCCPS

Abstract

This research introduces an innovative approach to enhancing clustering effectiveness in complex tabular datasets through Isolation Kernel-based Fuzzy C-Means (IK-FCM). Traditional clustering methods, such as fuzzy c-means, struggle with high-dimensionality, data complexity, and imbalanced distributions, leading to unreliable and biased outcomes. To address these challenges, the proposed IK-FCM framework integrates Isolation Kernels (IK)—a data-dependent kernel adept at capturing local density variations and facilitating anomaly detection—into the fuzzy c-means algorithm. IK-FCM employs multiple iterations of IK-based transformations, generating a nuanced representation of data structure. Utilizing cosine similarity in the clustering phase further optimizes cluster differentiation in the transformed binary space. Comparative experiments on diverse benchmark datasets demonstrate that IK-FCM consistently outperforms existing methods in accuracy, stability, and computational efficiency, validating its practical applicability and robustness in handling sophisticated real-world datasets.

3.1.5 Session 8: Theoretical Computer Science

Session Chair:Sunil Chandran, Chandan Saha
Faculty Organizer: Chaya Ganesh, Arindam Khan
Student Organizer: Vijayant Yadav, Shreeya, Kaushik Kumar
Location: ECE 1.07, ECE Department

Invited Talk 1:Geometry in Optimization: To Choose or Not to Choose

Speaker: Sujoy Bhore, Faculty Member, IIT Bombay.

Abstract
Geometry lies at the heart of optimization, where the seemingly simple decision of "to choose or not to choose an object" often uncovers profound insights into the structure and solutions of complex problems. This geometric perspective has wide-ranging applications across various fields, including machine learning, logistics, computer graphics, sensor networks, and many others. In this talk, I will focus on two fundamental aspects of geometric optimization problems: Packing and Independence.

Consider a set of D-dimensional objects (each with associated profits), and the goal is to find the maximum profit subset that can be packed non-overlappingly into a given D-dimensional hypercube. This problem is known as the Geometric Knapsack Problem. The packing of various kinds of objects has been extensively studied in Mathematics over the centuries. Interestingly, the problem becomes computationally intractable, even in rather simple settings, e.g., unit disks in 2D. In this talk, I will present a polynomial time approximation scheme for packing D-dimensional balls.

On the other hand, the Independent Set problem for a set of objects in D-dimensional space aims to find a maximum-cardinality subset of independent (i.e., pairwise-disjoint) objects. Independent set is one of the most fundamental problems in Theoretical Computer Science, and unfortunately, it is known to be inapproximable in the most general cases. There has been extensive research on polynomial-time algorithms with improved approximation ratios for geometric inputs, sometimes trading off efficiency in running times. In this talk, I will present near-linear time constant-factor approximation algorithms for various natural families of objects, e.g., rectangles, balls, etc.

Bio
Sujoy is a faculty member in the Department of Computer Science & Engineering at the Indian Institute of Technology Bombay and a visiting fellow in the Department of Mathematics at the London School of Economics. Previously, he was a postdoctoral research fellow at the Faculty of Informatics, TU Vienna, and the Department of Computer Science, ULB Brussels. He received his Ph.D. from the Department of Computer Science, Faculty of Natural Sciences, Ben-Gurion University, Israel. Sujoy has been the recipient of the Krietman doctoral fellowship, US-Israel BSF fellowship, London Mathematical Society fellowship, and Young Faculty Award at IIT Bombay.

Student Talk 1: Improved Approximation Algorithms for Three-Dimensional Bin Packing

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

Abstract

We study three fundamental three-dimensional (3D) geometric packing problems: 3D (Geometric) Bin Packing (3D-BP), 3D Strip Packing (3D-SP), and Minimum Volume Bounding Box (3D-MVBB), where given a set of 3D (rectangular) cuboids, the goal is to find an axis-aligned nonoverlapping packing of all cuboids. In 3D-BP, we need to pack the given cuboids into the minimum number of unit cube bins. In 3D-SP, we need to pack them into a 3D cuboid with a unit square base and minimum height. Finally, in 3D-MVBB, the goal is to pack into a cuboid box of minimum volume. It is NP-hard to even decide whether a set of rectangles can be packed into a unit square bin – giving an (absolute) approximation hardness of 2 for 3D-BP and 3D-SP. The previous best (absolute) approximation for all three problems is by Li and Cheng (SICOMP, 1990), who gave algorithms with approximation ratios of 13, 46/7, and $46/7+\varepsilon$, respectively, for 3D-BP, 3D-SP, and 3D-MVBB. We provide improved approximation ratios of 6, 6, and $3+\varepsilon$, respectively, for the three problems, for any constant $\varepsilon > 0$. For 3D-BP, in the asymptotic regime, Bansal, Correa, Kenyon, and Sviridenko (Math. Oper. Res., 2006) showed that there is no asymptotic polynomial-time approximation scheme (APTAS) even when all items have the same height. Caprara (Math. Oper. Res., 2008) gave an asymptotic approximation ratio of $T_\infty^2+\varepsilon \approx 2.86$, where T_∞ is the well-known Harmonic constant in Bin Packing. We provide an algorithm with an improved asymptotic approximation ratio of $T_\infty/2+\varepsilon \approx 2.54$. Further, we show that unlike 3D-BP (and 3D-SP), 3D-MVBB admits an APTAS.

Student Talk 2:Improved Approximation Algorithms for Three-dimensional Knapsack

Speaker: Venkata Naga Sreenivasulu Karnati, Department of Computer Science and Automation.

Abstract

We study the three-dimensional Knapsack (3DK) problem, in which we are given a set of axis-aligned cuboids with associated profits and an axis-aligned cube knapsack. The objective is to find a non-overlapping axis-aligned packing (by translation) of the maximum profit subset of cuboids into the cube. The previous best approximation algorithm is due to Diedrich, Harren, Jansen, Thöle, and Thomas (2008), who gave a $(7+\varepsilon)$-approximation algorithm for 3DK and a $(5+\varepsilon)$-approximation algorithm for the variant when the items can be rotated by 90 degrees around any axis, for any constant $\varepsilon > 0$. Chlebík and Chlebíková (2009) showed that the problem does not admit an asymptotic polynomial-time approximation scheme. We provide an improved polynomial-time $(139/29+\varepsilon) \approx 4.794$-approximation algorithm for 3DK and $(30/7+\varepsilon) \approx 4.286$-approximation when rotations by 90 degrees are allowed. We also provide improved approximation algorithms for several variants such as the cardinality case (when all items have the same profit) and uniform profit-density case (when the profit of an item is equal to its volume). Our key technical contribution is *container packing* – a structured packing in 3D such that all items are assigned into a constant number of containers, and each container is packed using a specific strategy based on its type. We first show the existence of highly profitable container packings. Thereafter, we show that one can find near-optimal container packing efficiently using a variant of the Generalized Assignment Problem (GAP).

Student Talk 3: Why Auctioneers Should Randomize Item Order for Submodular Bidders

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

Abstract

We show that if an auctioneer presents items in a uniformly random order in an auction where bidders have submodular valuations, then in expectation, the auctioneer's revenue—also known as the submodular welfare—improves by at least approximately 1% compared to the worst-case deterministic ordering of the items.

Student Talk 4: The Group Access Bounds for Binary Search Trees.

Speaker: Akash Pareek, Department of Computer Science and Automation.

Abstract

The access lemma is a property of binary search trees that implies interesting consequences such as static optimality, static finger, and working set property. However, there are known corollaries of the dynamic optimality that are not known to be derived via the access lemma, such as the dynamic finger, and any o(logn)-competitive ratio to the optimal BST. In this talk, we will talk about the group access bound that can be defined with respect to a reference group access tree. Group access bounds generalize the access lemma and imply properties that are far stronger than those implied by the access lemma.

3.1.6 Coffee break

Invited Talk 2:Meta-theorems for Parameterized Streaming Algorithms

Speaker: Pranabendu Misra, Chennai Mathematical Institute .

Abstract

The streaming model was introduced to parameterized complexity independently by Fafianie and Kratsch [MFCS14] and by Chitnis, Cormode, Hajiaghayi and Monemizadeh [SODA15]. Subsequently, it was broadened by Chitnis, Cormode, Esfandiari, Hajiaghayi and Monemizadeh [SPAA15] and by Chitnis, Cormode, Esfandiari, Hajiaghayi, McGregor, Monemizadeh and Vorotnikova [SODA16]. Despite its strong motivation, the applicability of the streaming model to central problems in parameterized complexity has remained, for almost a decade, quite limited. Indeed, due to simple $\Omega(n)$-space lower bounds for many of these problems, the $k^{O(1)} \cdot polylog(n)$-space requirement in the model is too strict.

Thus, we explore *semi-streaming* algorithms for parameterized graph problems, and present the first systematic study of this topic. Crucially, we aim to construct succinct representations of the input on which optimal post-processing time complexity can be achieved. We devise meta-theorems specifically designed for parameterized streaming and demonstrate their applicability by obtaining the first $k^{O(1)} \cdot n \cdot polylog(n)$-space streaming algorithms for well-studied problems such as Feedback Vertex Set on Tournaments, Cluster Vertex Deletion, Proper Interval Vertex Deletion and Block Vertex Deletion. In the process, we demonstrate a fundamental connection between semi-streaming algorithms for recognizing graphs in a graph class H and semi-streaming algorithms for the problem of vertex deletion into H. Based on joint work with Daniel Lokshtanov, Fahad Panolan, M. S.

Ramanujan, Saket Saurabh, Meirav Zehavi

Bio
I am an Assistant Professor in Computer Science at the Chennai Mathematical Institute (CMI), India.

In the recent past, I was a postdoctoral fellow in the Algorithms and Complexity department at the Max Planck Institute for Informatics, Saarbrucken, Germany. Earlier, I was a researcher in the Algorithms group at the Department of Informatics, University of Bergen, Norway.

I obtained my PhD in Computer Science, advised by Prof. Saket Saurabh, from the Institute of Mathematical Sciences (IMSc), India and my masters and undergraduate degree from CMI in Mathematics and Computer Science.

Student Talk 5: NP-Hardness of Testing Equivalence to Sparse Polynomials and to Constant-Support Polynomials

Speaker: Agrim Dewan, Department of Computer Science and Automation.

Abstract
An n-variate polynomial f is said to be s-sparse if the number of monomials with non-zero coefficients in f is at most s and sparse if s is a polynomially bounded function of n. Sparse polynomials have been studied extensively in algebraic complexity theory, particularly with regard to interpolation, factorization and polynomial identity testing. In this work, we study the Equivalence Testing problem for sparse polynomials (ETsparse), which asks to decide, for a given n-variate polynomial f(x) over a field F and a positive integer s, whether there is an n x n invertible matrix A over F and a vector b in F^n such that f(Ax+b) is s-sparse. In other words, is f equivalent to an s-sparse polynomial? An exponential in n^4 running time algorithm for ETsparse was given by Grigoriev and Karpinski (AAECC-10, 1993) over the rationals, with no significant progress since then. We show the NP-Hardness of ETsparse over any field F when f is given in the sparse representation, that is, as a list of non-zero coefficients and exponent vectors. This implies the NP-Hardness of MCSP (Minimum Circuit Size Problem) for a dense subclass of homogeneous depth-3 arithmetic circuits if the input polynomial is given in the sparse representation. We also show that it is NP-Hard to approximate the smallest s0 for a given s-sparse polynomial f such that f is equivalent to an s0-sparse polynomial within a factor of $s^(1/3 - epsilon)$ for any positive epsilon; observe that s-factor approximation is trivial as the input f is s-sparse. Finally, we show that for any constant sigma >= 5, it is NP-Hard to check if a polynomial f (given in the sparse representation) is equivalent to some polynomial g where each monomial in g has at most sigma many variables with a non-zero exponent. All the results are obtained via direct reductions from the 3SAT problem. This is a joint work with Omkar Baraskar, Chandan Saha and Pulkit Sinha.

Student Talk 6:Fair Division of Indivisible Items with Adjusted Supply

Speaker: Aditi Sethia, Department of Computer Science and Automation.

Abstract
In this talk, I will discuss existential results for fair allocation of indivisible items in settings wherein it is feasible to create copies of resources or dispose of tasks. We establish that exact maximin share (MMS) fairness can be achieved via limited duplication of goods even under monotone valuations. We also show that, when allocating chores under monotone costs, MMS fairness is always feasible with limited disposal of chores. Since monotone valuations do not admit any nontrivial approximation guarantees for MMS, our results highlight that such barriers can be circumvented by post facto adjustments in the supply of the items. We also present results for additive and identically ordered valuation classes.

Student Talk 7:Fault-tolerant quantum computing

Speaker: Abhi Kumar Sharma, DESE

Abstract Quantum computing has the potential to advance our understanding of fundamental physics and to contribute to the study of complex protein structures, which are important for drug design. However, current quantum computers are highly susceptible to noise, limiting their applicability to such advanced tasks. In this presentation, we will explore the principles of fault-tolerant quantum computing, focusing on the utilization of magic states as a resource for implementing non-Clifford gates. Additionally, we will examine fault-tolerant encoding strategies designed to mitigate error propagation through the use of multi-qudit gates.

Student Talk 8: Generalized Linear Bandits with Limited Adaptivity

Speaker: Nirjhar Das, Department of Computer Sccience and Automation

Abstract
We study the generalized linear contextual bandit problem within the constraints of limited adaptivity. In this paper, we present two algorithms, B-GLinCB and RS-GLinCB, that address, respectively, two prevalent limited adaptivity settings. Given a budget M on the number of policy updates, in the first setting, the algorithm needs to decide upfront M rounds at which it will update its policy, while in the second setting it can adaptively perform M policy updates during its course. For the first setting, we design an algorithm B-GLinCB, that incurs $O(\sqrt{T})$ regret when $M = \Omega(loglogT)$ and the arm feature vectors are generated stochastically. For the second setting, we design an algorithm RS-GLinCB that updates its policy $O(log^2 T)$ times and achieves a regret of $O(\sqrt{T})$even when the arm feature vectors are adversarially generated. Notably, in these bounds, we manage to eliminate the dependence on a key instance dependent parameter , that captures non-linearity of the underlying reward model. Our novel approach for removing this dependence for generalized linear contextual bandits might be of independent interest.

3.1.7 Session 9: Power Engineering and Cyber-Physical Systems

Session Chair: Gurunath Gurrala, Tapas Roy
Faculty Organizer: Tapas Roy
Student Organizer: Anjali, Shivam, Vamsi, Kanchana
Location: MP 30, ECE Department

Invited Talk 1:Thyristor based PWM CSI fed induction motor drive

Speaker: Kamalesh Hatua, Associate Professor, IIT Madras.

Abstract

Thyristor based Current Source Inverters require complex forced commutation circuits for driving induction motor loads. The reliability and complexity of these inverters are sacrificed heavily and lost their popularity in the past. In this talk, a low voltage VSI assisted PWM operation of thyristors is envisaged. A low voltage motor winding helps to boost these commutation voltages suitably to turn off thyristors. An induction motor is driven successfully by the proposed technique.

Bio

Kamalesh Hatua (Member, IEEE) was born in West Bengal, India. He received the B.E. degree in electrical and electronics engineering from Karnataka Regional Engineering College, Surathkal, India, in 2000, and the M.Sc. and Ph.D. degrees in electrical engineering from the Indian Institute of Science Bangalore, Bangalore, India, in 2004 and 2011, respectively. He was with Bharat Earth Movers Ltd., Mysore, India, for the development of computerized transmission controller for dumpers. He was also with the Honeywell Technology Solutions Laboratory, Bangalore, India, for the development of the inverter for aerospace applications. He was a Postdoctoral Research Fellow with the Future Renewable Electrical Energy Delivery and Management Center, North Carolina State University, Raleigh, NC, USA, for the development of the SiC device based solid-state transformer from 2010 to 2012. He is currently an Associate Professor with the Department of Electrical Engineering, Indian Institute of Technology Madras, Chennai, India. His research interests include medium-voltage electric drives, automotive drives, polyphase induction motor drives, active gate driving for SiC switches, solid-state transformer, power electronics application in power system, and design of highly efficient power converters using SiC power switches.

Student Talk 1:A 10 kW Reconfigurable Multi-port AC-DC PFC Converter for Battery Charging Application

Speaker: Himanshu Bhusan Sandhibigraha, Department of Electrical Engineering.

Abstract

With the growing number of electric vehicles (EV), the demand for public charging infrastructure is on the rise. The nominal battery voltage of electric 2/3-wheelers is within 48-72 V, whereas the same for a 4-wheeler is 350-500 V. Due to the lack of standardisation of battery voltage and current levels, it is challenging to design and develop off-board chargers in a charging facility that can cater to multiple vehicles from different manufacturers and segments simultaneously. In this work, a 10 kW

reconfigurable multi-port AC-DC PFC Converter is proposed for charging of electric 2/3/4-wheelers. The converter supports charging of three 2/3 wheelers simultaneously with power up to 3.3 kW each or a single 4-wheeler with power up to 10 kW. Design considerations for the proposed converter are presented along with its experimental validation and test results.

Student Talk 2: Reconfigurable Step-Up/Down Series-Pass Partial Power Processing Converter for Battery Charging

Speaker: Aabid Ahmad Dar, Department of Electrical Engineering.

Abstract

This talk presents a systematic methodology to analyze series-pass Partial Power Processing (PPP) schemes for battery charging applications. All feasible Step-Up and Step-Down PPP schemes are evaluated and analyzed. Suitable performance metrics are derived to compare the various schemes from the perspective of wide voltage variation seen in battery charging applications. A systematic methodology to derive Step-Up/Down type PPP converters that facilitate bidirectional power flow is elucidated. A phase-shifted full-bridge converter (PSFBC) topology is selected to implement the PPP battery interface converter. The PPP approach improves the overall system efficiency, reduces switch stresses, and reduces the size of the power converter. The design and modelling considerations for the PSFBC topology for battery charging are elucidated. The designed topology is validated using switching circuit simulations and experimental results. Experimental results are provided to demonstrate that a PSFBC that is rated to handle an active power of 1 kW can be used to transfer 3.6 kW of power to charge the battery while achieving a system efficiency of 97.5%.

Student Talk 3: Parallel Node-Breaker based Simulation Tool for Dynamic Simulation of Cascading Failure Outages in Power Systems

Speaker: Vibuti Sahu, Department of Electrical Engineering.

Abstract

Dynamic simulations play a critical role in understanding and ensuring the stability of modern power systems. Node-breaker models are essential in dynamic simulations as they provide a detailed representation of the power system's topology. Unlike bus-branch models, node-breaker models allow for precise simulation of switching operations, fault clearing, and protection coordination, which are critical for assessing system stability and operational reliability. However, this level of detail significantly increases the computational complexity and simulation time. As power grids grow in complexity, tools that support efficient and accurate simulations using node-breaker models are increasingly vital. To address the computational challenges, parallelization techniques must be adopted to accelerate these simulations, enabling system operators and planners to evaluate contingencies, identify vulnerabilities, and develop robust strategies for maintaining grid resilience under dynamic conditions. My work focuses on addressing these challenges by leveraging parallelization techniques to accelerate simulations while maintaining accuracy. The importance of node-breaker models in dynamic simulations is explored with the computational complexities they introduce, and the development of efficient tools and methodologies to enhance their performance. An algorithm is developed that converts MATPOWER-based bus-branch data into ANSI/IEEE C37.97-compliant node-breaker configurations, supporting up to seven standard substation configurations. The method

demonstrates exceptional scalability, successfully processing networks with up to 13,000 buses in approximately 0.275 seconds using parallel computing. A dynamic simulation platform is developed in C++, incorporating Sparse Tableau methods to perform transient stability simulations. The platform integrates detailed models for power system elements, including synchronous machines, loads, transmission lines, relays, and circuit breakers, providing realistic replication of substation arrangements. Algorithms for the automatic population of relays for each station in a network are developed. The CT/PT placements in a substation are also considered in the simulation. Scalability and speed are achieved through Multi-Area Thevenin Equivalent (MATE) based parallelism using OpenMP for a shared-memory paradigm. The network partitioning is performed using the METIS library, and an algorithm is developed for assigning weights to electrical nodes to balance the computational load. The platform supports various linear matrix solvers and is benchmarked on a 13k bus system with impressive performance metrics. The simulator enables cascading failure analysis by identifying vulnerable N-k contingencies, simulating breaker failures, and assessing remedial actions. It predicts blackout scenarios through relay operations and system dynamics, paving the way for advanced cascading failure studies.

Student Talk 4: Emulation of Ternary Pumped Storage Hydro Plants on a Laboratory Micro-Alternator

Speaker:Durvesh Kalke,Department of Electrical Engineering.

Abstract

Thyristor based Current Source Inverters require complex forced commutation circuits for driving induction motor loads. The reliability and complexity of these inverters are sacrificed heavily and lost their popularity in the past. In this talk, a low voltage VSI assisted PWM operation of thyristors is envisaged. A low voltage motor winding helps to boost these commutation voltages suitably to turn off thyristors. An induction motor is driven successfully by the proposed technique.

3.1.8 Coffee Break

Invited Talk 2 : Bridging Sustainability and Stability: The Role of Inverters in Grid Interactive Microgrids

Speaker: Subhra Sankha Ghosh, Delta Electronics.

Abstract

In an era where renewable energy is at the forefront of global sustainability efforts, microgrids (MGs) have emerged as a crucial solution for delivering reliable, high-quality power to local consumers. MGs integrate distributed generation and storage, ensuring resilience and efficiency in both grid-connected and islanded operations. The key to their optimal performance lies in inverter control, with decentralized approaches offering enhanced reliability and scalability. This keynote will explore the critical role of inverters in MG operations, addressing essential functionalities such as seamless mode transitions, proportional load sharing, islanding detection, and grid synchronization. Special emphasis will be placed on the challenges of maintaining voltage quality while serving

non-linear and unbalanced loads, ensuring compliance with IEEE standards. As the energy landscape evolves, understanding these technical intricacies will be vital for researchers, engineers, and policymakers striving to enhance microgrid performance and accelerate the global shift toward sustainable energy solutions.

Bio

Subhrasankha Ghosh received the B.E. degree in electrical engineering from Bengal Engineering and Science University, Shibpur, Kolkata, India, in 2009 and M.S degree in electrical engineering from Indian Institue of Technology Kharagpur, Kharagpur, India, in 2021. From 2009 to 2011, he was with Larsen & Toubro Limited, India, as a Senior Engineer in the construction division. From 2011 to 2016, he was with M. N. Dastur & Company (P) Ltd. Consulting Engineers, Kolkata, India, as a Senior Engineer in the engineering design section. Since, 2021 he has been working with Delta Electronics India Pvt. Ltd. in the capacity of Assistant General Manager, R&D with focus on the development of high-power medium voltage converters. His research interests include design and control of grid-interactive and standalone operation of photovoltaic inverters in microgrid application, decentralized paralleling of inverters, and the operation and control of high-power multilevel converters.

Student Talk 5:Solid State Marx Generators and Development of Resonant Converters for Rapid Capacitor Charging in Repetitive Pulsed Power Applications

Speaker: Dr. Deepak Kaushik, Department of Electrical Engineering.

Abstract

Marx generators are widely used to produce transient high-voltage pulses. This work explores the evolution of solid-state Marx generators (SSMGs) and their ability to generate flexible pulse modulation. It demonstrates how replacing resistors with diodes and switches significantly improves energy efficiency and how square-wave pulses are generated by SSMGs. Marx Generator has wide applications in various field such as industrial, medical, agricultural, environmental , etc. Solid state marx generators can also be designed to have pulse widths that are narrow enough for military applications that includes ultrawide band antennas, jamming systems, and pulse radar systems. In all solid state marx generators, capacitor banks form the backbone of various pulsed power systems across these applications. The capacitors must be rapidly charged and discharged for repetitive pulsed power applications. Therefore, a capacitor-charging high-voltage power supply (CCPS) is inevitable to efficiently charge capacitors to high voltages for applications like plasma material processing, electromagnetic forming, particle accelerators, etc. The authors have developed a compact resonant converter topology that efficiently utilizes the parasitics of the high-voltage transformer and the secondary end rectifier. Initially, the authors analyzed various resonant converter topologies and compared their feasibility for pulsed power applications. The developed converter is based on an LCLC-resonant tank operating at 150 kHz using SiC devices. The high-frequency operation compacts the converter by significantly reducing the size of magnetic components. In addition, the primary switches operate under ZVS (zero-voltage switching) during the entire charging cycle. The resonant tank is designed to use the voltage-balancing network parameters in the secondary

high-voltage rectifier, which reduces the final component count. The developed converter has inherent short-circuit and open-circuit protection for pulsed power applications. The converter can operate on a full ripple DC voltage, eliminating the need for a front-end bulky filter electrolytic capacitor in the AC rectifier. Finally, a controller based on Constant Current and Constant Power (CC-CP) mode, employing a variable frequency control technique, has been designed to control the charging rate of the capacitor banks. The designed converter also exhibits modularity to increase the voltage and current rating of the final applications. The developed system is capable of both single-shot and burst-mode operations. The authors have simulated the result in PLECS and are developing a 1 kW prototype.

Student Talk 6: Data-Driven Minimum-Gain Pole Placement

Speaker: Ananta Kant Rai, ECE

Abstract

Minimum-gain pole placement is a classical problem that aims to find a static state feedback matrix with the minimum norm that places the closed-loop poles at desired locations. In this paper, we present the direct data-driven formulation of this problem without identifying the system model. We derive and discuss the conditions for pole placement using data matrices, and propose a projection-based gradient descent algorithm to solve the problem. We also consider sparsity constraints on the feedback matrix and obtain approximately sparse solutions. Our simulations show that the proposed direct method is more accurate than the model-based approach in placing the poles as well as in obtaining a feedback matrix with lower norm.

3.1.9 Session 10: Cyber-Physical Systems

Session Chair: Tarun Rambha, Vijay Kovvali
Faculty Organizer: Ravi Prakash
Student Organizer: Tirthajit Baruah, Rankit Kachroo, Saumya
Location: IDR Seminar Hall (G22)

Invited Talk 1: Towards Human-guided Robot Task Execution

Speaker: Rohan Paul, Associate Professor, Department of Computer Science and Engineering , IIT Delhi .

Abstract
Emerging AI-based robotic technology is set to transform autonomous robot operation in complex real world settings. This talk will present recent work in interpret high-level tasks, perform spatio-temporal reasoning and robustly execute plans. I will share insights from integrated experiments on real robotic platforms in laboratory conditions demonstration autonomous task execution driven by high-level human commands. Cumulatively, the research efforts lays the foundation for an "intelligence architecture" for a robot to perform tasks involving planning, reasoning and knowledge of the environment context.

Bio
Rohan Paul is an Associate Professor at the Department of Computer Science and Engineering, Indian Institute of Technology Delhi, India with Joint Appointment with the Yardi School of Artificial Intelligence. He obtained B. Tech. and M.Tech. degrees at the Indian Institute of Technology (IIT) Delhi, D.Phil. degree at Oxford University and was Postdoctoral Associate at the Computer Science and AI Laboratory (CSAIL), Massachusetts Institute of Technology, USA. His research lies at the intersection of robotics and AI with emphasis on robot decision making, semantic mapping, human interaction, and active learning with experimental demonstrations on autonomous manipulators, ground robots and mobile manipulators. His research has appeared in ICRA, RSS, IJRR, AAAI, IJCAI, IROS, receiving Best Paper Awards/Nominations at RSS 2016, IROS 2013 and ICRA 2010. He is a recipient of two national awards and named one of 35 global innovators under the age of 35 by MIT Review. Currently, he leads research in intelligent robotics for human assistance supported through research grants from DRDO DIA-COE, ICMR, MoE and DST in India.

Student Talk 1: Data Driven Adaptive Koopman Modelling for Control of Nonlinear Systems

Speaker:Rajpal Singh, PhD , ME

Abstract

Precise control of nonlinear dynamical systems remains a critical problem across diverse scientific and engineering disciplines. Unfortunately, a unifying mathematical framework for the control of such complex systems remains elusive. The well-developed field of linear control theory offers a robust toolbox for analyzing and controlling linear systems. Consequently, there is significant appeal in synthesizing global linear representations for nonlinear systems. To this end, data-driven Koopman operator-theoretic methods have emerged as a powerful approach for identifying such linear embeddings, enabling the use of linear control strategies in inherently nonlinear systems. However, these methods often struggle to generalize beyond training data and lack robustness to changes in system dynamics caused by intrinsic or environmental factors. This study tackles these challenges by introducing an adaptive Koopman architecture designed to dynamically adapt to evolving system dynamics. We leverage the fact that the uncertainties/disturbances in system dynamics can be linearly parameterized through prelearned Koopman embeddings or sufficiently approximated through their projections onto them with sufficient accuracy. We employ an autoencoder-based neural network that utilizes input-output data from the nominal system to learn the corresponding Koopman embedding offline and subsequently augment it with an online neural learning architecture that modifies the nominal dynamics in response to any deviation between the predicted and observed lifted states, leading to improved generalization and robustness to a wide range of uncertainties and disturbances compared to contemporary methods. By integrating the adaptive Koopman framework into a Model Predictive Control approach across multiple robotic platforms, we demonstrate its robustness and superior performance against leading contemporary designs.

Student Talk 2 :A Cyber-Physical Modeling and Vulnerability Assessment Framework for Smart Grids

Speaker:Shashank S, PhD , RBCCPS

Abstract

The power grid is composed of a coordinated, extensive network of smaller network portions comprising of physical and cyber (or communication) layers. In bulk power systems, most of the cyber and physical components interaction takes place in substations. However, in most of the cyber-physical power system models the physical layer is typically done using the bus-branch (BB) model, where each substation is considered as a single node. This approach will not capture the details of the cyber layer. Thus, a detailed representation of the system is essential for better analysis and assessment of the system with respect to vulnerabilities. Security of substations is important to ensure reliability and integrity of the power grid. We provide a vulnerability assessment framework for a Substation Automation System (SAS) based substation. The framework uses Common Vulnerabilities and Exposures (CVE) database as its foundation. We use a Natural Language Processing (NLP) based model to identify and map the vulnerabilities present in each CVE entry. Common Weakness Enumeration (CWE), which represents the root cause of a vulnerability is used to map the vulnerabilities. These mapped vulnerabilities are then used to determine various attack paths using Bayesian networks. We also compute the exploitation probabilities of the vulnerability nodes and the attack paths in the network. Our study provides an overall vulnerability landscape of the network which can be used to identify weak points and implement remedial security

measures to fix them.

Student Talk 3:Formally verified Neural network controller synthesis ensuring incremental input-to-state stability for unknown systems

Speaker: Ahan Basu, RBCCPS

Abstract
This work aims to synthesize a controller that ensures that an unknown discrete-time system is incrementally input-to-state stable (δ-ISS). The notion of -ISS control Lyapunov function (-ISS-CLF) is introduced which, in conjunction with the controller, ensures that the closed-loop system is incrementally ISS. To address the unknown dynamics of the system, we parameterize the con- troller as well as the -ISS-CLF as neural networks and learn them by utilizing the sampled data from the state space of the unknown system. To formally verify the obtained -ISS- CLF, we develop a validity condition and incorporate the condition into the training framework to ensure a provable correctness guarantee at the end of the training process. Finally, the usefulness of the proposed approach is proved using multiple case studies.

Student Talk 4:A Formal Quantification of Sim2Real Gap via Neural Simulation Gap Function

Speaker: Sangeerth P, RBCCPS

Abstract
In this paper, we introduce the notion of neural simulation gap functions, which formally quantifies the gap between the mathematical model and the model in the high-fidelity simulator, which closely resembles reality. Many times, a controller designed for a mathematical model does not work in reality because of the unmodelled gap between the two systems. With the help of this simulation gap function, one can use the existing model-based tools to design controllers for the mathematical system and formally guarantee a decent transition from the simulation to the real world. Eventhough in this work, we have quantified this gap using a neural network, which is trained using a finite number of data points, we give formal guarantees on the simulation gap function for the entire state space including the unseen data points. We collect data from high-fidelity simulators leveraging recent advancements in Real-to-Sim transfer to ensure close alignment with reality. We demonstrate our results through two case studies - a Mecanum bot and a Pendulum.

3.1.10 Coffee Break

Invited Talk 2: Stuck in Traffic – Understanding Congestion and Safety

Speaker: Vijay Kovvali,Research Professor, IISc Bengaluru.

Abstract
Few of us enjoy being stuck in traffic, and many believe that technology holds the key to eliminating congestion. However, the reality is far more complex, shaped by a dynamic interplay of infrastructure, policy, human behavior, and economic forces. In this talk, I will explore the interconnected factors that contribute to both congestion and accidents, shedding light on the challenges we face and the solutions that can help us move toward a smoother, safer future on the roads.

Bio

Dr. Vijay Kovvali is a Research Professor at the Centre for Infrastructure, Sustainable Transportation, and Urban Planning (CiSTUP) at the Indian Institute of Science (IISc), Bengaluru. He holds a Ph.D. from Texas A&M University and brings over 25 years of experience in transportation engineering, focusing on intelligent transportation systems (ITS), traffic engineering, road safety, and public transport systems. Prior to joining IISc, he served as a Professor of Practice at IIT Delhi and held leadership roles in the industry, contributing to diverse projects in smart cities, traffic modeling, multimodal integration, and data analytics. He is actively engaged in research projects leveraging artificial intelligence to enhance mobility solutions.

Student Talk 5:Event-Triggered Parameterized Control for Networked Control Systems

Speaker: Anusree Rajan, RBCCPS

Abstract

This presentation deals with a novel control method called event-triggered parameterized control for networked control systems where the controller and the actuator communicate over a communication network. In this control method, between two successive communication instants, each control input to the plant is a linear combination of a set of linearly independent scalar functions, and the coefficients of the parameterized control law are updated in an event-triggered manner. The proposed control method allows for generating a time-varying control input to the plant, even between two successive communication instants, by transmitting limited information over the communication network and by using limited computational resources at the actuator. This control method is showcased for the task of stabilization of nonlinear systems and trajectory tracking by unicycle robots. A similar method is used for co-designing control and communication strategies for multi-loop networked control systems. For each task, theoretical guarantees are provided, and numerical simulations are done to illustrate the results.

Student Talk 6: Opinion dynamics for agents with resource limitations

Speaker: Prashil Wankhede, Department of Electrical Engineering.

Abstract

We propose a continuous-time nonlinear model of opinion dynamics with resource limited utility-maximizing agents connected via a social influence network. A distinguishing feature of the proposed model is the inclusion of an opinion-dependent resource-penalty term in the utilities, which limits the agents from holding opinions of large magnitude. This model is applicable in scenarios where the opinions pertain to the usage of resources, such as money, time, computational resources, etc. Each agent myopically seeks to maximize its utility by revising its opinion in the gradient ascent direction of its utility function, thus leading to the proposed opinion dynamics. We show that for any arbitrary social influence network, opinions are ultimately bounded. For networks with weak antagonistic relations, we show that there exists a globally exponentially stable equilibrium using contraction theory. We establish conditions for the existence of consensus equilibrium and analyze the relative dominance of the agents at consensus. We also conduct a game-theoretic analysis of the underlying opinion

formation game, including on Nash equilibria and on prices of anarchy in terms of satisfaction ratios. In addition, we also investigate the oscillatory behavior of opinions in a two-agent scenario.

Student Talk 7: Event-Triggered Polynomial Control for Trajectory Tracking by Unicycle Robots

Speaker: Harini V, RBCCPS

Abstract

Trajectory tracking for mobile robots is a well-studied problem with many applications, such as industrial automation, military surveillance and multi-robot coordination. An important challenge in these applications is constrained resources, such as communication, computation, and energy. In this work we propose an event-triggered polynomial control method for trajectory tracking by unicycle robots. Here, each control input between two consecutive events is a polynomial and its coefficients are chosen to minimize the error in approximating a continuous-time control signal. We design an event-triggering rule that guarantees uniform ultimate boundedness of the tracking error and non-Zeno behavior of inter-event times. We illustrate our results through a suite of numerical simulations and experiments, which indicate that the number of events generated by the proposed controller is significantly less compared to that by a time-triggered controller or a event-triggered controller based on zero-order hold while guaranteeing similar tracking performance.

Student Talk 8: Reinforcement learning aided decision making for multi-agent coordination problems in dynamic environments

Speaker: Nishchal Hoysal, RBCCPS

Abstract

Optimal multi-agent coordination over multiple decision steps (finite/infinite) is a complex and, often an NP-hard problem. Many real-world applications require solving such similar problem instances frequently and with severe computation time constraints and safety constraints. We explore the use of reinforcement learning (RL) to solve such problems near-optimally and in a highly scalable manner, by exploiting the common structure in these problems instances. In this talk, we explore the use of RL, specifically for two use cases, namely, (a) Communication and energy constrained multi-agent surveillance and reporting and (b) Safe and efficient unsignalized intersection management. We demonstrate that trained RL policies coupled with some simple search methods can provide highly scalable and provably safe near-optimal policies which outperform existing methods.

3.2 Plenary Speaker Talks

Session Chair: Chaya Ganesh (CSA), Gurunath Gurrala (EE), Rajesh Sundaresan (ECE)
Location: A V Ramarao Auditorium, 2nd floor, Division of Chemical Science Building

3.2.1 Plenary Talk 2: ANRF Overview and Principles

Speaker: Plenary 2: Prof. Shivakumar Kalyanaraman ,ANRF .

Abstract
Anusandhan National Research Foundation (ANRF) has been recently established as a statutory body with a governing board chaired by the Honorable PM. This body is aimed at driving a significant transformation in Research and Innovation across all stakeholders in India. This includes all of government, academia (public, private), industry, startups, CSR, Foundations and diaspora. Collaboration across disciplines, teams vs individuals, institutions, international and quality / impact will be a major focus. The talk will also outline principles and high level approaches ANRF will consider (subject to discussion and EC / GB approval) to driving collaborations and co investments across stakeholders.

Bio
Shivkumar Kalyanaraman is the CEO, Anusandhan National Research Foundation (ANRF). He was previously CTO, Energy Industry, Asia at Microsoft. Previously he was Executive General Manager of Growth Offerings at GE Power Conversion responsible for new Line of Business development in e-Mobility, Commercial & Industrial Solar and digital/AI innovations. Earlier he was at IBM Research - India, and the Chief Scientist of IBM Research - Australia. Before IBM, he was a tenured Full Professor at Rensselaer Polytechnic Institute in Troy, NY, USA. Shivkumar Kalyanaraman has degrees from Indian Institute of Technology, Madras (B.Tech, CS), Ohio State University (MS, PhD) and RPI (Executive MBA). He is a Distinguished Alumnus Awardee of IIT Madras (2021, recognizing 0.3% of IITM's alumni over the years) & Ohio State University (2021), Fellow of the IEEE (2010), Fellow of Indian National Academy of Engineering (2015), ACM Distinguished Scientist (2010), Microsoft Gold Club (2024), MIT Technology Review TR100 young innovator (1999)

3.2.2 Plenary Talk 3: A new era of AI powered Development in India

Speaker: Kyle Daigle,GitHub.

Abstract
Join GitHub COO , Kyle Daigle to learn about the evolution of GitHub's AI pair programmer, GitHub Copilot, how Indian Developers are shaping the future of software development and how GitHub is empowering the next generation of developers. The talk will be followed by a fireside chat with Prof. Yogesh Simmhan about the rise of AI and LLMs and how they relate to education and ethical and legal considerations developers should keep in mind when using AI-generated code. We will then open the floor to an ask my anything session where students are welcome to ask the GitHub COO about questions ranging from his foray into software development to career advice and more.

Bio
Kyle is Chief Operating Officer at GitHub, leading teams responsible for culture, developer outreach, operations, and communications. Joining GitHub in 2013, Kyle built and scaled GitHub's ecosystem engineering teams and worked on the acquisitions of Semmle, npm, and others. Nearly 12 years (and many ships) later, Kyle is just as committed to driving growth across the business and its people, leading GitHub's own AI adoption strategy across a workforce of 3,000+ talented Hubbers. As a developer himself, Kyle is passionate about bringing software practices to operations and works to preserve and grow the spirit of GitHub as an AI-integrated, developer-first company. Prior to GitHub, Kyle took on developer-focused challenges as an engineering and product leader in startups, working in FinTech, real estate, and consulting. When he isn't collaborating with Hubbers and customers, he's building home automations with Home Assistant, working with nonprofits to make technology available and accessible to all, gaming (hello Xbox), and traveling with family.

3.2.3 Coffee Break

3.2.4 Plenary Talk 4: The Complexity of Formal Proofs

Speaker: Prof. Meena Mahajan,IMSc.

Abstract
A proof of a statement convinces the person/entity addressed that the statement is true. Intuitively, a good proof is short, and easy to verify. A formal proof must convince an automated checking program (that may have limited resources). This talk discusses why we care about formal proofs, how we can design good formal proofs, and situations where we hit a wall.

Bio

Meena Mahajan is a professor at The Institute of Mathematical Sciences, HBNI, Chennai, India, which she joined in 1994. An alumna of IIT Bombay (CSE BTech and MTech) and IIT Madras (PhD), her interests span most of theoretical computer science. Her research focusses primarily on understanding the limits of efficient computation, and encompasses many aspects of complexity theory, including Boolean function complexity, algebraic circuits, and proof complexity.

Meena is a Fellow of the Indian Academy of Sciences, and a recipient of the J C Bose Fellowship. She is currently an editor of the journal Logical Methods in Computer Science LMCS. She is also currently a member of the editorial boards of the ACM Book series and the Leibniz International Proceedings in Informatics LIPIcs, the advisory board of the journal TheoretiCS, the Steering Committee of the Satisfiability conference, and the executive council of the Indian Association for Research in Computer Science IARCS, and has served on several conference program committees as well as award committees.

As recreation, Meena loves solving jigsaw puzzles (creating order out of disorder), and also solving combinatorial puzzles, which crop up in real-life situations far oftener than one may think. Less nerdy interests include reading fiction, enjoying nature, cooking, and spending time with family and friends

3.3 Award Distribution and Closing Ceremony

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