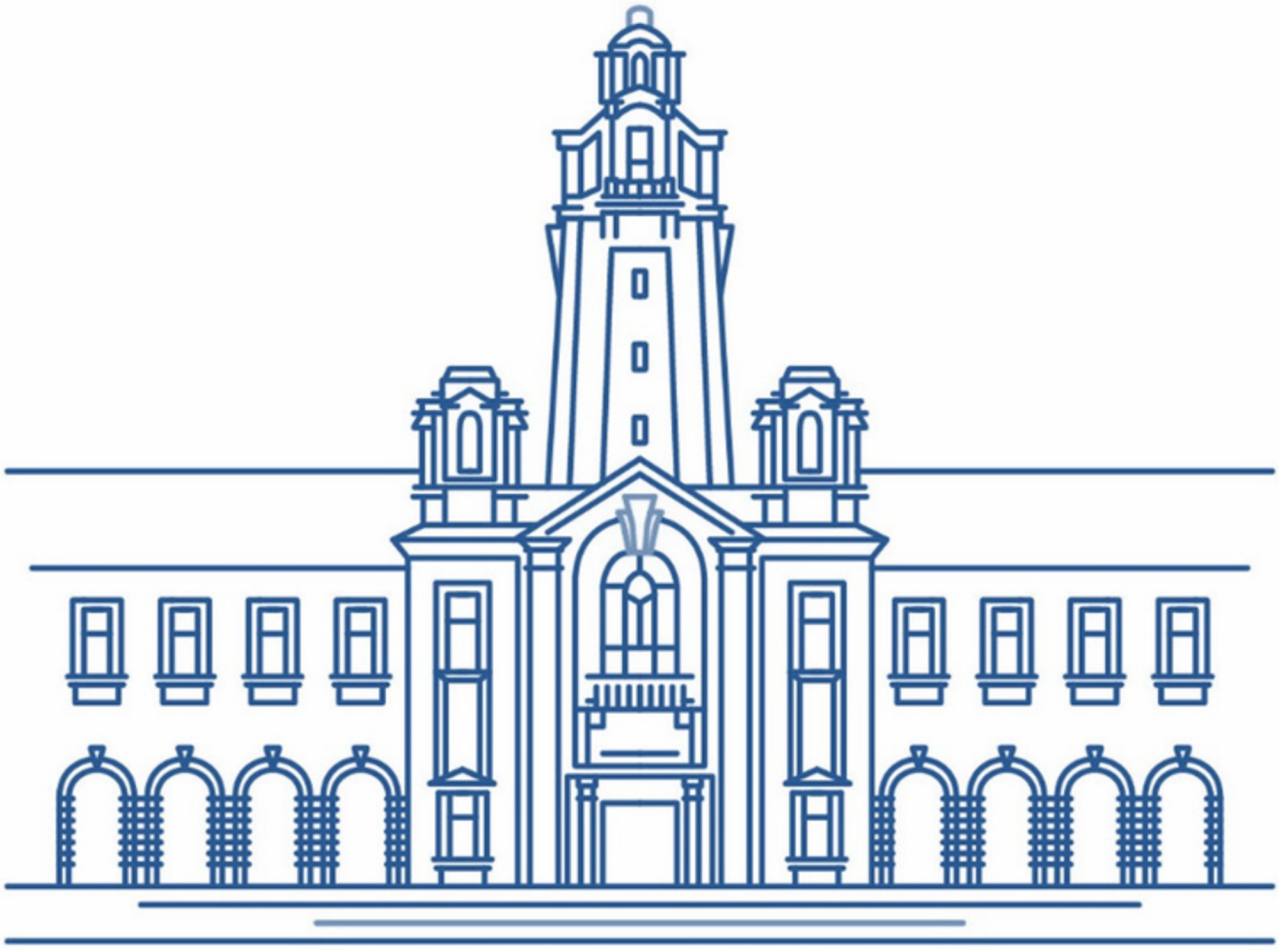
CyPhySS 2024

8TH CYBER-PHYSICAL SYSTEMS SYMPOSIUM

25TH -27TH, JULY 2024

INDIAN INSTITUTE OF SCIENCE, BANGALORE



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CyPhySS – 2024 Schedule

Thursday, 25 July 2024

09.00-10.00	***Keynote:*** **Security of Cyber-Physical Systems: Theory and Applications of the Dynamic Watermarking Method** (Prof. P R Kumar)
10.00-11.00	**Tea Break + Poster Presentations**
11.00-11.45	**In-Orbit Assembly Missions: Advancements in Robotics, Automation and AI** (Prof. Mini C. Rai)
11.45- 12.30	**Safe AI-enabled Robot Autonomy** (Prof. Yiannis Kantaros)
12.30- 13.45	**Lunch Break**
13.45- 14.30	**Autonomy at Scale: Where Are We Headed?** (Dr. Arjun Jain)
14.30- 16.00	***Tutorial:*** **Reinforcement Learning: Connecting AI Innovations to Practical Solutions** (Dr. Mayank Baranwal)
16.00- 16.30	**High Tea**
16.30- 18.30	**Research Session**

Friday, 26 July 2024

09.00-10.00	***Keynote:*** **Resilience and Distributed Decision-making in a Renewable-rich Power Grid** (Prof. Anuradha Annaswamy)
10.00-11.00	**Tea Break + Poster Presentations**
11.00-11.45	**Self-Navigation in crowded environments** (Prof. Leena Vachhani)
11.45- 12.30	**The three Ms: Microrobot, Magnetism, and Manipulation** (Dr. Dharmveer Agarwal)
12.30- 13.45	**Lunch Break**
13.45- 14.30	**Large Action Robot System** (Biswajit Biswas)
14.30- 16.00	***Tutorial:*** **Smart Transportation and Hard Real-Time Cyber Physical System: Challenges and Opportunities** (Prof. Hrishikesh Venkataraman)
16.00- 16.30	**High Tea**
16.30- 18.30	**Research Session**

Saturday, 27 July 2024

09.00-10.00	***Keynote:*** **Bridging the Innovation Gap: The ongoing story of ARTPARK** (Prof. Bharadwaj Amrutur)
10.00-11.00	**Tea Break + Poster Presentations**
11.00-12.30	***Tutorial:*** **Assume-guarantee contracts for Control: From Continuous to Hybrid Systems and from Safety to Temporal Logic Specifications** (Prof. Adnane Saoud)
12.30- 13.45	**Lunch Break**
13.45- 14.30	**2024: Dawn of Legged Robotics?** (Dr. Rajesh Kumar)
14.30- 16.00	**Research Session | Hackathon**
16.00- 16.30	**High Tea**
16.30- 17.00	**Closing Note + Prize Announcements**

KEYNOTES

Security of Cyber-Physical Systems: Theory and Applications of the Dynamic Watermarking Method

Prof. P R Kumar (Texas A&M University)

Abstract

The coming decades will see the large scale deployment of networked cyber–physical systems to address global needs in energy, water, health care, transportation, etc. However, as recent events have shown, such systems are vulnerable to cyber attacks. We present a general purpose technique, called "dynamic watermarking," for detecting malicious activity in networked systems of sensors and actuators. It provides a provable guarantee of detection of any non-zero power attack. This method has been implemented in several systems of interest. We present the results of attacks on an autonomous automobile, a grid-tied photovoltaic system, a process control system, and a tethered helicopter. We also present the results of simulation studies of attacks on larger scale systems such as the power grid through attacks on its automatic gain control loop, and attacks on the Tennessee-Eastman model, an open source benchmark that has been developed for the purpose of evaluating process control technology used in industries such as chemical plants and oil refineries.

Brief Bio

P. R. Kumar, B. Tech (1973, IIT Madras) and D.Sc. (1977, Washington Univ., St. Louis), was a faculty member in the Math Dept at University of Maryland, Baltimore County (1977-84), ECE and CSL at the University of Illinois, Urbana-Champaign (1985-2011), and has been at Texas A&M University since 2011. He has conducted research in game theory, adaptive control, simulated annealing, machine learning, queueing networks, manufacturing systems, scheduling wafer fabrication plants, wireless networks and network information theory. His current application focus includes renewable energy, power systems, security, privacy, automated transportation, unmanned aerial vehicle traffic management, millimeter wave 5G, and cyber-physical systems. He is a member of the U.S. National Academy of Engineering, The World Academy of Sciences, and Indian National Academy of Engineering. He was awarded a Doctor Honoris Causa by ETH, Zurich. He received the Alexander Graham Bell Medal of IEEE, the IEEE Field Award for Control Systems, the Outstanding Contribution Award of ACM SIGMOBILE, the Donald Eckman Award of AACC, the Ellersick Prize of IEEE Communication Society, the Infocom Achievement Award, the SIGMOBILE Test-of-Time Paper Award, and COMSNETS Outstanding Contribution Award. He is a Fellow of IEEE, ACM and IFAC. He is an Honorary Professor at IIT Hyderabad.

Resilience and Distributed Decision-making in a Renewable-rich Power Grid

Prof. Anuradha Annaswamy (Massachusetts Institute of Technology)

Abstract

The power grid has evolved from a physical system to a cyber-physical system that consists of digital devices that perform measurement, control, communication, computation, and actuation. With increased penetration in distributed energy resources (DER) that include renewable generation, flexible loads, and storage, these devices can be as large as 8 billion in number just in the US grid, many of whom are cap. The power grid has evolved from a physical system to a cyber-physical system that consists of digital devices that perform measurement, control, communication, computation, and actuation. With increased penetration in distributed energy resources (DER) that include renewable generation, flexible loads, and storage, these devices can be as large as 8 billion in number just in the US grid, many of whom are capable of monitoring and making crucial decisions. While these devices provide extraordinary opportunities for improvements in efficiency and sustainability, they also introduce new vulnerabilities in the form of cyberattacks. This brings up the following question: How can we ensure grid resilience in the face of escalating cyber threats while accommodating the intermittent and distributed nature of DERs?

In this talk, we'll dive into this important question, and explore a framework that enables distributed decision-making and control. This framework is built around a local electricity market with a hierarchical structure that accommodates the distributed ownership of DERs, both in location and time as well as physical constraints due to power physics. This talk will explore the relation between market mechanisms, distributed optimization, and resilience for the grid. A variety of attack surfaces including those that compromise large IoT (internet-of-things) networks will be considered. The use of distributed visibility and the related situational awareness to the operators will be examined through simulation studies of a distribution grid with 100,000 nodes. The role of distributed decision-making principles of optimization and control in prevention, resilience, and detection & isolation will be examined.

Brief Bio

Dr. Anuradha Annaswamy is Founder and Director of the Active-Adaptive Control Laboratory in the Department of Mechanical Engineering at MIT. Her research interests span adaptive control theory and its applications to aerospace, automotive, propulsion, and energy systems as well as cyber physical systems such as Smart Grids and Smart Cities. She has received best paper awards (Axelby, 1986; CSM, 2010), as well as Distinguished Member and Distinguished Lecturer awards from the IEEE Control Systems Society (CSS), best paper award from the IFAC journal Annual Reviews in Control for 2021-23, and a Presidential Young Investigator award from NSF, 1991-97. She is a Fellow of IEEE and International Federation of Automatic Control. She is the recipient of the Distinguished Alumni award from Indian Institute of Science.

Anu Annaswamy is the author of a graduate textbook on adaptive control, a coauthor of a 2021 report on Future of Electric Power in the United States, and a 2023 report on the Role of Net-metering in the Evolving Electricity System, both published by National Academy of Sciences, Engineering, and

Medicine. She served as the President of CSS in 2020. She has been serving as a Faculty Lead in the Electric Power Systems workstream in the MIT Future Energy Systems Center since September 2021.

Anu has served as the Associate Editor of IEEE Transactions on Automatic Control and Automatica. She has served as the Editor in Chief of a Special Issue on Control Theory and Technology in the IEEE Transactions on Smart Grid, and as a Guest Editor on Smart City Networks in the IEEE Transactions on Control of Network Systems. She is on the editorial board of the IEEE Open Journal of Control Systems, IEEE Access, the IFAC Annual Reviews in Control, and Asian Journal of Control. She has served as the Deputy Editor of Annual Reviews in Control from 2016-2020. With Tariq Samad, she co-edited the CSS report on Impact of Control Technology (first edition: 2011; second edition 2013). With Karl Johansson and George Pappas, she edited the CSS report "Control for societal-scale Challenges: Road Map 2030," published in 2023. She is currently serving as the President-elect of the American Automatic Control Council. She will serve as the Editor in Chief of IEEE Control Systems magazine from January 2025.

Bridging the Innovation Gap: The ongoing story of ARTPARK

Prof. Bharadwaj Amrutur (Indian Institute of Science, Bangalore)

Abstract

Deep technology innovations will be a key driver for realizing the target of a 5Trillion economy in India. Such innovations will have their genesis in industrial or academic research labs. However, the process of converting a research result into a viable commercial product is an art which few have mastered. At IISc we embarked on this journey in the area of Cyber-Physical Systems, about 13 years back by first creating the Robert Bosch Center for Cyber Physical Systems (RBCCPS) and then ARTPARK (AI & Robotics Technology Park). While RBCCPS has now established itself as a thriving academic center, ARTPARK has focused on innovations and is home to about 30 startups. In this talk, we will look at this journey and important lessons we have learnt along the way along with sharing some of the technology innovations being commercialized by these startups.

Brief Bio

Bharadwaj Amrutur is a Professor in Indian Institute of Science (IISc). He chairs the Robert Bosch Center for Cyber-Physical Systems – an interdisciplinary research and academic center in IISc. He is also the Co-Founder and Director Executive of ARTPARK (AI & Robotics Technologies Park), a technology business incubatory, setup by IISc. He obtained his BTech degree in Computer Science and Engineering from IIT Bombay in 1990 and his MS and PhD in Electrical Engineering from Stanford University in 1994 and 1999 respectively.

INVITED TALKS

In-Orbit Assembly Missions: Advancements in Robotics, Automation and AI

Prof. Mini C. Rai (University of Lincoln)

Abstract

Breakthroughs in Robotics, Automation, and Artificial Intelligence (RAAI) are vital to realise a multitude of in-orbit space missions. The advances in cyber-physical systems for Space missions are pivotal for transitioning to Space 5.0. In this talk, Prof Rai will present how RAAI solutions will unearth a new era of in-orbit capabilities for constructing high-value, large-scale infrastructures beyond the Earth. Prof. Rail will introduce two challenging mission scenarios on Space-Based Solar Power (SBSP) and Large Aperture Space Telescope (LAST). The design of an End-over-End Walking Robot (E-Walker), its system dynamics and control, and task-sharing using inter-connected robots for assembling LAST and SBSP stations will be covered. The next generation of innovative dexterous walking robotic manipulators, presented in this talk, is suitable for a range of orbital infrastructure assembly and disassembly missions.

Brief Bio

Prof. Mini C. Rai is the Global Chair in Robotic Engineering and leads Space Engineering research at the University of Lincoln, UK. Her expertise is in Robotics, Automation, and Control. To drive a sustainable space economy, Prof. Rai is involved in global initiatives on In-Orbit Servicing, Manufacturing, Assembly, Active Debris Removal and Recycling studies. Prof. Rai is also active in terrestrial robotics to maximise cross-domain impact through technology transfer.

Safe AI-enabled Robot Autonomy

Prof. Yiannis Kantaros (Washington University in St. Louis)

Abstract

Recent groundbreaking advances in computer vision, AI, and control theory have revolutionized the capabilities of autonomous robots in accomplishing diverse tasks in unknown environments such as package delivery, mapping of underground environments, surveillance, and environmental monitoring. However, with the rise of AI-enabled autonomous systems, new challenges regarding safety and reliability have surfaced. This talk particularly focuses on the safe integration of AI-enabled components for perception and decision making in autonomous systems.

In the first part of the talk, I will present a safe perception-based mission planning algorithm designed for teams of mobile robots, equipped with AI-enabled perception systems, that operate in unknown semantic environments. This algorithm enables robots to complete high-level semantic tasks (e.g., surveillance, delivery, etc.), expressed using formal languages, with user-specified probability, by actively mitigating environmental uncertainty stemming from imperfect perception. If time permits, in the second part of the talk, I will present a safe task planning algorithm for language-instructed multi-robot systems. Unlike the first part of the talk, the overarching mission will be described in natural language. The proposed algorithm primarily relies on pre-trained Large Language Models (LLMs) and statistical uncertainty quantification methods. Our approach enables robots to reason about their tasks and locally make probabilistically safe decisions to accomplish their collaborative missions. We show both empirically and theoretically that the proposed language-based planner scales well with the number of robots due to its decentralized nature while achieving desired mission success rates. Several case studies that include aerial and ground robots will be presented to demonstrate the proposed algorithms.

Brief Bio

Yiannis Kantaros is an Assistant Professor in the Department of Electrical and Systems Engineering, Washington University in St. Louis (WashU), St. Louis, MO, USA. Before joining WashU, he was a postdoctoral associate in the Department of Computer and Information Science, University of Pennsylvania, Philadelphia, PA. He received the Diploma in Electrical and Computer Engineering in 2012 from the University of Patras, Patras, Greece. He also received the M.Sc. and the Ph.D. degrees in mechanical engineering from Duke University, Durham, NC, in 2017 and 2018, respectively. His current research interests include machine learning, distributed planning and control, and formal methods with applications in robotics. He received the Best Student Paper Award at the IEEE Global Conference on Signal and Information Processing (GlobalSIP) in 2014, a Best Multi-Robot Systems Paper Award, Finalist, at the IEEE International Conference in Robotics and Automation (ICRA) in 2024, the 2017-18 Outstanding Dissertation Research Award from the Department of Mechanical Engineering and Materials Science, Duke University, and a 2024 NSF CAREER Award.

Autonomy at Scale: Where Are We Headed?

Dr. Arjun Jain (Fast Code AI)

Abstract

In this talk, Dr. Arjun Jain will delve into the complex world of Autonomous Vehicles and their myriad subsystems. He will begin with a brief historical overview, followed by an examination of critical modules such as perception, localization, prediction, planning, and control that are pivotal for Autonomous Driving. Furthermore, he will explore the enabling technologies that grant an agent autonomy and the integration of these technologies to safely navigate vehicles through the streets. The discussion will also cover the current challenges faced by these technologies and propose discussions on potential solutions.

Brief Bio

Arjun Jain is the Founder and CEO @ Fast Code AI. With a Ph.D. in Computer Science from the Max-Planck Institute for Informatics in Germany, Arjun's research sits at the intersection of computer graphics, computer vision, and machine learning. He is an Adjunct Faculty at the CDS department at IISc, leading a deep learning research group. He has taught Computer Vision at IIT Bombay and worked for companies such as Yahoo!, Weta Digital, and Apple. Arjun has been credited for his work on Weta Digital's motion capture system, used in feature films such as Steven Spielberg's The Adventures of Tintin. His work has resulted in academic publications with over 7000 citations, 5 patents, and mainstream media features in outlets like Vogue, Wired, and The Hollywood Reporter, among others.

Self-Navigation in crowded environments

Prof. Leena Vachhani (Indian Institute of Technology, Bombay)

Abstract

Navigating safely through crowded spaces where multiple dynamic obstacles/robots are moving independently presents significant challenges. Our main goal is to develop a new type of navigation system for robots that allows them to move safely and efficiently without the need for predicting the trajectory of dynamic entities in the environment. This system relies on real-time sensor data to make immediate navigation decisions. We designed a specialized control mechanism based on invariant set that has geometric meaning to define safe regions for navigation. The naturally induced trajectories in the safe regions as seen by sensor take account of motion constraints of the robot rendering a solution to an integrated planning, control and safety problem. Results on navigation while not following the traffic rule and actual robots show that the navigation controller can be used to learn the environment for global planning.

Brief Bio

Leena Vachhani is a professor at the Center of Systems and Control Engineering and the Professor-in-Charge of the Technology Innovation Hub (TIH) for IoT & IoE of Indian Institute of Technology Bombay, Mumbai, India. She has made significant contributions in the areas of embedded control and robotic applications that include topics on multi-agent mapping, exploration, patrolling and coverage. She has recently published an IEEE-Wiley book titled "Embedded Control for Mobile Robot Applications" and offered Swayam course on "Intelligent Feedback and Control" for highlighting practical approaches to control. She has developed laboratories on embedded control systems and autonomous robots and multi-agent systems with unique concepts. She is faculty advisor of AUV-IITB team since its inception in 2010. Her current research interests are perception modeling for single and multi-agent applications, edge computing for IoT, and multi-agent applications for IoT framework.

The three Ms: Microrobot, Magnetism, and Manipulation

Dr. Dharmveer Agarwal (Indian Institute of Technology, Kanpur)

Abstract

Magnetic microrobots have gained much traction in recent decades for their potential applications in biomedical areas such as targeted drug delivery and biomechanical property estimation of cellular objects. In this talk, I shall present an image-guided approach for the actuation and feedback control of convex-shaped ferromagnetic microrobots. These microrobots are actuated by the magnetic field generated by a set of electromagnetic coils. A manoeuvre planner is developed to invoke certain motion manoeuvres of the microrobot so as to ensure its effective manipulation in the desired manner. Using this approach, the microrobot is made to deform zebrafish (Danio rerio) embryos to determine their Young's moduli. Furthermore, a model-predictive path planner is developed to determine collision-free optimal paths in cluttered experimental scenarios having ambient fluid flow. The associated motion planning plans the motion of the microrobot in the presence of dynamic obstacles such that the microrobot is able to navigate via a given path in a collision-free manner. The proposed approach holds tremendous promise in manipulating large microscopic cellular objects and it is envisaged that these autonomous microrobotic approaches shall open new vistas in the realm of targeted drug delivery and lab-on-chip biological devices.

Brief Bio

Dharmveer Agarwal is presently working as a Research Associate with Dr. Abhilash Patel in the Department of Electrical Engineering, Indian Institute of Technology Kanpur. He earned his doctorate in the area of microrobotics from the Indian Institute of Technology Patna in 2024. He received his Master of Engineering degree in CAD/CAM Engineering from Thapar University, Patiala in 2016 and his Bachelor of Engineering in Mechanical Engineering from Birla Institute of Technology, Mesra, Ranchi in 2013. Post B.E., he has also worked as a Graduate Engineer Trainee with Gmmco Limited during 2013-2014 catering to marine engines and DG sets installed onboard Indian Navy and Indian Coast Guard ships. His research interests broadly lie in the area of motion planning and control of magnetic microrobots.

Large Action Robot System

Biswajit Biswas (Tata Elxsi)

Abstract

Large action systems are the new frontiers in the era of Generative AI. This is next logical step for the AI evolution and just a stop before the holy grail of AGI or Artificial General Intelligence. But Large action systems are more application / solution centric . Here focus is more towards how to solve complex and dynamic problems. Large action models which are one of the building block of Large action system have already changing the way we are programming the next generation of robots. In fact there is no more programming at all. On the contrary Large Action models will enable process automation using robots which can perform actions which needs complex human like cognitive skill. In this talk we will discuss how Large action models can be used in Robotics systems and some simulation example implemented.

Brief Bio

Biswajit Biswas is the Chief Data Scientist and General Manager in Tata Elxsi driving the innovation in Artificial Intelligence and Advanced Computing Technology. He is leading the charge at Tata Elxsi for AI, GenAI and Quantum computing. Driving a high performance team developing AI powered autonomous systems, deep learning and machine learning models for predictive/prescriptive systems.

He has over 25 years of Industry experience, career spanning in multiple roles in Digital and Statistical signal processing, Computer Vision, Wireless Communication. Under his leadership AI team has developed and contributed to products for media and broadcast, autonomous driving systems , healthcare products, smart appliances and Industry 4.0. Holds 3 patents on AI based solutions media and communication. Biswajit has Masters in Computer Science from BITS Pilani and BE from Jadavpur Univ Calcutta, and has done his Data Science certification from Massachusetts Institute of Technology (MIT, US).

2024: Dawn of Legged Robotics?

Dr. Rajesh Kumar (Addverb)

Abstract

Legged Robots and Collaborative Robots have been around for a long long time. Since the 1950s where the legged machines were explored as bulky equipments. Then came the leg lab era of MIT where the "robotic" avatar came into limelight. Mid 2000s saw cobots come out of labs with universal robots making it available at the door of every industry. Now we are standing at the cusp of another moment. Advent of more stable and robust cobots, haptics, exos, quadrupeds, humanoids have led to them coming out of their research labs aka homes to the real industrial world and making people amazed with their skills. Will robots stand with us in a legged / human or an arm form. Is it a scifi or a great crafted set of machines and software? Let's talk about it, the status, the challenges and a bit about Addverb becoming a core of robotics revolution from India, for the world.

Brief Bio

Dr. Rajesh Kumar is a graduate from Indian Institue of Technology, Delhi and a has PhD in Robotics. Have been working primarily on software, AI and development for Cobots, Haptics, Quadruped robots at Addverb. His prior experiences include working with wheeled robots, cable driven robots etc. Controls, vision, and planners are the three broad areas in which he is currently working.

Reinforcement Learning: Connecting AI Innovations to Practical Solutions

Dr. Mayank Baranwal (Tata Consultancy Services)

Abstract

In this tutorial, we will explore the fundamentals of Reinforcement Learning (RL) and its real-world applications. We'll cover key concepts such as states, actions, rewards, and policies, along with popular RL algorithms like Q-learning and Deep Q-Networks (DQN).

We will then transition from theory to practice, showcasing how RL is transforming industries such as robotics, finance, healthcare, and gaming. Through case studies and interactive examples, attendees will learn to apply RL techniques to solve complex real-world problems.

As a special bonus, we will introduce human-centric reward design using Large Language Models (LLMs). This advanced approach enhances RL systems by creating more intuitive and human-aligned reward functions. Participants will learn how to integrate LLMs into the RL framework to better understand and fulfill human preferences and values.

By the end of this tutorial, attendees will have a solid grasp of RL principles, practical applications, and advanced techniques for human-centric reward design, equipping them to bridge the gap between AI and real-world solutions.

Brief Bio

Mayank Baranwal is a Senior Scientist with the research division of Tata Consultancy Services (TCS) in Mumbai. He also holds an Adjunct appointment with the Systems and Control group at the Indian Institute of Technology, Bombay (IITB), and a Guest appointment with the Indian Institute of Management, Mumbai (IIM-Mumbai). Prior to joining TCS, he was a postdoctoral scholar in the Department of Electrical and Computer Engineering at the University of Michigan, Ann Arbor. He received his Bachelors in Mechanical Engineering in 2011 from Indian Institute of Technology, Kanpur (IITK), and MS in Mechanical Science and Engineering in 2014, MS in Mathematics in 2015 and PhD in Mechanical Science and Engineering in 2018, all from the University of Illinois at Urbana-Champaign (UIUC). His research interests are in modeling, optimization, control and inference in network systems with applications to distributed optimization, supply-chain network, power networks, control of microgrids, bioinformatics and computational biology, and deep learning theory. Mayank is a recipient of the Institute Silver Medal in 2011 (from IIT Kanpur), the ME Outstanding Publication Award in 2017 (from the University of Illinois), the Young Scientist Award in 2022 (Tata Consultancy Services), the Gold Award for Best Smart Technology in Electricity Transmission in 2023 (India Smart Grid Forum), and the third-prize in the L2RPN-Delft Challenge in 2023.

Smart Transportation and Hard Real-Time Cyber Physical System: Challenges and Opportunities

Prof. Hrishikesh Venkataraman (Indian Institute of Information Technology, Sri City)

Abstract

This talk would begin with the amount of real-time interaction between human being and a cyber physical system. As per SAE, the vehicle today has different levels of autonomous, starting from L0 (Zero autonomy) to L5 (Complete autonomous driving). In the Indian context, there are heterogeneous vehicles (2-wheelers, bikes, autos, cars, trucks, etc) each of which have their own average speed, weight, height; and dimensions. Importantly, most of them do NOT follow lane discipline. This creates significant problems towards safe driving, even for a semi-autonomous mode. Having said that, the advent of sensors such as RADAR, LiDAR and camera and processing capabilities provides several opportunities for researchers and architects to work and devise new and suitable solutions.

Brief Bio

Prof. Hrishikesh Venkataraman completed his Master's from IIT Kanpur, India in 2004 and Ph.D. from Jacobs University Bremen, Germany in 2007. He worked in the Irish national research center – RINCE, from 2008-2013; and as Technical Architect in the Tech Mahindra CTO office from 2013-2015. He has been a German DAAD fellow with TU Dresden from 2003-2004 and a fellow of the Irish Research Council from 2008-2010. Currently, Dr. Venkataraman is an Associate Professor and heads the "Smart Transportation Research Group". He is an Associate Editor of the SAE Journal of Connected and Automated Vehicles. He has published more than 100 research papers in journals and conferences including ACM, Elsevier, IET, IEEE, and Springer. He has 1 granted trademark, 3 granted patents, 6 patents published and 3 filed. He has got around 14 projects, including in IEEE ITS, UKIERI, British Council, Enterprise Ireland, etc. and has been a visiting Professor at TU Munich, Germany. He is a Senior Member of IEEE and Fellow of both IE (India) and IET (UK).

Assume-guarantee contracts for Control: From Continuous to Hybrid Systems and from Safety to Temporal Logic Specifications

Prof. Adnane Saoud (University Mohammed VI Polytechnic)

Abstract

In this talk, we present a general framework for compositional reasoning using assume-guarantee contracts for continuous-time systems. This framework applies to very general systems with arbitrary interconnections, and makes it possible to reason on very general properties. We introduce weak and strong semantics and show that the weak semantics are sufficient to reason on acyclic interconnections and strong semantics are necessary for cyclic interconnections.

We first show how this framework can be combined with symbolic control techniques and applied to safety controller synthesis problems. We consider the scenario where a system is made of interconnected components, each component is equipped with a sampled-data controller (with its own sampling period), and where the controller of a component can receive partial information on the state of other components through a given information structure. The considered global system can be seen as distributed, multiperiodic and with partial information. We then present how funnel-based control approaches make it possible to deal with more general contracts to deal with complex signal temporal logic specifications. Finally, we show how the proposed assume-guarantee contracts framework can be extended to deal with the general class of hybrid systems, where systems can exhibit both continuous and discrete behaviours.

The theoretical results will be illustrated on different case studies ranging from adaptive cruise control problems to DC microgrids and robots.

Brief Bio

Adnane SAOUD is an Assistant Professor at University Mohammed VI Polytechnic (UM6P), Benguerir, Morocco. Between September 2021 and August 2023 he was an Assistant Professor (Maitre de conférences) at CentraleSupelec, France. Between January and August 2021, he was a Postdoctoral Research Fellow in the Electrical and Computer Engineering Department at the University of California, Berkeley, USA. Between January and December 2020, he was a Postdoctoral Research Fellow in the Electrical and Computer Engineering Department at the University of California, Santa Cruz, USA. He received the Ph.D. degree in Control from CentraleSupelec, France, in 2019. In 2018, he was selected as one of the top three finalists for the Best student paper award at the European Control Conference, ECC. In 2020, he was selected as a finalist of the French national Best PhD award Discerned by the GdR MACS. In 2021, he was selected as one of the top three finalists of the EECI PhD award, recompensing the best PhD work in Europe in the field of Control. In 2024, He received the “Best Repeatability Prize” at the IFAC Conference on Analysis and Design of Hybrid Systems, ADHS . He obtained the M.Sc. degree in control from CentraleSupelec, France, in 2016, and Electrical Engineering degree from Ecole Mohammadia d’ingénieurs, (EMI), Morocco, in 2014. His current research interests include control of Cyber-Physical systems, machine learning for control and formal methods for control.

RESEARCH PRESENTATIONS

Presentations by research students and post-docs during the **Research Session** on 25th 26th and 27th of July 2024.

Day – 1 (25th July)

1. ***Safe Human-Robot Interaction using Switched Model Reference Admittance Control***

   Chayan Kumar Paul (Indian institute of Technology, Delhi)

   This study focuses on Physical Human-Robot Interaction (pHRI) tasks that require a close coupling between safety constraints and compliance with human intentions. To address this, the authors propose a novel switched admittance controller for an n-link manipulator to comply with external forces while ensuring safety in the workspace. The controller switches between two reference models to generate a reference trajectory that maintains the safety constraints. Stability analysis of the switched reference model is performed by selecting an appropriate Common Quadratic Lyapunov Function (CQLF), which ensures the asymptotic convergence of the trajectory tracking error. The effectiveness of the proposed controller is demonstrated through simulation on a 4-DOF SCARA (RRPR) robot manipulator.

2. ***Network Small Gain Theorem***

   Swati Singh (Indian Institute of Technology, Bombay)

   The network stabilization problem in a heterogeneous multi-agent system with diffusive connections is investigated in this paper. It is demonstrated that, under the assumption that the agents are finite-gain $\mathcal{L}_2$--stable and zero state observable, the interconnection is zero input asymptotically stable, and all agents' dynamics converge to the origin. The stability analysis is based on small-gain theory. We provide the maximum bound on the $\mathcal{L}_2$--gain of the controller using various optimization methods when the $\mathcal{L}_2$--gain of each agent is known. A study on the variation of $\mathcal{L}_2$--gain bound of the controller with the Laplacian eigenvalues of the underlying graph is provided. Numerical examples, which support and illustrate the analytical results, are also included.

3. ***Three-Dimensional Nonlinear Impact Time Guidance Considering Field-of-View Constraints***

   Kakoli Majumder (Indian Institute of Technology, Bombay)

   This letter proposes a three-dimensional nonlinear guidance strategy that guarantees the interception of stationary targets at the desired impact time while accounting for the onboard seeker's field-of-view constraints. The proposed approach for designing guidance law does not require a time-to-go estimation. It utilizes range-to-go, free from time-to-go approximations, allowing the interceptor to control the time of interception. Guidance command, derived using prescribed constraint function and sliding mode control considering coupled and nonlinear engagement kinematics, continuously maintains the target within its field-of-view bound and achieves guidance objectives. The proposed guidance strategy performs effectively, even for large deviations from the collision course, where pitch and yaw channels may be strongly coupled. Finally, the proposed guidance scheme is shown to be superior to existing strategies through numerical simulations.

4. ***Computation of Maximal Admissible Robust Positive Invariant Sets for Linear Systems with Parametric and Additive Uncertainties***

Anchita Dey (Indian Institute of Technology, Delhi)

In this work, we address the problem of computing the maximal admissible robust positive invariant (MARPI) set for discrete-time linear time-varying systems with parametric uncertainties and additive disturbances. The system state and input are subject to hard constraints, and the system parameters and the exogenous disturbance are assumed to belong to known convex polytopes. We provide necessary and sufficient conditions for the existence of the non-empty MARPI set, and explore relevant features of the set that lead to an efficient finite-time converging algorithm with a suitable stopping criterion.

5. ***Three-Dimensional Nonlinear Path-Following Guidance for UAVs***

Saurabh Kumar (Indian Institute of Technology, Bombay)

We devise a nonlinear guidance law in a three-dimensional setting that steers the UAV onto its desired path using limited information. The proposed solution to the three-dimensional path following is expected to provide greater flexibility and adaptability in the UAV's motion compared to two-dimensional alternatives in performing more complex tasks in various scenarios, e.g., urban air mobility and space exploration. The proposed guidance law allows a generic treatment of the path following problem by eliminating the dependency on the path's geometry, unlike previous methods. Most of the previous methods consider the path to be either a straight line, a circular arc, or any combination of these two path primitives. It is also worth mentioning that when the desired path is composed of several paths, a separate mid-way guidance strategy is needed and is complicated. In contrast, the proposed guidance strategy does not depend on the type of path that needs to be followed. Therefore, it does not require any switching when following a curve composed of different paths, so the proposed treatment is generic in nature. Unlike previous methods, where a three-dimensional problem was treated as multiple two-dimensional problems, the kinematic model under our consideration accounts for the persistent influence of vertical motion control on the horizontal motion. As a result, this model maintains the strong cross- coupling between the yaw and pitch channels. To the best of the authors' understanding, these aspects have not been comprehensively incorporated into the general path following problem thus far. Nonetheless, their inclusion is pivotal for addressing a range of motion planning. The proposed path following guidance law allows for global convergence to the path by ensuring fixed-time convergence of the error variables. In other words, the UAV converges to its desired path within a fixed time, irrespective of the initial conditions. Such a design also allows us to choose the settling time for different variables as per the requirements only using the design parameters, which gives an extra degree of freedom to the designer.

6. ***Event-Triggered Fault Reconstruction Using Sliding Mode Observer.***

Dr. Saikat Mondal (Indian Institute of Science, Bangalore)

In this paper, we study event-triggered fault reconstruction using sliding mode observer (SMO) for a linear time-invariant system. Here, the SMO is designed with an event condition in which output measurements are transmitted over the network. The observer provides the state estimates using the sampled output values in the presence of fault signals. It is shown that with a suitable (switching) gain and the triggering parameter, the observer states converge to the true states (in the practical sense), and thus, the fault signals can be reconstructed with an accuracy dependent on the steady-state error bound. Finally, simulation results are shown to illustrate fault detection employing the proposed approach.

7. ***Guidance for Terminal Direction and Final Time Constrained-Approach Towards a Moving Target***

Vivek A (Indian Institute of Technology, Madras)

Approaching a moving target at a desired time along a desired direction is an essential requirement for many applications such as formation flights, aerial deliveries, rendezvous, docking, and interdiction missions. Most works that address this issue in the literature are developed considering a stationary target. Extending such guidance strategies against moving targets using the concept of predicted intercept point could degrade its performance. Instead, considering the engagement against a lower-speed moving but nonmaneuvering target directly, in this paper, a proportional navigation-based integrated guidance strategy is developed to address this problem of simultaneous control of terminal angle and final time. The desired terminal angle is achieved by suitably selecting the navigation gain and manipulating the lateral acceleration applied. At the same time, the final time requirement is satisfied by changing the purser's speed suitably. The proposed guidance scheme is validated through numerical simulations for different terminal requirements starting from same initial engagement geometry.

8. ***Approximate Stability Radius Analysis and Design in Linear Systems***

Ananta Kant Rai (Indian Institute of Science, Bangalore)

The robustness of the stability properties of dynamical systems in the presence of unknown/adversarial perturbations to system parameters is a desirable property. In this paper, we present methods to efficiently compute and improve the approximate stability radius of linear time-invariant systems. We propose two methods to derive closed-form expressions of approximate stability radius, and use these to re-design the system matrix to increase the stability radius. Our numerical studies show that the approximations work well and are able to improve the robustness of the stability of the system.

Day – 2 (26th July)

1. ***Graph-based Prediction and Planning Policy Network (GP3Net) for Scalable Self-Driving in Dynamic Environments using Deep Reinforcement Learning***

   Jayabrata Chowdhury (Indian Institute of Science, Bangalore)

   Recent advancements in motion planning for Autonomous Vehicles (AVs) show great promise in using expert driver behaviors in non-stationary driving environments. However, learning only through expert drivers needs more generalizability to recover from domain shifts and near-failure scenarios due to the dynamic behavior of traffic participants and weather conditions. A deep Graph-based Prediction and Planning Policy Network (GP3Net) framework is proposed for non-stationary environments that encodes the interactions between traffic participants with contextual information and provides a decision for safe maneuver for AV. A spatiotemporal graph models the interactions between traffic participants for predicting the future trajectories of those participants. The predicted trajectories are utilized to generate a future occupancy map around the AV with uncertainties embedded to anticipate the evolving non-stationary driving environments. Then the contextual information and future occupancy maps are input to the policy network of the GP3Net framework and trained using Proximal Policy Optimization (PPO) algorithm. The proposed GP3Net performance is evaluated on standard CARLA benchmarking scenarios with domain shifts of traffic patterns (urban, highway, and mixed). The results show that the GP3Net outperforms previous state-of-the-art imitation learning-based planning models for different towns. Further, in unseen new weather conditions, GP3Net completes the desired route with fewer traffic infractions. Finally, the results emphasize the advantage of including the prediction module to enhance safety measures in nonstationary environments.

2. ***MRFP: Learning Generalizable Semantic Segmentation from Sim-2-Real with Multi-Resolution Feature Perturbation***

   Aniruddh Sikdar (Indian Institute of Science, Bangalore)

   Semantic segmentation is a fundamental computer vision task with diverse downstream applications, such as autonomous driving, medical image analysis, landcover classification, and building detection. Deep learning models used for segmentation generally follow an under-complete architecture, i.e., the input images undergo compression in the encoder to extract semantic information followed by decompression in the decoder. To detect small structures in both medical imaging and remote sensing community, over-complete architectures were proposed to address the structural limitation of these under-complete networks. In over-complete models, the input is projected to higher dimensions (in a spatial sense) in the intermediate layers to restrict the size of the receptive field deeper into the network. This constriction forces the network to focus on smaller, intricate features of the input images.

   We focus on introducing overcomplete models for the task of domain generalization. Domain generalization focuses on training deep learning models, and inferencing them on unseen real-world target datasets, with the goal of reducing the domain gap. There are two primary challenges with training models on synthetic datasets as source domains: 1) It is not feasible to synthetically generate all potential unseen domains. 2) Models trained on synthetic data do not generalize to real-world scenarios due to the domain gap that persists when deployed in real-world situations.

   To address this, we propose a novel feature perturbation technique known as Multi- Resolution Feature Perturbation (MRFP), especially in a Sim-2-Real Single Domain Generalization (SDG) setting. The objective of MRFP is to selectively perturb domain-variant Low Frequency and High

Frequency features, aiming to improve the generalizability of DNNs. It operates in the feature space by extracting fine-grained characteristics via a decreasing receptive field from a randomly initialized overcomplete autoencoder, serving as perturbations to prevent domain-variant feature overfitting. Deep learning models focus on low-frequency features in the initial stages of vanilla training and shift their focus mainly to domain-variant HF (very-fine) features, covering the entire spectrum. Introducing variability with Style Perturbation (NP+) and High-Resolution Feature Perturbation (HRFP) at both ends of the spectrum shifts the model's focus to domain in-variant features. Randomizing these features during the training process restricts the model from drawing inherent source domain specific patterns. Extensive experiments over seven urban semantic segmentation datasets show that the proposed MRFP model achieves superior performance for single and multi- domain generalization tasks in a Sim-2-Real setting, even for corrupted environmental settings.

3. ***Transfer in Sequential Multi-armed Bandits via Reward Samples***

NR Rahul (Indian Institute of Science, Bangalore)

We consider a sequential stochastic multi-armed bandit problem where the agent interacts with the bandit over multiple episodes. The reward distribution of the arms remains constant throughout an episode but can change over different episodes. We propose an algorithm based on UCB to transfer the reward samples from the previous episodes and improve the cumulative regret performance over all the episodes. We provide regret analysis and empirical results for our algorithm, which show significant improvement over the standard UCB algorithm without transfer.

4. ***Identifying Discriminative Components for Editing Deep Neural Networks***

Chaitanya Murti (Indian Institute of Science, Bangalore)

Model editing is a growing area of research that is particularly valuable in contexts where modifying key model components, like neurons or filters, can significantly impact the model's performance. The key challenge lies in identifying important components useful to the model's predictions. We apply model editing to address two active areas of research, Structured Pruning, and Selective Class Forgetting. In this work, we adopt a distributional approach to the problem of identifying important components, leveraging the recently proposed discriminative filters hypothesis, which states that well-trained (convolutional) models possess discriminative filters that are essential to prediction. To do so, we define discriminative ability in terms of the Bayes error rate associated with the feature distributions, which is equivalent to computing the Total Variation (TV) distance between the distributions. However, computing the TV distance is intractable, motivating us to derive novel witness function-based lower bounds on the TV distance that require no assumptions on the underlying distributions; using this bound generalizes our prior work that relied on Gaussianity assumptions on the feature distributions. With these bounds, we are able to discover critical subnetworks responsible for classwise predictions, and derive DisCEDitP and DisCEDitU, algorithms for structured pruning requiring no access to the training data and loss function, and selective forgetting respectively. We apply DiscEditU to selective class forgetting on models trained on CIFAR10 and CIFAR100, and we show that we can reduce accuracy on a single class by over 80% with a 1.2% improvement in test accuracy on the remaining classes. Similarly, on Structured pruning problems, we obtain 40.8% sparsity on ResNet50 on Imagenet, with only a 2.6% drop in accuracy with minimal fine-tuning.

5. ***Opinion Dynamics for Utility Maximizing Agents: Exploring the Impact of the Resource Penalty***

Prashil Wankhede (Indian Institute of Science, Bangalore)

This research work is focused on opinion dynamics which falls under the broad field of research on social network analysis. The aim is to capture a variety of social phenomena through agent-based modeling. Opinion dynamics in social groups or networks is an important research topic with applications in diverse areas such as sociology, economics, public health, transportation, etc. Agent-based opinion dynamic models aim to capture different types of opinion evolution behaviors among a group of agents forming opinions on single or multiple topics. The models are useful for analyzing different equilibrium opinion behaviors such as consensus, clustering, polarization, etc. The models also help us identify the most influential agent in the social network using the notion of social power. Some interesting works in the literature consider a game theoretic or utility maximization approach for modeling opinion dynamics which is still in a nascent stage, and not many works have appeared so far. Motivated by this approach, we propose a single-topic continuous time non-linear opinion dynamics model with an aim to capture the effect of heterogeneous resources available to the agents on their opinions. The major contribution of this work is that we start by defining utility function for each agent to capture the tradeoffs between attachment to internal preferences and social influence. We then derive the opinion dynamics from the utility assuming each agent myopically seeks to maximize its utility. The novelty of this work comes from the inclusion of a non-linear resource penalty term in the utility function representing that the influencing capabilities and the opinion values of the agents are limited by its resources such as wealth, time etc. The resource penalty keeps the opinions bounded and restricts an agent with less resources from holding extreme opinions. We analyze the asymptotic properties of the model and provide conditions for existence of consensus equilibrium. If agents reach a consensus, we prove a dominance result which uses the dominance weights to indicate the most dominating agent at consensus who has the consensus value closest to its internal preference. The dominance weight of every agent depends on the resources available to it. The opinion formation process under the proposed dynamics can be thought of as a one-shot non-cooperative game played by the agents which we refer to as the opinion formation game. We carry out a Nash equilibrium and price of anarchy analysis of the game. We provide conditions for this game to have unique Nash equilibrium and show that if these conditions hold true, opinions under the proposed dynamics always converge to it. We also show that consensus equilibrium is a socially optimal outcome. Finally, we study the oscillatory behavior of opinions for two agent dynamics. We show that it is necessary for an agent to be sufficiently contrarian for the two agent dynamics to have periodic solutions.

6. ***Detection of adversarial attacks in cyber-physical systems***

Souvik Das (Indian Institute of Technology, Bombay)

Cyber-physical systems (CPSs) monitor and regulate several critical large-scale infrastructures such as smart grids, transportation systems, and wearable medical systems. Recent cyber-attacks, such as the Stuxnet computer worm attack in Iran and the cyber assault on Ukraine's power grid demonstrate the security vulnerabilities of large-scale CPSs. With the increasing complexities of the CPSs around us, the possibilities available to the attackers to launch sophisticated attacks have increased; consequently, there is an emergent need to devote considerable attention to the issue of the security of CPSs.

I will present a new detection scheme to identify the presence of adversaries in CPSs that are intelligent, history-dependent, and assume no model, and discuss some fundamental results in this direction. The core idea of this technique is based on the classification of two classes of observations --- those generated under adversarial attack and those generated under normal

situations --- from the underlying CPS.

7. ***Reinforcement learning aided decision making for multi-agent coordination problems in dynamic environments***

Nishchal Hoysa G (Indian Institute of Science, Bangalore)

Optimal multi-agent coordination problems in dynamic environments typically involve repeatedly solving computationally complex optimization programs with different parameters (eg. agent position, importance, battery level etc). We treat these parameters as the state of an MDP and explore the use of reinforcement learning (RL) to solve optimal multi-agent coordination problems. We demonstrate the effectiveness of this approach in the following two problems, yielding near optimal and state-of-the-art solutions with low computational complexity during inference.

1. Communication and energy constrained persistent surveillance over a graph with central situational awareness

2. Safe and efficient unsignalized intersection management for random robot streams

In the surveillance problem, we consider planning movements for energy and communication constrained agents among the nodes of a graph to reduce some notion of node idleness weighted by priorities and how often each agent uploads data to some station nodes. There may also be a need for unpredictability in such plans. The unknown dynamics of random and time varying node priorities pose computational complexity in various ways. We consider node priorities, their initial idleness and initial agent locations as problem parameters and use RL to decide the next optimal node to visit for each agent given the parameters. We use a rolling horizon approach to deal with randomly varying node priorities.

Autonomous unsignalized intersection management finds applications in autonomous warehouses. Here we consider planning safe and efficient continuous time trajectories for random streams of lane-following robots entering a region of interest with random priorities, so that, a notion of average time to cross for robots weighted by their priorities is minimized. The unknown future arrivals of robots and their priorities and crossing orders being combinatorial in number of robots pose computational challenges. We consider the current traffic state (position, velocity, priorities etc. of the involved robots) as the problem parameters, capturing the state for the RL agent. We let the RL agent decide the crossing order and use a sequential optimization framework to decide the trajectories for the robots in that order ensuring safety. We keep solving such problems periodically leading to a persistent intersection management algorithm. We also implement the algorithm in real- time in a lab setting.

For both the problems, through simulations, we demonstrate that the trained RL agent gives several orders of magnitude advantage in computation time against optimization methods, while providing near-optimal solutions outperforming several state-of-the-art approaches.

8. ***Learning Low-Rank Latent Spaces with Simple Deterministic Autoencoder: Theoretical and Empirical Insights***

Alokendu Mazumder (Indian Institute of Science, Bangalore)

The autoencoder is an unsupervised learning paradigm that aims to create a compact latent representation of data by minimizing the reconstruction loss. However, it tends to overlook the fact that most data (images) are embedded in a lower-dimensional latent space, which is crucial for effective data representation. To address this limitation, we propose a novel approach called Low-Rank Autoencoder (LoRAE). In LoRAE, we incorporated a low-rank regularizer to

adaptively learn a low-dimensional latent space while preserving the basic objective of an autoencoder. This helps embed the data in a lower-dimensional latent space while preserving important information. It is a simple autoencoder extension that learns low-rank latent space. Theoretically, we establish a tighter error bound for our model. Empirically, our model's superiority shines through various tasks such as image generation and downstream classification. Both theoretical and practical outcomes highlight the importance of acquiring low-dimensional embeddings.

Day – 3 (27th July)

1. ***Combining RL and MPC for Biped Walking***

   Prakrut Kotecha (Indian Institute of Science, Bangalore)

   The fusion of Reinforcement Learning (RL) with Model Predictive Control (MPC) is a promising approach that leverages the strengths of model-based and model-free paradigms for learning complex control policies for highly nonlinear, dynamic high-dimensional systems. It provides improved sample efficiency, faster learning, and flexibility to incorporate constraints. In this work, we study two approaches to the H-step lookahead policies, viz. LOOP and TD-MPC, which leverage trajectory optimization over a learned dynamics model over a horizon H and terminal value function to account for future rewards. We have tested both methods on benchmark tasks and also implemented them for a custom biped. The performance of both algorithms on Walker 2D has been compared and the challenges in their application to train more complex custom environments have been brought out. Another contribution of this work is the theoretical proof for finding an optimality bound for the value function for TD-MPC. The video of results can be found at https://youtu.be/-Ud4vcf_2LY .

2. ***Adaptive IBVS based Planar Non-Holonomic Target Tracking for Quadrotors***

   Yogesh Kumar (Indraprastha Institute of Information Technology, Delhi)

   We present an adaptive Image-Based Visual Servoing (IBVS) kinematic controller for quadrotors, designed to track a planar non-holonomic target moving with a constant body-fixed linear velocity and arbitrary angular velocity along the z-axis, with an unknown desired feature depth. Utilizing virtual image plane optical measurements, we derive image moment-based features to establish a decoupled dynamically feasible reference for the quadrotor's translational and angular motion. We introduce a novel target heading reconstruction-based constant target velocity parameterization to address the bilinear estimation problem within an adaptive control framework. From the resultant error dynamics, we develop a translational velocity adaptive controller that incorporates a smooth and bounded translational target velocity estimator, accounting for the uncertainty in the desired feature depth. Additionally, we design a heading controller to manage the unknown angular motion of the target. The derived velocity commands are assumed to be tracked by an inner-loop controller. Stability and error convergence for both translational and rotational subsystems are demonstrated using Lyapunov analysis, considering the closed- loop error dynamics. The efficacy of the proposed method is validated through realistic Software-In-The-Loop (SITL) simulations in a high-fidelity environment supplemented by model-in-the-loop simulations. The results also highlight the adaptability of the proposed approach to piecewise constant target motion profiles. While the results demonstrate excellent target tracking performance with the proposed scheme, current efforts are focused on refining the problem formulation to achieve faster transient response in translational tracking errors and ensure exact parameter convergence.

3. ***Co-design of polynomial Control Law and Communication Scheduling Strategy for Multi-Loop Networked Control Systems***

   Anusree Rajan (Indian Institute of Science, Bangalore)

   Recent advances in communication technology have increased the popularity of networked control systems, especially multi-loop networked control systems. There are different fields of applications for multi-loop networked control systems, such as traffic control of mobile robots on a factory floor, formation control of a swarm of robots, and real-time control of autonomous

vehicles. In many of these applications, the communication network is shared and limited. Thus, it is important to ensure efficient utilization of communication resources while achieving the control objective. In this work, we consider the problem of stabilization of a multi-loop networked control system with a finite number of independent control subsystems whose feedback loop is closed through a shared communication network. We co-design a polynomial control law and a communication scheduling strategy, based on the earliest deadline first algorithm, that guarantee global asymptotic stability of each control subsystem. We provide a necessary and sufficient condition that ensures feasibility of the proposed communication scheduling strategy. We illustrate our results through numerical examples.

4. ***State Constrained Model Reference Adaptive Control with Input Amplitude and Rate Saturation***

Poulomee Ghosh (Indian Institute of Technology, Delhi)

This paper proposes a Model Reference Adaptive Controller (MRAC) for uncertain multi-input multi-output (MIMO) linear time-invariant (LTI) plants with user-defined constraints on the plant states, input amplitude and rate. By considering the input magnitude and rate as states, the augmented vector is constrained by employing a Barrier Lyapunov Function (BLF), while state constraints are handled using another BLF. The effect of input saturation is tackled by introducing an auxiliary error dynamics, followed by transformation of constraints. The proposed two-layer BLF-based modified adaptive control laws ensure that the plant states, the input amplitude and the input rate remain bounded within pre-specified bounds and all the closed-loop signals are proven to be bounded. To the best of the authors' knowledge, this is the first result on tracking controller design for uncertain systems with state, input and input rate constraints. Sufficient conditions to check the feasibility of the control policy are provided. Simulation results show the efficacy of the proposed algorithm.

5. ***Trajectory tracking control of surface vessels with constrained input in the presence of disturbances***

Ram Milan Kumar Verma (Indian Institute of Technology, Bombay)

This study focuses on the problem of controller design for trajectory tracking of marine surface vessels while actively considering the limitations of the actuator, such as input saturation, in presence of bounded disturbances. Actuator input saturation is typical in physical systems, often resulting in performance degradation. Since actuator input bounds are typically known, integrating actuator saturation considerations into the control law design process can yield enhanced performance and more precise trajectory tracking.

In this paper, we propose a nonlinear feedback controller developed using the Lyapunov function and backstepping method concepts while augmenting the system dynamics with a smooth control input saturation model, along with using an observer to estimate the disturbance terms. Through Lyapunov stability analysis, we demonstrate the system's stability under the proposed controller for the vessel, ensuring adherence to actuator constraints provided their initial values fall within the prescribed bounds. Numerical simulations are performed to validate the effectiveness of the proposed controller for surface vessels. Results indicate satisfactory performance in trajectory tracking tasks, affirming the viability of the controller in practical applications.

POSTER PRESENTATIONS

Poster presentations by research students during the poster presentation sessions on 25th 26th and 27th of July 2024.

Day – 1 (25th July)

1. ***Enhancing Explainability of Multi-Modality Vision Transformers for Safety-Critical Applications***

   Selventhiran Rengaraj (Indian Institute of Technology, Palakkad)

2. ***Q-Learning for prompting strategies for robot assisted ASD interventions***

   Nabanita Paul (Indian Institute of Science, Bangalore)

3. ***Traffic Monitoring using UAV***

   Parikshit Singh Rathore (Indian Institute of Science, Bangalore)

4. ***Design and development of a Web-APP based User Interface to control and operate an Automated Mobile Robot***

   Samsaptak Ghosh (Indian Institute of Technology, Roorkee)

5. ***Detection and Mitigation of False Data Injection Attacks in Connected and Automated Electric Vehicles using Unsupervised Learning Approach***

   Thulasi M Santhi (National Institute of Technology, Tiruchirappalli)

6. ***BEST-GD: Beltrami Inspired Spectral Graph Diffusion***

   Ram Samarth B B (Indian Institute of Information Technology, Kottayam)

7. ***Fault Tolerant Multi-Modal Sensor Fusion for Autonomous Driving***

   Saksham Bhutani (Indian Institute of Science, Bangalore)

Day – 2 (26th July)

1. ***Time Constrained Interception with Bounded Field-of-View and Input using Barrier Lyapunov Approach***

   Swati Singh (Indian Institute of Technology, Bombay)

2. ***Graph Resistance-based Approach for Connectivity Maintenance against Node Failure***

   Sahaya Aarti D (Indian Institute of Technology, Bombay)

3. ***Agri Bot***

   Suvankar Pramanik (Adamas University)

4. ***Formation control of double integrators over directed graphs using bearings and bearing rates***

   Susmitha T Rayabagi (Indian Institute of Technology, Bombay)

5. ***Iron Fish -- Test bed for Unmanned Underwater Vehicles***

   Ram Milan Kumar Verma (Indian Institute of Technology, Bombay)

6. ***Distributed bearing-based control of three-link planar redundant manipulators***

   Hemanta Hazarika (Indian Institute of Technology, Bombay)

7. ***Spatiotemporal tube to meet prescribed-time reach-avoid-stay task: A data-driven approach***

   *Ahan Basu (*Indian Institute of Science, Bangalore)

Day – 3 (27th July)

1. ***Version Age Optimal Content Update and Transmission in an Edge Caching System***

   Anu Krishna (Indian Institute of Science, Bangalore)

2. ***Design and Modelling of TorsioSquid: A squid-inspired underwater bot***

   Naman Khetan (Indian Institute of Technology, BHU)

3. ***Nested Sliding Mode Control Based Impact Angle Guidance with Bounded Input***

   Prajakta Surve (Indian Institute of Technology, Bombay)

4. ***Signal Temporal Logic Compliant Co-design of Planning and Control for Single and Multi-Agent Systems***

   Tushar Dilip Kurne (Indian Institute of Science, Bangalore)

5. ***Bi-DRRRT*: An Efficient Path Planning Algorithm in Narrow Passage***

   Siddhartha Upadhyaya (National Institute of Technology, Silchar)

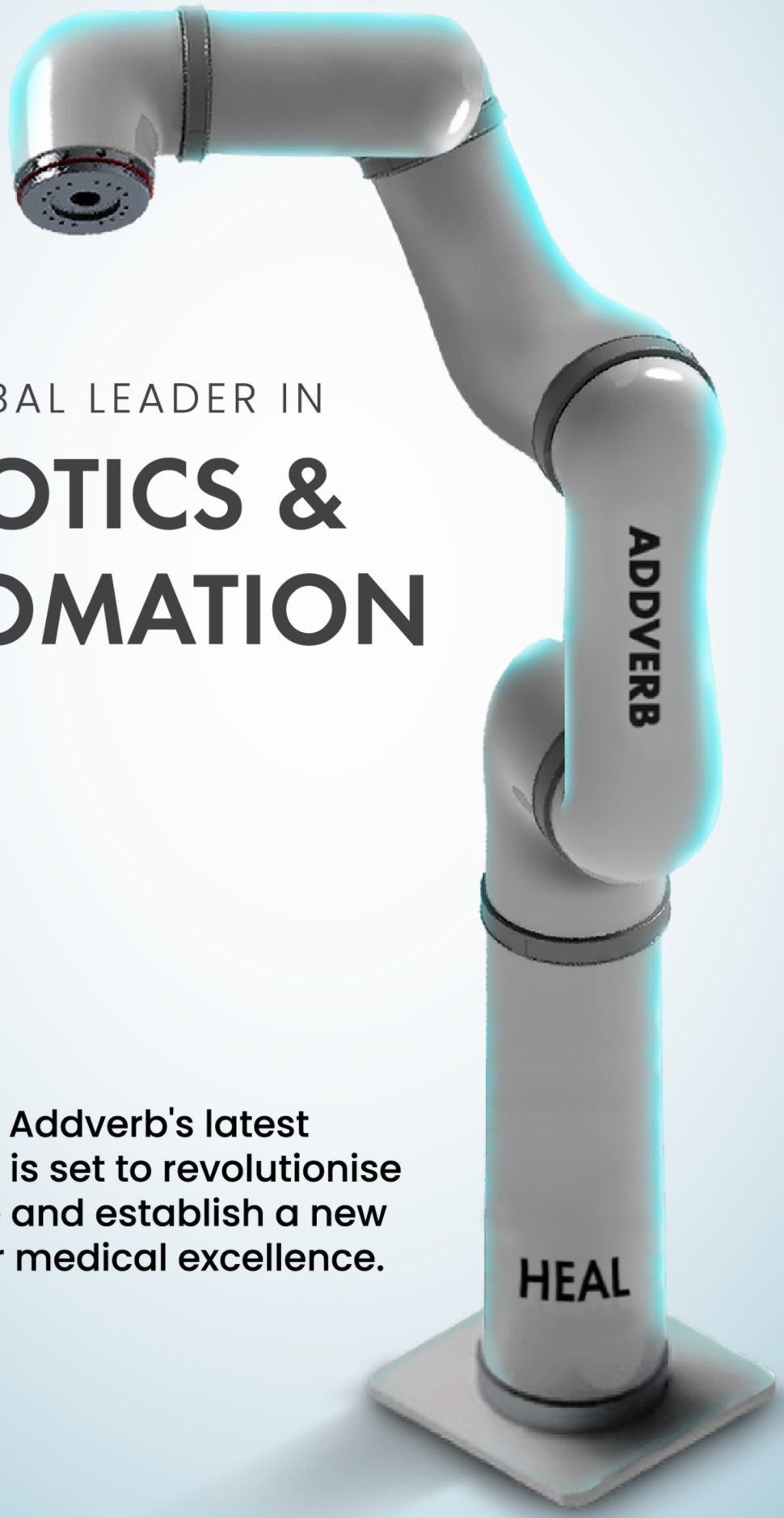
6. ***Deep Reinforcement Learning Approach to Minimize Task Wait Times in Dynamic Vehicle Routing***

   Saswata Sarkar (Indian Institute of Science Education and Research, Bhopal)

7. ***On Convergence of ADAM with constant step size and beyond***

   Alokendu Mazumder (Indian Institute of Science, Bangalore)

ADDVERB



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