IEEE

SPCOM

International Conference on Signal Processing and Communications

16th - 19th JULY 2018

12th International Conference on
Signal Processing and Communications

Indian Institute of Science, Bangalore

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MESSAGE FROM THE GENERAL CO-CHAIRS

It is our pleasure to welcome you to the twelfth edition of the International Conference on Signal Processing and Communications (SPCOM). The biennial SPCOM conference series, which began in 1990, is now widely acknowledged to be a premier conference in India covering the fields of signal processing and communications. In this year's edition of SPCOM, we have continued the tradition of blending a high-quality contributed program with a large number of invited talks, thus providing students and researchers in Indian academia and industry exposure to world-class, cutting-edge research.

New features in this SPCOM include a "Graduation day" session, where seven selected senior PhD students will present fifteen minute summary of their research work. This event will be held 14:30 – 16:00 hrs on July 19, 2018, at the J. N. Tata Auditorium. This time, we are presenting a "A Lifetime in Research" – a felicitation program for Prof. T. V. Sreenivas, Dept. of ECE, IISc, who has made key contributions to speech and audio signal processing over a career spanning more than four decades. This will be held 17:45 – 18:45 hrs on July 18, 2018, at the JN Tata Auditorium.

The number of papers submitted to SPCOM events continues to rise—an indication of the growing importance of this event among the research community. The 2018 edition of SPCOM features three plenary and thirty-eight invited speakers from around the world, in addition to 102 contributed paper presentations. Six tutorials on topics of current interest have been organized on the first day of the conference. This time, the conference proceedings will be available via download from the internet, rather than the traditional CD/pen-drive form. The proceedings will also be accessible via IEEEXplore. In addition, four best paper awards and two best graduation day talks have been instituted with the support of Springer Nature.

The success of SPCOM depends on the efforts of the various organizing committees and the volunteers from among the students and staff at IISc. We sincerely thank all the committee chairs and members for doing a stellar job with the various aspects of organizing a major conference. In particular, we applaud the efforts of the technical program committee in putting together an excellent technical program. We also would like to express our gratitude to our army of student and staff volunteers for ensuring the smooth running of the conference. Finally, we extend our thanks to the sponsors whose financial contributions made this conference possible. These sponsors will be exhibiting

their cutting-edge products in their respective booths, and we encourage you to visit them.

We invite you to participate in and enjoy SPCOM 2018.

Chandra R Murthy and **KJ Vinoy**
General Co-Chairs, SPCOM 2018

Chandra R Murthy

KJ Vinoy

MESSAGE FROM THE TPC CO-CHAIRS

It gives us great pleasure to welcome you to SPCOM 2018. The reputation of the past SPCOMs made it easy for us to put together an excellent program this year.

We are delighted to have Alexander Vardy, David Gesbert, and Volkan Cevher as our plenary speakers. As always, additional invited talks from leading national and international researchers occupy a place of pride in our technical program. They are organized under different themes this year. Staying true to the SPCOM tradition, we also have an excellent set of 6 tutorials on cutting-edge research topics.

Some statistics: This year, we had 285 submitted papers. Of these, we accepted 102, resulting in an acceptance ratio of 35.7%. All the papers were assigned to three or more reviewers. We secured at least two reviews per paper, with the vast majority of the papers receiving at least 3 reviews.

We would like to thank all the TPC members and the reviewers for their timely and sincere efforts in ensuring the high quality of the program. We also thank the student volunteers for helping run SPCOM. We thank Rajiv Soundararajan and Praneeth Netrapalli for putting together an excellent tutorial program, and thank Aditya Gopalan for handling the website.

Last, but not least, we thank you – the authors, presenters, and attendees at SPCOM 2018. This conference belongs to you, and the success of SPCOM is ultimately because of your contributions! We look forward to personally interacting with many of you during the conference, and wish you an enjoyable SPCOM 2018!

With best regards,
Neelesh B. Mehta, Srikrishna Bhashyam, and **David Wipf**
TPC Co-Chairs, SPCOM 2018

Neelesh B. Mehta

Srikrishna Bhashyam

David Wipf

Day	Time	ECE GJH	ECE 1.08	ECE 1.07
Monday (16th July)	08:00 - 09:30	**Registration for SPCOM 2018 at Dept of ECE**		
	09:30 - 13:00	**AM1:** PCA and Robust PCA for Modern Datasets	**AM2:** 5G: An Evolution Towards a Revolution	**AM3:** Teasing out the multi-scale representational space of cross-modal speech perception: Methods and mechanisms
	13:00 - 14:15	**Lunch**		
	14:15 - 17:45	**PM1:** Introduction to Reinforcement Learning	**PM2:** Video Streaming: On Rate-Adaptation, Multipath, Virtual Reality, and Content Distribution Network	**PM3:** Need for Low Power Communications and Localization

Day	Time	JN Tata Auditorium	Hall A	Hall B	Hall C
Tuesday (17th July)	08:00 - 09:00	**Registration for SPCOM 2018 (JN Tata Auditorum)**			
	09:00 - 09:15	**Conference Inauguration [JN Tata Auditorium]**			
	09:15 - 10:30	**TU01:** Coding for Data Communications and Storage	**TU02:** Audio and Speech Recognition and Classification	**TU03:** Optical Communications and Networks	**TU04:** Compressive Sensing and Applications
	10:30 - 11:00	**Coffee Break**			
	11:00 - 12:00	**Plenary Talk by Prof. Alexander Vardy [JN Tata Auditorium]**			
	12:00 - 12:15	**Break**			
	12:15 - 13:15	**TU05:** Cognitive Radio	**TU06:** Applications of Audio and Speech Processing	**TU07:** RF Systems for Communication - 1	**TU08:** Energy Harvesting Communication Systems
	13:15 - 14:15	**Lunch**			
	14:15 - 15:30	**TU09:** RF Systems for Communication - 2	**TU10:** Audio and Speech Processing - 1	**TU11:** Image and Video Signal Processing	**TU12:** Signal Processing Algorithms and Architecture
	15:30 - 16:00	**Coffee Break**			
	16:00 - 17:45	**SP.TU13:** Full Duplex and LPWAN	**SP.TU14:** Caching in cellular networks	**SP.TU15:** Computational Imaging	**SP.TU16:** Estimation and information theory

Day	Time	JN Tata Auditorium	Hall A	Hall B	Hall C
Wednesday (18th July)	08:00 - 09:00	**Registration for SPCOM 2018 at JN Tata Auditorum**			
	09:00 - 10:15	**WE01:** Wireless, Vehicular and Smart Grid Networks	**WE02:** Speech Recognition	**WE03:** OFDM and Multicarrier Techniques	**WE04:** VLSI for Communication and Signal Processing
	10:15 - 10:45	**Coffee Break**			
	10:45 - 11:45	**Plenary Talk by Prof. David Gesbert [JN Tata Auditorium]**			
	11:45 - 12:00	**Break**			
	12:00 - 13:00	**WE05:** NB-IoT	**WE06:** Spoken Language Processing	**WE07:** Forensics and Security	**WE08:** Physical Layer Security
	13:00 - 14:00	**Lunch**			
	14:00 - 15:15	**WE09:** Massive MIMO	**WE10:** Audio and Speech Processing - 2	**WE11:** Machine Learning/AI for Signal Processing	**WE12:** Bio Signal Processing
	15:15 - 15:45	**Coffee Break**			
	15:45 - 17:30	**SP.WE13:** Speech Processing	**SP.WE14:** Full Duplex Communications	**SP.WE15:** Security and privacy	**SP.WE16:** Quantum information technology
	17:45 - 18:45	**TVS Felicitation [JN Tata Auditorium]**			
	19:00 - 21:00	**Conference Dinner [Main Guest House Lawns]**			

Day	Time	JN Tata Auditorium	Hall A	Hall B	Hall C
Tuesday (19th July)	08:00 - 09:00	**Registration for SPCOM 2018 at JN Tata Auditorum**			
	09:00 - 10:15	**TH01:** Information Theory	**TH02:** Topics in Signal Processing	**TH03:** Machine Learning/AI and Applications	**TH04:** Cooperative and Visible Light Communications
	10:15 - 10:20	**Break**			
	10:20 - 11:20	**Plenary Talk by Prof. Volkan Cevher [JN Tata Auditorium]**			
	11:20 - 11:45	**Coffee Break**			
	11:45 - 13:30	**SP.TH05:** 5G and next generation networking	**SP.TH06:** Mm-wave and THz systems	**SP.TH07:** Deep learning	
	13:30 - 14:30	**Lunch**			
	14:30 - 16:00	**Graduation Day**			

A Lifetime in Research

Venue: J.N. Tata Auditorium / **Time:** 17:45 to 18:45 hrs

Date: July 18, 2018

Overview of the session:

This session is being organized in honor of Prof. Thippur V. Sreenivas, Department of Electrical Communication Engineering (ECE), Indian Institute of Science (IISc.), who will be superannuating on July 31, 2018. Prof. TVS, as he is fondly called, joined the ECE department in 1990. He received a PhD degree from Tata Institute of Fundamental Research, Mumbai in 1981. Prior to joining the ECE department, he spent about four years at Electronics and Radar Development Establishment (LRDE), Bangalore. He was also a postdoctoral fellow at Norwegian University of Science and Technology, Trondheim, Norway, and Marquette University, Milwaukee, USA before joining the department. He held visiting positions at Fraunhofer Institute of Technology, Ilmenau, Germany; Griffith University, Brisbane; and Royal Institute of Technology (KTH), Stockholm, Sweden. Over a research career spanning four decades, he supervised and mentored several PhD and Masters students and produced seminal results in signal processing, in particular, speech and audio processing. Several of his past students are now holding faculty positions in reputed institutions in the country and elsewhere in the world. His passion and enthusiasm for research and teaching are infectious. He has been instrumental in setting up the IEEE Signal Processing Society, Bangalore Chapter. Early on in his career, he shouldered the responsibility of organizing the SPCOM series of conferences. The Winter School on Speech and Audio Processing (WiSSAP) series of focused thematic schools is also his brainchild. It was his vision to create a knowledge-sharing platform for the speech and audio signal processing researchers from all over the country to meet on a regular basis. The WiSSAP series took root in IISc. and then moved on to the other premier institutions within the country. It has successfully completed thirteen editions so far without a break ever since it started. The WiSSAP series attracts the best minds from within the country and expert speakers from universities abroad working in the broad area of speech and audio processing. Research students have been the greatest beneficiaries of WiSSAP.

TV Sreenivas

This session is being organized to felicitate him for his seminal academic contributions and organizational achievements throughout his tenure at IISc. and to wish him a happy and healthy post-retirement life.

P1

P1: Past, Present, and Future of Polar Coding

Alexander Vardy

(University of California San Diego, USA)

July 17, 11:00-12:00

Venue: JN Tata Auditorium

Abstract: Polar coding, invented by Arikan ten years ago, is one of the most original and profound developments in coding theory to date. We will not attempt to summarize 10 years of polar coding in one talk. Instead, we hope this talk will provide a glimpse into several topics curated from the past, present, and future of polar codes. No prior knowledge of polar coding is assumed; we will begin with a brief tutorial on polarization theory and polar codes. We will then describe the list-decoding algorithm for polar codes, and how it is used in the 5G standard. We will also present our recent results on polar codes with large kernels. In particular, we will show that such codes not only approach capacity, but do so as fast as theoretically possible, at least on the binary erasure channel. Finally, if time permits, we will speculate on how polar codes can be used to correct synchronization errors, such as deletions and insertions.

Bio: Alexander Vardy was born in Moscow, U.S.S.R, and grew up in Israel. He graduated summa cum laude from the Technion – Israel Institute of Technology in 1985, and completed his Ph.D. in 1991 at the Tel Aviv University. He is currently the Jack Keil Wolf Endowed Chair Professor at the University of California San Diego, where he is affiliated with the Department of Electrical & Computer Engineering and the Department of Computer Science.

He received an IBM Invention Achievement Award in 1993, and NSF Research Initiation and CAREER awards in 1994 and 1995. In 1996, he was appointed Fellow in the Center for Advanced Study at the University of Illinois, and was named a Fellow of the David and Lucile Packard Foundation. He received the IEEE Information Theory Society Paper Award (jointly with Ralf Koetter) for the year 2004. In 2005, he received the Fulbright Senior Scholar Fellowship, and the Best Paper Award at the IEEE Symposium on Foundations of Computer Science (FOCS). In 2017, his work on polar codes was recognized by the the IEEE Communications & Information Theory Societies Joint Paper Award.

P2

P2: Learning from the Sky: Autonomous Flying Access Networks for Beyond 5G

David Gesbert

(EURECOM, Sophia Antipolis, France)

July 18, 10:45-11:45

Venue: JN Tata Auditorium

Abstract: The use of flying robots (drones) carrying radio transceiver equipment is the new promising frontier in our quest towards ever more flexible, adaptable and spectrally efficient wireless networks. Beyond obvious challenges within regulatory, control, navigation, and operational domains, the deployment of autonomous flying radio access network (Fly-RANs) also come with a number of exciting new research problems such as the issue of autonomous real-time placement of the drones in non-trivial propagation scenarios (i.e. scenarios where the optimal placement is not just dictated by a trivial geometry or statistical argument due to shadowing effects, e.g. in cities). We present several different approaches, lying at the cross-roads between machine learning, signal processing and optimization. Some approaches involve the reconstruction of a city map from sampled radio measurements which can have application beyond the realm of communications.

Bio: David Gesbert (IEEE Fellow) is Professor and Head of the Communication Systems Department, EURECOM. He obtained the Ph.D degree from Ecole Nationale Superieure des Telecommunications, France, in 1997. From 1997 to 1999 he has been with the Information Systems Laboratory, Stanford University. He was then a founding engineer of Iospan Wireless Inc, a Stanford spin off pioneering MIMO-OFDM (now Intel). Before joining EURECOM in 2004, he has been with the Department of Informatics, University of Oslo as an adjunct professor. D. Gesbert has published about 270 papers and 25 patents, some of them winning the 20015 IEEE Best Tutorial Paper Award (Communications Society), 2012 SPS Signal Processing Magazine Best Paper Award, He held visiting professor positions in KTH (2014) and TU Munich (2016). Since 2017 he is also a visiting Academic Master within the Program 111 at the Beijing University of Posts and Telecommunications as well as as a member in the Joint BUPT-EURECOM Open5G Lab. Since 2015, he holds the ERC Advanced grant "PERFUME" on the topic of smart device Communications in future wireless networks.

P3

P3: Trade-offs in Resource Constrained Machine Learning Systems

Volkan Cevher

(Ecole Polytechnique Federale de Lausanne, Switzerland)

July 19, 10:20-11:20

Venue: JN Tata Auditorium

Abstract: Massive data poses a fundamental challenge to learning algorithms, which is captured by the following computational dogma: the running time of an algorithm increases with the size of its input data. The available computational power, however, is growing slowly relative to data sizes. Hence, large-scale machine learning problems of interest require increasingly more time to solve.

Our research demonstrates that this dogma is false in general, and supports an emerging perspective in computation: data should be treated as a resource that can be traded off with other resources, such as running time. For data acquisition and communications, we have also shown related sampling, energy, and circuit area trade-offs.

This talk will summarize our work confronting these challenges by building on the new mathematical foundations on how we generate data via sampling, how we set up learning objectives that govern our fundamental goals, and how we optimize these goals to obtain solutions and to make optimal decisions. We then demonstrate task-specific, end-to-end trade-offs (e.g., samples, power, computation, storage, and statistical precision) in broad domains.

Bio: Volkan Cevher received the B.Sc. (valedictorian) in electrical engineering from Bilkent University in Ankara, Turkey, in 1999 and the Ph.D. in electrical and computer engineering from the Georgia Institute of Technology in Atlanta, GA in 2005. He was a Research Scientist with the University of Maryland, College Park from 2006-2007 and also with Rice University in Houston, TX, from 2008-2009. Currently, he is an Associate Professor at the Swiss Federal Institute of Technology Lausanne and a Faculty Fellow in the Electrical and Computer Engineering Department at Rice University. His research interests include signal processing theory, machine learning, convex optimization, and information theory. Dr. Cevher was the recipient of the IEEE Signal Processing Society Best Paper Award in 2016, a Best Paper Award at CAMSAP in 2015, a Best Paper Award at SPARS in 2009, and an ERC CG in 2016 as well as an ERC StG in 2011.

AM1

AM1: PCA and Robust PCA for Modern Datasets

Namrata Vaswani

(Iowa State University, USA)

July 16, 09:30-13:00

Venue: Golden Jubilee Hall, Department of Electrical Communication Engineering

Abstract: In today's big data age, there is a lot of data generated everywhere around us. Examples include texts, tweets, network traffic, changing Facebook connections, or video surveillance feeds coming in from one or multiple cameras. Before processing any big dataset, the first step is to perform dimension reduction and noise/outlier removal. Traditionally, dimension reduction is done by solving the principal components' analysis (PCA) problem. While this is a very old problem, many of the traditional techniques fail if the data is corrupted by anything other than small and uncorrelated noise. PCA and robust PCA and their streaming counterparts have a very large number of applications since dimension reduction is a key first step in a very large variety of applications. Some examples include exploratory data analysis, video analytics, recommendation system design, and many more.

The tutorial will begin with a brief introduction to the basic random matrix theory results needed by some of the theoretical guarantees that will be discussed (depending on audience background and interest). Most of the tutorial will talk about the original PCA problem; about PCA when data and noise are correlated (correlated-PCA); and about PCA in the presence of large but structured, e.g., sparse, noise (robust PCA). Moreover, because all the data cannot be stored, or because there is a need to make decisions in real-time, and/or because the structure of the data could itself change significantly over time, there is a lot of interest in streaming algorithms for PCA or robust PCA and their dynamic (tracking) counterparts. About half of the tutorial will talk about old and new approaches to streaming PCA and streaming dynamic robust PCA.

PCA has been a problem that has been studied for almost a century dating back to the work of Hotelling from the 1930s among others. However, the correlated-PCA problem has received almost no attention until very recently. Robust PCA has also been studied for a few decades. However, the new series of works on provably correct and practically usable robust PCA started appearing in 2011 and later. The work on provably correct streaming or dynamic robust PCA techniques only started appearing in 2014 and later. There has

been older work on streaming or online PCA, but there has been much a renewed interest in recent years on online PCA, streaming (memory-optimal single pass) solutions for PCA, and on fast algorithms for partial SVD.

Bio: Namrata Vaswani is a Professor of Electrical and Computer Engineering, and (by courtesy) of Mathematics, at Iowa State University. She received a Ph.D. in 2004 from the University of Maryland, College Park and a B.Tech. from Indian Institute of Technology (IIT-Delhi) in India in 1999. Her research interests lie at the intersection of statistical machine learning / data science, computer vision, and signal processing. She is a recipient of the Harpole-Pentair Assistant Professorship and the Iowa State Early Career Engineering Faculty Research Award at Iowa State. In 2014, she received the IEEE Signal Processing Society (SPS) Best Paper Award for her Modified-CS work that was co-authored with her graduate student Lu in the IEEE Transactions on Signal Processing in 2010. Vaswani has served the SPS and IEEE in various capacities. She is an Area Editor for IEEE Signal Processing Magazine and has served twice as an Associate Editor for IEEE Transactions on Signal Processing. She is the Lead Guest Editor for a Proceedings IEEE Special Issue on Rethinking PCA for Modern Datasets, and of a Signal Processing Magazine Feature Cluster on Exploiting Structure in High-dimensional Data Recovery, both of which will appear in 2018.She is also the Chair of the Women in Signal Processing (WiSP) Committee, a steering committee member of SPS's Data Science Initiative, and an elected member of the SPTM and IVMSP Technical Committees.

AM2: 5G: An Evolution Towards a Revolution

Karthik Sundaresan
(NEC Laboratories America, USA)

July 16, 09:30-13:00

Venue: ECE 1.08, Department of Electrical Communication Engineering

Abstract: The aim of this tutorial is to give the audience an overview of the landscape of the future generation of mobile networks, namely 5G. Contrary to popular view, 5G is not expected to be anchored on a single disruptive technology but rather supported by an amalgamation of multiple technologies. In essence, it is an evolution of several key technical advancements, whose synergy is expected to revolutionize the heterogeneity of use cases that can be "simultaneously" enabled by a single network. Such use cases range from throughput-focused mobile broadband (Gigabit peak rates) to latency/reliability-focused mission critical (e.g. augmented/virtual reality, autonomous driving) and density-focused massive connection (IoT) services.

While physical layer advancements in the form of New Radio (NR) are an integral part of 5G, realizing the diverse use cases envisioned, will equally require innovation and flexible orchestration of its access, network and computing layers as well. This tutorial will provide an overview of some of these innovative ingredients that will constitute 5G, from the perspective of not just radio access network, but also core network and services/applications. It will cover topics ranging from communication and networking to architectural designs, automation and use cases, including but not limited to

1. Radio: new radio (NR), mmWave, flexible OFDM numerology, advanced coding
2. Access: IoT-optimized access, hybrid access (licensed, shared and unlicensed spectrum)
3. Network: cloud deployments, virtualization and network slicing
4. Computing: network function virtualization, scalable core design, mobile edge computing
5. Automation: network access, provisioning and management
6. Case studies: Augmented reality over LTE networks, self-configuring UAV-based LTE networks

Bio: Karthik Sundaresan is a senior researcher in the mobile communications and networking research department at NEC Labs America. His research interests are broadly in wireless networking and mobile computing, and span both algorithm design as well as system prototyping. He is the recipient of ACM Sigmobile's Rockstar award (2016) for early career contributions to the field of mobile computing and wireless networking, as well as several best paper awards at prestigious ACM and IEEE conferences. He holds over thirty patents and received a business contribution award from NEC for the technology commercialization of an LTE small-cell interference management technology. He has participated in various organization roles for IEEE and ACM conferences, and served as the PC co-chair for ACM MobiCom'16. He is a senior member of IEEE and currently serves as an associate editor for IEEE Transactions on Mobile Computing

AM3: Teasing out the Multi-Scale Representational Space of Cross-Modal Speech Perception: Methods and Mechanisms

Arpan Banerjee

(National Brain Research Center, India)

July 16, 09:30-13:00

Venue: ECE 1.07, Department of Electrical Communication Engineering

Abstract: Multisensory integration has excited a large group of researchers from psychologists, computer scientists, neurphysiologists and finally neuroimaging community and triggered a wide body of research. Yet, the representational space of multisensory processing such as during cross-modal speech perception remains elusive. In this talk I would like to delimit the boundaries of this representational space using the results obtained from multimodal neuroimaging techniques, EEG and fMRI.

In the first part of this talk I will talk about network analysis tools that are currently used in the literature for analysis of EEG/ MEG and functional MRI data. Network methods have become an important tool to identify and characterize neural mechanisms of various cognitive process as well as quantifying neurological and neuropsychiatric disorders. I will also present some existing issues with EEG/ MEG source analysis techniques and discuss the use of these methods with empirical data sets. I will talk about neurobiologically realistic modeling tools using dynamic systems theory. Thereafter I will illustrate how the latter approach is important in interpreting the outcome of network analysis tools in particular validation of ground truth.

In the second part of the talk, I would talk about a behavioral paradigm with which we have been able to track cross-modal speech perception using psychophysical control parameters such temporal ordering of audio-visual stimulus. Using EEG and fMRI recordings on human volunteers, I will illustrate how the spatiotemporal functional network patterns can be used to understand the processing of behavior. Finally I would present a computational model inspired by neurobiologically realistic parameters that attempts to link the behavioral results with patterns of activity observed in neuroimaging recordings. The overarching goal of the talk is to build a mechanistic understanding of the neural dynamics observed at individual brain regions and across a functional network comprised of multiple brain areas underlying speech perception.

Bio: Arpan Banerjee received his PhD in Complex Systems and Brain sciences from Florida Atlantic University, USA primarily working in the area of bimanual motor coordination in humans. He has completed his post-PhD training at Center for Neural Sciences, New York University and The National Institutes of Health, USA working in signal processing and spike train, LFP and MEG recordings. Currently his interests are in using computational neuroscience and multimodal brain imaging EEG/MEG/ fMRI to understand accurately where (spatial) and when (temporal) task-related differences in information processing occur in the brain during multisensory integration, higher order visual processing and cognition. The key research question that he wants to address is how large networks of neurons coordinate amongst each other to form organized assemblies at only specific instants of time to orchestrate ongoing behavior. Demystifying the tunes that govern this neural orchestra will shed light to subtle differences in human brain function across normal individuals, across patients and eventually lead to developing neuro-markers for spectrum disorders such as autism.

PM1: Introduction to Reinforcement Learning

Harm van Seijen

(Microsoft Research, Montreal, Canada)

July 16, 14:15-17:45

Venue: Golden Jubilee Hall, Department of Electrical Communication Engineering

PM1

Abstract: This talk will give an overview of reinforcement learning, a machine learning approach to learn optimal behavior that has gained a lot of traction in the last few years. In the reinforcement-learning setting, an agent interacts with an initially unknown environment and tries to maximize the total reward it receives via a trial-and-error process. By using deep neural networks as internal representation, reinforcement learning methods have become substantially more powerful in recent years, achieving above-human performance on many challenging tasks, from robotic control to the ancient game of Go. We will discuss the basic theory behind reinforcement learning and discuss the relation with other popular machine learning approaches. Furthermore, we will discuss recent results, as well as remaining challenges and active areas of research.

Bio: Harm van Seijen is the research manager of the reinforcement learning team at Microsoft Research, Montreal. His work focuses on fundamental challenges in reinforcement learning. He obtained his PhD in 2011 from the University of Amsterdam on the topic of reinforcement learning under space and time constraints. Prior to his position at Microsoft, he was a Postdoctoral Fellow at the University of Alberta, working together with Professor Richard Sutton on novel reinforcement-learning methods, and was affiliated with the startup company Maluuba.

PM2

PM2: Video Streaming: On Rate-Adaptation, Multipath, Virtual Reality, and Content Distribution Network

Vaneet Aggarwal
(Purdue University, USA)

July 16, 14:15-17:45

Venue: ECE 1.08, Department of Electrical Communication Engineering

Abstract: Mobile video has emerged as a dominant contributor to cellular traffic. It already accounts for around 40-55 percent of all cellular traffic and is forecast to grow by around 55 percent annually through 2021. While its popularity is on the rise, delivering high quality streaming video over cellular networks remains extremely challenging. In particular, the video quality under challenging conditions such as mobility and poor wireless channel is sometimes unacceptably poor. Almost every viewer at some point in time can relate to experiences of choppy videos, stalls, etc. This tutorial aims to provide fundamental approaches to improve the quality of experience (QoE) for video viewing at the end users.

Not surprisingly, a lot of attention from both research and industry in the past decade has focused on the development of adaptive streaming techniques for video on demand that can dynamically adjust the quality of the video being streamed to the changes in network conditions. In this tutorial, we will start with explaining the basics of adaptive bit-rate video streaming, and some of the existing algorithms. Further, we will theoretically formulate the problem of adaptive video streaming with the knowledge of future bandwidth. The non-convex integer-constrained streaming problem will be showed to be solvable optimally in linear time complexity, giving a new class of algorithms in combinatorial optimization which in complexity class P. The algorithms can be extended to window-based online mechanisms, with harmonic mean or crowd-sourced imperfect bandwidth prediction. Results over a realistic testbed will also be demonstrated. Further extensions to multiple paths, and link preference (eg. WiFi over LTE) will be provided.

The 360-degree technology is shaping the video industry. 360-degree videos provide users a panoramic view creating a unique viewing experience. 360-degree videos, also known as immersive or spherical videos, are essential parts of the virtual reality (VR) which are changing the user's experience of video streaming. VR is projected to form a big market of $120 billion by 2020. 360-degree videos are very popular on major video platforms such as YouTube, Facebook. However, the current popular technologies for streaming try to fetch the all the portion of the chunk in the same quality including both the visible and invisible portions. Though this method is simple, it has some disadvantages. For example, the bandwidth utilization is high as the chunks in the 360-degree videos are of larger sizes compared to the traditional ones. Thus, if the network is congested or the bandwidth is low, it will lead to a poor-quality video. Hence, without smart algorithms, it can easily consume the wireless bandwidth. Even the wireline capacity may not be enough for such 360-degree videos. We will provide the challenges in designing bandwidth-efficient streaming algorithm for 360-degree videos for maximizing the quality of service (or quality of experience) of the users. Such approaches use head movement prediction, which brings new challenges in addition to the bandwidth prediction.

So far, we considered the aspect of the last hop, which is wireless. In the final part, we will present the network side of the video transfer. The network designers can only control the wired part. With the same network controlling multiple users, the network becomes a bottleneck. We will provide a holistic framework considering the multiple network control knobs to optimize delivery from the network. Over-the-top video streaming, e.g., Netflix and YouTube, has been dominating the global IP traffic in recent years. The traffic will continue to grow due to the introduction of even higher resolution video formats such as 4K on the horizon. As end-users consume video in massive amounts and in an increasing number of ways, service providers need flexible solutions in place to ensure that they can deliver content quickly and easily regardless of their customer's device or location. More than 50% of over-the-top video traffic is now delivered through content distribution networks (CDNs). Even though multiple solutions have been proposed for improving congestion in the CDN system, managing the ever-increasing traffic requires a fundamental understanding of the system and the different design flexibilities (control knobs) to make the best use of the hardware limitations. The service providers typically use two-tiered caching approach to improve the streaming service. In addition to the distributed cache servers provided by the CDN, the edge router can also have a cache. The different control knobs include the choice of distributed server, caching, queue management, etc., to optimize the end user QoE.

Bio: Vaneet Aggarwal received the B.Tech. degree in 2005 from the Indian Institute of Technology, Kanpur, India, and the M.A. and Ph.D. degrees in 2007 and 2010, respectively from Princeton University, Princeton, NJ, USA, all in Electrical Engineering.

He is currently an Assistant Professor at Purdue University, West Lafayette, IN (2015-current) and a VAJRA Adjunct Professor at IISc Bangalore (2018-current). Prior to this, he was a Senior Member of Technical Staff Research at AT&T Labs-Research, NJ (2010-2014),

and an Adjunct Assistant Professor at Columbia University, NY (2012-2014). He is an IEEE Senior Member (2015-current). His current research interests are in communications and networking, video streaming, cloud computing, and machine learning.

Dr. Aggarwal is on the editorial board of the IEEE Transactions on Communications and the IEEE Transactions on Green Communications and Networking. He was the recipient of Princeton University's Porter Ogden Jacobus Honorific Fellowship in 2009, the AT&T Key Contributor award in 2013, AT&T Vice President Excellence Award in 2012, and AT&T Senior Vice President Excellence Award in 2014. He was also the recipient of the 2017 Jack Neubauer Memorial Award, recognizing the Best Systems Paper published in the IEEE Transactions on Vehicular Technology.

PM3: Need for Low Power Communications and Localization

Dinesh Bharadia

(University of California San Diego, USA)

July 16, 14:15-17:45

Venue: ECE 1.07, Department of Electrical Communication Engineering

Abstract: Low Power communication and localization has applications in sensing and measuring of our environment, to building smart cities and smart transportation systems and so on. In this tutorial, I would present a communication and localization system which can connect to existing WiFi infrastructure while using low power backscatter techniques. Specifically, I would elaborate use of network coding principles to build the above communication system. I would show a real-time demonstration of the low power system using an embedded systems platform built during the project.

Bio: Dinesh Bharadia is faculty in ECE at University of California San Diego. Prior to UCSD, Dinesh Bharadia received his Ph.D. from Stanford University was a Postdoctoral Associate at MIT. Specifically, in his dissertation, he built the prototype of a radio, that invalidated a long-held assumption in wireless is that radios cannot transmit and receive at the same time on the same frequency. In recognition of his work, Dinesh was named to Forbes 30 under 30 for the science category worldwide list. Dinesh was also named a Marconi Young Scholar for outstanding wireless research and awarded the Michael Dukakis Leadership award. He was also named as one of the top 35 Innovators under 35 in the world by MIT Technology Review in 2016. Dinesh is also the recipient of the Sarah and Thomas Kailath Stanford Graduate Fellowship. From 2013 to 2015, he was a Principal Scientist for Kumu Networks, where he worked to commercialize his research on full-duplex radios, building a product that underwent successful field trials at Tier 1 network providers worldwide like Deutsche Telekom and SK Telecom. This product is currently under deployment. His research interests include advancing the theory and design of modern wireless communication systems, wireless imaging, sensor networks and data-center networks.

Venue: JN Tata Auditorium
Time: 14:30-16:15 / **Date:** July 19, 2018

Graduation Day Session will highlight the research of PhD students close to graduation. We received several nominations and selected the following candidates from universities across India and other participating institutions. Out of these shortlisted candidates, two talks will be chosen as the Best Graduation Day Session talks and awarded a certificate and a gift voucher from Springer. Please join us and get a fifteen-minute summary of these outstanding research efforts.

Lan Vinh Truong
National University of Singapore
Advisor: Vincent Y. F. Tan
Thesis title: Refined Asymptotics for the Fundamental Limits of Communications with Feedback
Thursday, July 19, 14:30-14:45

Asit Kumar Pradhan
Indian Institute of Technology Madras, India
Advisor: Andrew Thangaraj
Thesis title: Capacity-approaching protograph based LDPC codes with block-error threshold
Thursday, July 19, 14:45-15:00

Dixita Limbachiya
Dhirubhai Ambani Institute of Information and Communication Technology Gandhinagar, India
Advisor: Manish K. Gupta
Thesis title: On Designing DNA Codes and their Applications
Thursday, July 19, 15:00-15:15

Amrit Singh Bedi
Indian Institute of Technology Kanpur, India
Advisor: Ketan Rajawat
Thesis title: Distributed and Online Learning with Stochastic Gradient Methods
Thursday, July 19, 15:15-15:30

Abhijeet Bishnu
Indian Institute of Technology Indore, India
Advisor: Vimal Bhatia
Thesis title: Receiver Design for TV White Space
Thursday, July 19, 15:30-15:45

Chandu DS
Indian Institute of Information Technology Design & Manufacturing Kancheepuram, India
Advisor: S. S. Karthikeyan
Thesis title: Investigations and Implementation of Novel Methods in the Design of Circularly Polarized Printed Antennas
Thursday, July 19, 15:45-16:00

Sharu Theresa Jose
Indian Institute of Technology Bombay, India
Advisor: Ankur A. Kulkarni
Thesis Title: Linear Programming-based Finite Blocklength Converses in Information Theory
Thursday, July 19, 16:00-16:15

TU01

TU01 - Coding for Data Communications and Storage

Tuesday, July 17, 09:15 - 10:30

Venue: JN Tata Auditorium

Chair: P Vijay Kumar (Indian Institute of Science Bangalore, India)

On the Exact Rate-Memory Trade-off for Multi-access Coded Caching with Uncoded Placement

09:15 - 09:33

Srinivas Reddy Kota (Indian Institute of Technology Bombay, India)
Nikhil Karamchandani (Indian Institute of Technology Bombay, India)

We study a cache-aided content delivery network consisting of a central server which hosts a catalog of N files, and K caches each with limited memory M which store content related to the files. There are K users, each of which requests a file from the catalog, and has access to the data stored in $L \ge 1$ neighboring caches (with a cyclic wrap-around). The server transmits a common message to all the users, so that each of them can recover their requested file. This setup was recently studied in \cite{hachem2017codedmulti}, where a coloring-based placement and coded-delivery policy was proposed and the required server transmission size was shown to be \textit{order-optimal} with respect to information-theoretic bounds. We propose an alternate index coding-based placement and delivery scheme for this setup, which performs better than the previously proposed strategy. Furthermore, for multiple special cases including the $(N, K \le 4, L)$ and $(N, K, L = K-1)$-setups, we show that the scheme is \textit{exactly optimal} under the restriction of uncoded placement. This extends other recent work \cite{wan2016optimality,yu2017exact} which studies exact optimality for the single cache-access case ($L=1$) to the multi cache-access case $(L > 1$).

Stall-Quality Tradeoff for Cloud-based Video Streaming

09:33 - 09:52

Abubakr O. Al-Abbasi (Purdue University, USA)
Vaneet Aggarwal (Purdue University, USA)

In this paper, video streaming over distributed storage is considered where the video segments are encoded using an erasure code for better reliability. There are multiple parallel streams between each server and the edge router. For each client request, we need to determine the subset of servers to get the data, as well as one of the parallel stream from each chosen server. In order to have this scheduling, this paper proposes a two-stage probabilistic scheduling. The selection of video quality is also chosen with a certain probability distribution. Based on this, we formulate an optimization problem to jointly optimize the convex combination of mean stall duration and average video quality for all requests, where the two-stage probabilistic scheduling, probabilistic video quality selection, bandwidth split among parallel streams, and auxiliary bound parameters can be chosen. This non-convex problem is solved using an efficient iterative algorithm. Numerical results show significant improvement in QoE metrics for cloud-based video as compared to the considered baselines.

A Novel Truncation Rule for the EMS Decoding of Non-binary LDPC Codes

09:52 – 10:11

Kuntal Deka (Indian Institute of Technology Goa, India)
Alentattil Rajesh (Indian Institute of Technology Guwahati, India)
Prabin Kumar Bora (Indian Institute of Technology Guwahati, India)

This paper presents a novel truncation rule for the extended min-sum (EMS) decoding of non-binary low-density parity-check (NB-LDPC) codes. The conventional NB-LDPC decoders involve vector-messages of length equal to the field size q. The complexity of these decoders increases significantly as q increases. In the EMS algorithm, the vector-messages are truncated by discarding the less-likely symbols. In this paper, we propose a truncation rule so that the lengths of the vector-messages are reduced to the so-far best limit without compromising on the error correction capability. We devise a proximity matrix which helps to identify the essential components of a vector-message for truncation. The proposed truncation rule has been applied to several NB-LDPC codes of different field sizes. Simulation results for these codes show that the proposed rule can achieve the maximum truncation with negligible performance loss.

Locality and Availability with Multiple Erasure Correction

10:11 - 10:30

Ujwal Deep Kadiyam (Indian Institute of Technology Guwahati, India)

Locally recoverable codes that can correct one or more erasures in each local group exist. An LRC is said to have availability if each symbol has disjoint recovery sets and the symbol can be recovered from any of the disjoint sets. Tamo and Barg constructed optimal codes with availability, but different disjoint repair groups can have different locality for each information symbol. No bound on minimum hamming distance exists for codes with availability in this scenario. Codes with availability can also locally correct multiple erasures in a local group. But the disk I/O is higher. We construct codes with different locality for different disjoint repair groups for each information symbol and derive a bound on the minimum hamming distance of these codes. We show that different disjoint repair groups can be protected by local codes of different minimum hamming distances. We show that optimal codes can be constructed based on pyramid codes.

TU02

TU02 - Audio and Speech Recognition and Classification
Tuesday, July 17, 09:15 - 10:30
Venue: Hall-A
Chair: Hemant A. Patil (Dhirubhai Ambani Institute of Information and Communication Technology Gandhinagar, India)

Exploring the Role of Speaking-Rate Adaptation on Children's Speech Recognition
09:15 - 09:33
Syed Shahnawazuddin (National Institute of Technology Patna, India)
Hemant Kathania (National Institute of Technology Sikkim, India)
Chaman Singh (National Institute of Technology Patna, India)
Waquar Ahmad (National Institute of Technology Sikkim, India)
Gayadhar Pradhan (National Institute of Technology Patna, India)
Earlier studies have shown that, both intra-speaker and inter-speaker variabilities affect the recognition performance of any automatic speech recognition (ASR) system. The differences in speaking-rate among the speakers is one such factor affecting the system performance. An extreme example where speaking-rate variations become detrimental is the task of recognizing children's speech on an ASR system trained using adults' speech. In the context of such mismatched ASR tasks, only a few works on speaking-rate adaptation (SRA) through time-scale modification (TSM) have been reported. In addition to that, effect of TSM was explored on ASR systems developed using Gaussian mixture models (GMM). Motivated by these facts, the role of SRA is studied in this work in the context of ASR systems employing deep neural networks (DNN) for statistical modelling. Further, adaptation is done by changing the frame-length and overlap during front-end speech parameterization phase. SRA leads to significant reductions in errors as demonstrated by the experimental evaluations reported in this work. The effect of combining SRA with explicit pitch modification is also studied in this paper. Pitch modification is reported to be very effective in the case of children's mismatched ASR. Combining the two techniques results in additive reductions in errors.

Proportionate Subband Filtering Technique with L1-Norm for Feedback Cancellation in Hearing Aids
09:33 - 09:52
Vasundhara Vasundhara (Indian Institute of Technology Bhubaneswar, India)
Niladri Puhan (Indian Institute of Technology Bhubaneswar, India)
Ganapati Panda (Indian Institute of Technology Bhubaneswar, India)
Adaptive feedback cancellers (AFCs) based on normalized subband adaptive filtering (NSAF) exploiting the proportionate adaptation technique (PNSAF) have been recently reported for alleviating the feedback effect. The PNSAF algorithm exhibits faster convergence at the initial stage of adaptation whereas stagnating the convergence at later phase of the estimation process. An attempt has been made in this work to maintain the AFC convergence and misalignment in such conditions by introducing a penalty element in the cost function of PNSAF algorithm obtained from l_1 norm of the coefficients. This results in inclusion of the zero attracting term during weight update mechanism and hence the proposed algorithm is termed as zero attracting PNSAF (ZA-PNSAF). Furthermore, prediction error method is utilized to reduce the bias related issues encountered in adaptive feedback cancellation for hearing aids. The derivations and convergence analysis of the proposed algorithm have been carried out. Simulation results demonstrate the efficacy of the proposed feedback cancellation method as compared to existing techniques using speech segments as input signal. The proposed ZA-PNSAF based AFC enables 3.5 dB more lowering of misalignment value in comparison to other algorithms while maintaining faster convergence.

Poetic Meter Classification Using Acoustic Cues
09:52 – 10:11
Rajeev Rajan (Rajiv Gandhi Institute of Technology Kottayam, India)
Anu Raju (Rajiv Gandhi Institute of Technology Kottayam, India)
Poems, which communicate through rhythm and its apparent meaning, have a vital role in any literary. Meter, a set of well-defined rules gives rhythm to the poetry. In this paper, a meter classification scheme using fusion of low level, mid-level and high-level musical texture features, computed from recited poems are addressed. The performance of the proposed system is evaluated using a newly created poetic corpus in Malayalam language, one of the classical languages in India. Initially, a baseline system with mel-frequency cepstral coefficient (MFCC) feature set is performed. In the second phase, experiment is conducted with musical texture features. Finally, the experiment is extended to the early fusion of MFCC with the feature set considered in the second phase. Support vector machine (SVM) based classifier is used for classification in all the three phases. Whilst MFCC system reports an overall accuracy of 60%, the second phase reported an accuracy of 68%. In the third phase, complementary information provided by the MFCC and musical texture improved system performance (accuracy, 90%). The experimental study shows the promise of early fusion of MFCC with musical texture feature set in poetic meter classification and its analysis.

Classification of Story-Telling and Poem Recitation Using Head Gesture of the Talker
10:11 - 10:30
Valliappan CA (Indian Institute of Science Bangalore, India)
Anurag Das (Indian Institute of Science Bangalore, India)
Prasanta Ghosh (Indian Institute of Science Bangalore, India)
In this work, we investigate the nature of head gestures in spontaneous speech during story-telling in comparison to that in poem recitation. We hypothesize that head gestures during poem recitation would be more repetitive and structured compared to those in case of spontaneous speech. To quantify this, we proposed a measure called degree of repetition (DoR). We also perform a story-telling vs poem recitation classification experiment using deep neural network (DNN). For the classification, both DoR as well as context dependent raw head gesture data are used. Analysis and experiments are performed using a database of 24 subjects each telling five stories and a different set of 10 subjects each reciting 20 poems, three times each, thus having data of comparable durations for

story telling and poem recitation. Analysis of head gestures using DoR reveals that the DoR, on average, is higher during poem recitation compared to that during story-telling. A four-fold classification experiment between story-telling and poem recitation using DNN demonstrates that the raw head gestures result in an average classification accuracy of 85.79% and an average F-score of 89.05% while the DoR results in an average accuracy and F-score of 80.59% and 82.30% respectively indicating that the features learnt by DNN from raw head gestures are more discriminative than DoR features. While these accuracy and F-score are less than those (94.67% & 95.60%) obtained using acoustic feature such as Mel frequency cepstral coefficients (MFCCs), raw head gestures and MFCCs together yield a higher average accuracy (98.62%) and F-score (98.92%), indicating that the head gestures are complementary to the acoustic features for the classification task.

TU03

TU03: Optical Communications and Networks
Tuesday, July 17, 09:15 - 10:30,
Venue: Hall-B
Chair: Kumar Appaiah (Indian Institute of Technology Bombay, India)

A Novel Protection Strategy for Elastic Optical Networks Based on Space Division Multiplexing

09:15 - 09:33
Sridhar Iyer (Jain College of Engineering Bangalore, India)
Shree Prakash Singh (Netaji Subhas Institute of Technology Delhi, India)

The emergence of elastic optical networks (EONs) has been viewed as a solution to the diverse bandwidth requests that will occur in the next generation's network applications and Internet which are anticipated to handle a traffic growth at a rate greater than Petabit per second level. However, the crunch in fiber capacity will persist owing to use of only two dimensions of multiplexing in the EONs. With the adoption of space division multiplexing (SDM), an extra freedom degree can be used such that the EONs will be able support the required capacity of the future diverse traffic. Further, with an increase in the rate(s) of transmission(s),to counter the network failures, there will occur the need for protection mechanisms, specifically those, which can protect routes and provision solutions which are end-to-end. In the current work, as an initial step for protecting an EON based on SDM, we design a strategy which (i) is independent of the failure(s), and (ii) protects the route(s). We evaluate our proposed strategy considering realistic assumptions, topologies and parameters, and for different traffic load values. The obtained simulation results reveal that (i) our proposed strategy is efficient in provisioning of protection which is pre-configured, and (ii) the considered network topology's node degree significantly affects both, the blocking and the evaluated route's length in the protected EON based on SDM.

Limited Feedback and Interpolation of Principal Modes in Spatially Multiplexed WDM Fiber Links

09:33 - 09:52
Jinesh C Jacob (Indian Institute of Technology Bombay, India)
Kumar Appaiah (Indian Institute of Technology Bombay, India)

Wavelength division multiplexing (WDM), commonly used to enhance the capacity of single-mode fibers, can also be extended to few-mode fibers (FMF) to simultaneously utilize the both spatial as well as wavelength degrees of freedom. However, intermodal coupling in FMFs varies across different carrier wavelengths. Principal modes (PMs), which are linear combinations of the ideal fiber modes derived from the mode coupling properties of the fiber, provide a means to achieve nearly dispersion-free transmission through the FMF. However, information about the PMs, estimated at the receiver, need to be communicated to the transmitter using a low rate feedback channel. In this paper, we discuss methods quantization and feedback of PMs in FMF links using effective compression and interpolation techniques to reconstruct PMs for use at the transmitter WDM channels. Simulations reveal that the degradation of the fiber frequency response in a 40 channel system in 6-mode FMFs is less than 2.5 dB when 20 bits of feedback are used, and falls further to just 0.5 dB when 40 bits are used for feedback.

Utility of Delayed CSI Feedback in Mode Division Multiplexed Multimode Fiber Links

09:52 – 10:11
Rohan Prasad (Indian Institute of Technology Bombay, India)
Kumar Appaiah (Indian Institute of Technology Bombay, India)

The use of multiple-input multiple-output (MIMO) communication using mode division multiplexing (MDM) in multimode fiber links increases the data rate of the fiber efficiently. However modal dispersion limits the data rate and increases processing requirements at the receiver and increasing complexity. The use of channel state feedback in MDM links can help, since transmissions can be precompensated to simplify receiver implementation, though the channel parameters may evolve in time by the time they are used at the transmitter. We develop a model that considers the temporal evolution of the channel parameters, and study how using channel state feedback at the transmitter can help improve performance and how to delay in feedback affects performance. We perform simulations to study how delayed feedback helps in links 10 Gb/s per mode systems that use few-mode and large core links, both in the weak and strong mode coupling regimes. We find that, as the length of the fiber ranges from 1 km to 100 km, for many practical lengths, the use of delayed feedback is effective for predistortion, but larger processing delays significantly diminish their utility.

Demonstration of Polarization Diversity Based SH-QPSK System with PSK Modulated Carrier

10:11 - 10:30
Rashmi Kamran (Indian Institute of Technology Bombay, India)
Shalabh Gupta (Indian Institute of Technology Bombay, India)

Polarization diversity based self-homodyne systems offer local oscillator(lo)-less and

low cost coherent receiver solution for short distance applications. However, as one polarization is used to send carrier, outcome in terms of bits/symbol for these systems is half as compared to conventional dual polarization optical coherent systems. This paper presents a novel idea of using a phase modulated carrier in place of an unmodulated carrier for polarization diversity based self-homodyne systems. Here, the modulated carrier also carries additional data that results in enhanced capacity of the system. Mathematical expressions are presented to prove recovery of the transmitted data signals with phase modulated carrier. For confirming practical feasibility of this idea, a 6 Gb/s self-homodyne quadrature phase shift keying system with a polarization multiplexed and phase shift keying modulated carrier is experimentally demonstrated for a back to back setup and with a 200m single mode fiber channel. The polarization multiplexed and phase modulated carrier is employed as a local oscillator at the coherent receiver, enhances the outcome from 2 bits/symbol to 3 bits/symbol without reducing the Euclidean distance. This scheme can be extended for higher order modulation formats. The performance of self-homodyne 16 QAM system with a QPSK modulated carrier is also studied through simulation results.

TU04

TU04: Compressive Sensing and Applications
Tuesday, July 17, 09:15 - 10:30
Venue: Hall-C
Chair: Abhay Sharma (Indian Institute of Science Bangalore, India)

Sinusoid Signal Estimation Using Generalized Block Orthogonal Matching Pursuit Algorithm

09:15 - 09:33
Manoj A (Indian Institute of Technology Madras, India)
Arun Pachai Kannu (Indian Institute of Technology Madras, India)

We consider general block sparse vectors, which consist of non-zero blocks placed at arbitrary non-overlapping locations and the block partitioning information is unavailable a priori. We propose a generalized block orthogonal matching pursuit (G-BOMP) algorithm to recover the general block sparse vectors, from a set of noisy compressive measurements. We then establish that the sinusoidal signal estimation problem can be solved using the G-BOMP algorithm, by exploiting the structure of spectral leakage in the Fourier domain. We study the performance of the G-BOMP algorithm via simulations and compare it with other algorithms such as OMP, BOMP, Newtonized OMP (N-OMP) and spectral compressive sensing (SCS). We observe that our G-BOMP algorithm outperforms OMP, BOMP and SCS methods and is comparable to N-OMP with much lower computational complexity.

Binary Compressive Sensing and Super-Resolution with Unknown Threshold

09:33 - 09:52
Subhadip Mukherjee (Indian Institute of Science Bangalore, India)
Anjany Kumar Sekuboyina (Indian Institute of Science Bangalore, India)
Chandra Sekhar Seelamantula (Indian Institute of Science Bangalore, India)

We consider the problem of binary compressive sensing (CS), where random linear projections of a sparse signal are encoded using threshold-crossing information. The threshold used by the binary encoder for acquisition is unknown to the decoder and is estimated jointly with the signal. We cast the problem of signal reconstruction and threshold estimation as one of learning a hyperplane that separates the sampling vectors corresponding to the +1 and -1 measurements and develop are construction algorithm that entails iterative minimization of a reweighted l1-norm subject to a set of linear constraints that enforce measurement separability. The proposed algorithm leads to are construction performance comparable with that obtained using a popular binary CS algorithm, namely binary iterative hard-thresholding, which assumes that the threshold is set to zero. We consider binary super-resolution as an application, where a signal consisting of point sources needs to be estimated from sign measurements of its blurred version. The proposed algorithm successfully recovers the locations and amplitudes of the point sources, even in the presence of significant blurring.

A Singular Value Relaxation Technique for Learning Sparsifying Transforms

09:52 – 10:11
Subhadip Mukherjee (Indian Institute of Science Bangalore, India)
Chandra Sekhar Seelamantula (Indian Institute of Science Bangalore, India)

In this paper, we address the problem of learning data-adaptive square sparsifying transforms subject to a condition number constraint. An alternating minimization (alt. min.) strategy is adopted to solve the problem. We propose a quadratic program based approach in every iteration of alt. min. to update the singular values of the transform so that the condition number constraint is satisfied. The set of updated singular values, as it turns out after applying the Karush-Kuhn-Tucker conditions for optimality, can be expressed as an affine transformation applied to the current set of singular values. We refer to the resulting technique as singular value relaxation (SVR). The SVR-based transform learning algorithm is employed in signal sparsification and denoising applications. Performance evaluations of SVR show that it is about three times faster than K-SVD for denoising images of size 512x512 and results in a PSNR gain of about 0.5 to 1 dB over K-SVD for synthesized signals, and about 0.2 to 0.3 dB for natural images. The PSNR gains of SVR are shown to be comparable with a recently proposed transform learning algorithm that employs a closed-form transform-update rule.

A Low Complexity Orthogonal Least Squares Algorithm for Sparse Signal Recovery

10:11 - 10:30
Samrat Mukhopadhyay (Indian Institute of Technology Kharagpur, India)
Siddhartha Satpathi (University of Illinois Urbana–Champaign, USA)
Mrityunjoy Chakraborty (Indian Institute of Technology Kharagpur, India)

Recently, multiple orthogonal least squares (mOLS) was proposed as an extension of the well known orthogonal least squares (OLS) algorithm, which generalizes the support identification strategy of OLS by selecting multiple columns per iteration, thereby enhancing the convergence rate significantly. In this paper, we propose a modified multiple least squares algorithm, termed as m2OLS, which refines the mOLS iteration step by first

preselecting a subset of columns of the measurement matrix by a suitable greedy principle. The selected subset is then used for identification of multiple, possibly true support indices using mOLS. Restricting the computationally demanding mOLS calculations only to a smaller subset of the columns reduces the overall computational overhead substantially. Further, like mOLS, preselection in m2OLS is also based on correlation of the columns of the measurement matrix with the residual vector, thus enabling m2OLS to achieve similar recovery performance as mOLS a fact that is also borne out by simulation studies. The paper presents convergence conditions for the proposed m2OLS for both noise free and noisy observations. It also provides a comparative complexity analysis of mOLS and m2OLS demonstrating the superior computational performance of m2OLS vis-a-vis mOLS.

TU05

TU05: Cognitive Radio
Tuesday, July 17, 12:15 - 13:15
Venue: JN Tata Auditorium
Chair: Swades De (Indian Institute of Technology Delhi, India)

Optimal Power Allocation for Multicasting in Multiple Antenna Cognitive Radio Networks
12:15 – 12:35
Sangeeta Bhattacharjee (Indian Institute of Engineering Science and Technology Shibpur, India)
Tamaghna Acharya (Indian Institute of Engineering Science and Technology Shibpur, India)
Uma Bhattacharya (Bengal Engineering & Science University Shibpur, India)
This paper outlines non-orthogonal multiple access (NOMA) scheme for multicasting in a cognitive radio network (CRN). The network consists of a common base station (BS) which serves a primary user multicast group (PU-MG) and a secondary user multicast group (SU-MG). The SU-MG is located in between the BS and the PU-MG. Our proposed spectrum sharing protocol comprises of three transmission phases. The first phase is utilized by the BS for multicasting both PUs' and SUs' signals, using NOMA transmission. In the second phase, to overcome fading impairments, the BS exploits spatial diversity among SUs, by seeking their cooperation to relay PUs' message signal. The BS, as an incentive, leases a time slot in the third phase, exclusively for supporting multicast to SU-MG over PUs' licensed spectrum. Analytical expressions for outage probabilities of both PU-MG and SU-MG are derived and validated using simulations.

On Outage Secrecy Minimization Using Jammer Selection in Energy Harvesting Cognitive Radio
12:35 – 12:55
Avik Banerjee and Santi Prasad Maity (Indian Institute of Engineering Science and Technology Shibpur, India)
Ritesh Das (Indian Institute of Engineering Science and Technology Shibpur, India)
This work considers a cognitive radio network (CRN) model that consists of a secondary transmitter-receiver pair and operates in an underlay mode on two non-overlapping time slots in presence of an Eavesdropper (Eav) and multiple cooperative jammers. In the first time slot, the secondary transmitter (SUT) and the jammers harvest energy from the interference signal of the primary user (PU). During the remaining slot, SUT transmits its data to its receiver maintaining a target interference threshold to the primary receiver (PUR). The jammer with the minimum signal-to-interference ratio at Eav is selected to counter measure eavesdropping. Closed form expressions for the total power budget, the optimal power fraction used by SUT and the fraction of the time slot for energy harvesting are derived to minimize the secrecy outage probability under the constraints of secondary outage probability, interference to PUR and energy causality for both SUT and the jammers. Simulation results show that the minimum value of the secrecy outage probability is ~18.69% less for the proposed method compared to the existing work.

Preventing Collusion Attacks in Cooperative Spectrum Sensing
12:55 – 13:15
Shivanshu Shrivastava (Indian Institute of Technology Kanpur, India)
Cooperative spectrum sensing is prone to attacks by malicious users. These attacks become more severe when launched in collusion. In this paper, a collision penalty based attack prevention method is proposed to defend individual and collusion attacks in all the possible attack scenarios. We identify the possible attack strategies in each scenario and prevent them with appropriate bounds on the collision penalty. Simulation results verify the effectiveness of the proposed scheme.

TU06

TU06: Applications of Audio and Speech Processing
Tuesday, July 17, 12:15 - 13:15
Venue: Hall-A
Chair: Chandra Sekhar Seelamantula (Indian Institute of Science Bangalore, India)

Processing Linear Prediction Residual Signal to Counter Replay Attacks
12:15 – 12:35
Jagabandhu Mishra (National Institute of Technology Nagaland, India)
Madhusudan Singh (National Institute of Technology Nagaland, India)
Debadatta Pati (National Institute of Technology Nagaland, India)
Replay attack is a method of using targets pre-recorded speech samples for acquiring unauthorized access to the automatic speaker verification (SV) system. This work investigates the usefulness of processing linear prediction (LP) residual signal to counter replay attacks. In detecting replay signals the major clues lie in tracing the record and playback devices characteristics that dominantly reflect at low frequency regions due to loud speaker, and at high frequency regions due to two-stage A/D conversions. Unlike speech, the spectral pattern of the impulse-like linear prediction (LP) residual signal is spread across entire frequency range, and so conjectured to be more useful. Based on the distribution nature of the mel-scale that tightly spaced in low frequency regions

and reverse in inverse mel-scale, residual mel-frequency cepstral coefficients (RMFCC) and residual inverse mel-frequency cepstral coefficients (RIMFCC) features are used as the representative features. The effectiveness of these features is demonstrated on ASVspoof2017 database. The initial study is made on deciding the suitable prediction order. In terms of equal error rate (EER), RMFCC features provide the best performance of 14.75% from 20th order LP analysis and RIMFCC of 16.20% from 10th order LP analysis. These results show that residual signals effectively capture the low frequency distortions with higher order LP analysis and vice versa. The higher performance in case of RMFCC features may due to the significant distortion from loud speakers. The fusion of RMFCC and RIMFCC features further improves the performance to 10.40%, that is comparatively better than the state-of-the-art spectral centroid magnitude coefficients (SCMC) feature performance of 11.49%. Finally, the fusion of RMFCC and RIMFCC features together with SCMC provides 9.77%. These outcomes demonstrate the usefulness of processing LP residual signals to counter replay attacks.

Detecting Developmental Dysphasia in Children Using Speech Data

12:35 – 12:55

Ramarao D (National Institute of Technology Patna, India)
Chaman Singh (National Institute of Technology Patna, India)
Syed Shahnawazuddin (National Institute of Technology Patna, India)
Nagaraj Adiga (Indian Institute of Technology Guwahati, India)
Gayadhar Pradhan (National Institute of Technology Patna, India)

Developmental dysphasia or specific language impairment (SLI) is a disorder that is known to delay the process of acquiring language skills in children without other disabilities. Approximately 5-7% of children in kindergarten group are affected with SLI as reported in literature. Boys are more prone to be affected by this disorder compared to girls. In this paper, we present our preliminary attempts towards detecting SLI in children using their speech data. In this regard, we have used Mel-frequency cepstral coefficients (MFCC) for front-end speech parameterization. We have also presented an analysis to show how MFCC features help in discriminating the healthy children from those affected with SLI. The MFCC feature vectors are then used to develop two-class classifiers for discriminating healthy children from those suffering from SLI. The said two-class classifiers are developed using extreme learning machine (ELM) trained and tested on speech data collected from healthy children as well as those affected with SLI. ELM are fast to train and are known to be quite effective even when the training data is sparse. For extracting utterance-level features to be given as input to the ELM, Gaussian posteriograms learned on frame-level acoustic features are used. Several different types of ELMs are explored in this work and the kernel ELM is noted to outperform the rest with an accuracy of 99.41%.

Hypernasality Detection Using Zero Time Windowing

12:55 – 13:15

Akhilesh Dubey (Indian Institute of Technology Guwahati, India)
S. R. Mahadeva Prasanna (Indian Institute of Technology Guwahati, India)
Samarendra Dandapat (Indian Institute of Technology Guwahati, India)

The hypernasality in Cleft Palate speech is characterized by the presence of nasal peak in the vicinity of first formant of vowel spectrum. A high spectral resolution technique, which can resolve these two peaks, is desirable for the automatic detection of hypernasality. This work uses the zero time windowing (ZTW) technique for the hypernasality detection. In this technique, the speech signal is windowed with a highly decaying impulse-like window of approximately a pitch period size. The technique gives the instantaneous vocal tract spectrum free from the pitch and harmonics effect. The spectral resolution loss due to short windowing is restored by the successive differentiation in frequency domain. The numerator of group delay is used to resolve closely spaced nasal peak and first formant formants. The cepstral features are extracted from the instantaneous spectrum and is used for the automatic detection of hypernasality using SVM classifier. The accuracy of the classification are 76.51 \% for the vowel /a/ and 80.36 \% for the vowel /i/. The accuracy further increases when the proposed feature is fused at score level with the mel-frequency cepstral coefficient (MFCC) feature.

TU07: RF Systems for Communication - 1

Tuesday, July 17, 12:15 - 13:15

Venue: Hall-B

Chair: T Venkata Prabhakar (Indian Institute of Science Bangalore, India)

TU07

Novel Approach for Enhanced Reduction of SAR in a Mobile Phone Antenna Using High Impedance FSS

12:15 – 12:35

Adeline Mellita (Indian Institute of Information Technology Design and Manufacturing Kancheepuram, India)
Chandu DS (Indian Institute of Information Technology Design and Manufacturing Kancheepuram, India)
Sholampettai Subramanian Karthikeyan (Indian Institute of Information Technology Design and Manufacturing Kancheepuram, India)

In this paper, we investigate the performance of periodic reflecting surfaces for reducing the energy absorption of human head from a mobile phone antenna. A six-layered human head model and a conventional planar inverted-F antenna (PIFA) designed to operate at the IMT- LTE band (1.8-2.3 Ghz) are chosen for specific absorption rate (SAR) analysis. The reflector is placed between the human head model and the antenna to study the amount of SAR reduction. Initially, a mono layer frequency selective surface (FSS) is modelled on an FR4 substrate with overall dimensions of 0.084λ0× 0.084λ0×0.011λ0 and an SAR reduction by 64.7% was observed. To overcome few disadvantages of these conventional reflecting surfaces, a high impedance surface (HIS) which is a special case of FSS is designed for SAR reduction with an overall dimensions of 0.21λ0×0.21λ0× 0.011λ0. (λ0 is the free space wavelength at 2.1 GHz). The proposed HIS showed 85.3% reduction in SAR, when compared with the SAR level observed in a conventional mobile phone and head phantom setup.

A Novel Circular Quarter-Mode SIW Cavity-Backed Diversity Antenna with Dual-Circular Polarization

12:35 – 12:55

Chandu DS (Indian Institute of Information Technology Design and Manufacturing Kancheepuram, India)
Tharani D (Indian Institute of Information Technology Design and Manufacturing Kancheepuram, India)
Sholampettai Subramanian Karthikeyan (Indian Institute of Information Technology Design and Manufacturing Kancheepuram, India)

This paper presents a dual-circularly polarized (CP) quarter-mode substrate integrated waveguide (QMSIW) antenna with 100% usable bandwidth. The design consists of a circular QMSIW excited using two orthogonal co-axial fed 50-ohm RF ports to achieve polarization diversity. A section of diagonal vias are introduced on either sides of the quasi-magnetic wall of the QMSIW antenna to enhance the isolation between the RF ports and segment the QMSIW into two cavities. In addition, two narrow rectangular slots are etched out from the center of the orthogonal radial lines of the QMSIW and shorting vias are introduced along the periphery of the waveguide between these slots. This combination of slots with vias generates circular polarization (CP) for the TE101 mode of the antenna. The antenna radiates with right hand circular polarization (RHCP) when excited at port 1 and left hand circular polarization (LHCP) is obtained by exciting port 2. A prototype of the dual-CP QMSIW is fabricated and tested. The measured isolation between the ports is greater than 25 dB. The proposed antenna has a 3-dB axial ratio bandwidth (AR-BW) of 3.23% centered at 10.215 GHz that completely overlaps with the impedance bandwidth. The antenna exhibits unidirectional radiation patterns with a gain of 6.44 dBi in the operating band. The diversity performance of the fabricated dual-CP prototype is verified by measuring the envelope correlation coefficient (ECC) and mean efficient gain (MEG).

Design of Substrate Integrated Coaxial Line (SICL) Fed Planar Quasi-Yagi Antenna for Millimeter Wave Application

12:55 – 13:15

Naman Baghel (Indian Institute of Technology Jodhpur, India)
Soumava Mukherjee (Indian Institute of Technology Jodhpur, India)

A printed Quasi-Yagi Antenna with a new feed, Substrate Integrated Coaxial Line (SICL) working in the millimetre frequency range is presented. This new feeding technique makes the antenna design simple, surpasses the need to have balun and reflector. The antenna design presented here operates at 26GHz with a frequency band of 6.3 GHz, providing a gain of 7.2dB and Front to Back Ratio of better than 21dB. The SICL section exhibits good shielding ability which is advantageous for circuits implemented in millimeter wave frequency range. It also enhances the performance of the antenna by providing a shielding to feed network. It also reduces the complexity of the feeding network and makes it compact. This antenna is suited for ultra wideband automotive radar application operating at K Band (18- 26 Ghz).

TU08: Energy Harvesting Communication Systems

Tuesday, July 17, 12:15 - 13:15

Venue: Hall-C

Chair: Ketan Rajawat (Indian Institute of Technology Kanpur, India)

Performance of a Cooperative Network with Direct Link and an Energy-Buffer Aided Relay

12:15 – 12:35

Dileep Bapatla (Indian Institute of Technology Delhi, India)
Shankar Prakriya (Indian Institute of Technology Delhi, India)

In this paper, we analyze performance of a cooperative communication link that uses an energy harvesting relay based on the harvest-store-use (HSU) architecture. We assume that the relay harvests ambient RF energy. Unlike most other works, we do not ignore presence of a direct link. We assume that the destination node combines the direct and the relayed signals using maximal ratio combining (MRC). Prior works related to energy buffers are based on discretizing the number of levels in the buffer even though the energy harvested is a continuous variable. In this paper, we use a continuous state space Markov chain to model the energy buffer, and present expressions for outage and throughput. We compare performance with an architecture referred to as harvest-use (HU) that does not use energy buffers. We also compare performance with a scheme that does not use relays. Simulation results are presented to validate the derived analytical expressions.

Optimal Harvest-or-Transmit Strategy for Energy Harvesting Underlay Cognitive Radio Network

12:35 – 12:55

Kalpant Pathak (Indian Institute of Technology Kanpur, India)
Adrish Banerjee (Indian Institute of Technology Kanpur, India)

An underlay cognitive radio network with energy harvesting is considered which operates in slotted fashion. The primary user (PU) transmits with a constant power in each slot, while the secondary user (SU) either harvests energy from primary's transmission or transmits its data. We propose an optimal offline harvest-or-transmit strategy where in each slot, SU takes a decision whether to harvest energy or transmit its data limiting interference at the primary receiver. We aim to maximize the achievable sum rate of SU under energy causality and interference constraints. The optimization problem is formulated as a mixed integer non-linear program and the optimal harvest-or-transmit policy is obtained using generalized Benders decomposition algorithm. Through simulations, we analyze the effects of various system parameters and interference constraint at the primary receiver on the optimal policy.

On Outage Analysis in Cooperative Cognitive Radio Network with RF Energy Harvesting

12:55 – 13:15

Sutanu Ghosh (Indian Institute of Engineering Science and Technology Shibpur & JIS GROUP, India) Tamaghna Acharya (Indian Institute of Engineering Science and Technology Shibpur, India)
Santi Prasad Maity(Indian Institute of Engineering Science and Technology Shibpur, India)

In this paper, we investigate the performance of a cooperative cognitive radio network which supports both spectrum sharing and radio frequency (RF) energy harvesting using power splitting relaying (PSR) protocol. The system model consists of a pair of primary users (PU), each equipped with multiple antennas and a pair of secondary users (SU), each equipped with a single antenna. The secondary transmit node harvests energy from the received signal of PUs and use this energy for forwarding the PUs signals and its own message signal. The exact closed form expressions for PU and SU system outage are derived. A large set of simulation results are reported that validate the analytical outputs.

TU09

TU09: RF Systems for Communication - 2

Tuesday, July 17, 14:15 - 15:30

Venue: JN Tata Auditorium

Chair: Gaurab Banerjee (Indian Institute of Science Bangalore, India)

Cross-Polarization Reduction of a Cylindrical Dielectric Resonator Antenna with Parasitic Strip Loading

14:15 - 14:33

Praveen Kumar AV (Birla Institute of Technology and Science Pilani, India)
Anuj Ojha (Birla Institute of Technology and Science Pilani, India)

A microstrip fed cylindrical dielectric resonator antenna (DRA) with parasitic metal loading is proposed for reduced cross-polarized radiation. The proposed DRA comprises of a cylindrical dielectric resonator (DR), partially wrapped with a metal strip to detune the higher order modes, which is then excited by a 50 Ohm microstrip feed loaded with a second parasitic strip on the substrate to improve the symmetry. Resulting DRA has a peak cross-polarization level about 14 dB below that of a conventional DRA. The DRA is fabricated and measurement shows an improvement in cross-polar level by 8 dB.

Slot Antenna Miniaturization with Equal Electrical Path Length Using Different Shape of Loops

14:33 – 14:52

Sk. Moinul Haque (Aliah University Kolkata, India)
Khan Masood Parvez (Aliah University Kolkata, India)

This work describes the effect of using different shapes of loops with equal electrical path length in antenna miniaturization. Emphasis has been given on equal electrical path length in antenna miniaturization. The loops considered for current antenna topologies are

circular, triangular and square keeping the perimeter of loop close to equal in each cases. We have observed the return loss, radiation pattern, input impedance plot, H-field plot, and efficiency for each antenna topology. The reduction in resonant frequency for the cases of circular, triangular and square loops are 22.92%, 22.43% and 36.09%. The reduction is maximum for the case of square loop for better coupling of magnetic field around the square loops in comparison with other loops. Also a huge improvement of -10 dB bandwidth (95.23% to 160.22%) is observed in loaded antennas compared to reference antenna topology. We have also observed that efficiency is in the range of 95.17% to 96.59%. We have compared the simulated results with measured results.

Copper Coin Loaded Miniaturized Slot Antenna

14:52 – 15.11

Khan Masood Parvez (Aliah University Kolkata,India)
Sk. Moinul Haque (Aliah University Kolkata, India)
Enamul Khan (Aliah University Kolkata, India)

This article presents a new technique of slot antenna miniaturization using a copper coin loading at a location close to the canter position of the slot. The resonant frequency for reference antenna and loaded antenna are 2.86 GHz and 1.45 GHz respectively. As a result, the frequency of loaded antenna reduces by a factor of 49.30% compared to the reference antenna topology with good radiation characteristics. A prototype of the proposed antenna is fabricated on an FR4 microwave substrate with ground plane size 100x100mm2, and its reflection coefficient, E-plane, H-plane, and efficiency are compared with the simulation results.

Design of Wideband Coaxial-to-Substrate Integrated Coaxial Line (SICL) Planar Transition

15.11 – 15:30

Satya Krishna Idury (Indian Institute of Technology Jodhpur, India)
Soumava Mukherjee (Indian Institute of Technology Jodhpur, India)

This article, presents a novel technique to model a wideband coaxial to substrate integrated coaxial line (SICL) transition. The proposed design is a planar implementation of the male to female connection usually observed in coaxial connections in conventional circuit. Firstly, a 50 ohm SICL section is designed, the coaxial probe of equal impedance passing through a metallic via with slightly greater diameter is then connected to the inner conductor of SICL. The reactive component produced at the SICL-Coaxial junction is nullified by placing a short-circuit section at an optimal distance from it. The proposed transition demonstrates a broadband matching of greater than 20 dB for 0 to 32.7 GHz with very low insertion loss of better than 0.1 dB throughout the band. The robustness of the proposed transition is validated for different dielectric constant and thickness. The designed back to back transition exhibits wideband matching with very low insertion loss making it worthy for practical applications.

TU10

TU10: Audio and Speech Processing - 1
Tuesday, July 17, 14:15 - 15:30
Venue: Hall-A
Chair: Sriram Ganapathy (Indian Institute of Science Bangalore, India)

Instantaneous Fundamental Frequency Estimation of Speech Signals Using tunable-Q Wavelet Transform

14:15 - 14:33
Anurag Nishad (Indian Institute of Technology Indore, India)
Ram Bilas Pachori (Indian Institute of Technology Indore, India)

This paper presents a novel method to estimate the instantaneous fundamental frequency (IFF) of speech signals using tunable-Q wavelet transform (TQWT). The proposed method uses a TQWT based filter-bank which has common or nearly uniform bandwidth for all sub-bands. This filter-bank is used to decompose the speech signal. The fundamental frequency component (FFC) of speech signal maybe present in many sub-bands at different time intervals. The time interval at which FFC is present, in a sub-band, is identified using time-domain segmentation (TDS) section. In the similar way, the harmonic of FFC can also be present in different sub-bands at different time durations. The proposed method extracts FFC from different sub-bands and constructs an FFC for entire speech signal. Then, Hilbert transform is applied on constructed FFC to obtain IFF of speech signal. In order to show the efficacy of proposed method, its performance has been compared with performance of other existing methods in terms of gross error in percentage.

Enhanced Directional Sensitivity Using Acoustic Dish Reflector

14:33 – 14:52
Sawant Vilas (Indian Institute of Science Bangalore, India)
Anirban Bhowmick (Indian Institute of Science Bangalore, India)
Thippur V. Sreenivas (Indian Institute of Science Bangalore, India)

An acoustic reflector is a passive device which is used with microphones to reflect and focus sound waves from a longer distance. They are effective for long-range sound recording without intrusion, such as to record wildlife sounds. In this paper, our objective is to investigate the feasibility of using a dish reflector microphone for indoor activity monitoring of large premises. Acoustic gain and frequency response of the microphone with different parabolic, near parabolic and non-parabolic reflectors are compared with that of the same microphone without the reflector. It is observed that the use of dish reflector does significantly enhance the directivity and sensitivity of sound recording. Keeping to a moderate size reflector, among various shapes and materials, the best reflector has given a 14 dB gain improvement over microphone without reflector at 0 degree azimuth. We also found that among steel and plastic dish reflector of approximately same size and shape, steel dish reflector does give a higher performance as expected. Increased directivity of the dish reflector is giving a significant improvement in indoor monitoring and also for sound source tracking.

Excitation Source Feature for Discriminating Shouted and Normal Speech

14:52 – 15.11
Shikha Baghel (Indian Institute of Technology Guwahati, India)
S. R. Mahadeva Prasanna (Indian Institute of Technology Guwahati, India)
Prithwijit Guha (Indian Institute of Technology Guwahati, India)

Dynamics of shouted speech production significantly vary from that of normal speech. These variations can be analyzed from excitation source information by using differenced electroglottogram (DEGG) signal. This work has two contributions. First, the proposal of a novel Glottal Open Phase Tilt (GOPT) feature derived from DEGG signal for discrimination of shouted and normal speech. Second, the construction of a database of speech and corresponding EGG samples for performance analysis of the proposed feature. In case of shouting, vocal folds vibrate faster and close abruptly. This leads to relative proximity of Glottal opening and the following closing instances. This motivated the proposal of tilt feature for discriminating shouted from normal speech. The proposed feature is also extracted from ILPR signals that are known to approximate DEGG signals. Experiments on the collected dataset have provided shouted speech detection rate of 90.9 % for DEGG and 76.37 % for ILPR signals.

Frequency Contour Modeling to Synthesize Natural Flute Renditions for Carnatic Music

15.11 – 15:30
Pranav Prasad (National Institute of Technology Karnataka, India)
Anand Ashtamoorthy (National Institute of Technology Karnataka, India)
Shashank Dhar (National Institute of Technology Karnataka, India)
Deepu Vijayasenan (National Institute of Technology Karnataka, India)

Hidden Markov Models used for computer music synthesis do not satisfactorily reproduce Indian Carnatic music and also require large training datasets. The essence of Indian Carnatic music is its micro-tonal frequency variations called Gamakas. In this work, we study the flute note properties, features that characterize the Gamakas, and hence attempt to devise a generalized method that helps in synthesizing Carnatic music compositions. Our method uses additive sinusoidal synthesis coupled with a stochastic noise model. In time domain, splines are used to model the amplitude envelope to ensure a natural reconstruction. Integrated frequency contours are used for smooth concatenation of notes and modeling of Gamakas and Notes. In order to evaluate our synthesis, we use a Mean Opinion Score (MOS) survey to compare our results with the baseline and the original recordings. The MOS of the proposed method is around 3.5 while the baseline is 2.3.

TU11

TU11: Image and Video Signal Processing
Tuesday, July 17, 14:15 - 15:30
Venue: Hall-B
Chair: Venkatesh Babu Radhakrishnan (Indian Institute of Science Bangalore, India)

Fast Non-local Means Denoising for MR Image Sequences
14:15 - 14:33
Hemalata Bhujle (SDM College of Engineering & Technology Dharwad, India)
Basavaraj Vadavadagi (SDM College of Engineering & Technology Dharwad, India)
Denoising algorithms are used for the enhancement of magnetic resonance (MR) images. MR images possess more structural details compared to normal images which have to be preserved for better diagnosis. Non-local means (NLM) filter is proved to be the best in preserving edges, however demands higher computations. From diagnostic perspective, the denoising algorithms should be computationally fast and accurate. The aim of this paper is to improve the accuracy and computational efficiency of unbiased NLM filter for MR image sequences. In this work we propose to do so by useful alternative of NLM technique in-conjunction with principal components for Rician noise. The variants of PCA based denoising techniques developed so far compute PCA locally for each image, thus decreasing computational efficiency. In this work, we propose to compute PCA only once globally for each shot. A modified preprocessing step of shot boundary detection is employed to segregate 3D MR sequences in various shots based on its content similarity. Further denoising is carried out in non-local means framework with reduced dimensionality. We compare results with the existing NLM based MR denoising techniques and show that the proposed method is competitive in terms of attaining higher accuracy and computational efficiency. The performance of the proposed algorithm is evaluated with PSNR, SSIM and visual perception.

Diagnostic Information Based Super-Resolution of Retinal Optical Coherence Tomography Images
14:33 – 14:52
Vineeta Das (Indian Institute of Technology Guwahati, India)
Samarendra Dandapat (Indian Institute of Technology Guwahati, India)
Prabin Kumar Bora (Indian Institute of Technology Guwahati, India)
This paper presents a novel diagnostic information based super-resolution (SR) of the optical coherence tomography (OCT) images of the human retina. First, the edge preserving, guided image filtering is applied on the low resolution OCT image to remove the speckle noises. Then an appropriate section for scrutiny is selected by the physician. Histogram of oriented gradients (HoG) is computed on the selected OCT section to encode clinically relevant information. A probabilistic framework based on the Gaussian mixture model (GMM) is applied on the HoG features to obtain the Gaussian posteriorgram features. The posteriorgram features minimize the intra-class variability and maximize the inter-class variability. The performance of the proposed feature for classification of the diagnostically significant sections (DSS) in the OCT images is evaluated using the k-nearest neighbour (k-NN) classifier. Based on the clinical relevance of the selected section, highly accurate learning based SR methods or simple bicubic interpolation is applied to the selected section. The proposed method achieves a sensitivity, specificity and accuracy of 74.93%, 97.88% and 92.57% for classification.

Object-based Compression of 3D Animation Geometry
14:52 – 15.11
Sanjib Das (Indian Institute of Technology Guwahati, India)
Prabin Kumar Bora (Indian Institute of Technology Guwahati, India)
In multi-object based three-dimensional (MO-3D) animations, the geometry data of the multiple 3D objects constituting the animation change across the frames. Moreover, they require large disk space for storage and high bandwidth for real-time transmission over network compared to single-object based 3D (SO-3D) animations. The existing geometry compression methods for 3D animations consider the constituent 3D objects per frame as a single 3D object for compression. This global consideration of the multiple 3D objects as a single object does not exploit the local spatio-temporal redundancies exhibited by the individual 3D objects for the animation duration. Moreover, it requires large memory and computational resources to apply the compression algorithm globally. This work proposes an efficient geometry compression method for MO-3D animations by segmenting the animation geometry data across the frames into objects followed by applying the principal component analysis (PCA) based compression on the geometry data of the segmented individual 3D objects. To compare the performance of the proposed method, a few MO-3D animations are created using the existing public domain SO-3D animations. The simulation results show that the proposed object-based PCA (OPCA) method gives better performance in terms of objective and subjective quality metrics compared to the other PCA based geometry compression methods applied globally on the MO-3D animations.

Learning Representations with Strong Supervision for Image Search
15.11 – 15:30
Konda Reddy Mopuri (Indian Institute of Science Bangalore, India)
Vishal Athreya Baskaran (PayPal Inc & Birla Institute of Technology and Science Hyderabad, India)
Venkatesh Babu Radhakrishnan (Indian Institute of Science Bangalore, India)
Deep learning exploits large volumes of labeled data to learn powerful models. When the target data set is small, it is a common practice to perform transfer learning using pre-trained models to learn new task specific representations. However, pre-trained CNNs for image recognition are provided with limited information about the image during training, which is label alone. Tasks such as scene retrieval suffer from features learned from this weak supervision and require stronger supervision to better understand the contents of the image. In this paper, we exploit the features learned from caption generating models to learn novel task specific image representations. In particular, we consider the state-of-the art captioning system Show and Tell[1] and the dense region description model DenseCap[2]. We demonstrate that, owing to richer supervision provided during the process of training, the features learned by the captioning system perform better than those of CNNs. Further,

we train a siamese network with a modified pair-wise loss to fuse the features learned by Show and Tell and DenseCap and learn image representations suitable for retrieval. Experiments show that the proposed fusion exploits the complementary nature of the individual features and yields state-of-the art retrieval results on benchmark datasets.

TU12

TU12: Signal Processing Algorithms and Architecture
Tuesday, July 17, 14:15 - 15:30
Venue: Hall-C
Chair: K. V. S. Hari (Indian Institute of Science Bangalore, India)

Time-Frequency Analysis of Gravitational Waves
14:15 - 14:33
Pushpendra Singh (Bennett University, Greater Noida & Indian Institute of Technology Delhi, India)
Amit Singhal (Jaypee Institute of Information Technology, India)
Shiv Dutt Joshi (Indian Institute of Technology Delhi, India)

The instantaneous frequency (IF) is a vital parameter for time-frequency analysis of a nonstationary signal such as gravitational wave. In this paper, IF of gravitational waves, recorded by the Laser Interferometer Gravitational-Wave Observatory detectors, is estimated by applying the energy preserving empirical mode decomposition and the Fourier decomposition method. The frequency values corresponding to minimum inspiral strain, maximum strain that indicates the merger of binary black holes, and the subsequent ringdown are obtained as (a) GW150914: 30--160--264 Hz, and (b) GW151226: 19--164--265 Hz. The proposed methods demonstrate a superior performance in terms of better time-frequency resolution as compared to the widely used continuous wavelet transform.

A Novel Recursive Filter Realization of Discrete Time Filters
14:33 – 14:52
Ganesan Thiagarajan (MMRFIC Technology Private Limited Bangalore, India)
Joydeep Bhattacharya (MMRFIC Technology Private Limited Bangalore, India)
Srinivasan Bhuramoorthy (MMRFIC Technology Private Limited Bangalore, India)
Ashwini Kamate (MMRFIC Technology Private Limited Bangalore, India)

This paper presents a new “Recursive Digital Filter” (RDF) architecture for discrete time filters. This novel architecture allows decomposition of any discrete time filter into recursive filter of multiple order systematically. This decomposition results in reduction of the hardware when compared to conventional implementation. This hardware complexity reduction is feasible for both fixed and programmable filter coefficients. As an illustrative example, the hardware reduction is demonstrated for a programmable 100 tap symmetric FIR filter. Here, the complexity is quantified in terms of number of multipliers and adders with specific bit widths needed. Matlab numerical results are provided to compare the performance between the conventional and RDF implementation. The resources utilized in both architectures (conventional as well as RDF) are compared for Xilinx Kintex-7 FPGA device.

A Novel Weight Window Design Approach
14:52 – 15.11
Sachin Bharadwaj (Indian Institute of Science Bangalore, India)
Sriram Murali (Texas Instruments, India)

Weight windows are extensively used in spectral analysis of signals, e.g., range, Doppler and angle estimation in radars, audio processing and many other applications. In this paper, we present a novel approach for designing weight window functions, which, unlike the well-known repertoire of standard windows used in spectral analysis, provides the flexibility to shape the leakage profile of the designed weight window differently in different frequency bands, allowing one to make a more controlled trade-off between the key performance metrics of the window. We demonstrate the efficacy of some example weight windows designed using the proposed method in the context of FMCW radar FFT processing.

A Novel Scaling Criterion for Optimal Trade-off Between Time and Frequency Resolution in S-transform
15.11 – 15:30
Neha Singh (Indian Institute of Technology Roorkee, India)
Pyari Mohan Pradhan (Indian Institute of Technology Roorkee, India)

S-transform (ST) maps a one-dimensional time domain signal into a two-dimensional time-frequency distribution (TFD). ST uses a scalable Gaussian window for multiresolution analysis. The major drawback of conventional ST is its poor frequency resolution for mid and high frequency voices. This is primarily due to linear scaling in frequency domain. To improve the scaling criterion, various schemes have been proposed in literature such as modified linear scaling, power scaling and sigmoid scaling. The existing criteria are unable to provide fair trade-off between time and frequency resolution for all voices. To this extent, a novel scaling criterion is proposed which can provide proportional window width variation in time and frequency domain. The proposed scaling criterion uses a tangent function to scale the width of the Gaussian window in both time and frequency domain. The performance of proposed scaling approach is examined using a synthetic signal having multiple power quality disturbances. The simulation results indicate the superiority of the proposed scaling approach in terms of the trade-off between time and frequency resolution in TFD.

SP.TU13

SP.TU13: Full Duplex and LPWAN
Tuesday, July 17, 16:00 - 17:45
Venue: JN Tata Auditorium
Chair: Rajesh Sundaresan (Indian Institute of Science Bangalore, India)

QoS-Constrained Energy-Efficient AF Two-Way Full-Duplex Relaying with Massive Antennas
16:00 – 16:26
Ekant Sharma (Indian Institute of Technology Kanpur, India)
Rohit Budhiraja (Indian Institute of Technology Kanpur, India)
We consider a system where multiple full-duplex (FD) user pairs exchange information via a shared FD massive multiple-input multiple-output (MIMO) two-way relay. Most of the previous massive MIMO relaying works maximize the spectral efficiency. We maximize the global energy efficiency (EE) with quality-of-service (QoS) constraints, expressed as the rate required by the users. The problem is non-convex and is solved by approximating it as a sequence of pseudo-concave problem, which is then solved using the Dinkelbach method.

Full Duplex Wireless: A solution for next generation or not yet?
16:26 – 16:52
Dinesh Bharadia (University of California San Diego, USA)
Full Duplex radios is an ability to transmit and receive on the same spectrum, more fundamentally it revolutionizes the physical layer. In recent times, full duplex radios have undergone successful commercial field trials by Tier 1 Telecom. However, even with the lowest layer of networking stack would undergo a major shift, there hasn't been a domino effect on higher layers. The question still remains unanswered: how can we use full duplex? Is it just 2x throughput only? I would present some future directions of using full-duplex radios and building full duplex networks.

Recent Developments in IOT: A system perspective
16:52 – 17:18
Ganesan Thiagarajan (MMRFIC Technology Private Limited Bangalore, India)
This talk summarizes recent developments in all four main components of IoT namely, connectivity, hardware, internet and (software) platform. The terms IoT and IoT platform are differentiated and the developments in these above mentioned four components are categorized. As a case study, the latest developments in NB-IOT standards (3GPP Release 13 and 14) are reviewed in the context of PHY layer and network features. The various IoT standards are compared from a system point of view and application point of view. Finally, future trends in IoT is presented from a system architect's point of view.

Compressed Sensing Based Uncoordinated and Unsourced Multiple Access
17:18 – 17:45
Jean-Francois Chamberland-Tremblay (Texas A&M University College Station, USA)
We will first review some connections between multiple access in wireless networks and compressed sensing. Then, we present a novel divide-and-conquer compressive sensing (CS) based approach for the uncoordinated and unsourced random access problem introduced by Polyanskiy. In the proposed scheme, each user's data is first encoded using an outer linear block code and the outer codewords are split into several sub-blocks. Each sub-block is encoded using a compressed sensing based encoder. At the receiver, the sub-blocks are decoded using compressed sensing decoder and their outputs are combined together using a low-complexity tree based algorithm. The proposed scheme outperforms existing practical coding schemes in the literature and is only approximately 4.3 dB away from the Polyanskiy's achievability scheme using a random Gaussian codebook. We will also present some results on the trade-off between complexity and gap from capacity for this scheme (Vamsi Amalladinne, Krishna Narayanan and Jean-Francois Chamberland).

SP.TU14

SP.TU14: Caching in cellular networks
Tuesday, July 17, 16:00 - 17:45
Venue: Hall-A
Chair: Vinod Sharma (Indian Institute of Science Bangalore, India)

Content Caching and Delivery with Partial Adaptive Matching
16:00 – 16:26
Nikhil Karamchandani (Indian Institute of Technology Bombay, India)
Caching of popular content during off-peak hours is a strategy to reduce the network load during peak hours. We consider a model where multiple caches store pre-fetched content and when users request files, they are matched to caches based on the request pattern. In particular, we focus on the case where caches are divided into clusters and each user can only be assigned to a unique cache from a specific cluster. This is a generalization of two popular models which are the extremes of the proposed model: one where each user is pre-attached to a cache irrespective of what it demands (static matching, popularly known as `coded caching') and the other where each user can be assigned to any cache in the entire network (fully adaptive matching). We show that neither the coded delivery strategy (approximately optimal when the user-cache assignment is pre-fixed) nor the uncoded replication strategy (approximately optimal when all caches belong to a single cluster) is sufficient for all memory regimes. We propose a hybrid solution that combines ideas from both schemes and that performs strictly better than both. Finally, we show that this hybrid strategy is approximately optimal in several scenarios and also discuss some of the open questions.

Approximate optimality of separation in cache-aided wireless interference networks.
16:26 – 16:52
Suhas Diggavi (University of California Los Angeles, USA)
We study the role of caches in wireless interference networks. We focus on content caching and delivery across a Gaussian interference network, where both transmitters and receivers are equipped with caches. We provide a constant-factor approximation of

the system's degrees of freedom (DoF), for arbitrary number of transmitters, number of receivers, content library size, receiver cache size, and transmitter cache size (as long as the transmitters combined can store the entire content library among them). We demonstrate approximate optimality with respect to information-theoretic bounds that do not impose any restrictions on the caching and delivery strategies. The approximate DoF is achieved using a strategy that separates the physical and network layers, demonstrating the approximate optimality of such a separation architecture between the physical layer transmissions and caching in wireless interference networks. We also show that this separation architecture has an interface between the physical and network layer based on a particular message delivery structure that depends on the cache memories. As a side result, solving the caching problem required formulating and solving a new communication problem, the symmetric multiple multicast X-channel, for which we provide an exact DoF characterization. This is joint work with Jad Hachem and Urs Niesen.

Coded Caching Schemes with Reduced Subpacketization from Linear Block Codes
16:52 – 17:18
Aditya Ramamoorthy (Iowa State University, Ames, USA)
Coded caching is a technique that generalizes conventional caching and promises significant reductions in traffic over caching networks. However, the basic coded caching scheme requires that each file hosted in the server be partitioned into a large number (i.e., the subpacketization level) of non-overlapping sub-files. From a practical perspective, this is problematic as it means that prior schemes are only applicable when the size of the files is extremely large. In this work, we propose coded caching schemes based on combinatorial structures called resolvable designs. These structures can be obtained in a natural manner from linear block codes whose generator matrices possess certain rank properties. We obtain several schemes with subpacketization levels substantially lower than the basic scheme at the cost of an increased rate. Depending on the system parameters, our approach allows us to operate at various points on the subpacketization level vs rate tradeoff. Joint work with Li Tang (Iowa State Univ.)

Caching in Cellular Networks: A Learning Theoretic Perspective
17:18 – 17:45
Bharath N. Bettagere (Indian Institute of Technology Dharwad, India)
Caching in cellular network is a promising technique to enhance the performance of 5G and beyond wireless systems. Higher performance is achieved by having faster access to the requested information/files through caching of "popular files" in the memories of the Base Stations (BSs), Small BSs (SBSs) and even users. Regardless of the mechanism used to cache the files, the knowledge of the popularity of the files is essential. My talk focuses on a framework to analyze the performance of caching mechanism in a cellular network with non-stationary and possibly correlated requests for the files. Towards the end of the talk, I will touch upon the use of recommendation mechanism to enhance the performance of caching in future wireless cellular systems.

SP.TU15: Computational Imaging
Tuesday, July 17, 16:00 - 17:45
Venue: Hall-B
Chair: Chandra Sekhar Seelamtula (Indian Institute of Science Bangalore, India)

Structured low-rank algorithms: a novel framework for super-resolution recovery of curves and images
16:00 – 16:26
Mathews Jacob (University of Iowa, Iowa City, USA)
The recovery of signals from very few and noisy measurements using compactness priors had been an active area of research in the compressed sensing. Most of the current methods rely on discrete signal models, which are not ideally suited for the super-resolution setting, where the primary objective is to improve the resolution beyond the limits of physical imaging systems. The main focus of the talk is to introduce a novel framework for the continuous domain recovery of images and curves from few of their measurements. The proposed structured low-rank methods are ideally suited to recover signals that are support limited on curves or surfaces in high dimensions, unlike current atomic norm minimization methods that are designed for the recovery of Diracs or spikes. The similarity of the resulting algorithms to widely used kernel methods and graph Laplacian regularization will also be covered. The application of the framework will be demonstrated in several applications including MRI and optical imaging.

Solving Inverse Computational Imaging Problems using Deep Pixel-level Priors
16:26 – 16:52
Kaushik Mitra (Indian Institute of Technology Madras, India)
Signal reconstruction is a challenging aspect of computational imaging as it often involves solving ill-posed inverse problems. Recently, deep feed-forward neural networks have led to state-of-the-art results in solving various inverse imaging problems. However, being task specific, these networks have to be learned for each inverse problem. On the other hand, a more flexible approach would be to learn a deep generative model once and then use it as a signal prior for solving various inverse problems. We show that among the various state of the art deep generative models, deep auto regressive models are especially suitable for our purpose. We demonstrate the efficacy of our proposed approach in solving three computational imaging problems: Single Pixel Camera (SPC), LiSens and FlatCam.

SPToF: Signal processing for Time-of-Flight cameras
16:52 – 17:18
Adithya Pediredla (Rice University, Houston, USA)
During the last decade, we have been witnessing the continued development of new time-of-flight imaging devices, and their increased use in numerous and varied applications. Unfortunately, due to the expensive hardware setups, very few signal processing techniques exist for designing the imaging and image processing pipelines for the time-of-flight cameras. To mitigate these problems, we propose a physics-based rendering technique that can accurately simulate the functionality of the time-of-flight devices for arbitrary geometries, scene BRDFs, and light bounces. The proposed rendering algorithm

efficiently samples paths with a predetermined length and is tailored towards simulating different time-of-flight sensors, such as gated and transient cameras. We use our open-source implementation to demonstrate improved rendering performance in a variety of scenes. We also show two signal processing-based applications of our renderer: (1) to reconstruct planar facets beyond line-of-sight, (2) to design depth-selective codes for continuous-wave time-of-flight camera.

Sparsity Assisted Optical Phase Imaging
17:18 – 17:45
Kedar Khare (Indian Institute of Technology Delhi, India)
Imaging phase of an optical wavefront is a challenging problem since all detectors at visible wavelengths only respond to energy or amplitude of light waves. Phase however carries a lot of meaningful information that is useful for a number of imaging applications. Single shot phase imaging poses severe data incompleteness problems for both interferometric as well as non-interferometric imaging configurations. For example the spatial resolution in single-shot off-axis interferometric data is considered limited by overlap of the dc and cross terms in Fourier space. Non-interferometric iterative phase retrieval from Fourier magnitude data for complex valued objects on the other hand is considered difficult due to the twin stagnation problem. In this talk I will describe our work on incorporating sparsity ideas for phase imaging that allows us to outperform several “text-book” limitations on resolution, noise and data incompleteness issues. Our recent efforts on converting the new algorithmic ideas for applications such as live cell microscopy and pathological diagnosis will also be discussed. Overall I will show that the computational imaging framework can question several long-held Physics limits on phase imaging and in the process enable a number of low cost imaging devices.

SP.TU16

SP.TU16: Estimation and information theory
Tuesday, July 17, 16:00 - 17:45
Venue: Hall-C
Chair: Parimal Parag (Indian Institute of Science Bangalore, India)

Proving strong converse is difficult?
16:00 – 16:26
Shun Watanabe (Tokyo University of Agriculture and Technology Fuchu, Japan)
The strong converse for a coding theorem shows that the optimal asymptotic rate possible with vanishing error cannot be improved by allowing a fixed error. The strong converse for multi-terminal problems typically requires some sophisticated techniques such as the blowing-up lemma, and it has been regarded as a difficult problem. In this talk, it is demonstrated that the strong converse for multi-terminal problems, including some open problems in the literature, can be proved by a quite simple argument. This is a joint work with Himanshu Tyagi.

Secret Sharing for Secure and Private Distributed Coded Computation.
16:26 – 16:52
Salim El Rouayheb (Rutgers University, USA)
I will describe the communication efficient secret sharing (CESS) problem and introduce explicit constructions of CESS schemes, called Staircase Codes, which achieve optimal communication and read costs. Then, I will describe an application of Staircase codes to minimizing latency against stragglers in secure distributed coded computations. Time permitting, I will also talk about Staircase codes for constructing universally-robust private information retrieval schemes. This is a joint work with Rawad Bitar and Parimal Parag.

Gaussian Process bandits with adaptive discretization
16:52 – 17:18
Tara Javidi (University of California San Diego, USA)
In this paper, the problem of maximizing a black-box function real-valued function f with domain X is studied in the Bayesian framework with a Gaussian Process (GP) prior. In particular, a new algorithm for this problem is proposed, and high probability bounds on its simple and cumulative regret are established. The query point selection rule in most existing methods involves an exhaustive search over an increasingly fine sequence of uniform discretizations of X. The proposed algorithm, in contrast, adaptively refines X which leads to a lower computational complexity, particularly when X is a subset of a high dimensional Euclidean space. In addition to the computational gains, sufficient conditions are identified under which the regret bounds of the new algorithm improve upon the known results. Finally an extension of the algorithm to the case of contextual bandits is proposed, and high probability bounds on the contextual regret are presented. This is joint work with Shubhanshu Shekhar.

Estimation of discrete distributions under local differential privacy
17:18 – 17:45
Alexander Barg (University of Maryland College Park, USA)
We consider minimax estimation of a discrete distribution under privacy constraints. A privatization scheme is applied to each raw sample independently, and the problem is to estimate the distribution of the raw samples from the privatized samples. Previous works were devoted to the high-privacy and low-privacy regimes. We propose a new family of privatization schemes and estimators that cover the entire range of parameters and improve upon the known schemes in the medium-privacy case. We prove that our procedure is asymptotically optimal for the L2 estimation loss and order-optimal for the L1 loss. Joint works with Min Ye (UMD/Princeton).

WE01

WE01: Wireless, Vehicular and Smart Grid Networks
Wednesday, July 18, 09:00 - 10:15
Venue: JN Tata Auditorium
Chair: Jean-Francois Chamberland (Texas A&M University, USA)

Age-of-Information Aware Scheduling
09:00 – 09:18
Prakirt Raj Jhunjhunwala (Indian Institute of Technology Bombay, India)
Sharayu Moharir (Indian Institute of Technology Bombay, India)
We study the task of scheduling in a multi-source system where sources report their time-varying information to a central monitoring station via multiple orthogonal channels. The Age-of-Information of a source is defined as the amount of time elapsed since the latest update from that source was received at the monitoring station. At each time instant, the system pays a cost that is a function of the current Ages-of-Information of the sources. Our goal is to design scheduling policies to minimize this cost. We draw a novel parallel between our scheduling problem and the minimum mean cost cycle problem in weighted graphs and use this insight to design optimal scheduling policies for a very general class of cost functions. In addition, we compare the performance of our policy with naive greedy policies. We show that while greedy policies can be optimal if the cost function is symmetric with respect to the sources, our policy strictly outperforms greedy policies when the cost function is asymmetric across sources.

Platform Competition for Throughput in Two-sided Freelance Markets
09:18 – 09:37
Mansi Sood (Indian Institute of Technology Bombay, India)
Ankur A. Kulkarni (Indian Institute of Technology Bombay, India)
Sharayu Moharir (Indian Institute of Technology Bombay, India)
We address the problem of price competition between platforms that facilitate the immediate exchange of services between freelance workers and customers in two-sided markets. We consider two competing platforms offering identical services to the users at potentially different prices. The objective of each platform is to maximize its throughput by announcing a suitable price. We assume that customers have a preference or loyalty to the platforms, and all users route themselves to the platforms in a manner that maximizes their social welfare. We show that for each value of the loyalty, there exists a pure strategy Nash equilibrium and characterize it.

Routing and Scheduling Transient Flows for QoS in Multi-hop Wireless Networks
09:37 – 09:56
Vinay Siram (Indian Institute of Science Bangalore, India)
Karthikeshwar Varma Dasaraju (Indian Institute of Science Bangalore, India)
Prakas Barman (Indian Institute of Science Bangalore, India)
Surekha Yellisetty (Mediatek Bangalore Pvt Ltd, India)
Padma Desiraju (CAIR DRDO, India)
Saurabh Mandal (CAIR DRDO, India)
Suvina M Vijayan (CAIR DRDO, India)
Prakash Chand (DRDO, India)
Utpal Mukherji (Indian Institute of Science Bangalore, India)
Vinod Sharma (Indian Institute of Science Bangalore, India)
We consider the problem of routing and scheduling of transient real time and non-real time flows to provide Quality of Service (QoS) in multi-hop wireless networks. Routing and scheduling are obtained via multicommodity flow optimization. Furthermore, admission control, and processor sharing of non-real time flows, ensure a more effective QoS management and fair allocation of resources on a short time scale. Blocking probabilities, mean sojourn times, and real time packet end-to-end delays, of flows are obtained via link independence approximation.

Menu-Based Pricing for Profitable Electric Vehicle Charging with Vehicle-to-Grid Service
09:56 - 10:15
Arnob Ghosh (Purdue University & University of Pennsylvania, USA)
Vaneet Aggarwal (Purdue University, USA)
The paper considers a bidirectional power flow model of the electric vehicles (EVs) in a charging station. The EVs can inject energy by discharging via a Vehicle-to-Grid (V2G) service which can enhance the profits of the charging station. However, frequent charging and discharging degrade the battery life. A proper compensation needs to be paid to the users to participate in the V2G service. We propose a menu-based pricing scheme, where the charging station selects a price for each arriving user for the amount of battery utilization, the total energy, and the time (deadline) that the EV will stay. The user can accept one of the contracts or rejects all depending on their utilities. The charging station can serve users using a combination of the renewable energy and the conventional energy bought from the grid. The charging station is not aware of the exact utilities, finding the optimal price is computationally difficult. We show that a guaranteed fixed profit pricing scheme in a myopic scenario can maximize the expected profit over a large class of distribution function. In the menu-based pricing, when the harvested renewable energy is small, the users have higher incentives for the V2G service.

TECHNICAL PROGRAM

WE02

WE02: Speech Recognition
Wednesday, July 18, 09:00 - 10:15
Venue: Hall-A
Chair: Bhavani Shankar Mysore R (Interdisciplinary Centre for Security, Reliability and Trust, Luxemburg)

Enhancing Pitch Robustness of Speech Recognition System Through Spectral Smoothing

09:00 – 09:18

Bandarupalli Tarun Sai (National Institute of Technology Patna, India)
Ishwar Chandra Yadav (National Institute of Technology Patna, India)
Syed Shahnawazuddin (National Institute of Technology Patna, India)
Gayadhar Pradhan (National Institute of Technology Patna, India)

In this paper, we present a novel approach for front-end speech parameterization that is more robust towards pitch variations than the most commonly used technique. Earlier works have shown that, insufficient smoothing of magnitude spectrum leads to pitch-induced distortions. This in turn results in poor performance of speech recognition system especially for high-pitched child speakers. To overcome this shortcoming, the short-time magnitude spectrum is first decomposed into several components using a modified version of empirical mode decomposition (EMD). Next, the lowest-order component is discarded and the spectrum is reconstructed using the rest of the higher-order modes for sufficiently smoothing the spectrum. The Mel-frequency cepstral coefficients (MFCC) are then extracted using the smoothed spectra. The signal domain analyses presented in this paper demonstrate that the ill-effects of pitch variations get significantly reduced by the inclusion of proposed spectral smoothing module. In order to statistically validate the same, an automatic speech recognition system is developed using speech data from adult speakers. To simulate large pitch differences, evaluations are performed on a test set which consists of speech data from child speakers. Inclusion of proposed spectral smoothing module leads to a relative improvement of 12% over the baseline system employing acoustic modeling based on deep neural network.

Some Experiments on Context Mismatched Speech Recognition

09:18 – 09:37

Abhishek Dey (GUIST Gauhati University, Guwahati, India)
Syed Shahnawazuddin (National Institute of Technology Patna, India)
Rohit Sinha (Indian Institute of Technology Guwahati, India)

An automatic speech recognition (ASR) system is required to normalize a number of intra- and inter-speaker variability as well as session, channel and ambiance differences in order to be effective. Some of the variability factors are gender, age, accent, emotion, speaking rate, etc., of the speakers. To address these sources of variability, speech data from a large number of speakers catering to varied conditions is pooled together for training the context-dependent triphone models. Furthermore, several feature-space normalization and speaker-space adaptation techniques are also incorporated into the system development. Another important factor of mismatch is frequency of occurrence of triphone contexts in the training and test data. In the case of hidden Markov modeling, regression-tree-based state tying is performed to model the seen contexts and to deal with unseen ones. In those cases, where the trained triphones occur less frequently (or are absent) in the test data, the recognition performance gets degraded. In this paper, we present our efforts to improve the performance of such context mismatched ASR tasks. In this regard, we explore the role of varying the number of senones on the recognition performance. It is hypothesized that, using lower number of senones is beneficial in such cases.

Detection of Vowel Offset Points Using Non-Local Similarity Between Speech Samples

09:37 – 09:56

Avinash Kumar (National Institute of Technology Patna, India)
Syed Shahnawazuddin (National Institute of Technology Patna, India)
Gayadhar Pradhan (National Institute of Technology Patna, India)

Automatic detection of vowels is not only an important but also a challenging problem. Vowel offset point (VEP) is the instant of ending of a vowel. Like vowel onset points (VOPs), VEPs are equally important for accurate marking of vowels and analysis of speech signal. The transition in the signal magnitude at the VEPs is quite different when compared to the VOPs. Consequently, most of the front-end features proposed for the detection of VOPs fail to detect the VEPs. Performance of the existing features also reduces significantly in the case of noisy speech signals. In this work, a robust front-end speech parametrization approach is proposed for enhancing the discrimination at the VEPs. In the proposed approach, weight values are assigned to each of the sample points by computing the similarity present in the samples belonging to two different frames within a search neighborhood. The weight values (WVs) computed from the non-local similarity (NLS) is significantly less when the frames under consideration are similar in comparison to the dissimilar ones. Since the vowels are longer regions and exhibit periodicity, there will be more similarity in the case of frames belonging to these regions. On the other hand, the frames belonging to the non-vowel regions and noises will be dissimilar. In this work, WVs computed from the NLS is used as a feature for detecting the VEPs in a given speech signal. The proposed method is observed to outperform the deep neural network-hidden Markov model based classifier under both clean and noisy test conditions even after the inclusion of a recently proposed speech enhancement module.

Improving Children's Speech Recognition Through Time Scale Modification Based Speaking Rate Adaptation

09:56 - 10:15

Hemant Kathania (National Institute of Technology Sikkim, India)
Syed Shahnawazuddin (National Institute of Technology Patna, India)
Waquar Ahmad (National Institute of Technology Sikkim, India)
Nagaraj Adiga (University of Crete, Greece, India)
Sanjay Jana (National Institute of Technology Sikkim, India)
Arun Samaddar (National Institute of Technology Sikkim, India)

In the work presented in this paper, we have explored the effect of speaking-rate adaptation on children's speech recognition using acoustic models trained on adults' speech. It is well known that the shape of the vocal organs, pitch and speaking-rates are significantly different for adult and child speakers. Consequently, the recognition performance for children's speech in such mismatched setup is reported to be extremely poor. To address the acoustic mismatch resulting from the differences in pitch and vocal-tract geometry, a large number of studies have been reported that have presented a myriad of techniques. But, only a few works have studied the role of speaking-rate adaptation on children's speech recognition. Furthermore, those studies were performed on systems employing Gaussian mixture models. Motivated by these facts, we have explored speaking-rate adaptation in the context of systems employing deep neural network based acoustic modeling. Time-scale modification using an approach based on phase-independent iterative spectrogram inversion is employed for speaking-rate adaptation. Significant reductions in errors are noted by adapting the speaking-rates. Furthermore, the effect of combining speaking-rate adaptation with vocal-tract length normalization and pitch scaling is also studied. Additive improvements are obtained by combining the explored techniques with speaking-rate adaptation.

WE03

WE03: OFDM and Multicarrier Techniques

Wednesday, July 18, 09:00 - 10:15

Venue: Hall-B

Chair: Adrish Banerjee (Indian Institute of Technology Kanpur, India)

Non-orthogonal Trans multiplexers for FBMC with Controlled ISI

09:00 – 09:18

Arjun R and Ashish Sukhwani (Indian Institute of Technology Bombay, India)
Kumar Appaiah (Indian Institute of Technology Bombay, India)
Vikram M. Gadre (Indian Institute of Technology Bombay, India)

Multicarrier modulation techniques, such as OFDM, are enabled by the use of transmultiplexers. In general, multicarrier modulation does not require perfect reconstruction of the transmitted carriers at the receiver, since near perfect reconstruction may provide similar performance with lower complexity or higher spectral efficiency. Near perfect reconstruction transmultiplexers which have low out of band ripples are seen extensively in literature. However, they exhibit a significant amount of inter-symbol interference (ISI), and closeness to orthogonality is imposed by an optimization criteria that determines the same. We propose a transmultiplexer that structurally has controlled ISI. The interference is strictly restricted to a predefined set of points that do not depend on the optimization performance, thereby reducing receiver complexity. A novel first order near-perfect reconstruction (NPR) block is proposed. This block is cascaded N times to generate an N-th order polyphase matrix which satisfies the NPR property, and this is then used to create controlled ISI transmultiplexers. We validate the fact that the out-of-band energy is limited even in the presence of ISI, using simulations.

Iterative Channel and Symbol Estimation for OFDM and for SIMO Diversity

09:18 – 09:37

Yash Vasavada (Dhirubhai Ambani Institute of Information and Communication Technology, India)
Jeffrey Reed (Virginia Tech, USA)
A. A. (Louis) Beex (DSPRL - Wireless@VT & Virginia Tech, USA)

This paper proposes a new approach of Iterative Channel and Symbol Estimation (ICSE) with applications in Orthogonal Frequency Division Multiplexing (OFDM) and Single Input Multiple Output (SIMO) diversity systems. Our method extends the traditional approaches of Pilot Symbol Assisted Method (PSAM) and Decision Directed Method (DDM) for symbol detection. This paper describes the key mathematical methods for (i) estimating the log-likelihood ratio of the unknown information bearing symbol given an uncertain estimate of the channel (derived using sparsely-transmitted pilot symbols), and (ii) subsequently re-estimating the channel coefficients using this log likelihood ratio. Formulations in this paper, thus, establish the underlying methods that enable the ICSE. The main contributions of this paper are to (i) provide a specific method of estimating the channel coefficients using uncertain symbol/bit estimates, (ii) show mathematical equivalence of this method with the method of deriving the symbol log-likelihood ratio, and (iii) describe the applicability of the proposed ICSE scheme to the OFDM receiver and the SIMO receiver. A simulation and analytical (Cramer-Rao Bound) evaluation of the proposed method provides demonstration of the potential performance benefit of the proposed approach.

Time-domain Complexity Analysis of Impulse Noise Sources for xDSL/PLC Systems

09:37 – 09:56

Neelima Singh (Indian Institute of Technology Delhi, India)
Brejesh Lall (Indian Institute of Technology Delhi, India)

Impulse noises originating from domestic electronic appliances impact the performance of indoor communication systems severely. These noises are mostly being generated by non-linear devices and thus are either in form of random isolated impulses or bursts consisting of various sub-impulses which look like train of spikes. For the cases where many sub-impulses constitute bursts, spectrogram analysis reveals various types of patterns. Thus depending on the type of patterns, these noises have different levels of time-domain and spectral complexities. These complexities due to different patterns can be quantified using various types of complexity measures. In this paper, we have proposed time-domain analysis based on evaluating information theory estimates of complexity measures such as approximate entropy and sample entropy of these impulse noises. We have demonstrated in this paper that above mentioned entropy measures are able to capture and quantify the variability of impulse noises generated by electronic appliances and thus proposed noise analysis may aid in identifying the primary disturber (i.e., the active impulse noise source).

Multiplexing Reference Signals and Data in a DFT-s-OFDM Symbol
09:56 - 10:15
Chandrashekhar Thejaswi Pataguppe Suryanarayan Bhat (Samsung R&D Institute, Bangalore, India)
SaiDhiraj Amuru (Samsung, India)
Jinesh P Nair (Nokia Networks, India)
Atanu Guchhait (Samsung R&D Institute, Bangalore, India)
In this paper, we consider the transmission of DFT spread OFDM (DFT-s-OFDM or SCFDM or SC-FDE) for a cellular uplink, and address the problem of multiplexing reference signals (RS) and data within a single DFT-s-OFDM symbol. Traditionally, RS and data information are transmitted in a time-division-multiplexed fashion with dedicated symbols for RS and data. Different from the traditional approach, multiplexing RS and data within a single DFT-s-OFDM symbol enables mechanisms to transmit short uplink transmissions containing only a single DFT-s-OFDM symbol. This finds applications in the upcoming 3GPP NR systems which have designed short uplink control transmissions for latency constrained applications and for embedding phase tracking reference signals in the uplink transmissions of mmWave systems. A naive approach to multiplex RS and data in a single symbol might harm the single carrier property of DFT-s-OFDM symbol leading to peak-to-average power ratio (PAPR) problems. Therefore, there is a trade-off between performance and PAPR. In this paper, we optimize this trade-off by exploiting the structural properties of discrete Fourier transform (DFT), and propose a novel idea to multiplex RS and data involving frequency domain RS assignment and time domain redundancy. Numerical results are presented to show the efficacy of the proposed design.

WE04

WE04: VLSI for Communication and Signal Processing
Wednesday, July 18, 09:00 - 10:15
Venue: Hall-C
Chair: Shalabh Gupta (Indian Institute of Technology Bombay, India)

Floorplan Based Performance Evaluation of 3D Variants of Mesh and BFT Networks-on-Chip
09:00 – 09:20
Bheemappa Halavar (National Institute of Technology Karnataka, India)
Basavaraj Talawar (National Institute of Technology Karnataka, India)
Network on Chips (NoC) emerged as the reliable communication framework in CMPs and SoCs which enables in increase the number and complexity of cores. Many 2-D NoC architectures have been proposed for efficient on-chip communication. Cycle accurate simulators model the functionality and behavior of NoCs by considering micro-architectural parameters of the underlined components to estimate performance metric. Using 3D IC technology in NoC can lead to improved communication latency and power compared to their 2D counterpart with use of through-silicon via (TSVs) as vertical interconnect. In this paper, we explore the design space of 3D variants of the Mesh and Butterfly Fat Tree (BFT) NoCs using floor plan driven wire and TSV lengths. Cycle accurate simulators extended to support 3D TSV delay and analyzed the performance of 2D and 3D variants of the Mesh and the Butterfly Fat Tree topologies by injecting two synthetic traffic pattern. Results of our experiments show that for the injection rates from the average network latency of a 4-layer 3D Mesh shows on chip communication performs better compared to other 3D variants. On chip communication performance improvement of 2.2× in 4-layer 3D Mesh compare to 2D Mesh and 5× than 4-layer 3D BFT for uniform traffic pattern.

Low Complexity Algorithm for Multi-path Video Streaming
09:20 – 09:40
Anis Elgabli (Purdue University, Indiana, USA)
Vaneet Aggarwal (Purdue University, Indiana, USA)
Ke Liu (Purdue University, Indiana, USA)
In this paper, we propose a multi-path (e.g., WiFi, and LTE) video streaming algorithm for videos encoded using Scalable Video Coding (SVC) in which each chunk of the video is encoded into a single base layer and multiple enhancement layers. The multi-path SVC streaming subject to the available bandwidth of the different paths and the chunk deadlines is formulated as a non-convex optimization problem. The objective is to minimize the skip/stall duration as the first priority, maximize the average quality as the second priority, and minimize the quality switching rate as the third priority. A novel algorithm is developed to solve this non-convex optimization problem in a complexity that is quadratic in the video length and it is shown to be optimal. Extensive emulated experiments with real SVC encoded videos and real bandwidth traces of public data set reveal the robustness of our scheme and show its significant performance improvement compared to other multi-path algorithms.

Affine Boolean Classification with FPGA Implementation on Secret Image Sharing
09:40 – 10:15
Tapasi Bhattacharjee (WBUT, India)
Hirak Maity (College of Engineering and Management Kolaghat, India)
Santi Prasad Maity (Indian Institute of Engineering Science and Technology Shibpur, India)
This paper proposes an (n,n)-threshold secret image sharing (SIS) scheme with identical shares size obtained through affine Boolean classification. The two sets of bit patterns formed from the fixed and the variable bit positions of this classification are used to develop the shares. Simplicity in Boolean operations leads to its hardware realization in Field Programmable Gate Array (FPGA) platform using Xilinx ISE design suite 14.5 (device family XC3S700A-4FG484). While the proposed SIS scheme shows robustness against various operations including random gain scaling, the FPGA architecture, for an 8bits/pixel (8 X 8) secret image, offers a throughput of 133.4 Mbps at frequency of 288.749 MHz.

WE05

WE05: NB-IoT
Wednesday, July 18, 12:00 - 13:00
Venue: JN Tata Auditorium
Chair: Kiran Kuchi (Indian Institute of Technology Hyderabad, India)

Reference Signals Based Time and Frequency Tracking in NB-IoT
12:00 – 12:20
Sriharsha Magani (Indian Institute of Technology Hyderabad, India)
Kiran Kuchi (Indian Institute of Technology Hyderabad, India)

Narrowband Internet of Things (NB-IoT) is the technology developed by 3GPP to bring the connectivity among IoT devices. The main aim of this technology is to improve the coverage and support massive number of IoT devices with long battery life. Coverage is enhanced by data repetitions over an extended period of time. The battery life at the User Equipment (UE) is extended by incorporating long DRX cycles of 10.24 sec. Preserving timing and frequency synchronization under such long repetitions and DRX cycles poses a challenge for NB-IoT. In this paper we propose Narrowband Reference signals (NRS) based tracking of residual timing and frequency offsets. The proposed method assume that the initial synchronization has been carried out using NB Primary (NPSS) and Secondary synchronization (NSSS) signals. The results obtained from the initial synchronization serves as the coarse estimates for the proposed method. Inherent non rapid channel variations across NRS carrying subcarriers of successive OFDM symbols is exploited to estimate residual offsets. The extracted residual offsets from NRS signals of two antenna ports are combined to refine the estimates. The performance results of presented algorithm and its processing time to yield the estimates at -12 dB SNR obtained by computer simulations are presented.

Digital Predistortion for Narrowband IoT Applications
12:20 – 12:40
Yuva Kumar (Keio University, Tokyo, Japan)
Seetharam Kashyap (Lekha Wireless Solutions, India)
Sreenath Ramanath (Lekha Wireless Solutions, India)

Narrowband Internet-of-Things (NB-IoT) applications can be deployed in licensed and unlicensed bands. Spectrum allocation for Narrowband IoT is often in-between licensed spectrum or available white space frequency bands and the designer is expected to meet stringent spectral mask requirements. Further, Narrowband IoT applications have range requirements in the order of few kilometers to tens of kilometers, which necessitates the use of high power amplifiers. This introduces significant non-linearity for systems which employ multiple access techniques like orthogonal frequency division multiple access (OFDMA). This affects the quality of the transmitted signal as well as introduces undesired adjacent channel emissions. In this paper, we describe a design approach for implementing a digital pre-distorter (DPD) for Narrowband IoT applications. We use a memory polynomial DPD model to trade-off performance and implementation complexity. By careful tuning of the parameters of the model, we demonstrate the system meeting the expected spectral mask and transmission quality requirements.

Low Complexity ML Synchronization for 3GPP NB-IoT
12:40 – 13:00
Sripada Kadambar (Samsung R&D Institute, Bangalore, India)
Ashok Kumar Reddy Chavva (Samsung Electronics, India)

Narrowband internet of things (NB-IoT) is a 3GPP standard introduced in Rel-13 for supporting IoT applications characterized by low cost, small data rate and long battery life. Applications typically need small data exchanges between long sleep cycles, hence needs to acquire frequency and time synchronization from network before setting up communication. This mandates the need for synchronization algorithms optimized in terms of both power and performance. But due to extreme channel conditions NB-IoT applications are expected to support, it is challenging for algorithms to optimize both, hence typically design approaches trade-off between low complexity and performance. In this paper, we propose a maximum likelihood synchronization algorithm that achieves optimal performance at low complexity. We describe approaches for reducing complexity by lowering sampling rate and using optimal frequency hypotheses placement. Using simulations, we show that our algorithm can improve synchronization performance by 50% while using 18.75% lesser computations compared to state of the art.

WE06

WE06: Spoken Language Processing
Wednesday, July 18, 12:00 - 13:00
Venue: Hall-A
Chair: Thippur Sreenivas (Indian Institute of Science Bangalore, India)

An SVD Based Approach for Spoken Language Identification
12:00 – 12:30
Manish Jain (Indian Institute of Technology Madras, India)
Malarvizhi Sundaresan Saranya (Indian Institute of Technology Madras, India)
Hema A Murthy (Indian Institute of Technology Madras, India)

In this paper, we revisit the classical Singular Value Decomposition (SVD) based approach for dimension reduction in Language Identification (LID). This is proposed as an alternative to the state-of-the-art TVS based framework. A UBM-GMM is first built as in the state-of-the-art system. The training utterances are aligned with UBM using MAP adaptation to yield supervectors. The training supervectors are stacked row-wise to form a matrix. SVD is performed on this matrix of supervectors. The issue of ill-conditioned matrix is solved using a novel proxy projection technique. The supervectors are then projected along the top L singular vectors. An SVM-based classifier is trained on the projected supervectors. During testing, the test supervector obtained by aligning with the UBM-GMM is projected along the same L directions. The reduced dimension test vector is then classified using the SVM classifier. The proposed system shows an absolute improvement of 8.4% over the best i-vector based LID system for 30 second utterances of the CallFriend dataset with 12 languages. Proxy projection technique gives >=3% absolute improvement over ordinary projection. As the T-matrix obtained in the TVS does not have orthogonal basis,

the i-vectors are projected in orthogonal basis through SVD, which gives an absolute improvement of 6.4%. The proposed approach scales well with an accuracy of 93.87% on the Topcoder dataset with 176 languages.

Enhancement of Bone Conducted Speech Signal by Wavelet Transform
12:30 – 13:00
Premjeet Singh (Birla Institute of Technology Mesra, India)
Manoj Mukul (Birla Institute of Technology Mesra, India)
Rajkishore Prasad (Bihar National College, Patna, India)
To acquire the speech generated by the user, communication devices makes use of an air microphone which, by far, is the most common and simple signal acquisition method. This leads to gathering of background noise along with the actual speech signal and makes the whole communication link noisy. To prevent this, proposal of using bone conducted signal is made. As bone prevents passing of vibration signals which are of frequencies greater than 1.5kHz, transmitted signal will remain inherently free of ambient noise. However, bone conducted signals are usually inferior in intelligibility and SNR as compared to the microphone signals, hence, two signal processing approaches, using MFCC and wavelet transform, are proposed which can improve such parameters with an attempt to increase the quality of communication link between transmitter and receiver.

WE07

WE07: Forensics and Security
Wednesday, July 18, 12:00 - 13:00
Venue: Hall-B
Chair: Sandeep K. Shukla (Virginia Polytechnic and State University, USA)

DeepPalm- A Unified Framework for Personal Human Authentication
12:00 – 12:20
Gaurav Jaswal (National Institute of Technology Hamirpur, India)
Aditya Nigam (Indian Institute of Technology Mandi, India)
Amit Kaul and Ravinder Nath (National Institute of Technology Hamirpur, India)
Palm print recognition has been studied extensively in both contact and contactless environments. Robust features and effective matching are the most important requirements for any authentication problem. However, the most of state of artworks don't focus to handle variations of translation, rotation, and blurriness of flexion creases and ridges of palm that largely degrade its performance. In this paper, we have proposed a novel generalized segmentation Network (PSegNet), that automatically categorize the palm print image obtained from multiple sensory resources and then detect the fixed size ROIs accurately. To best of our knowledge, this is the first attempt, an end-to-end trained object detector inspired by Deep Learning technique namely faster R-CNN (Region based Convolutional Neural Network) has been employed to detect and localize the position of palm. Then, the ROI image is well enhanced and transformed into illumination invariant visual representation. Over this, handcrafted features are computed patch-wise and the

sub-patches are recursively matched using a deformable dense matching technique called as Deep-Matching. The experimental results are examined on four publicly available databases named as Poly-U Palm print, and CASIA Palm print, IITD Contactless Palm print, and GPDS-CL1 databases. The proposed approach achieves equal error rate (EER) of 0.06 %, decidability index (DI) of 2.94 and rank-1 identification rates (CRR) of 100% that justifies the role of CNN based ROI segmentation and multi-scale Deep-Matching criterion.

Tensor Total Variation Regularized Moving Object Detection for Surveillance Videos
12:20 – 12:40
Anju Jose Tom (National Institute of Technology Calicut, India)
Sudhish N George (National Institute of Technology Calicut, India)
The classical Background Subtraction (BS) and Moving Object Detection (MOD) problems function on the matrix framework considering each frame as a matrix, or by operations such as matricization of the 3D video data. These methods also give priority to static background video sequences. Inspired by the aforementioned factors, this work proposes a method in which the video data is treated as a tensor throughout the implementation and thereby ensuring efficient utilization of the structural properties of video volume. It also addresses the dynamic background issue by solving a tensor optimization algorithm of a convex formulation that is convergent in nature. Moreover, the low rank property is used to extract the structured part of the scene while Tensor Total Variation (TTV) is incorporated to draw out the foreground part from the emotive surroundings. The excellence of this method lies in the reduced computational complexity, quickness, and on the superiority acquired in quantitative evaluation based on F-measure, Recall, Precision with respect to the other methods.

Replay Attack Detection in Speaker Verification Using Non-Voiced Segments and Decision Level Feature Switching
12:40 – 13:00
Malarvizhi Sundaresan Saranya (Indian Institute of Technology Madras, India)
Hema A Murthy (Indian Institute of Technology Madras, India)
Padmanabhan Rajan (Indian Institute of Technology Mandi, India)
This paper proposes a novel approach for replay attack detection, using reverberation and channel information from non-voiced (silence and unvoiced) segments of utterances. The non-voiced segments are determined using a voice activity detector. These non-voiced segments are likely to contain reverberation and channel information. Multiple feature representations are used to capture the remnant vocal tract information in non-voiced segments. Gaussian mixture models are used to build three different baseline systems corresponding to that of three different features. Voting is performed to decide whether a given input utterance is replayed or not. Equal error rate (EER) is computed using the likelihood ratio of the genuine and spoofed model from the best baseline system. Evaluation on the ASV-Spoof-2017 challenge dataset shows that the proposed approach outperforms the best baseline system with a relative improvement of 37% in terms of EER

WE08

WE08: Physical Layer Security
Wednesday, July 18, 12:00 - 13:00
Venue: Hall-C
Chair: B.Sundar Rajan (Indian Institute of Science Bangalore, India)

Two Receiver Relay Broadcast Channel with Mutual Secrecy
12:00 – 12:20
Krishnamoorthy Iyer (Indian Institute of Technology Bombay, India)

We consider mutual secrecy requirements in a two receiver relay broadcast channel, where the dedicated relay is trusted by all parties. In our scheme, the relay decodes and forwards the respective messages to their intended destinations. Coherent transmission by the transmitter and relay is achieved by employing the Marton-Marton coding technique. Double random binning is then used to provide mutual secrecy. While our encoding is irregular, the decoding at the receivers employs forward sliding windows. This not only improves the flexibility, but also reduces the decoding delay when compared to backward decoding. This will be welcomed by wireless engineers. The multi-block equivocation calculation also has some features of interest.

Practical Physical-Layer Group Secret-Key Generation in Three-User Wireless Networks
12:20 – 12:40
J Harshan (Indian Institute of Technology Delhi, India)
Manish Rao (Indian Institute of Technology Delhi, India)

Group secret-key (GSK) generation using temporal variation in wireless channels is an effective way of synthesizing symmetric keys across multiple nodes (more than two) in wireless networks. Unlike the case of two-node key-generation, GSK generation necessitates some nodes to act as facilitators by transmitting linear combinations of the channel realizations. However, in practice, radio devices are designed to transmit baseband signals from finite complex constellations. Due to such practical constraints, the linear combinations of channel realizations are typically quantized by the facilitator which in turn impacts the overall secret-key rate. Identifying this practical issue, we propose a practical GSK generation protocol in a network of three nodes. Under special conditions, we analytically show that the proposed method provides higher key-rate than the case when only the facilitator quantizes the channel realizations before transmission. Through simulations, we show that the proposed method yields higher key-rate than the baselines when the facilitator employs finite constellations such as 4-,16-, and 64-QAM.

Jammer Assisted SEE Maximization in Decode-and-Forward Relay Network
12:40 – 13:00
Kirti Kant Sharma (Indian Institute of Technology Delhi, India)
Ranjan Bose (Indian Institute of Technology Delhi, India)

In this paper, the energy efficiency of secure communication in a wireless decode-and-forward (DF) relay network is studied using friendly jammer. Our objective is to maximize the secure energy efficiency (SEE), measured as the numbers of bits transmitted secretly per unit of energy consumed under power constraint on each node and target secrecy rate constraint. SEE maximization requires the optimal selection of helper nodes as relays and jammer, and then the power allocation among them. The SEE maximization is achieved by joint power allocation between the source, relays and a jammer in global channel state information (CSI) scenario. In this paper, the optimal jammer and relay set is selected iteratively by a simple jammer and relay selection scheme to avoid mix integer formulation of the optimization problem. The resulting problem is solved by a joint application of fractional programming, exact penalty, alternate search, and difference of convex functions programming.

WE09

WE09: Massive MIMO
Wednesday, July 18, 14:00 - 15:15
Venue: JN Tata Auditorium
Chair: A. Chockalingam (Indian Institute of Science Bangalore, India)

Uplink Training for Massive MIMO Systems Under Channel Aging
14:00 - 14:18
Ribhu Chopra (Indian Institute of Technology Guwahati, India)

In this paper, we study the effect of the choice of a frame structure on the performance of a massive MIMO system under channel aging. For this purpose, we compare the rates achievable using two popular frame structures, viz. training via lumped pilots, and training via interspersed pilots. We use Kalman filter based channel estimation to track the channel evolution. We first show that in an aging channel, the mean squared channel estimation error at a given instant is a function of the training instant and hence the user index. We then derive the deterministic equivalents of the per user achievable SINR, and use these to show that the achievable rate for any user at a given instant is a function of the training instant for the given user. Following this, we use the derived results to comment on the relative fairness of the two frame structures in question. Finally, numerical results are presented to illustrate the effect of the choice of a frame structure on the fairness of a massive MIMO system under channel aging.

Single-User mmWave Massive MIMO: SVD-based ADC Bit Allocation and Combiner Design
14:18 – 14:37
Fnu I. Zakir Ahmed (University of California Santa Cruz, USA)
Hamid Sadjadpour (University of California Santa Cruz, USA)
Shahram Yousefi (Queen's University Canada, USA)

In this paper, we propose a Singular-Value-Decomposition-based (SVD-based) variable-resolution Analog to Digital Converter (ADC) bit allocation design for a single-user Millimeter wave (mmWave) massive Multiple Input Multiple Output (MIMO) receiver. We derive the condition for the bit allocation under a power constraint. This condition ensures that the performance of the receiver is optimized in the Mean Squared Error (MSE)

sense. We derive the expression for the MSE and show that the expression for the MSE approaches the Cramer-Rao Lower Bound (CRLB). The CRLB is seen to be a function of the analog combiner, the digital combiner, and the bit allocation matrix. We attempt to minimize the CRLB with respect to the bit allocation matrix by making suitable assumptions regarding the structure of the combiners. In doing so, the bit allocation design reduces to a set of simple inequalities consisting of ADC bits, channel singular values and covariance of the quantization noise along each RF path. This results in a simple and computationally efficient bit allocation algorithm.

Kalman Filter Based Tracking for Channel Aging in Massive MIMO Systems
14:37 – 14:56
Vikas Arya (Indian Institute of Technology Bombay, India)
Kumar Appaiah (Indian Institute of Technology Bombay, India)
We consider the problem of channel aging in massive multi-user multiple-input-multiple-output (MIMO) wireless systems using the Kalman filters without knowledge of channel correlation statistics. Although Wiener filtering can be used to estimate the channel state information to construct accurate precoders and decoders, their use is limited in the case where regular adaptation to channel changes is needed. In addition, since different users exhibit different mobility conditions, use of an adaptive Kalman filter is advantageous when compared to conventional estimation approaches. We build a general model that allows a wide range of user mobilities in each cell. Simulations using the model reveal that the Kalman filter is effective in predicting channel coefficients to build an effective precoder. In addition, we perform both uplink and downlink analysis and show that with poorer channel tracking, the achievable rates in massive MIMO diminish unless more accurate channel estimates are present.

Hybrid Block Diagonalization for Massive MIMO Two-Way Half-Duplex AF Hybrid Relay
14:56 – 15:15
Arpita Chauhan (Indian Institute of Technology Kanpur, India)
Ekant Sharma (Indian Institute of Technology Kanpur, India)
Rohit Budhiraja (Indian Institute of Technology Kanpur, India)
We consider a multi-pair two-way amplify-and-forward massive multi-input multi-output (MIMO) hybrid relay with MIMO user-pairs. A hybrid relay has lesser number of radio frequency (RF) chains than the antennas, which significantly reduces the implementation cost. We employ block-diagonalization-based baseband processing at the hybrid relay to cancel the inter user-pair interference and equal-gain-combining-based RF processing to maximize the beamforming gain. We also use an algebraic norm maximizing relay transmit strategy to maximize the spectral efficiency (SE) of each user-pair. We numerically show that the proposed hybrid relay has only marginally inferior SE than a full RF-chain relay.

WE10: Audio and Speech Processing - 2
Wednesday, July 18, 14:00 - 15:15
Venue: Hall-A
Chair: V. Lalitha (International Institute of Information Technology Hyderabad, India)

Broad Phoneme Class Specific Deep Neural Network Based Speech Enhancement
14:00 - 14:18
Pavan Karjol (Indian Institute of Science Bangalore, India)
Prasanta Kumar Ghosh (Indian Institute of Science Bangalore, India)
In this work, we present a speech enhancement algorithm using broad phoneme class specific deep neural networks (DNNs). We build a classifier network to obtain the probabilities of each class in every test frame. The enhanced speech is obtained as the linear combination of the outputs from these class specific DNNs with combination weights as the probabilities predicted by the classifier network. We experiment with two (vowel and non-vowel) and four (vowel, stop, fricative, nasal) broad phoneme classes. Experiments are performed using speech data from TIMIT corpus, nine noise types (four seen and five unseen), and four SNR conditions. Experimental results show that the proposed class specific DNN approach outperforms the single DNN based speech enhancement scheme for both seen and unseen noise types in all SNR conditions considered.

Radial Filter Design Using Kaiser Window Polynomials for Speech Source Separation
14:18 – 14:37
Vishnuvardhan Varanasi (Indian Institute of Technology Kanpur, India)
Ayushya Agarwal (Indian Institute of Technology Kanpur, India)
Rajesh M Hegde (Indian Institute of Technology Kanpur, India)
Separation of coincident speech sources using microphone arrays is a challenging problem. Radial filters can be designed in the spherical harmonic domain to separate coincident speech sources effectively. Limited studies have been conducted on polynomial based near-field radial filter design in the spherical harmonic domain earlier. In this paper, a radial filter design method using a frequency domain Kaiser window function is proposed. The magnitude response of the Kaiser window function exhibits sharp notches, making it a good candidate for the design of radial notch filters. The polynomial expansion of the Kaiser window can be utilized for modeling the spherical array beam former output. Improved white noise gain and directivity index are noted in the radial filters designed using the Kaiser window function. The radial filter is also used to separate co-incident speech sources. Experimental results on coincident speech source separation indicate better LSD, PESQ and SDR scores than existing approaches.

Feature Extraction from Temporal Phase for Speaker Recognition

14:37 – 14:56

Ami Gandhi (Infinium Solutionz Pvt. Ltd, India)
Hemant A. Patil (Dhirubhai Ambani Institute of Information and Communication Technology, India)

Feature extraction is important for pattern recognition problems in speech research. Most of the methods of feature extraction exploit primarily spectral information than the phase information. Even though phase is an important characteristic of the speech signal, its use is not much exploited. In this work, in addition to state-of-the-art Mel Frequency Cepstral Coefficients (MFCC), we use features derived from temporal phase (i.e., T-Phase) of the speech signal for speaker recognition application. The proposed method extracts Linear Prediction Coefficients (LPC) from T-Phase of the speech signal at frame-level. Experiments are carried on standard NIST 2002 SRE using standard GMM-UBM system. It is observed that the score-level fusion of MFCC and T-Phase features gives 76.18 % identification rate which is a 4% and 8% improvement than MFCC and LPC alone, respectively. In addition, experiments show that fusion reduces the % EER by 2 % and 4 % than MFCC and LPC alone, respectively.

Model Order Estimation Using Ratio of Cumulative Sums of Eigenvalues

14:56 – 15:15

Palakkal Vishnu (Indian Institute of Technology Madras, India)
C S Ramalingam (Indian Institute of Technology Madras, India)

Determination of model order is an important task in many problems such as sinusoidal parameter estimation. In this paper we consider the data matrix corresponding to the given sequence and introduce the Ratio of Cumulative Sums (RCS) of eigenvalues. We then exploit the structure of RCS to obtain a performance that is comparable to the Cumulative Sums based method of Shah and Tufts. However the advantage is that we do not require knowledge of the noise level; moreover, our method is computationally cheaper. RCS can also be used in conjunction with existing methods to improve performance: we showcase improved results for Cheng and Hua's least-squares (LS) method when RCS information is used. When there are three closely spaced sinusoids, our method out performs both the ST and LS methods.

WE11

WE11: Machine Learning/AI for Signal Processing
Wednesday, July 18, 14:00 - 15:15
Venue: Hall-B
Chair: Rajiv Soundararajan (Indian Institute of Science Bangalore, India)

Recursive Network with Explicit Neighbor Connection for Image Captioning

14:00 - 14:18

Mohammedsayeemuddin Shaikh (DA-IICT, India)
Manjunath V. Joshi (DA-IICT, India)

Generating natural image descriptions by machine is a non-trivial task. Many researchers have worked in this area and the most common approach is to use encoder-decoder frame work based models. Here an image is encoded into feature vector by the encoder and then decoded by the decoder to arrive at the image caption. Generally convolutional neural network (CNN) and recurrent neural network (RNN) are used as the encoder and the decoder, respectively. In this paper, we modify the decoder to have explicit memory connection to the previous sample in the sequence. We use gated recurrent unit (GRU) architecture for decoder and train it on Flickr8K and Flickr30K datasets. For Flickr8K data set, results show that having explicit memory link improves the BLEU-4 score by more than 10 percent when compared to that without the explicit memory link. Also, comparing it with the model which uses RNN without the explicit link as the decoder gives an improvement in BLEU-4 score by 20 percent.

Estimating Confidence for Deep Neural Networks Through Density Modeling

14:18 – 14:37

Akshayvarun Subramanya (Indian Institute of Science Bangalore, India)
Suraj Srinivas (Indian Institute of Science Bangalore, India)
Venkatesh Babu Radhakrishnan (Indian Institute of Science Bangalore, India)

State-of-the-art Neural Networks can be easily fooled into providing incorrect high-confidence predictions for images with small amounts of adversarial noise. Does this expose a flaw with deep neural networks, or do we simply need a better way to estimate confidence? In this paper we consider the problem of accurately estimating predictive confidence. We formulate this problem as that of density modelling, and show how traditional methods such as softmax produce poor estimates. To address this issue, we propose a novel confidence measure based on density modelling approaches. We test these measures on images distorted by blur, JPEG compression, random noise and adversarial noise. Experiments show that our confidence measure consistently shows reduced confidence scores in the presence of such distortions - a property which softmax lacks.

Decentralized Asynchronous Stochastic Gradient Descent: Convergence Rate Analysis

14:37 – 14:56

Amrit Singh Bedi (Indian Institute of Technology Kanpur, India)
Hrusikesha Pradhan (Indian Institute of Technology Kanpur, India)
Ketan Rajawat (Indian Institute of Technology Kanpur, India)

Decentralized algorithms for multi-agent networks have attracted a considerable research interest. Stochastic gradient descent and its variations are popularly used for developing such algorithms. This paper considers a stochastic gradient descent algorithm in which each node is randomly selected to carry out the update. The stringent computational and communication requirements of the synchronous framework are overcome by proposing an asynchronous variant that allows updates to be carried out using delayed gradients. The performance of the proposed algorithm is analyzed by developing non-asymptotic

bounds on the optimality gap, as a function of the number of iterations, and for various diminishing step-size rules. The bounds indicate that the effect of asynchrony on the algorithm convergence rate is minimal. The theoretical findings of this work are further illustrated through solving a distributed estimation problem over a large network. We conclude by presenting the performance comparison of the proposed algorithm against the classical cyclic incremental algorithm.

Dynamic Network Latency Prediction with Adaptive Matrix Completion
14:56 – 15:15
Ruchi Tripathi (Indian Institute of Technology Kanpur, India)
Ketan Rajawat (Indian Institute of Technology Kanpur, India)
Last few decades have observed exponential growth in network demands due to increased popularity of real time applications, such as live chat, gaming etc. The resulting infrastructure growth has made it difficult for the service providers to abide by the service level agreements, especially with regards to the quality of service guarantees. Predicting network latencies from noisy and missing measurements has therefore emerged as an important problem, and a plethora of solutions have been proposed for the same. Existing network latency predictions rely either on Euclidean embedding or matrix completion methods. This work considers the estimation and prediction of network latencies from a sequence of noisy and incomplete latency matrices collected over time. An adaptive matrix completion algorithm is proposed that can handle streaming data at low computational complexity. The performance of the proposed algorithm is characterized both in theory and using a real data-set, demonstrating its viability as a network monitoring tool.

WE12

WE12: Bio Signal Processing
Wednesday, July 18, 14:00 - 15:15
Venue: Hall-C
Chair: Ranjitha Prasad (Tata Consultancy Services, India)

Compressed Sensing Recovery Using Modified Newton Gradient Pursuit Algorithm and Its Application to ECG with Denoising
14:00 - 14:18
Anupama Arun (Indian Institute of Space Science and Technology Trivandrum, India)
Sheeba Rani J (Indian Institute of Space Science and Technology Trivandrum, India)
Thomas James Thomas (Indian Institute of Space Science and Technology Trivandrum, India)
Compressed sensing (CS) is a novel sampling paradigm which states that with prior knowledge of the domain in which the signal is sparse, it is possible to reconstruct the signal with fewer measurements than required by the Nyquist Theorem. In this paper, we propose a novel iterative greedy algorithm called modified Newton Gradient Pursuit (m-NGP) for practical CS reconstruction. Empirical evidence suggests that this algorithm achieves improved performance with comparable computational complexity over the existing state

of art greedy algorithms. The algorithm also does not require prior information about the sparsity, making it suitable in real world problems where exact sparsity information may not be available. Further, we demonstrate the advantages of our algorithm, in a practical scenario for recovering the denoised ECG signal from 25% compressive measurements. By using a suitable sparsifying dictionary, the noisy components due to base line wander (BW), power line interference (PLI) and high frequency noises can be removed from the signal. Our algorithm out performs other greedy algorithms in recovering the ECG signal and is able to achieve a PSNR of 71.72 dB compared with 68.23 dB obtained using OMP for record 104 from the MIT-BIH Arrhythmia database corrupted with BW and PLI.

Suppression of Artifacts from Seismocardiogram Signal Using Two-Stage Kalman Filtering Model
14:18 – 14:37
Tilendra Choudhary (Indian Institute of Technology Guwahati, India)
L N Sharma (Indian Institute of Technology Guwahati, India)
Manas Kamal Bhuyan (Indian Institute of Technology Guwahati, India)
In this paper, a unified denoising framework is proposed to suppress the noises and artifacts from a seismocardiogram (SCG) signal. The proposed method consists of a unique set of two Kalman filter models in a cascaded fashion. Each of the Kalman filters is modelled separately to serve two different purposes. First stage Kalman filter (KF1) is modelled to reduce the irregularity and the intermittency of the noisy signal. It also predicts the displacement and the velocity of the chest wall, produced due to cardiac mechanics. The low frequency artifact is predicted in the second stage Kalman filter (KF2) and then it is removed from the KF1 resulted SCG signal. The performance of our proposed frame work is tested using SCG signals from CEBS database available at Physionet archive. The proposed method achieves an average normalized cross correlation (NCC) of 94% for signals having contaminations of AWGN noise with 15 dB input signal-to-noise ratio (SNR). The qualitative analysis of experimental results and comparison with existing methods clearly show that the proposed method produces promising noise suppression results without distorting the clinical features.

Detection of Heart Sound Using Logistic Function Amplitude Moderator and Teager-Kaiser Energy Operator
14:37 – 14:56
Alex Paul Kamson (Indian Institute of Technology Guwahati, India)
L N Sharma (Indian Institute of Technology Guwahati, India)
Samarendra Dandapat (Indian Institute of Technology Guwahati, India)
In this paper, we have proposed a new morphological feature to improve the detection of S1 and S2 sounds from noisy or pathological phonocardiogram (PCG) signals. This feature is based on logistic function amplitude moderator (LFAM) and Teager-Kaiser energy operator (TKEO). The LFAM is used to enhance the intensity of weak heart sounds so that the intensities of envelope peaks are uniform. The LFAM is operated at two modes: low amplitude mode and high amplitude mode. The selection of the operational mode is decided based on probability density function (PDF) derived from intensity

based histogram analysis. Then the homomorphic envelope of the resulting waveform is calculated. Finally, TKEO is applied to the envelope signal to track the instantaneous energy of signal oscillation. This feature will capture prominent peaks for heart sounds and nullify the effect of noises and murmurs that have more or less uniform envelope intensity distribution. PCG database from the University of Washington has been used for evaluation. There is a significant improvement in detection of S1 and S2 sound as sharp dune-shape envelope peaks in noisy or pathological PCG signals.

Discriminative Periodic Component Analysis for SSVEP Based BCI
14:56 – 15:15
Kiran Kumar Guruswamy Ravindran (Indian Institute of Technology Madras, India)
RamasubbaReddy Machireddy (Indian Institute of Technology Madras, India)
Spatial filters for steady-state visual evoked potential (SSVEP) detection rely on the purely periodic assumption of the signal components. In this study, we propose discriminative periodic component analysis (DπCA) that takes advantage of the almost periodic nature of SSVEP without depending on ideal rigid templates. DπCA tries to maximize the SNR of SSVEP components by utilizing the time structure of the stimulus frequencies embedded in the electroencephalogram (EEG) data. The performance of the proposed method was compared with standard canonical correlation analysis (CCA) using data collected from ten subjects. The results suggest that the DπCA provides better detection accuracy compared to standard CCA across various window lengths and subjects. Furthermore, the statistical tests show that the DπCA provides consistent and significant performance improvement than CCA even at short window lengths.

SP.WE13

SP.WE13: Speech Processing
Wednesday, July 18, 15:45 - 17:30
Venue: JN Tata Auditorium
Chair: K. Suresh (College of Engineering Thiruvananthapuram, India)

Automatically derived acoustic sub-word units: Paradigms in speech coding, stochastic pronunciation modeling, spoken language identification and automatic speech recognition
15:45 – 16:11
V. Ramasubramanian (International Institute of Information Technology Bangalore, India)
As part of this special session organized as a felicitation of Prof. T. V. Sreenivas, IISc, on the occasion of his retirement, this talk will focus on my work done in collaboration with him and his students during 2000-04 in the framework of automatically derived acoustic sub-word units (AD-ASWU). This framework was first proposed at Bell Labs in the late 1980s and early 90s for automatic speech recognition as an efficient data-driven alternative to the more conventional notion of linguistically defined units such as phonetic-units. This framework, however, was relegated to the background, amidst the progress of the then de facto HMM based acoustic modeling of linguistically defined sub-word units, and its use in

LVCSR techniques and applications. Here, I will outline the renewed attention we brought to this AD-ASWU framework in 2000-04, to examine the efficacy of 'speech units' which are automatically derived and modeled. This talk will highlight our contributions from this work (reported in the flagship 'speech' conferences Interspeech '02, '03, '05 & ICASSP '02, '03, '04, '05) which applied the concept of AD-ASWUs to diverse problem spaces yielding varied formulations such as, a) automatically derived units for low bit- rate speech coding, b) stochastic pronunciation modeling for automatic speech recognition in the form of ergodic HMMs of acoustic sub-word units, and c) spoken language identification by acoustic sub-word unit based ergodic-HMM modeling of spoken languages. I will close this talk by pointing to the continued relevance of the notion of AD-ASWUs in a very recent work on weakly supervised acoustic sub-word unit discovery (and modeling) in speech recognition for low resource settings and far more importantly point to its potential role in the emerging trends of end-to-end speech recognition in deep-learning paradigms (e.g. RNN/LSTM based sequence-to-sequence learning, CTC loss functions etc.).

Is there more to the spectrogram than meets the eye?
16:11 – 16:37
Chandra Sekhar Seelamantula (Indian Institute of Science Bangalore, India)
The spectrogram, which is the workhorse of time-frequency analysis, is an indispensable tool in the analysis of speech signals. It normally comes in two flavours -- the narrowband one, which has a high spectral resolution and the wideband one, which has a high temporal resolution. We shall consider the narrowband spectrogram and argue that it is actually a 2D modulated signal. We then introduce a new tool to carry out the demodulation, namely, the Riesz transform, which is a higher dimensional extension of the well known Hilbert transform. We show how the Riesz transform allows for a neat separation of the spectrogram into the 2D baseband signal and the high-frequency carrier components. The baseband signal turns out to be the vocal tract spectrogram and the carrier is effectively constituted by the pitch harmonics. The demodulation perspective gives deeper insights. For instance, it allows for a categorization of the time-frequency plane into nearly periodic and aperiodic components. The aperiodicity map thus obtained could be used to separate the speech signal into its voiced and unvoiced constituents. Similarly, analyzing the orientation of the pitch tracks allows for a richer characterization of the excitation and intonation. We also show how the various hidden aspects of the spectrogram could be used in speech synthesis.

Variant and invariant characteristics in speech articulation
16:37 – 17:03
Prasanta Kumar Ghosh (Indian Institute of Science Bangalore, India)
Speech articulation varies across speakers for producing speech sounds due to the differences in their vocal tract morphologies, though the speech motor actions are executed in terms of relatively invariant gestures. While the invariant articulatory gestures are driven by the linguistic content of the spoken utterance, the component of speech articulation that varies across speakers reflects speaker-specific and other paralinguistic information. This talk will present a formulation to decompose the speech articulation from multiple

speakers into the variant and invariant aspects when they speak the same sentence. Using the variant component as a representation, this talk will also present results that demonstrate the capability of the variant component for discriminating speakers.

Unsupervised Representation Learning for Speech Signals.
17:03 – 17:30
Sriram Ganapathy (Indian Institute of Science Bangalore, India)
Unsupervised learning is the branch of machine learning that deals with discovery of the hidden structure from large amounts of raw unlabeled data. While the current deep learning paradigms are built using large labeled datasets and significant compute power, the evidence from human studies suggest that efficient learning can be achieved using unsupervised learning with a small amount of supervision. In this talk, an approach for deriving acoustic sub-word units in a language independent fashion is explored for an unsupervised term discovery problem. This task involves the extraction of audio representations that are highly similar for the same words spoken by two different speakers. Several applications in zero resource speech processing will be discussed.

SP.WE14

SP.WE14: Full Duplex Communications
Wednesday, July 18, 15:45 – 17:30
Venue: Hall-A
Chair: Srikrishna Bhashyam (Indian Institute of Technology Madras, India)

Self-interference Modeling and Digital Cancellation Along with Full-Duplex Wireless System Analysis
15:45 – 16:11
Dani Korpi (Tampere University of Technology, Finland)
Taneli Riihonen (Tampere University of Technology, Finland)
Lauri Anttila (Tampere University of Technology, Finland)
Mikko Valkama (Tampere University of Technology, Finland)
My presentation highlights recent contributions on the inband full-duplex (IBFD) technology by providing an overview of the related research carried out at Tampere University of Technology, Finland, thus far. In particular, we have considered the challenges caused by the own transmitter, which is now a powerful source of self-interference, while also studying a potential system-level application of the IBFD technology. The former issue was analyzed by presenting advanced signal models for canceling the SI in the digital domain of the receiver. The signal models were derived such that they take into account the most significant analog impairments. As for the system-level application, we proposed a self-backhauling IBFD-capable access node that can serve users and backhaul data using the same frequency resources at the same time. This reduces transmit power consumption over reference schemes that rely on half-duplex operation. Altogether, the findings reported in Dani Korpi's doctoral dissertation (Dec. 2017) and highlighted herein demonstrate that the IBFD technology can significantly enhance the spectrum usage of the future wireless networks.

Self-Interference Cancellation via Beamforming in an Integrated Full Duplex Circulator-Receiver Phased Array
16:11 – 16:37
Mahmood Baraani Dastjerdi (Columbia University New York, USA)
Tingjun Chen (Columbia University New York, USA)
Negar Reiskarimian (Columbia University New York, USA)
Gil Zussman (Columbia University New York, USA)
Harish Krishnaswamy (Columbia University New York, USA)
This paper describes how phased-array beamforming can be exploited to achieve wideband self-interference cancellation (SIC) with no additional power consumption while minimizing link budget (transmitter (TX) and receiver (RX) array gain) penalty by repurposing spatial degrees of freedom. Unlike prior works that rely only on digital transmit beamforming, this work takes advantage of analog/RF beamforming capability that can be easily embedded within an integrated circulator-receiver array. This enables (i) obtaining SIC through beamforming on both TX and RX sides, thus increasing the number of degrees of freedom that can be used to obtain SIC and form the desired beams, while (ii) sharing the antenna array between TX and RX. A 65nm CMOS scalable 4-element full-duplex circulator-receiver array is demonstrated in conjunction with a TX phased-array implemented using discrete components. A tiled 8-element system shows (i) 50dB overall RF array SIC over 16.25MHz (WiFi-like) bandwidth (BW) with < 3.5/3dB degradation in TX and RX array gains, respectively, and (ii) 100dB overall array SIC including digital SIC, supporting +16.5dBm TX array power handling. (Authors: Mahmood Baraani Dastjerdi, Tingjun Chen, Negar Reiskarimian, Gil Zussman, Harish Krishnaswamy).

Performance of LTE and 5G-NR cellular networks with full-duplex nodes
16:37 – 17:03
Radhakrishna Ganti (Indian Institute of Technology Madras, India)
Full-duplex nodes theoretically double the achievable per-link data rate. In this talk, we look at how full-duplex nodes fit in the existing wireless standards and if their impact on the network throughput. Current cellular standards are not designed for enabling full-duplex wireless communications. For example, in LTE, the eNodeB and all the UEs in a cell have to follow the same TDD configuration, and this makes full-duplex in-feasible. We will look at techniques to enable FD in the framework of existing 4G standard and look at network implications of FD. The current release of 5G standard does not have direct support for FD. However, it has several features like flexible-duplexing which might enable FD in the future releases. We will touch upon these features and discuss the gains of using FD in these networks.

Full-Duplex Communication with Imperfect Self-Interference Cancellation
17:03 – 17:30
Andreas Burg (École Polytechnique Fédérale de Lausanne Switzerland)
Full-Duplex communication promises a 2x increase in communication capacity under ideal condition. Unfortunately, this requires perfect suppression of the strong self-interference (SI) which is very difficult to achieve. Luckily, there are several alternatives, where full-

duplex capability can be exploited even with imperfect SI suppression. In this talk, we will first summarize our work on SI suppression and point out the limitations. We will then focus on discussing options to exploit full-duplex capability with residual SI.

SP.WE15

SP.WE15: Security and privacy
Wednesday, July 18, 15:45 - 17:30
Venue: Hall-B
Chair: Himanshu Tyagi (Indian Institute of Science Bangalore, India)

Backdoored Neural Networks (BadNets)
15:45 – 16:11
Siddharth Garg (New York University New York, USA)

Deep neural networks are typically computationally expensive to train, requiring weeks of computation on many GPUs; as a result, many users outsource the training procedure to the cloud or rely on pre-trained models that are then fine-tuned for a specific task. The first part of this talk we will highlight how outsourced training introduces new security risks: an adversary can create a maliciously trained network (a backdoored neural network, or a BadNet) that has state-of-the-art performance on the user's training and validation samples, but behaves badly on specific attacker-chosen inputs. We demonstrate backdoors on a U.S. street sign classifier that identifies stop signs as speed limits when a special sticker is added to the stop sign; the backdoor persists even if the network is later retrained for another task. The second part will discuss potential solutions for high-assurance outsourced training and execution of deep neural networks. Specifically, I will describe how secure delegation of computation techniques can be brought to bear on this problem.

Software-defined security for next generation networks
16:11 – 16:37
Vyas Sekar (Carnegie Mellon University Pittsburgh, USA)

The state of network security today is quite abysmal. Security breaches and downtime of critical infrastructures continue to be the norm rather than the exception, despite the dramatic rise in spending on network security. Attackers today can easily leverage a distributed and programmable infrastructure of compromised machines (or botnets) to launch large-scale and sophisticated attacks. In contrast, the defenders of our critical infrastructures are crippled as they rely on fixed capacity, inflexible, and expensive hardware appliances. This forces them into adopting weak and static security postures, as they face unpleasant tradeoffs between false positives and false negatives. Continuing along this trajectory means that attackers will always hold the upper hand as defenders are stifled by the inflexible and impotent tools in their arsenal. The goal of this project is to reverse this long-standing asymmetry and fundamentally change the dynamics of this attack-defense equation. Instead of developing attack-specific defenses, we focus on empowering defenders with the right tools and abstractions to tackle the constantly evolving attack landscape. To this end, we envision a new software-defined approach to network security, where we can rapidly develop and deploy novel in-depth defenses and dynamically customize the network's security posture to the current operating context. Realizing this vision raises fundamental challenges that transcend conventional networking and security technologies and necessitates a radical rethink across the entire "stack".

Signal Processing Problems in Cyber Physical System Security.
16:37 – 17:03
Sandeep K. Shukla (Indian Institute of Technology Kanpur, India)

Power Grid, Manufacturing Automation Systems, Water/Sewage Systems, and other example of Cyber Physical Systems (CPS) have two interacting components, a physical one whose dynamics is governed by the laws of physics and a cyber part that includes sensors, actuators, control systems, and network that carries information between the sensors/actuators to control and back. There are many ways a cyber-attacks can happen in such systems through vulnerabilities in the cyber components. However, one can consider more potent attacks by changing the dynamics of the system through false data injection, or by overtaking the cyber components through malware injection. However, in order to reduce the possibility of an ongoing attack to be thwarted by anomaly detection systems, the attacker needs to know more about the state of the system, as well as the topology of the system. The most powerful attacks are those which can control a few sensors, or apply man-in-the middle attack to capture sensor measurements to estimate the state of the system, and/or the topology of the system. Systems whose state can be adequately estimated or whose topology and parameters can be effectively estimated through minimal amount of snooping on sensor measurements are most vulnerable to such attacks which cannot be easily detected through standard anomaly detection in the physical dynamics of the system. In this talk we will talk about a few problems that are germane to signal processing and statistical estimation techniques – which arise for the attackers when trying to estimate state or topological structure/parameters through minimal sensor snooping. We will also discuss some of the techniques relevant to detect or thwart such attacks. The talk will be more tutorial in nature than new research work.

Data Privacy for a ρ-Recoverable Function
17:03 – 17:30
Prakash Narayan (University of Maryland College Park, USA)

This talk is based on joint work with Ph.D. student Ajaykrishnan Nageswaran. A user's data is represented by a finite-valued random variable. Given a function of the data, a querier is required to recover, with at least a prescribed probability, the value of the function based on a query response provided by the user. The user devises the query response, subject to the recoverability requirement, so as to maximize privacy of the data from the querier. Privacy is measured by the probability of error incurred by the querier in estimating the data from the query response. We analyze single and multiple independent query responses, with each response satisfying the recoverability requirement, that provide maximum privacy to the user. Achievability schemes with explicit randomization mechanisms for query responses are given and their privacy compared with converse upper bounds.

SP.WE16

SP.WE16: Quantum information technology
Wednesday, July 18, 15:45 - 17:30
Venue: Hall-C
Chair: Shayan Garani (Indian Institute of Science Bangalore, India)

Quantum Communications: Concepts and Prospects
15:45 – 16:11
Apoorva Patel (Indian Institute of Science Bangalore, India)
How do quantum communications differ from classical ones? What advantages do they offer? What resources do they require? What is their technological status at present? What is the road map for the future? I will attempt to answer these questions with an overview of the subject, together with descriptions of basic tasks and simple examples.

Efficient measurement of high-dimensional quantum states
16:11 – 16:37
Anand Kumar Jha (Indian Institute of Technology Kanpur, India)
The fact that a photon in a light beam can carry orbital angular momentum (OAM) in the integer multiples of ħ has made OAM a very important degree of freedom for quantum information protocols. However, one of the major challenges faced in the implementation of OAM-based high-dimensional protocols is the efficient detection of quantum states in the OAM basis. In this talk, we will describe the existing techniques for measuring quantum states in the OAM basis and also discuss their limitations. We will then present a new experimental technique that we have developed in order to efficiently measure high-dimensional quantum states through just two intensity measurements.

Quantum Communication Using Coherent Rejection Sampling
16:37 – 17:03
Rahul Jain (National University of Singapore)
Compression of a message up to the information it carries is key to many tasks involved in classical and quantum information theory. Schumacher provided one of the first quantum compression schemes and several more general schemes have been developed ever since. However, the one-shot characterization of these quantum tasks is still under development, and often lacks a direct connection with analogous classical tasks. Here we show a new technique for the compression of quantum messages with the aid of entanglement. We devise a new tool that we call the `convex split lemma', which is a coherent quantum analogue of the widely used `rejection sampling procedure' in classical communication protocols. As a consequence, we exhibit new explicit protocols with tight communication cost for `quantum state merging' and `quantum state splitting'. We also present a port-based teleportation scheme which uses less number of ports in presence of information about input.
Very recently our framework has found applications in several important settings in quantum network theory, such as a quantum version of the Gel'fand-Pinsker channel; the quantum broadcast channel and to obtain a new achievability bound on quantum state redistribution, in terms of smooth-max information and hypothesis testing relative entropy.

Convex-split lemma has also found applications in the context of catalytic decoupling; privacy in quantum communication (the wiretap channel); a generalized quantum Slepian-Wolf result ; a bound for the important and consequential task of measurement compression using classical shared randomness and to obtain optimal bounds on the classical capacity of entanglement-assisted compound channels.
Given the broad applicability of the convex-split technique as exhibited in these recent works, we expect more applications in quantum network theory in the future.
Talk based on: Quantum communication using coherent rejection sampling. Anurag Anshu, Vamsi Krishna Devabathini, Rahul Jain. Physical Review Letters (PRL), Vol. 119, Issue 12-22 September 2017.

The theory and practice of quantum key distribution (QKD)
17:03 – 17:30
Prabha Mandayam (Indian Institute of Technology Madras, India)
As classical cryptosystems are rendered vulnerable with the advent of quantum computers, quantum key distribution (QKD) promises unconditional security based on fundamental properties of quantum states. While several QKD schemes have been demonstrated experimentally, realising the full potential of QKD for regular commercial applications remains a challenge. In this talk, we will focus on Differential-phase-shifted QKD, which is based on the B92 protocol and is most amenable for implementation over conventional fibre-optics networks. We will compare and contrast variants of DPS-QKD in terms of their secure key rate and ease of implementation. Finally, we will present the DPS-protocol being implemented at IIT-Madras and QuNu, Bangalore. We will discuss the details of the experimental set-up, the resulting quantum bit error rate (QBER), and the practical challenges involved in improving the secure key rate. This is Joint work with Prof. Anil Prabhakar, IIT Madras.

TH01

TH01: Information Theory
Thursday, July 19, 09:00 - 10:15
Venue: JN Tata Auditorium
Chair: Ankur A. Kulkarni (Indian Institute of Technology Bombay, India)

Degraded Relay Channel with Non-causal State Information at the Source and Relay
09:00 – 09:20
Viswanathan Ramachandran (Indian Institute of Technology Bombay, India)
Sibi Raj B Pillai (Indian Institute of Technology Bombay, India)
Vinod M Prabhakaran (Tata Institute of Fundamental Research Bombay, India)
A state-dependent discrete memoryless degraded relay channel is considered, with non-causal side information available at both the sender and the relay. The capacity of this relay model is an open problem. We improve upon the known achievable regions for this setting, in addition to proving an outer bound. The key idea in the proof of achievable region is to employ a modified decode-forward scheme. The characterization is then extended to

a relay broadcast setting, where an improved inner bound over existing schemes and an outer bound are exhibited.

New Finite Blocklength Converses for Asymmetric Multiple Access Channels via Linear Programming
09:20 – 09:40
Sharu Jose (Indian Institute of Technology Bombay, India)
Ankur A. Kulkarni (Indian Institute of Technology Bombay, India)
This paper presents a systematic method to synthesize new finite blocklength converses for the channel coding of asymmetric multiple access channels (A-MAC) from point- to-point converses, by employing the linear programming (LP) based framework in [1]. A direct synthesis yields a converse that extends the Polyanskiy-Poor-Verdu´ metaconverse to A-MAC. Employing a more sophisticated non-linear synthesis, we derive a new, code-independent converse that is asymptotically tight.

A Lower Bound on Channel Capacity of a Nonlinear Fiber Optic Channel with Memory
09:40 – 10:15
Konchady Gautam Shenoy (Indian Institute of Science Bangalore, India)
Vinod Sharma (Indian Institute of Science Bangalore, India)
We consider a nonlinear fiber optic channel with memory and signal dependent noise. We provide an achievable rate via an i.i.d. complex Gaussian input. This improves on an existing bound. We also argue that our bound is close to the capacity of the channel.

TH02

TH02: Topics in Signal Processing
Thursday, July 19, 09:00 - 10:15
Venue: Hall-A
Chair: Soma Biswas (Indian Institute of Science Bangalore, India)

Analysis of Downsampling of DCT-Graphs
09:00 – 09:18
Nileshkumar Vaishnav (Dhirubhai Ambani Institute Of Infromation And Technology Gandhinagar, India)
Aditya Tatu (Dhirubhai Ambani Institute Of Infromation And Technology Gandhinagar, India)
The discrete cosine transform (DCT) finds variety of applications in the field of signal processing. Due to its significant data compression properties, it forms a key component of image compression algorithms. Algebraic Signal Processing theory provides a graph representation for the DCT. In this representation, the DCT becomes a special case of Graph Fourier Transform. In this paper, we analyze the DCT in the context of downsampling using various graph-downsampling techniques. We provide proofs for various downsampling outcomes and validate our findings with experiments on 1-D and 2-D data.

Improved Noncoherent Receiver for Joint Range and Symbol Estimation
09:18 – 09:37
Sanjeev Sharma (Indian Institute of Technology Indore, India)
Abhijeet Bishnu (Indian Institute of Technology Indore, India)
Anubha Gupta (Indraprastha Institute of Information Technology Delhi, India)
Vimal Bhatia (Indian Institute of Technology Indore, India)
The noncoherent receiver (NCR) has, recently, gained importance due to its simple design and low-complexity for the internet of things and wireless communications. However, NCR's performance is sub-optimal as compared to a coherent receiver due to the presence of noise. In this paper, we propose an NCR for joint ranging and data symbol estimation for pulse- based communication such as ultra-wideband and Terahertz band communication. The proposed NCRs (referred as pulse auto-correlation NCR (PA-NCR) and iterative PA-NCR (IPA- NCR)) utilize apriori information about the transmitted pulse and channel statistics for enhancing the system's signal-to-noise ratio. The proposed IPA-NCR's performance is improved using an iterative algorithm for a block-wise data symbol detection and ranging estimation, while considering the channel to be static during the block length. The PA-NCR and IPA-NCR are the best choice for fast varying (i.e. vehicular communication) and slow varying (i.e. indoor communication) channels respectively. Performance of the proposed NCR is analyzed over standard IEEE 802.15.4a channels and is also compared with some existing NCRs.

Interference Localization On-Board the Satellite Using Drift Induced Virtual Array
09:37 – 09:56
Aakash Arora (SnT, University of Luxembourg)
Sina Maleki (Ericsson, Luxembourg)
Bhavani Shankar Mysore R (Interdisciplinary Centre for Security, Reliability and Trust & University of Luxembourg)
Joel Grotz (SES, Luxembourg)
Björn Ottersten (University of Luxembourg)

Herein, we investigate the interference received from other wireless networks into a satellite communication (SATCOM) link, and review approaches to identify the interference location on-board satellite processing. Interference is an increasing problem for satellite communication links, and while receiving signals from gateways or user terminals, the uplink is prone to disturbance by interference due to jammers or unintentional transmissions. In this paper, our aim is to localize unknown interference sources present on the ground by estimating direction of arrival (DOA) information using on-board processing (OBP) in the satellite, and the satellite drift inducing a virtual array. In this work, the signal sampled by the drifting single antenna feed is modeled as using an arbitrary array. Building on this model, we perform the 2-D DOA (azimuth and elevation) estimation. The key challenges in such a design include single snapshot based DOA estimation with low complexity and robustness, arising out of limited on-board computational complexity as well as uncertainty in parameters like the drift speed. Employing realistic satellite drift patterns,

the paper illustrates the performance of the proposed technique highlighting the accuracy in localization under adverse environments. We provide numerical simulations to show the effectiveness of our methodology.

Blind Equalization for Classification of Digital Modulations

09:56 - 10:15

Gaurav Jyoti Phukan (Indian Institute of Technology Guwahati & Bharat Electronics Ltd, India)
Prabin Kumar Bora (Indian Institute of Technology Guwahati, India)

Blind equalization for modulation classification (MC) in a frequency selective scenario is a non-trivial problem. In this paper, a new method to mitigate the inter-symbol interference (ISI) is proposed for the blind MC, where the modified constant modulus algorithm (M-CMA) precedes a modulation specific decision directed least mean square (DDLMS) stage in a cascaded equalizer scheme. The performance of the quasi hybrid likelihood ratio test (QHLRT) modulation classifier is examined under various levels of fading severity to establish the utility of the new method in practical applications.

TH03

TH03: Machine Learning/AI and Applications

Thursday, July 19, 09:00 - 10:15

Venue: Hall-B

Chair: Aditya Gopalan (Indian Institute of Science Bangalore, India)

Distributed Learning Algorithm for Interference Avoidance in Coexisting WBANs

09:00 – 09:18

Emy George (National Institute Of Technology Calicut, India)
Lillykutty Jacob (National Institute of Technology Calicut, India)

When multiple wireless body area networks (WBANs) exist in close proximity to each other, the inter-user interference considerably degrades the signal to interference plus noise ratio (SINR) of the hub nodes in the WBANs. One of the most effective coexistence schemes mentioned in the IEEE 802.15.6 WBAN standard is the channel hopping mechanism. But for a dense network of WBANs, the traditional random hopping mechanism specified in the standard doesn't consider its environment and thus fails to reduce the channel conflict among the coexisting WBANs. This exacerbates the inter-BAN interference when the operating frequencies are fewer. We propose a probabilistic channel hopping mechanism for a hub to select the channel with the least interference as the most probable for transmission. We formulate this channel selection problem as a finite repeated potential game and propose a distributed stateless Q-learning algorithm to achieve the Nash Equilibrium (NE). Numerical results show the convergence of the learning algorithm to the NE point of the game. Also, we find that the proposed algorithm significantly improves the network utility by reducing the interference when compared to the random hopping approach specified in the IEEE 802.15.6 standard.

Inference Algorithms for the Multiplicative Mixture Mallows Model

09:18 – 09:37

Ranjitha Prasad (Tata Consultancy Services, India)
Vincent Y. F. Tan (National University of Singapore)

A popular approach to obtain a consensus ranking from ranking data is based on the probabilistic, distance-based Mallows model comprising of a modal permutation and dispersion parameters. Often, the population consists of several subpopulations. As a result, finite mixture models are used to distinguish latent sub-groups of individuals in a heterogeneous population. Given a finite number of subpopulations each based on the Mallows model, a popular inference approach is the computationally intensive expectation maximization algorithm for additive models. We address the drawbacks of this model using a novel multiplicative mixture Mallows model (M4). Given complete ranking observations from a heterogeneous population, we derive inference algorithms for the joint estimation of the parameters and the consensus rankings of the component distributions. We numerically validate the permutation estimation performance of the proposed algorithms on synthetic datasets. We also demonstrate the goodness-of-fit using the Bayesian information criterion and the integrated complete likelihood on the real-world APA and Sushi datasets.

On a Class of Restless Multi-armed Bandits with Deterministic Policies

09:37 – 09:56

Prakirt Raj Jhunjhunwala (Indian Institute of Technology Bombay, India)
Sharayu Moharir (Indian Institute of Technology Bombay, India)
D. Manjunath (Indian Institute of Technology Bombay, India)
Aditya Gopalan (Indian Institute of Science Bangalore, India)

We describe and analyze a restless multi-armed bandit (RMAB) in which, at each time step, the instantaneous reward from the playing of an arm depends on the time since the arm was last played. This model is motivated by recommendation systems where the payoff from a recommendation depends the recommendation history. For an RMAB with N arms, and known reward functions for each arm that have a maximum memory of M steps, we characterize the optimal policy that maximizes the infinite horizon time-average of the reward. Specifically, using a weighted-graph representation of the system evolution, we show that a periodic policy is optimal. Further, we show that the optimal periodic policy can be obtained using an algorithm with polynomial time and space complexity. Several extensions to the basic model are also presented.

Automatic Classification of Indian Languages into Tonal and Non-tonal Categories Using Cascade Convolutional Neural Network (CNN)-Long Short-Term Memory (LSTM) Recurrent Neural Networks

09:56 - 10:15

Chuya China Bhanja (National Institute of Technology Silchar, India)
Dipjyoti Bisharad (National Institute of Technology Silchar, India)
Rabul Laskar (National Institute of Technology Silchar, India)

This work aims to develop an automatic tonal and non-tonal language classification system

of Indian languages using cascade-Convolutional Neural Network (CNN)-Long Short-Term Memory (LSTM) Recurrent neural networks (RNNs). Motivated by their success in modelling sequences, this study proposes LSTM-RNNs cascaded with CNN in context of tonal and non-tonal language classification. Here RNNs show its effectiveness to exploit temporal dependencies in acoustic data. This paper also proposes the use of pitch chroma spectrogram coefficients to address this classification tasks. The proposed feature is then combined with log-mel spectrogram coefficients to enhance the system performance. The system has been tested for NIT Silchar language database (NITS-LD) which is developed for 9 Indian languages using All India radio broadcast news. And it reports accuracies of 82.30% for 10s and 81.16% for 3s data. Performance of the proposed system is also analyzed on standard Oregon Graduate Institute Multi-Language Telephone-based Speech (OGI-MLTS) database. It shows accuracies of 77.2% and 74.95% for 10s and 3s data respectively.

TH04

TH04: Cooperative and Visible Light Communications

Thursday, July 19, 09:00 - 10:15

Venue: Hall-C

Chair: Vaneet Aggarwal (Purdue University, USA)

Partial CSI Based Relay Selection for TWR-FSO over Unified Exponentiated Weibull Links

09:00 – 09:18

Deepti Agarwal (Indira Gandhi Delhi Technical University for Women, India)

This paper analyzes the unified performance of partial relay selection protocol for multiple relay assisted free space optical (FSO) network over exponentiated weibull (EW) links. The unification has been done for heterodyne and intensity modulation/direct (IM/DD) detection techniques. We have considered a decode and forward (DF) based network consisting of multiple finite sized two way relays (TWR) between two distant terminals. In partial relay selection protocol, two TWRs are chosen in order to create the bidirectional communication path between the two terminals. The considered protocol compresses the requirement of channel state information (CSI) and provides receive diversity advantage at terminal nodes. More specifically, we derive the unified expressions for probability density function (PDF) and cumulative distribution function (CDF) of instantaneous signal to noise ratio (SNR) over EW turbulent FSO link along with pointing error and path loss. We then utilize the unified statistics in obtaining the outage probability expression for the considered network. It is shown by analytical and simulation results that the relay selection protocol based on partial CSI completely outperforms the single relay selection protocol for both detection techniques.

Estimate-and-Forward Relaying in Molecular Communication Using Brownian Motion with Drift

09:18 – 09:37

Satish Kumar Tiwari (Indian Institute of Technology Indore, India)
Prabhat Kumar Upadhyay (Indian Institute of Technology Indore, India)

In diffusion-based molecular communication (DMC) systems, the information-bearing molecular signal experiences high attenuation with long propagation delays. It is thereby essential to deploy an intermediate relay nanomachine to alleviate such problem. In this paper, we propose and investigate an estimate-and-forward (EF) relaying scheme for a two-hop DMC system using Brownian motion with drift. Moreover, we consider the quasi-constant statistics of residual and counting noises to account for the aberrations present in the system. The considered relaying scheme forwards an estimate of the transmitted number of molecules, which is derived based on maximum likelihood principle. Further, we obtain an expression for the end-to-end error probability by making use of energy detector. Numerical and simulation results validate our analysis and reveal the scenarios where EF scheme can be beneficial over the existing amplify-and-forward and decode-and-forward relaying schemes.

Spectral- And Energy-Efficiency for Massive MIMO Two-Way Full-Duplex Hybrid Processing AF Relay

09:37 – 09:56

Ekant Sharma (Indian Institute of Technology Kanpur, India)
Rohit Budhiraja (Indian Institute of Technology Kanpur, India)
Ashish Kant Shukla (Indian Institute of Technology Kanpur, India)

We consider two-way full-duplex relaying where multiple full-duplex user-pairs exchange information via a shared hybrid full-duplex relay with large antenna array of size N. We assume that the hybrid relay has smaller number of radio-frequency (RF) chains than antennas. With zero-forcing reception (ZFR)/zero-forcing transmission (ZFT) relay processing, we derive its analytical asymptotic spectral efficiency (SE) and energy efficiency (EE) expressions with $N \rightarrow \infty$. We show that the analytical SE and EE expressions match with their exact expressions, which can only be numerically evaluated. We also numerically demonstrate that a hybrid full-duplex relay has only marginally inferior SE and EE than its full-RF chain counterpart.

On the Spatial Performance of Users in Indoor VLC Networks with Multiple Reflections

09:56 - 10:15

Abhishek K Gupta (Indian Institute of Technology Kanpur, India)
Adrish Banerjee (Indian Institute of Technology Kanpur, India)

In this paper, we present a stochastic geometry based framework to analyze the performance of downlink indoor visible light communication (VLC) networks at a typical receiver while considering reflections from the walls. A typical receiver is a arbitrarily located user in the room and may not necessarily be at the center and hence sees an asymmetric transmitter location process and interference at itself. We first derive the

signal-to-interference-plus-noise ration (SINR) and rate coverage probability for a typical user. We then present a framework to model the impact of wall reflections and extend the analysis to study the performance of VLC network in the presence of wall reflections. We show that the impact of user's location and reflections is significant on the performance of the user.

SP.TH05

SP.TH05: 5G and next generation networking
Thursday, July 19, 11:45 - 13:30
Venue: JN Tata Auditorium
Chair: Neelesh B. Mehta (Indian Institute of Science Bangalore, India)

Fog and Software Defined Networking paradigms in 5th Generation Wireless Communication Networks
11:45 – 12:11
Abhay Karandikar (Indian Institute of Technology Kanpur, India)
The communication networks are undergoing profound changes due to many recent architectural innovations. Two of these innovative technologies, namely the Software Defined Networking (SDN) and Fog Computing have the potential to bring about paradigmatic/fundamental changes to the wireless communication network architecture and how services are delivered over them. In this talk, we elaborate on the architectural changes, these technologies are expected to bring about in 5th generation wireless communication networks (5G) and also explain how these technologies would complement each other in providing newer services to mobile users in future, which may not be possible today.

RF energy transfer channel models for sustainable IoT
12:11 – 12:37
Swades De (Indian Institute of Technology Delhi, India)
Self-sustainable IoT node operation can be realized with the help of controlled radio frequency energy transfer (RF-ET). However due to significant energy loss in wireless propagation, there is a need for novel schemes to improve the end-to-end RF-ET efficiency. In this presentation, we will first discuss our experimental demonstration and findings on multihop RF-ET, where we will also motivate the need for developing a channel model for accurately characterizing the harvested DC power. We will present a new channel model which incorporates the effects of non-line of sight (NLOS) component along with the other parameters, namely, radiation pattern of transmit and receive antennas, losses associated with different polarization of transmitting field, and efficiency of power harvester circuit. We will present an optimization problem formulation by accounting for the effect of NLOS component to maximize the RF-ET efficiency, which cannot be captured by the Friis formula. Finally, we will discuss our field measurements based findings on the statistical parameters of multipath fading channel for short-range RF-RT.

5G New Radio-India's contribution to IMT-2020
12:37 – 13.03
Kiran Kuchi (Indian Institute of Technology Hyderabad, India)
In this talk, I bring to light the key technical features and performance aspects of the recently released 5G technical specification, that is popularly known as, 5G New Radio (NR). We highlight the main differences with respect to 4G LTE, targeted deployment scenarios, new use cases etc. I will talk about enhanced mobile broadband (eMBB) with multi-Gbit user rates and the emerging Narrowband IoT (NB-IoT) networks that target ultra-low data rates with long-battery life that is on the order of 5-10 years. Historically, India has not contributed to 3GPP family of standards till 5G. The scenario has changed about 3 years ago with the emergence of TSDSI-India's telecom SDO. Indian members of 3GPP, comprising of both academia and industry including a prominent operator have made significant technical contributions to the Phase-1 of 5G NR standard. A new activity is kick started in TSDSI to amend the 3GPP 5G NR technical specifications. The aim is to introduce new features that are tailored for Indian market needs and domestic use cases such as support for large rural cells, a mandatory requirement set forth by ITU-R WP 5D as part of IMT2020 test criterion. In this talk, we will introduce a new waveform titled "pi/2 BPSK with spectrum shaping" that is introduced in the uplink of 5G NR. This waveform potentially doubles the transmit power by allowing handsets to transmit the signal near PA (power amplifier) saturation. This is the only new waveform adopted in 5G which is targeted for coverage expansion. Our other proposals include the use of a non-linear precoding technique for massive MIMO, especially for TDD bands where we exploit channel reciprocity to obtain massive spectral efficiency gains over LTE based MIMO. I will conclude the talk with a description of a massive MIMO testbed developed by our group at IIT Hyderabad and the recent field trail results.

Towards low power terabit per second optical interconnects
13.03 – 13:30
Shalabh Gupta (Indian Institute of Technology Bombay, India)
With rapid growth in the use of cloud based applications and the Internet, the carbon footprint of data centers is becoming a major concern. The data centers are becoming more communications centric, and their switch interface speeds are expected to reach 1.6 terabit/second in near future. To keep up with power consumption budget, reliability and form factor requirements, the use of optical coherent techniques for future data center interconnects is being proposed. However, coherent links have traditionally used high-speed ADCs (analog-to-digital converters) followed by DSP (digital signal processing) for recovering transmitted data, which consumes a lot of power. To significantly reduce power consumption, the all analog domain signal processing approach, first proposed by our group, is now under serious consideration for such applications. In this work, we present an overview of the technologies being used for data center interconnects and the future trends (including the analog-domain signal processing approach). We also show how the use of silicon photonics can help further in achieving low power high-speed data center interconnects.

SP.TH06

SP.TH06: Mm-wave and THz systems
Thursday, July 19, 11:45 - 13:30
Venue: Hall-A
Chair: K Vinoy (Indian Institute of Science Bangalore, India)

Enabling the Third Wireless Revolution through Transformative RF/mmWave Circuits, Systems and Wireless Communication and Sensing Paradigms

11:45 – 12:11
Harish Krishnaswamy (Columbia University New York, USA)
Over the past 30 years, we have reaped the benefits of two wireless communication revolutions, which have had significant social and economic impact. The period from 1990-2000 saw the mobile wireless communication revolution, as cellular mobile telephony enabled human beings across the globe to be instantly connected with each other. The period from 2000 to the present day is witness to the mobile wireless data revolution, as 3G and 4G networks have brought the Internet to our fingertips. However, as massive as the amount of data that exists on the Internet is, it pales in comparison to the amount of data inherently present in the constitution of our physical world. The next wireless revolution will be the mobile wireless-reality revolution, which will bring the physical world to our fingertips. RF, mmWave and terahertz communication, imaging and sensing devices will enable us to interrogate the physical world and create virtual or augmented worlds in ways that exceed and augment human sensory situational awareness. The wireless-reality revolution will require a quantum leap forward in our ability to control and manipulate the RF-to- THz electromagnetic spectrum, and in our ability to transmit, acquire, aggregate and process the associated data.
I will describe recent research on high-power and energy-efficient millimeter-wave power amplifiers, transmitters and large-scale phased arrays that have drawn interest for next-generation 5G cellular networks. I will also describe recent work on extreme-bandwidth (> 20Gbps) communication links at millimeter-waves for applications such as virtual and augmented reality. I will also briefly cover other novel wireless communication paradigms, including massive MIMO and full-duplex wireless, that enable extremely-high spectral efficiencies and data rates at lower RF frequencies. I will also talk about ongoing efforts towards the realization of city-scale testbeds that deploy advanced wireless hardware supporting mmWave, massive MIMO and full-duplex operation, enabling higher-layer systems research for the first time at city scales.

Non-Destructive Testing using THz imaging

12:11 – 12:37
Bala Pesala (Central Electrical and Electronics Engineering Research Institute,India)
Recent advances in THz sources and detectors have enabled rapid scanning imaging systems suitable for various industrial applications. In addition, most dry materials including plastics, composite materials have low absorption in the THz range. Hence, THz imaging has emerged as an optimal technique for Non-destructive testing and evaluation providing good spatial resolution and penetration depth. In this talk, I will discuss state-of-the art THz systems for NDE applications and our work related to defect detection in cement and FRP materials.

Periodic EM configurations and their applications for next generation Wireless systems.

12:37 – 13.03
P. H. Rao (SAMEER - Centre for Electromagnetics Chennai, India)
The talk introduces the importance of periodic configurations in Electromagnetic and Antenna applications. Periodic configurations for both radiating systems (Antennas) and circuit applications (Mixed signal systems) will be discussed. Metamaterials also known as Left Handed (LH) materials, exhibit simultaneous negative permittivity and permeability. These properties can be applied to several electromagnetic areas to improve the system performance. Metamaterials application in antennas, circuit miniaturization, and phase delay lines are considered for the next generation systems. Implementation of Split ring resonators (SRRs) and Complementary Split ring resonators (CSRRs) in circuit miniaturization and Flat lens design for MRI application will be demonstrated. The electromagnetic band gap (EBG) structures will be analyzed for various configurations. The design and applications of these EBGs will be demonstrated with practical realizations. The concept of CSRR loaded miniaturized Butler Matrix, low SLL array Antennas and Rotman Lens based Switched beam configurations will be introduced. Design approaches of Reflectarray antennas, Fabrication Techniques will be dealt in detail.

Communication and Systems at Millimeter and Terahertz Waves

13.03 – 13:30
Goutam Chattopadhyay (Jet Propulsion Laboratory, NASA, USA)
The millimeter-wave and terahertz frequency spectrum of the electromagnetic waves have mostly been used for high-resolution spectroscopic and radiometric studies for astrophysics, anetary science, and Earth science applications. However, in recent years, it has attracted significant interest among researchers for applications ranging from ultra-fast wireless communications to miniaturized high-resolution imaging radars, medical imaging, and imaging systems for collision avoidance and navigation. Millimeter-wave and terahertz frequencies provide enormous bandwidth compared to low-microwave frequencies. As a result, this band is very attractive for wireless communication systems. The current generation of wireless communication systems such as 4G/LTE is increasingly becoming inadequate due to the high data transfer demand, particularly for high resolution video transmissions. Millimeter-wave and terahertz frequencies could provide the paradigm shift needed for the next generation of wireless communication systems. Even though they provide significant bandwidth advantage, millimeter-wave and terahertz waves have their own set of challenges for use in a communication system. Due to the highly directive nature of these waves, line of sight at terahertz frequencies, they create a severe lack of angular diversity for communication applications. To overcome these, new technological breakthroughs are needed. In this talk, an overview of current technology roadmap for the insertion of communication systems using millimeter-wave and terahertz frequency based architecture will be discussed. High data rate terahertz communication systems demonstrated so far has used simple on-off-keying or similar modulation schemes. This talk will also discuss why it is so difficult to implement more popular schemes such as QPSK or QAM. The component technology and system integration for such communication

systems will also be presented. The research described herein was carried out at the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA, under contract with National Aeronautics and Space Administration.

SP.TH07

SP.TH07: Deep learning
Thursday, July 19, 11:45 - 13:30
Venue: Hall-B
Chair: David Wipf (Microsoft Research, P.R. China)

AMP-Inspired Deep Neural Networks, with Applications to Compressive Random Access and Massive-MIMO Channel Estimation

11:45 – 12:11

Phil Schniter (The Ohio State University Columbus, USA)

Deep learning has gained great popularity due to its widespread success on many inference problems. In this talk, we consider the application of deep learning to the sparse linear inverse problem, where one seeks to recover a sparse signal from a few noisy linear measurements. For this problem, we present two neural-network architectures that decouple prediction errors across layers in the same way that the approximate message passing (AMP) algorithms decouple them across iterations: through Onsager correction. First, we present a "learned AMP" network that significantly improves upon Gregor and LeCun's "learned ISTA." Second, inspired by the recently proposed "vector AMP" (VAMP) algorithm, we propose a "learned VAMP" network that offers increased robustness to deviations in the measurement matrix from i.i.d. Gaussian. In both cases, we jointly learn the linear transforms and scalar nonlinearities of the network. Interestingly, with i.i.d. signals, the linear transforms and scalar nonlinearities prescribed by the VAMP algorithm coincide with the values learned through back-propagation, leading to an intuitive interpretation of learned VAMP. Finally, we apply our methods to two important problems in 5G wireless communications: compressive random access and massive-MIMO channel estimation.

Regularized Discriminant Analysis: A Large Dimensional Study

12:11 – 12:37

Tareq Al Naffouri (King Abdullah University of Science and Technology Thuwal, Saudi Arabia)

We conduct a large dimensional study on discriminant analysis classifier with its three popular variants known as regularized LDA (R-LDA), regularized QDA (R-QDA) and regularized discriminant analysis (RDA). We start with the analysis of two special cases R-LDA and R-QDA, and finally generalize to RDA study. The analysis is based on the assumption that the data samples are drawn from a Gaussian mixture model with different means and covariances and relies on tools from random matrix theory (RMT). We consider the double asymptotic regime in which both the data dimension and training size with each class increases to infinity with fixed ratio. Under some mild assumptions, we show that the probability of misclassification error converges to a deterministic quantity which only depends on the class statistics and the data dimension. The result allows for a better understanding of the underlying classification algorithms in terms of their performances in practical large but finite dimensions. Further exploitation of the results permits to optimally tune the regularization parameters with the aim of minimizing the probability of misclassification error. The analysis is validated with numerical results involving synthetic as well as real data from the USPS dataset yielding a high accuracy in predicting the performances and hence making an interesting connection between theory and practice. This is joint work with Khalil Elkhalil, Xiaoke Yang, Abla Kammoun, and Slim Alouini.

Deep Learning Meets Sparse Coding

12:37 – 13.03

Chandra Sekhar Seelamantula (Indian Institute of Science Bangalore, India)

We develop specialized deep neural networks for sparse coding. Our approach relies on unrolling proximal gradient algorithms, which entail computations similar to that performed by a neural network. For sparse coding, we set the weights and biases of the network as prescribed by the iterative shrinkage-thresholding algorithm (ISTA) and model the nonlinear activation functions using a linear expansion of thresholds (LETs), which has been shown to be successful in image processing applications. The network thus constructed is referred to as LETnet. We demonstrate that the LET parametrization is parsimonious, induces a rich variety of sparsity encouraging regularizers, and effectively learns the sparsity prior from a training dataset. Further, the number of parameters to be learned in LETnet does not grow as the signal dimension increases. Improvements over LETnet are achieved using two mechanisms: (i) employing a second-order learning algorithm with superior convergence behavior; and (ii) building a deep residual network inspired by FISTA, an accelerated version of ISTA, having a superior convergence rate. We demonstrate successful application to super-resolution localization microscopy.

Hidden Talents of the Variational Autoencoder

13.03 – 13:30

David Wipf (Microsoft Research Beijing, China)

Variational autoencoders (VAE) represent a popular, flexible form of deep generative model that can be stochastically fit to samples from a given random process using an information-theoretic variational bound on the true underlying distribution. Once so-obtained, the model can be putatively used to generate new samples from this distribution, or to provide a low-dimensional latent representation of existing samples. While quite effective in numerous application domains, certain important mechanisms which govern the behavior of the VAE are obfuscated by the intractable integrals and resulting stochastic approximations involved. Moreover, as a highly non-convex model, it remains unclear exactly how minima of the underlying energy relate to original design purposes. We attempt to better quantify these issues by analyzing a series of tractable special cases of increasing complexity. In doing so, we unveil interesting connections with more traditional dimensionality reduction models, as well as an intrinsic yet underappreciated propensity for robustly dismissing sparse outliers when estimating latent manifolds. With respect to the latter, we demonstrate that the VAE can be viewed as the natural evolution of recent robust PCA models, capable of learning nonlinear manifolds of unknown dimension obscured by gross corruptions.

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Talawar, Basavaraj	WE04.1	64
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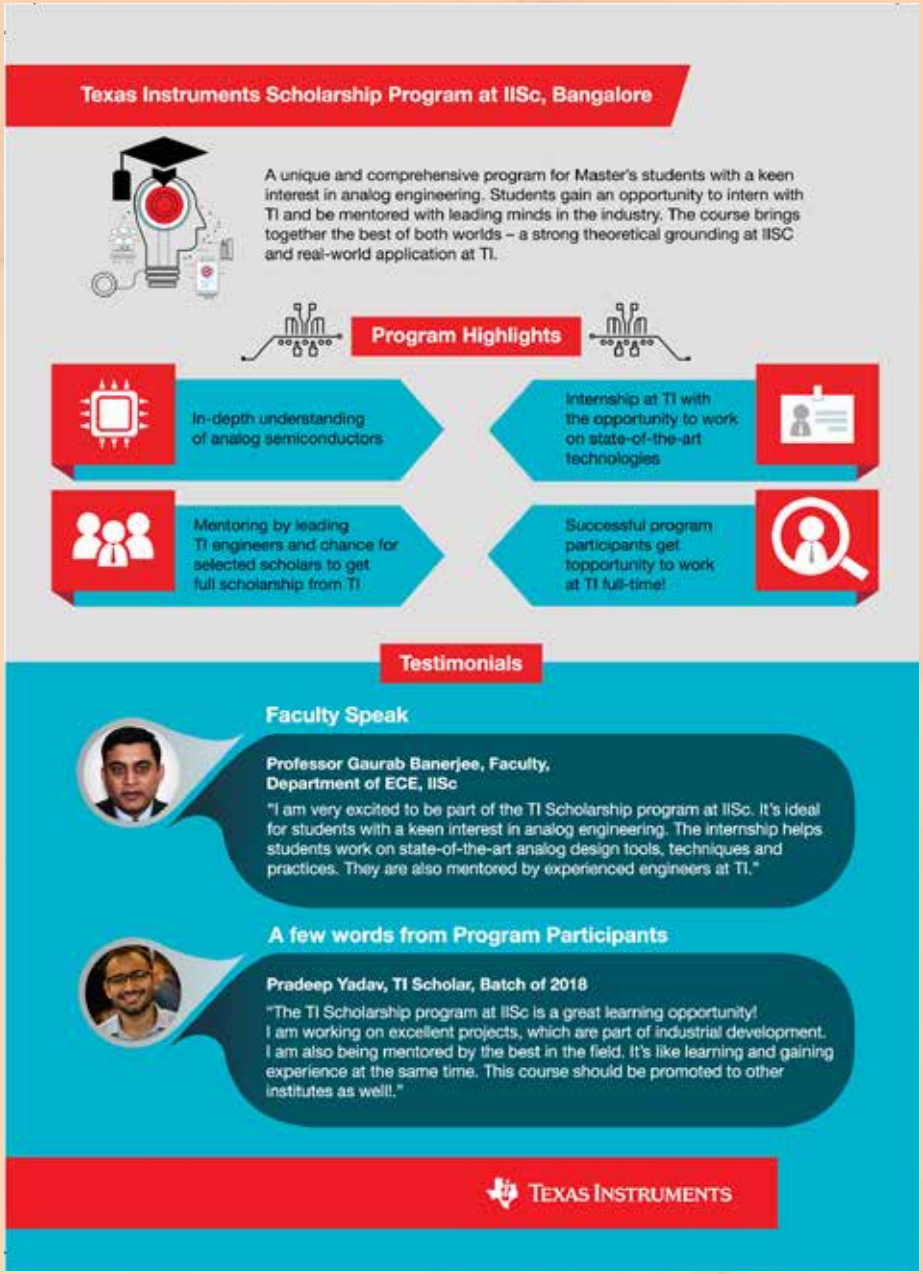
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Faculty Speak
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A few words from Program Participants
Pradeep Yadav, TI Scholar, Batch of 2018
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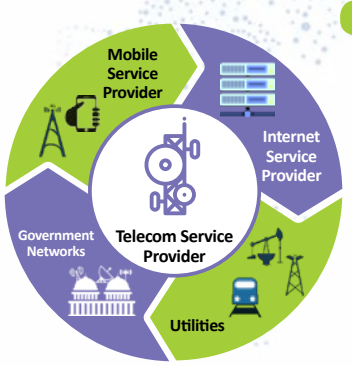

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Directions to IISc

From Bangalore Airport:

Ask a taxi to take you to the Tata Institute (which is what IISc is locally known as). This should suffice in most cases. Directions (if necessary): From Mekhri Circle, take the road towards Yeshwanthpur (called CV Raman Road). Keep straight at the first traffic signal (at Sadashiva Nagar Traffic Police Station). About 500m beyond this signal, you'll see the gates of IISc on the right-hand side.

It is recommended that you take one of the metered taxis (Meru/KSTDC/EasyCabs) that are queued up outside on your left as you exit the airport terminal building. A metered taxi from the airport to IISc should cost you approximately Rs. 850 (plus possibly a 10% extra charge at night). Payment must be in cash, so make sure that you have sufficient cash (Indian Rupees) in hand when you leave the airport. Also, please be aware that you will be asked to pay a toll of Rs. 120 as you enter the highway leading to the city. You can also opt for Ola/Uber also instead of Meru/EasyCabs etc. In that case, you don't need to pay the toll. However, you need to board them from a specific location. The directions for that is mentioned separately outside the airport.

There are public buses plying between the airport and Bangalore city. You can take bus # KIA-10 from the airport bus stand (to your right as you exit the airport terminal), get down at Mekhri circle, and then catch an auto from there. The institute gate will be about 2 km from Mekhri circle.

Please note that you cannot use the ATM/security gate to enter the campus. For convenience, please use the IISc main gate to enter the campus.

From the Railway Stations/Bus Terminals:

IISc is quite near and asking any taxi/auto driver to take you to Tata Institute should suffice. Try to take pre-paid taxis/ autos.

Restaurants and food joints on campus

Prakruthi: Open from 07:30 - 01:00 (veg.)

Nisarga: Open from 08:30 – 22:00 (veg.)

Nesara: Open from 08:30 – 22:00 (veg. and non-veg.)

Tattva: Open from 08:00 – 22:00 (veg. and non-veg.)

Gym Cafe: Open from 19:00 – 01:00 (veg. and non-veg.)

Cab/Taxi

You can arrange taxis from the IISc campus by contacting one of the following call taxi agencies.

Aishwarya Travels - +91-80-23374826 / +91-80-23647403 / +91-9341218070
Aum Travels - +91-80-41490452 / +91-9845402784
Varsha Tours and Travels - +91-80-23570029 / +91-9980873172

You can also choose to use one of the cab services such as (Ola/Taxi4Sure/Uber) via smartphone apps.

Auto rickshaws:

Malleshwaram (18th Cross) and Yeshwantpur circle are the best places to catch an auto rickshaw. But if you're lucky, you'll find an auto at Prof. CNR Rao circle or at Circle Maramma temple. Remember that autos cost 50% more early mornings (before 6am) and at night (after 10pm).

General Information

Phone numbers:

Security	+91-80-22932400/2225
IISc Health Centre	+91-80-22932227/34
Sadashivanagar Police Station	+91-80-23600358/22942589
Yeshwanthpur Police Station	+91-80-22942526
Malleshwaram Police Station	+91-80-22942519
MS Ramaiah Hospital	+91-80-23608888
Columbia Asia Hospital	+91-80-39898969
IISc Campus Map Smartphone App (developed by Gubbi Labs)	http://bit.ly/1O0PUv4

Medical Emergencies:

The campus Health Centre can be used in case of medical requirements. The Health Centre is located near Nesara Restaurant and the main Library. The nearest hospital outside IISc is the MS Ramaiah Hospital, located at New BEL Road.

Bank services/ATMs:

There are branches of State Bank of India and Canara Bank inside the institute campus. Four ATMs (two each of the above banks) are located inside the campus. Two ATMs are located near Prakruthi restaurant, while two other ATMs are located near the Hoysala House.

PEDL Stations inside the campus:

PEDL is a hassle-free smart cycle rental service by Zoomcar. You can use the cycles to travel inside the campus. Visit www.pedl.in to download the app and follow the instructions to rent a cycle. Please note that you are required to link your PayTM wallet to the PEDL app for payments. The rent is ₹ 3/half an hour.

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