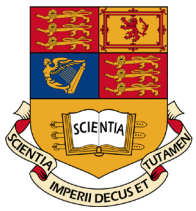
The 1st Imperial Workshop on Intelligent Communications

Workshop Program

15 October 2021, London



Imperial College London

1. About the workshop

The field of machine learning (ML) has a long and extremely successful history. It has shown overwhelming advantages in many areas, where it is normally difficult to find a concrete mathematical model for feature representation. Different from the existing ML applications, the development of traditional communication systems has vastly relied on theories and models, from information theory to channel modelling. These traditional approaches are showing serious limitations, especially in view of the increased complexity of communication networks. Therefore, research on ML applied to communications, especially to wireless communications, is currently experiencing an incredible boost. The objective of this annual workshop is to promote research activities in the area of intelligent communications and to facilitate collaborations among different universities and companies. The workshop is hosted mostly by the faculty from Imperial College London.

It will be open and free to all researchers, inside and outside Imperial. The speakers for the first workshop are by invitation only.

2. Organization committee

- Geoffrey Li
- Kin Leung
- Bruno Clerckx
- Danilo Mandic
- Deniz Gunduz
- Vanessa Rodriguez-Gonzalez
- Shenglong Zhou
- Fan Wang

3. Access

On-site Venue: Room 611, Electrical & Electronic Engineering, Imperial College London, South Kensington Campus, London SW7 2AZ, London, UK

Online access via Zoom:

https://imperial-ac-uk.zoom.us/j/97837339611?pwd=NUtXUkQ4TEVZMWgxamJkZFovYnU3QT09

Meeting ID: 978 3733 9611

Passcode: @1stIWIC

4. Timetable

Time (UK)	Speakers	Titles
08:20 – 08:30		**Welcome Remarks**
08:30 – 09:20	Dr. Wen Tong	*The New Framework for Systme-2 Communications Based on Machine Learning**
09:20 – 10:10	Dr. Howard Benn	*AI developments in 5G with a focus on NWDAF and RIC***
10:10 – 10:30		**Coffee Break**
10:30 – 11:20	Dr. Adnan Aijaz	*Multi-service Edge-Intelligence: A New Paradigm for Realizing Control over Wireless**
11:20 – 12:10	Prof. Lajos Hanzo	*On the Road from Classical to Quantum Communications**
12:10 – 13:30		**Lunch** (lunch boxes will be distributed for onsite attendees)
13:30 – 14:20	Prof. Jean Claude Belfiore	*Towards a Mathematical Theory of Semantic Communication**
14:20 – 15:10	Prof. Jiangzhou Wang	*Deep Reinforcement Learning for Multi-User Association in Fog Radio Access Networks**
15:10 – 15:30		**Coffee Break**
15:30 – 16:20	Prof. Osvaldo Simeone	*Channel Noise as Monte Carlo Sampling: Efficient Bayesian Distributed Learning in Wireless Systems**
16:20 – 17:10	Dr. Tingfang Ji	*What is the role of AI in the 5G future**
19:00 – 22:00		**Banquet** (by invitation only)

*On-line talks, **On-site talks.

5. Invited Talks

The New Framework for Systme-2 Communications Based on Machine Learning

Abstract: In this talk, we propose a 6G communications architecture to natively support the System-1 AI and can be evolved into System-2 AI. We present the deep learning-based AI technologies and associated open issues related with the 6G wireless. The deep-learning neural network (DNN) model is considered as a new entity for the future new communications, with this novel concept, the communication model for 6G will be advanced into a post Shannon paradigm, where the communications of "intelligence" can be performed on the sematic level with primarily the so-called the System-2 context and capabilities.

Wen Tong is the CTO, Huawei Wireless. He is the head of Huawei wireless research. In 2011, Dr. Tong was appointed the Head of Communications Technologies Labs of Huawei, currently, he is the Huawei 5G chief scientist and led Huawei's 10-year-long 5G wireless technologies research and development. Prior to joining Huawei in 2009, Dr. Tong was the Nortel Fellow and head of the Network Technology Labs at Nortel. He joined the Wireless Technology Labs at Bell Northern Research in 1995 in Canada.

Dr. Tong is the industry recognized leader in invention of advanced wireless technologies, Dr. Tong was elected as a Huawei Fellow and an IEEE Fellow. He was the recipient of IEEE Communications Society Industry Innovation Award in 2014, and IEEE Communications Society Distinguished Industry Leader Award for "pioneering technical contributions and leadership in the mobile communications industry and innovation in 5G mobile communications technology" in 2018. He is also the recipient of R.A. Fessenden Medal. For the past three decades, he had pioneered fundamental technologies from 1G to 5G wireless and Wi-Fi with more than 510 awarded US patents.

Dr. Tong is a Fellow of Canadian Academy of Engineering, and he serves as Board of Director of Wi-Fi Alliance.

AI developments in 5G with a focus on NWDAF and RIC

Abstract: Within 3GPP 5G is evolving into 5G Advanced (Rel-18), the ORAN Alliance have published their 4th release (Dawn), and the global telecoms research community are busy developing the new technologies for 6G. All these developments have one thing in common –

AI/ML is at the heart the architecture developments. In 3GPP it is NWDAF, the RIC in ORAN, and 6G is being built around an AI framework.

This presentation will talk about AI developments in 5G with a focus on NWDAF and RIC, then move on to look at the requirements for machine learning in 6G with a summary of recent development in this fascinating technical arena.

Howard Benn started his career in the fixed telecommunication sector (Plessey) back in 1982, did his degree and PhD at Bradford University, moving into radio-based communications in 1989. He started working in ETSI GSM standards committees in 1993, helping create 3GPP and chairing 3GPP RAN 4 from 1998 to 2007. He has been a board member of ETSI since 2008, a member of the ICANN Nomcom in 2013 currently advising the ICANN board on mobile technology, and a member of a number of advisory boards for UK universities and research programs. His current role is 'Vice President Communications Research' for Samsung Electronics R&D Institute in the UK, managing a team of engineers covering ETSI, 3GPP, and GSMA. His team are also very active in the EU Horizon 2020 program with a focus on the 5G PPP activities. He also sits on the UK5G government advisory committee looking at the future of communications technology in the UK, and an advisor to the UK government on international free trade agreements.

Multi-service Edge-Intelligence: A New Paradigm for Realizing Control over Wireless

Abstract: Recent advances in connectivity technologies like 5G are promising for untethering real-time control systems in industrial and consumer sectors. However, stability of control applications is not guaranteed under wireless imperfections (packet losses, jitter, latency, etc.). This talk introduces multi-service edge-intelligence as a new paradigm for realizing control over wireless and explores some of the key system-level design challenges. Differing from conventional 'control-aware wireless' and 'wireless-aware control' paradigms, multi-service intelligence provides tight coupling of edge-computing and artificial intelligence technologies, and the radio access network (RAN) to achieve guaranteed stability for control applications.

Adnan Aijaz studied telecommunications engineering at King's College London, UK, where he received a Ph.D. in 2014 for research in wireless networks. He joined the Bristol Research and Innovation Laboratory (BRIL) of Toshiba Corporation in 2015, where he is currently

leading the industrial 5G innovation programme. His recent research areas include industrial communication systems and automation networks, next-generation mobile/cellular (5G and beyond) and Wi-Fi technologies, cyber-physical systems, and robotics and autonomous systems. He has several patents and publications in these areas. He has been contributing to various national and international research projects and standardization activities related to 5G and industrial communication.

On the Road From Classical to Quantum Communications

Abstract: The marriage of ever-more sophisticated signal processing and wireless communications has led to compelling 'telepresence' solutions - at the touch of a dialling key. However, the 'quantum' leaps both in digital signal processing theory and in its nano-scale based implementation is set to depart from classical physics obeying the well-understood laws revealed by science. We embark on a journey into the weird & wonderful world of quantum physics, where the traveller has to obey the sometimes strange new rules of the quantum world. Hence we ask the judicious question: can the marriage of applied signal processing and communications extended beyond the classical world into the quantum world? Please join this exciting journey valued Colleague!

Lajos Hanzo, FREng, FIEEE, FIET, RS Wolfson Fellow, received his 5-year Master degree in electronics from the Technical University of Budapest in 1976, his doctorate in 1983 and his Doctor of Sciences (DSc) degree in 2004. During his career in telecommunications, he has held various research and academic posts in Hungary, Germany and the UK. Since 1986 he has been with the School of ECS, University of Southampton, UK, where he holds the Chair in Telecommunications. His current research interests are featured at http://www-mobile.ecs.soton.ac.uk.

Towards a Mathematical Theory of Semantic Communication

Abstract: This talk is an attempt to answer the question "How can intelligent machines efficiently communicate?" which is one of the main goals of the so-called "Semantic Communication". I will present a joint work with Daniel Bennequin which shows our progresses towards a mathematical theory of semantic communication, inspired by the foundational works of Claude Shannon and Alexander Grothendieck. To communicate

efficiently we need a language. Using category theory, we can define a category transporting the semantics of a language. We will see then that the notion of semantics depends on many aspects that can be found in machine learning: Sampling (the data), structures (a kind of presemantic that will be carefully defined), the language itself.

Some important mathematical notions as Grothendieck Toposes and Stacks will be introduced through simple examples and we will see how neural networks can be modelled this way). Finally, after showing how a language is transported through the layers of a neural network, we will give a definition of semantic information measures which are not scalar quantities as in Shannon information theory, but spaces. Some examples will show the validity of such a definition. We will also start proposing some semantic coding theorems.

Jean-Claude Belfiore graduated from Ecole Supérieure d'Electricité (Supelec), got his PhD from Telecom Paris and the Habilitation from Université Pierre et Marie Curie (UPMC). Until 2015, he has been with Telecom Paris as a full Professor in the Communications & Electronics department. In 2015, he joined the Mathematical and Algorithmic Sciences Lab of Huawei as the head of the Communication Science Department and now the Director of WTLab, Paris. Jean-Claude Belfiore has made pioneering contributions in modulation and coding for wireless systems (especially space-time coding) by using tools of number theory. He is also one of the co-inventors of the celebrated Golden Code of the Wi-Max standard. Jean-Claude Belfiore is author or co-author of more than 200 technical papers and communications and has served as an advisor for more than 30 Ph.D. students. He was Associate Editor of the IEEE Transactions on Information Theory for Coding Theory and has been the recipient of the 2007 Blondel Medal. In Huawei, he has been involved in 5G standardization process, essentially in Channel Coding (Polar Codes for 5G). He is now working in wireless 6G, on artificial reasoning and future wireless networks for intelligent machines.

Deep Reinforcement Learning for Multi-User Association in Fog Radio Access Networks

Abstract: Fog radio access networks (F-RANs) are a promising evolution for future mobile communications. The evolution is a hybrid centralised-distributed architecture to only centralised cloud radio access networks (C-RAN), aiming to alleviate strain on the fronthaul links used for communication. The new architecture comes with challenges that cannot be

tackled easily with the same algorithms used for solutions to problems raised by C-RAN. New efficient algorithms have to be developed to meet the requirements of the upcoming generation of mobile communications. Joint resource allocation and joint transmission are some of the ways that improvement is proposed, however they result in complex decision making processes, that are infeasible to solve for in real-time using brute force solutions. Reinforcement learning, particularly a recently introduced dual deep Q-network (DDQN) algorithm is acknowledged as a possible solution, however it has lengthy training times. This talk will present a novel distributed dual deep Q-network (3DQN) algorithm by introducing experience exchange in partially observable Markov decision process (POMDP) environments.

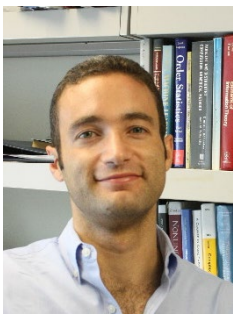
Prof. Jiangzhou Wang has been a Professor since 2005 at the University of Kent, U.K. His research interest is in the area of mobile communications. He is a Fellow of the Royal Academy of Engineering, U.K., Fellow of the IEEE, and Fellow of the IET. He was the Technical Program Chair of the 2019 IEEE International Conference on Communications (ICC2019), Shanghai, the Executive Chair of the IEEE ICC2015, London, and the Technical Program Chair of the IEEE WCNC2013.

Channel Noise as Monte Carlo Sampling: Efficient Bayesian Distributed Learning in Wireless Systems

Abstract: Conventional frequentist learning, as assumed by existing federated learning protocols, is limited in its ability to quantify uncertainty, incorporate prior knowledge, guide active learning, and enable continual model updates. Bayesian learning provides a principled approach to address all these limitations, at the cost of an increase in computational complexity. A standard approach to implement Bayesian learning is through Monte Carlo sampling, whereby the learner generates samples (approximately) drawn from the posterior distribution to enable Gibbs or ensemble predictors. Focusing on wireless distributed Bayesian learning, this talk introduces the idea of channel-driven MC sampling: Rather than treating channel noise as a nuisance to be mitigated, channel-driven sampling utilizes channel noise as an integral part of the MC sampling process.

Two specific settings are studied: a wireless data center system encompassing a central server and multiple distributed workers, and a federated system with an edge access point and distributed agents. For the first setting, the talk investigates for the first time the design of distributed one-shot, or "embarrassingly parallel", Bayesian learning protocols via consensus

Monte Carlo (CMC), while for the second we consider Langevin MC sampling schemes based on multiple communication rounds. In both cases, uncoded transmission is introduced not only as a means to implement "over-the-air" computing but also as a way to enable channel-driven sampling. Simulation results demonstrate that, if properly accounted for, channel noise can indeed contribute to MC sampling, and does not necessarily decrease the accuracy level.



Osvaldo Simeone is a Professor of Information Engineering with the Centre for Telecommunications Research at the Department of Engineering of King's College London, where he directs the King's Communications, Learning and Information Processing lab. He received an M.Sc. degree (with honors) and a Ph.D. degree in information engineering from Politecnico di Milano, Milan, Italy, in 2001 and 2005, respectively. From 2006 to 2017, he was a faculty member of the Electrical and Computer Engineering (ECE) Department at New Jersey Institute of Technology (NJIT), where he was affiliated with the Center for Wireless Information Processing (CWiP). His research interests include information theory, machine learning, wireless communications, and neuromorphic computing. Dr Simeone is a co-recipient of the IEEE Veh. Techn. Society 2021 Jack Neubauer Memorial Award, 2019 IEEE Communication Society Best Tutorial Paper Award, the 2018 IEEE Signal Processing Best Paper Award, the 2017 JCN Best Paper Award, the 2015 IEEE Communication Society Best Tutorial Paper Award and of the Best Paper Awards of IEEE SPAWC 2007 and IEEE WRECOM 2007. He was awarded a Consolidator grant by the European Research Council (ERC) in 2016. His research has been supported by the U.S. NSF, the ERC, the Vienna Science and Technology Fund, as well as by a number of industrial collaborations. He currently serves in the editorial board of the IEEE Signal Processing Magazine and is the vice-chair of the Signal Processing for Communications and Networking Technical Committee of the IEEE Signal Processing Society. He was a Distinguished Lecturer of the IEEE Information Theory Society in 2017 and 2018, and he is currently a Distinguished Lecturer of the IEEE Communications Society. Dr Simeone is a co-author of two monographs, two edited books published by Cambridge University Press, and more than 150 research journal papers. He is a Fellow of the IET and of the IEEE.

What is the role of AI in the 5G future?

Abstract: Today, artificial intelligent (AI) is delivering enhanced experiences and new capabilities to our society in more ways than ever. AI not only provides the ability for our devices to perceive, reason, and act intuitively, but also changes how we approach and solve

technical challenges. At Qualcomm Technologies, we are making AI ubiquitous through a system level approach that optimizes efficiency across hardware, software, and algorithms. At the same time, we're kicking off the 5G Advanced evolution (3GPP Release 18 and beyond). To accelerate 5G innovations, novel machine learning techniques can bring broad benefits to the table, fueling advancements across a wide range of technology areas. Looking forward, we are exploring the natural synergies of 5G and AI, as well as working with the entire mobile ecosystem to drive wireless innovations forward.

Tingfang Ji joined Qualcomm in 2003 and is currently a Senior Director of engineering in Wireless R&D. From 2003 to 2014, he made instrumental technical contributions towards the development of LTE/LTE-A technology and served as a vice chairman of the radio working group of 3GPP. Since 2014 his research project spear-headed Qualcomm's 5G NR air interface design/standardization efforts, pre-commercial 5G NR IODT/trials, 5G experimental macro networks, and long-term pre-6G research. Before joining Qualcomm, Tingfang was a member of the technical staff at Bell Labs. As an inventor, he has more than 1000 US patent applications.

Tingfang received his Ph.D. degree in E.E. from the University of Michigan, Ann Arbor in 2001, and also received a B.Sc. from Tsinghua University, Beijing.