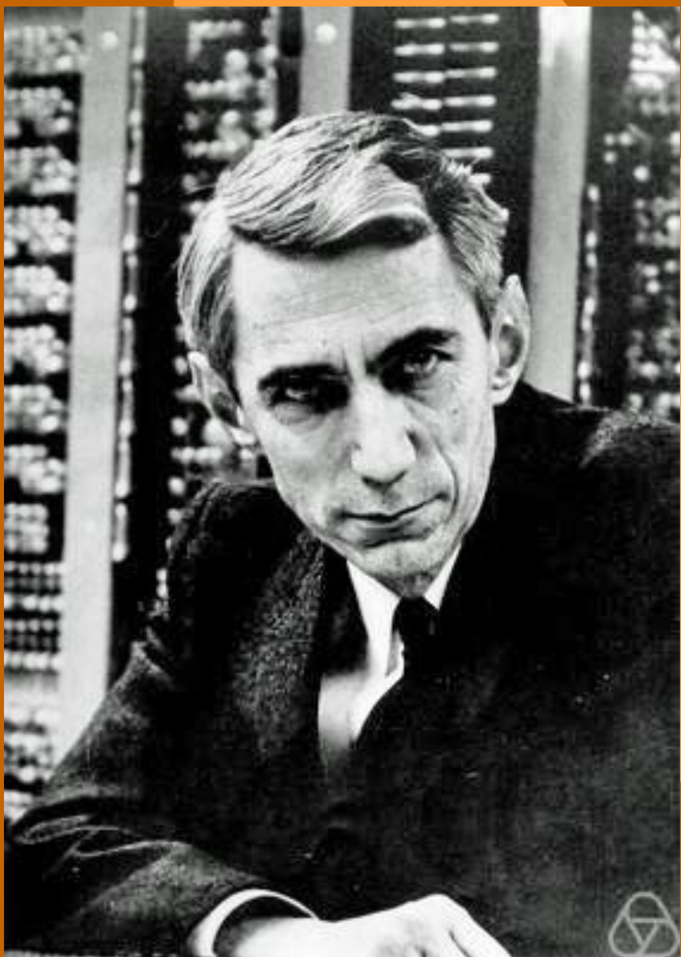
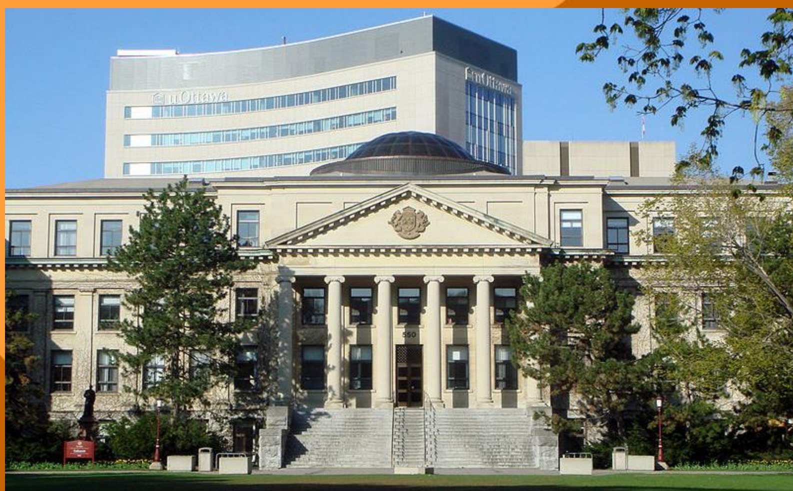
17th Canadian Workshop on Information Theory

WELCOME!

Ottawa, Ontario, Canada | June 5-8, 2022





uOttawa

CSIT SCTI

http://cwit.ca/2022/

Contents

Timetable 3
Sunday, 5 of June . . . 3
Monday, 6 of June . . . 3
Tuesday, 7 of June . . . 4
Wednesday, 8 of June . . . 5

List of Abstracts 6
Sunday, 5 of June . . . 6
Monday, 6 of June . . . 7
Tuesday, 7 of June . . . 12
Wednesday, 8 of June . . . 17

Timetable

Sunday, 5 of June

8:30–9:00	**Registration**		
9:00–12:00	Tutorial	**Dimitris Papailiopoulos** University of Wisconsin-Madison	**Learning by Pruning and the Hunt for Lottery Tickets** (online)
12:00–14:00	**Lunch (on Your Own)**		
14:00–17:00	Tutorial	**Augusto Gerolin** University of Ottawa	**A tutorial on Optimal Transport Theory**
19:00–22:30	Reception on Ottawa River Cruise		

Monday, 6 of June

8:50–9:00	**Welcome remarks**		
9:00-10:00	Keynote Lecture	**Muriel Médard** Massachusetts Institute of Technology	**It's not the code, it's the noise**
10:00–10:10	**Coffee Break**		
10:10–11:10	**Technical Session: Information Theory** **Session Chair: Steve Hranilovic** **On the Rényi Cross-Entropy** *Ferenc Cole Thierrin, Fady Alajaji and Tamas Linder (Queen's University)* **On the Capacity of IRS-Assisted Gaussian SIMO Channels** *Milad Dabiri and Sergey Loyka (University of Ottawa)* **Rényi Fair Information Bottleneck for Image Classification** *Adam Gronowski (Queen's University); William Paul (Johns Hopkins University); Fady Alajaji (Queen's University); Bahman Gharesifard (University of California, Los Angeles); Philippe Burlina (Johns Hopkins University)*		
11:10–11:20	**Coffee Break**		
11:20–12:20	**Technical Session: Coding Theory** **Session Chair: Frank Kschischang** **Protograph-based LDPC codes with chordless short cycles and large minimum distance** *Farzane Amirzade (Carleton University); Mohammad-Reza Sadeghi (Amirkabir University of Technology); Daniel Panario (Carleton University)* **Single-Minimum LDPC Decoding Offset Optimization Methods** *Daniel B Dermont, Jeremy Nadal and François Leduc-Primeau (Polytechnique Montreal)* **SAPA: Sparse Affine Projection Algorithm in ADMM-LP Decoding of LDPC Codes** *Amirreza Asadzadeh (University of Toronto); Masoud Barakatain (Huawei Technologies); Stark Draper (University of Toronto); Jeebak Mitra (Huawei Technologies)*		
12:20–14:00	**Lunch (on Your Own)**		
14:00–15:00	Keynote Lecture	**Michelle Effros** California Institute of Technology	**On Practical, Optimal Random Access Communication** (online)
15:00–15:10	**Coffee Break**		

15:10–16:10	**Technical Session: Compression** **Session Chair: Pradeepa Yahampath** **An Extension to Source-Channel Coding of Correlated Gaussian Sources for a Fading GMAC Using TCVQ** *Pradeepa Yahampath (University of Manitoba)* **Vector Quantization of Deep Convolutional Neural Networks With Learned Codebook** *Siyuan Yang and Yongyi Mao (University of Ottawa)* **A Lego-Brick Approach to Lossy Source Coding** (online) *Nadim Ghaddar (University of California, San Diego); Shouvik Ganguly (XCOM Labs);* *Lele Wang (University of British Columbia); Young-Han Kim (University of California, San Diego)*
16:10–16:20	**Coffee Break**
16:20–17:20	**Technical Session: Security** **Session Chair: Lutz Lampe** **Side-Channel Information Leakage of Code-Based Masked Implementations** *Wei Cheng, Olivier Rioul, Yi Liu and Julien Béguinot (Télécom Paris, Institut Polytechnique de Paris);* *Sylvain Guilley (Télécom Paris, Institut Polytechnique de Paris & Secure-IC S.A.S.)* **Distribution Simulation Under Local Differential Privacy** *Shahab Asoodeh (McMaster University)* **Modeling and Energy Analysis of Adversarial Perturbations in Deep Image Classification Security** (video) *Linfeng Ye, En-hui Yang and Ahmed Salamah (University of Waterloo)*
18:00–19:30	Posters (light food/beverage provided)

Tuesday, 7 of June

9:00-10:00	Keynote Lecture	**Wei Yu** University of Toronto	**Learn to Optimize for Wireless Communications**
10:00–10:10	**Coffee Break**		
10:10–11:40	**Invited Session on Communication and Coding on Nanonetworking and Biology** **Session Chair: Andrew Eckford** **From Competing Bacteria to Glucose Regulation: Applying a Multi-Scale Framework for Molecular Communication** *Speaker: Adam Noel (University of Warwick)* **Biological Coding Theory – A Mathematical Framework for Understanding and Engineering Biomolecular Systems** *Speaker: Elebeoba E. May (University of Houston)* **Role of Molecular Communication in Neuro-Degenerative Diseases** *Speaker: Hamdan Awan (Munster Technological University)* **Modeling of Molecular Communication Systems by Transfer Functions** *Speaker: Maximilian Schaefer (University of Erlangen-Nuremberg)*		
11:40–13:30	**Lunch (on Your Own)**		
13:30-14:30	Keynote Lecture	**Yi Ma** University of California, Berkeley	**CTRL: Closed-Loop Data Transcription via Rate Reduction**
14:30–14:40	**Coffee Break**		

14:40–15:40	**Invited Session on Data Science and Information Theory** **Session Chair: Lele Wang** **Inference in High Dimensions for Generalized Linear Models: the Linear, the Spectral and the Approximate** *Speaker: Marco Mondelli (Institute of Science and Technology Austria)* **Imbalance trouble in overparameterized learning** *Speaker: Christos Thrampoulidis (University of British Columbia)* **Understanding Generalization in Machine Learning Using Information-Theoretic Measures** *Speaker: Mahdi Haghifam (University of Toronto)*
15:40–15:50	**Coffee Break**
15:50–16:50	**Invited Session on Data Science and Information Theory** **Session Chair: Lele Wang** **Achieving Noisy Linear Convergence in CV@R Statistical Learning: SGD, Strongly Convex Losses and Beyond** (online) *Speaker: Dionysios S. Kalogerias (Yale University)* **Random Graph Matching in Geometric Models: the Case of Complete Graphs** (online) *Speaker: Jiaming Xu (Duke University)* **Collaborative and distributed learning for Healthcare: from Theory to Practice** (online) *Speaker: Xiaoxiao Li (University of British Columbia)*
17:00–18:20	CSIT annual meeting
18:40–21:30	Banquet at Courtyard Restaurant (Byward Market)

Wednesday, 8 of June

9:00–10:20	**Technical Session: Communication Systems** **Session Chair: Stark Draper** **Probabilistic Shaping Using a Block-Based Bit-Level Distribution Matcher** *Maxim Goukhshtein and Stark Draper (University of Toronto); Jeebak Mitra (Huawei Technologies)* **A Novel Differential Decode and Forward Scheme for Channel-Unaware Two-Way Relay Networks** *Salime Bameri and Ramy Gohary (Carleton University)* **Performance Evaluation of Media-based Modulation in Comparison with Spatial Modulations and Legacy SISO/MIMO** *Ehsan Seifi (Ciena); Mehran Atamanesh and Amir K. Khandani (University of Waterloo)* **Space-Time Interleaved OFDM Systems in Impulsive Noise and Mobile Fading Channels** (online) *Hen-Geul Yeh and Jun Zhou (California State University, Long Beach)*
10:20–10:30	**Coffee Break**
10:30–11:50	**Technical Session: Wireless Communications** **Session Chair: Steven Blostein** **Favorable Propagation for Wideband Massive MIMO with Non-Uniform Linear Arrays** *Elhamsadat Anarakifirooz and Sergey Loyka (University of Ottawa)* **A Hybrid Random-Greedy Approach to User Selection for MU-MIMO Based on Pairwise Metrics** *Omid Saatlou and Steven D Blostein (Queen's University)* **Sum Rate Maximization of Full-Duplex MIMO Monostatic Backscatter Networks Under Residual Self-Interference** *Azar Hakimi, Shayan Zargari and Chintha Tellambura (University of Alberta); Sanjeewa P. Herath (Huawei Technologies)* **Intra C-RAN Two-Way Multi-Pair Computation under Total Power and Fronthaul Capacity Constraints** *Mahmoud Hasabelnaby and Anas Chaaban (University of British Columbia)*

List of Abstracts

Sunday, 5 of June

Tutorial: Learning by Pruning and the Hunt for Lottery Tickets

Dimitris Papailiopoulos 9 AM-12 noon (online)

University of Wisconsin-Madison, USA

It has been widely observed that highly overparameterized neural networks can be significantly sparsified, with little accuracy loss, through a time-consuming “train, prune, re-train” approach. In 2018, Frankle and Carbin conjectured that we may be able to avoid this by instead training lottery tickets: sparse subnetworks, found right at initialization, trainable to high accuracy. This led to a flurry of algorithmic work attempting to find lottery tickets, and algorithms for pruning at initialization. In this tutorial I will survey these recent findings along with theoretical justifications for the existence of good subnetworks at initialization. I will list several algorithmic challenges for finding lottery tickets and will discuss open problems that fall in the intersection of information theoretic bounds and achievability results.

Tutorial: A Tutorial on Optimal Transport Theory

Augusto Gerolin 2 PM-5 PM

University of Ottawa, Canada

Optimal transport theory is the branch of mathematics and economics that nowadays is becoming a fundamental tool in Machine Learning research. In simple terms, it aims at studying and generalizing the idea of optimal matchings or assignments between two (or more) groups of observations.

This tutorial aims to provide a gentle introduction to mathematical and computational aspects of the theory, motivating its use in Machine Learning with some examples, following with some of the best-known results in the field. Focus will be given to the Entropy-regularization of Optimal Transport, whose solutions can be easily computed via the Sinkhorn algorithm.

This tutorial has few prerequisites and definitively no contraindications. Therefore, graduate students are warmly encouraged to attend. During the tutorial, the participants will be stimulated to be active in solving pedagogical problems, which can vary from pen & paper and coding - so bring your laptops with you!

Monday, 6 of June

Keynote Lecture: It's not the code, it's the noise

Muriel Médard 9 AM-10 AM

Massachusetts Institute of Technology, USA

Code design is notoriously intricate, yet theory tells us it need not be. The underlying assumption has always been that codes need to be carefully constructed so that they be practically decodable. Indeed, machine learning has been deployed to aid in such design of encoders and decoders. In this talk, we argue that we should return to theory - codes need not be structured. At the physical layer, when we consider error correction, we show that Guessing Random Additive Noise Decoding (GRAND), joint work with Ken Duffy, is a universal decoder, already realized in hardware with Rabia Yazicigil, that guesses noise effects sequentially until a correct decoding is obtained. In this manner, any knowledge of the noise can be fruitfully applied to aid in decoding. We show that almost any code, from a random linear code to a humble CRC, and even systems meant for cryptography rather than for error-correction, such as AES, performs equally well.

Technical Session (Information Theory): On the Rényi Cross-Entropy

Ferenc Cole Thierrin, Fady Alajaji, Tamas Linder 10:10 AM-11:10 AM

Queen's University, Canada

The Rényi cross-entropy measure between two distributions, a generalization of the Shannon cross-entropy, was recently used as a loss function for the improved design of deep learning generative adversarial networks. In this work, we examine the properties of this measure and derive closed-form expressions for it when one of the distributions is fixed and when both distributions belong to the exponential family. We also analytically determine a formula for the cross-entropy rate for stationary Gaussian processes and for finite-alphabet Markov sources.

Paper URL: http://cwit.ca/2022/papers/1570797945.pdf

Technical Session (Information Theory): On the Capacity of IRS-Assisted Gaussian SIMO Channels

Milad Dabiri, Sergey Loyka 10:10 AM-11:10 AM

University of Ottawa, Canada

Intelligent reflective surface (IRS) has recently emerged as a valuable addition to other key technologies for 5/6G to improve their energy efficiency and achievable rate at low cost. An IRS-assisted SIMO channel is studied here from an information-theoretic perspective. Its channel capacity includes an optimization over IRS phase shifts, which is not a convex problem and for which no closed-form solutions are known either. A number of closed-form bounds are obtained for the general case, which are tight in some special cases and thus provide a globally-optimal solution to the original problem. Based on a closed-form globally-optimal solution for the single reflector case, a computationally-efficient iterative algorithm is proposed for the general case. Its convergence to a local optimum is rigorously proved and a number of cases are identified where its convergence point is also globally optimal. Numerical experiments show that the algorithm converges fast in practice and its convergence point is close to a global optimum.

Paper URL: http://cwit.ca/2022/papers/1570797902.pdf

Technical Session (Information Theory): Rényi Fair Information Bottleneck for Image Classification

***Adam Gronowski*[1], *William Paul*[2], *Fady Alajaji*[1], *Bahman Gharesifard*[3], *Philippe Burlina*[2]** 10:10 AM-11:10 AM

[1]Queen's University, Canada; [2]Johns Hopkins University, USA; [3]University of California, Los Angeles, USA

We develop a novel method for ensuring fairness in machine learning which we term as the Rényi Fair Information Bottleneck (RFIB). We consider two different fairness constraints - demographic parity and equalized odds - for learning fair representations and derive a loss function via a variational approach that uses Rényi's divergence with its tunable parameter α and that takes into account the triple constraints of utility, fairness, and compactness of representation. We then evaluate the performance of our method for image classification using the EyePACS medical imaging dataset, showing it outperforms competing state of the art techniques with performance measured using a variety of compound utility/fairness metrics, including accuracy gap and Rawls' minimal accuracy.

Paper URL: http://cwit.ca/2022/papers/1570796577.pdf

Technical Session (Coding Theory): Protograph-based LDPC codes with chordless short cycles and large minimum distance

***Farzane Amirzade*[1], *Mohammad-Reza Sadeghi*[2], *Daniel Panario*[1]** 11:20 AM-12:20 PM

[1]Carleton University, Canada; [2]Amirkabir University of Technology, Iran

Controlling small size trapping sets and short cycles can result in LDPC codes with large minimum distance d_{min}. We prove that short cycles with a chord are the root of several trapping sets and eliminating these cycles increases d_{min}. We show that the lower bounds on d_{min} of an LDPC code with chordless short cycles, girths 6 (and 8), and column weights γ (and 3), respectively, are 2γ (and 10), which is a significant improvement compared to the existing bounds $\gamma + 1$ (and 6). We also show that d_{min} of an LDPC code with chordless short cycles, column weight γ and girth 8 is at least $\frac{3(\gamma-1)^2}{\gamma \ln \gamma - \gamma + 1}$. Several exponent matrices of protograph-based LDPC codes with chordless short cycles are proposed for any type of protographs, single-edge and multiple-edge, regular and irregular, to show that our method can be applied to any protograph-based LDPC code. The numerical results as well as simulations show that the removal of short cycles with a chord improves previous results in the literature.

Paper URL: http://cwit.ca/2022/papers/1570797917.pdf

Technical Session (Coding Theory): Single-Minimum LDPC Decoding Offset Optimization Methods

Daniel B Dermont, Jeremy Nadal, François Leduc-Primeau 11:20 AM-12:20 PM

Polytechnique Montreal, Canada

Low-density parity-check codes are widely used in communication systems. To meet the high throughput and energy efficiency requirements of current and future systems, it is desirable to further simplify the decoder. Quantized min-sum (MS) decoders are of particular interest for their low implementation complexity, which can be further reduced by computing a single minimum (SM) during check node update, instead of two. However, this simplification can lead to poor decoding performance unless it is carefully incorporated. In this paper, we formalize a general optimization problem for SM decoding, and propose search heuristics to solve it. In addition, we provide density evolution (DE) equations for the first two decoding iterations that properly take into account the lack of extrinsic update rule, and show that this DE result can be used to obtain good solutions to the SM optimization problem with low computational complexity.

Paper URL: http://cwit.ca/2022/papers/1570797862.pdf

Technical Session (Coding Theory): SAPA: Sparse Affine Projection Algorithm in ADMM-LP Decoding of LDPC Codes

Amirreza Asadzadeh[1], ***Masoud Barakatain***[2], ***Stark Draper***[1], ***Jeebak Mitra***[2] 11:20 AM-12:20 PM

[1]University of Toronto, Canada; [2]Huawei Technologies, Canada

We present a simplified alternating direction method of multipliers with linear programming (ADMM-LP) decoder for LDPC codes by developing a method of approximate projection onto the parity polytope. The algorithm projects onto the affine hull of the χ closest local codewords for each check of degree d, where χ can be much smaller than d. We name this SAPA, the "sparse affine projection algorithm". In contrast to exact projection, SAPA does not require a water-filling step and thus can be implemented with lower per-iteration complexity. We present numerical results which demonstrate not only that SAPA's performance, when used as part of an overall decoder, is close to that of exact projection, but also that the use of SAPA does not incur many additional iterations. This is in contrast to other approximate algorithms. Thus, SAPA is appropriate for use in limited-iteration decoders in high-throughput applications. Moreover, we analyze sparsity of polytope projections in the exact ADMM-LP decoding to explain the suitability of the proposed sparse approximation.

Paper URL: http://cwit.ca/2022/papers/1570796745.pdf

Keynote Lecture: On Practical, Optimal Random Access Communication

Michelle Effros 2 PM-3 PM (online)

California Institute of Technology, USA

Random access communication plays a central role in modern communication systems. For example, wireless devices that communicate through WiFi hotspots and cell phone towers, access the network through a random access channel. The key challenge that distinguishes random access communication from other multiple access communication scenarios is that the number of transmitters can vary widely and unpredictably from one use to the next, and neither the transmitters nor the receivers knows how many transmitters are in operation at any given time. Traditional methods for dealing with the resulting uncertainty either sacrifice performance for simplicity or pay a heavy price in overhead to eliminate transmitter-set uncertainty. This talk considers new methods for tackling random access communication, focusing on the competing goals of building practical codes and achieving the best possible performance. Central results include new coding strategies and bounds to capture some of their underlying complexity-performance tradeoffs.

Technical Session (Compression): An Extension to Source-Channel Coding of Correlated Gaussian Sources for a Fading GMAC Using TCVQ

Pradeepa Yahampath 3:10 PM-4:10 PM

University of Manitoba, Canada

Separate source-channel (SSC) coding is known to be sub-optimal for communicating correlated Gaussian sources over fading Gaussian multiple-access channel (GMAC). Considering the two-to-one GMAC with Rayleigh block fading and no transmitter-side channel-state information (CSI), a recent work demonstrated a simple fixed-rate joint source-channel (JSC) coding scheme referred to as *source-channel trellis coded vector quantization* (SC-TCVQ). This paper presents a new extension to SC-TCVQ which is shown to further improve performance with only a minor increase in encoder complexity. New results are presented which show that this finite block-length JSC coding scheme can beat the asymptotic performance upper bound of SSC coding.

Paper URL: http://cwit.ca/2022/papers/1570791114.pdf

Technical Session (Compression): Vector Quantization of Deep Convolutional Neural Networks With Learned Codebook

Siyuan Yang*, *Yongyi Mao 3:10 PM-4:10 PM

University of Ottawa, Canada

In this paper, we present a novel vector quantization technique, VQLC, for the compression of convolutional neural networks. Motivated by the hypothesis that better quantization codebooks exist beyond the neighbourhood of a pretrained model, we depart from the conventional strategy in which a codebook is constructed from a pretrained model and then fine tuned. In VQLC, the quantization codebook is randomly initialized and learned together with the training of the neural network. On several popular image classification benchmarks, we demonstrate the state-of-the-art performance of VQLC and show that VQLC is particularly effective on wide networks.

Paper URL: http://cwit.ca/2022/papers/1570797660.pdf

Technical Session (Compression): A Lego-Brick Approach to Lossy Source Coding

***Nadim Ghaddar*[1], *Shouvik Ganguly*[2], *Lele Wang*[3], *Young-Han Kim*[1]** 3:10 PM-4:10 PM (online)

[1]University of California, San Diego, USA; [2]XCOM Labs, USA; [3]University of British Columbia, Canada

Coding schemes for the lossy source coding problem are developed starting from point-to-point channel codes that are designed for symmetric channels. Bounds on the attained average distortion of the coding schemes are derived in terms of the parameters of the point-to-point channel codes. Assuming that the constituent channel codes satisfy some properties on the rate, the error probability and the input-output distribution of the decoding functions, the performance guarantees hold irrespective of other properties of the codes. Moreover, it is shown that the proposed coding schemes achieve the rate-distortion bound, provided that the constituent codes are rate-optimal. This would allow one to leverage commercial off-the-shelf codes for point-to-point symmetric channels in the practical implementation of lossy source codes.

Paper URL: http://cwit.ca/2022/papers/1570797522.pdf

Technical Session (Security): Side-Channel Information Leakage of Code-Based Masked Implementations

***Wei Cheng*[1], *Olivier Rioul*[1], *Yi Liu*[1], *Julien Béguinot*[1], *Sylvain Guilley*[12]** 4:20 PM-5:20 PM

[1]Télécom Paris, Institut Polytechnique de Paris, France; [2]Secure-IC S.A.S., France

Side-channel attacks (SCAs) are among the most powerful physical attacks against cryptographic implementations. To thwart SCAs, a well-established countermeasure is random masking. A recent code-based masking formalism unifies several known masking schemes and allows one to carry out an all-in-one leakage quantification.

In this paper, we investigate how a code-based masked implementation leaks in an information-theoretic setting, where the mutual information measures the impact of both the number and positions of probes in the probing attack model. We also establish that the mutual information decreases as the measurement noise variance increases, with an exponent equal to the dual distance of the masking code. Our findings quantitatively connect the attacker's capability to recover secret keys with the actual mutual information leakage of the protected implementation.

Paper URL: http://cwit.ca/2022/papers/1570796473.pdf

Technical Session (Security): Distribution Simulation Under Local Differential Privacy

Shahab Asoodeh 4:20 PM-5:20 PM

McMaster University, Canada

We investigate the problem of distribution simulation under local differential privacy: Alice and Bob observe sequences X^n and Y^n respectively, where Y^n is generated by a non-interactive ϵ-locally differentially private (LDP) mechanism from X^n. The goal is for Alice and Bob to output U and V from a joint distribution that is close in total variation distance to a target distribution P_{UV}. As the main result, we show that such task is impossible if the hypercontractivity coefficient of P_{UV} is strictly bigger than $(\frac{e^\epsilon-1}{e^\epsilon+1})^2$. The proof of this result also leads to a new operational interpretation of LDP mechanisms: if Y is an output of an ϵ-LDP mechanism with input X, then the probability of correctly guessing $f(X)$ given Y is bigger than the probability of blind guessing only by $\frac{e^\epsilon-1}{e^\epsilon+1}$, for any deterministic finitely-supported function f. If $f(X)$ is continuous, then a similar result holds for the minimum mean-squared error in estimating $f(X)$ given Y.

Paper URL: http://cwit.ca/2022/papers/1570796623.pdf

Technical Session (Security): Modeling and Energy Analysis of Adversarial Perturbations in Deep Image Classification Security

Linfeng Ye, En-hui Yang, Ahmed Salamah 4:20 PM-5:20 PM (video)

University of Waterloo, Canada

Despite the great success of deep neural networks (DNNs) in computer vision, they are vulnerable to adversarial attacks. Given a well-trained DNN and an image x, a malicious and imperceptible perturbation ϵ can be easily crafted and added to x to generate an adversarial example x0. The output of the DNN in response to x0 will be different from that of the DNN in response to x. To shed light on how to defend DNNs against such adversarial attacks, in this paper, we apply statistical methods to model and analyze adversarial perturbations ϵ crafted by FGSM, PGD, and CW attacks. It is shown statistically that (1) the adversarial perturbations ϵ crafted by FGSM, PGD, and CW attacks can all be modelled in the Discrete Cosine Transform (DCT) domain by the Transparent Composite Model (TCM) based on generalized Gaussian (GGTCM); (2) CW attack puts more perturbation energy in the background of an image than in the object of the image, while there is no such distinction for FGSM and PGD attacks; and (3) the energy of adversarial perturbation in the case of CW attack is more concentrated on DC components than in the case of FGSM and PGD attacks.

Paper URL: http://cwit.ca/2022/papers/1570796537.pdf

Tuesday, 7 of June

Keynote Lecture: Learn to Optimize for Wireless Communications

Wei Yu 9 AM-10 AM

University of Toronto, Canada

Machine learning will have an important role to play in the optimization of future-generation physical-layer wireless communication system design for the following two reasons. First, traditional wireless communication design always relies on the channel model, but models are inherently only an approximation to the reality. In wireless environments where the models are complex and the channels are costly to estimate, a machine learning based approach that performs system-level optimization without explicit channel estimation can significantly outperform the traditional channel estimation based approaches. Second, modern wireless communication design often involves optimization problems that are high-dimensional, nonconvex, and difficult to solve efficiently. By exploring the availability of training data, a neural network may be able to learn the solution of an optimization problem directly. This can lead to a more efficient way to solve nonconvex optimization problems. In this talk, I will use examples from optimizing a reconfigurable intelligent surface (RIS) system, precoding for a massive multiple-input multiple-output (MIMO) system, and active sensing for mmWave channel initial alignment to illustrate the benefit of learning-based physical-layer communication system design. We illustrate that matching the neural network architecture to the problem structure is crucial for the success of learning based approaches.

Invited Session (Communication and Coding on Nanonetworking and Biology): From Competing Bacteria to Glucose Regulation: Applying a Multi-Scale Framework for Molecular Communication

Adam Noel 10:10 AM-11:40 PM

University of Warwick, UK

Molecular communication (MC) engineering is inspired by the use of chemical signals as information carriers in cell biology. The biological nature of chemical signaling makes MC a promising methodology for interdisciplinary applications requiring communication between cells and other microscale devices. There have been many contributions to understand how MC signals propagate. However, these contributions have made limited impact beyond the boundaries of communications engineering research. In this talk, we present a hierarchical framework for signaling in cell biology. The framework describes how communication relies on the information available at individual cells, which in turn relies on how those cells process environmental signals, which itself relies on how those signals propagate. Thus, there can be a link between noisy signal propagation and behavior. We share how this framework is currently being applied to understand communication between organ cell cultures regulating glucose in a microfluidic platform and between competing heterogeneous bacterial communities.

Invited Session (Communication and Coding on Nanonetworking and Biology): Biological Coding Theory – A Mathematical Framework for Understanding and Engineering Biomolecular Systems

Elebeoba E. May 10:10 AM-11:40 PM

University of Houston, USA

Exploiting parallels between engineering communication and biomolecular information processing systems will not only enable us to investigate biological phenomena but can also facilitate the engineering of biological and hybrid systems. Originating from our prior work in modeling translation initiation in E. coli K12, we describe fundamental molecular processes such as hybridization using the mathematical basis of error control coding theory. In our successive work, coding theory frameworks are used in the design of in vitro deoxyribozyme computational biosensors (May, et al. 2017) for monitoring mutations in microbes. As part of this talk, I will consider the potential to connect the theoretical and engineering uses of biological coding theory to tackle challenges at the intersection of engineering and biology.

Invited Session (Communication and Coding on Nanonetworking and Biology): Role of Molecular Communication in Neuro-Degenerative Diseases

Hamdan Awan 10:10 AM-11:40 PM

Munster Technological University, Ireland

The incidence rate of neurodegenerative diseases such as Glioblastoma multiforme (GBM) and Epilepsy has been on the rise in recent years. In particular, GBM is one of the most aggressive malignant primary brain tumour whose treatment has the lowest success rate as compared to other malignancies. The past decade has experienced a number of research efforts towards our understanding of the complex biology associated with this tumour, however there are certain challenges that still need to be answered. One key challenge is to understand the process of communication between Glioblastoma stem cells and Glioma cells leading to GBM tumour growth. Our aim is to investigate the mechanism through which the information is transmitted from one tumour cell to another resulting in cell proliferation and tumour growth.

Invited Session (Communication and Coding on Nanonetworking and Biology): Modeling of Molecular Communication Systems by Transfer Functions

Maximilian Schaefer 10:10 AM-11:40 PM

University of Erlangen-Nuremberg, Germany

The accurate modeling of Molecular Communication (MC) systems is crucial for the analysis of naturally occurring and the design of synthetic ones. Ideally, a system model captures the complete dynamics of the transmitter, channel, and receiver, in an analytical form while fast numerical evaluation is preferable. As most practical MC systems try to mimic naturally occurring transport phenomena for information carrying particles, their transmission relies on a variety of different linear and non-linear mechanisms, i.e., different forms of reactions, advection and diffusion. The derivation of a system model mostly starts with an abstraction of those effects in terms of mathematical equations. The prevalent modeling techniques may be roughly divided into numerical and analytical methods. While numerical methods try to solve PDEs, e.g., by finite element methods, analytical modeling techniques try to find a closed form solution, e.g., in terms of Green’s functions. This talk provides an overview on several relevant phenomena occurring in practical MC systems and shows how they can be abstracted into a mathematical formulation. Moreover, the modeling of MC systems in terms of transfer functions is introduced by several recent practical examples such as the modeling of laminar flow channels, and the modeling of receptors in synaptic MC.

Keynote Lecture: CTRL: Closed-Loop Data Transcription via Rate Reduction

Yi Ma 1:30 PM-2:30 PM

University of California, Berkeley, USA

In this talk we introduce a principled computational framework for learning a compact structured representation for real-world datasets, that is both discriminative and generative. More specifically, we propose to learn a closed-loop transcription between the distribution of a high-dimensional multi-class dataset and an arrangement of multiple independent subspaces, known as a linear discriminative representation (LDR). We argue that the encoding and decoding mappings of the transcription naturally form a closed-loop sensing and control system. The optimality of the closed-loop transcription, in terms of parsimony and self-consistency, can be characterized in closed-form by an information-theoretic measure known as the rate reduction. The optimal encoder and decoder can be naturally sought through a two-player minimax game over this principled measure. To a large extent, this new framework unifies concepts and benefits of auto-encoding and GAN and generalizes them to the settings of learning a both discriminative and generative representation for multi-class visual data. This work opens many new mathematical problems regarding learning linearized representations for nonlinear submanifolds in high-dimensional spaces. More broadly and significantly, it may suggest potential computational mechanisms about how visual memory of multiple object classes could be formed jointly, incrementally, or unsupervisedly through a purely internal closed-loop feedback process.

Related papers can be found at: https://jmlr.org/papers/v23/21-0631.html and https://www.mdpi.com/1099-4300/24/4/456/html.

Invited Session (Data Science and Information Theory): Inference in High Dimensions for Generalized Linear Models: the Linear, the Spectral and the Approximate

Marco Mondelli 2:40 PM-4:50 PM

Institute of Science and Technology Austria, Austria

In a generalized linear model (GLM), the goal is to estimate a d-dimensional signal x from an n-dimensional observation of the form f(Ax, w), where A is a design matrix and w is a noise vector. Well-known examples of GLMs include phase retrieval, 1-bit compressed sensing, and logistic regression. We focus on the high-dimensional setting in which both the number of measurements n and the signal dimension d diverge, with their ratio tending to a fixed constant. Linear and spectral methods are two popular solutions to obtain an initial estimate, which can also be used as a 'warm start' for other algorithms. In particular, the linear estimator is a data-dependent linear combination of the columns of the design matrix, and its analysis is quite simple; the spectral estimator is the principal eigenvector of a data-dependent matrix, whose spectrum exhibits a phase transition. In this talk, I will first analyze the spectral method and prove that it leads to the information-theoretically optimal threshold for weak recovery in phase retrieval. Next, I will show how to optimally combine the linear and spectral estimators. Then, I will consider estimators based on approximate message passing (AMP) and prove how to initialize them with the spectral method. Finally, I will show how to go beyond the typical Gaussian design assumption and provide some results for the more general class of rotationally invariant models. Based on joint work with Kevin Kögler, Andrea Montanari, Christos Thrampoulidis and Ramji Venkataraman [https://arxiv.org/abs/1708.05932, https://arxiv.org/abs/2008.03326, https://arxiv.org/abs/2010.03460, https://arxiv.org/abs/2106.02356, https://arxiv.org/abs/2112.04330].

Invited Session (Data Science and Information Theory): Imbalance trouble in overparameterized learning

Christos Thrampoulidis 2:40 PM-4:50 PM

University of British Columbia, Canada

Overparameterized deep nets generalize well without significant effort on the algorithmic front: no explicit regularization or early-stopping is needed and off the shelf gradient-descent methods on standard losses suffice. On the other hand, we caution that the same models and methods might perform poorly in terms of fairness criteria in the presence of under-represented classes or groups with sensitive attributes. Then, based on formal optimization and statistical insights, we design alternative algorithms that provably improve fairness accuracy. We also show experiments on benchmark datasets that are consistent with the theoretically-driven algorithmic improvements.

Invited Session (Data Science and Information Theory): Understanding Generalization in Machine Learning Using Information-Theoretic Measures

Mahdi Haghifam 2:40 PM-4:50 PM

University of Toronto, Canada

Machine Learning (ML) technologies are being deployed rapidly across industry, the sciences, and government. Despite this expansion, the ML research community has a relatively limited understanding of the principles that explain when and why ML technologies work in real world applications. In this talk, I will discuss how we can use the language of Information Theory to provide generalization bounds (relating empirical performance to future expected performance) for ML algorithms.

First, I will talk about my work on information-theoretic approaches to understanding generalization of iterative learning algorithms, such as Stochastic Gradient Langevin Dynamics (a noisy version of SGD) and SGD itself. In this part, I will show that by using information-theoretic methods we can obtain distribution-dependent bounds that naturally adapt to the model of interest and the data distribution.

Then, I will talk about the expressiveness of the information-theoretic approaches and the prospect of using them to provide a unified framework for proving generalization bounds, and I will show that information-theoretic approaches for understanding generalization can tie together existing frameworks using the language of information theory.

Invited Session (Data Science and Information Theory): Achieving Noisy Linear Convergence in CV@R Statistical Learning: SGD, Strongly Convex Losses and Beyond

Dionysios S. Kalogerias 2:40 PM-4:50 PM (online)

Yale University, USA

Risk-awareness is becoming an increasingly important issue in modern statistical learning theory and practice, especially due to the need to meet strict reliability requirements in high-stakes, critical applications. Examples appear naturally in many areas, such as energy, finance, robotics, radar/lidar, networking and communications, autonomy, safety, and the Internet-of-Things. In such settings, risk-aware learning formulations are particularly appealing, since they can explicitly balance the performance of optimal predictors between average-case and "difficult" to learn, infrequent, or worst-case examples, inducing a form of statistical robustness in the learning outcome. In particular, among all measures of risk, Conditional Value-at-Risk (CV@R) is by far one of the most popular (if not the most), and has been recently considered as a performance criterion in supervised statistical learning, as it is also related to desirable operational features, such as safety, fairness, distributional robustness, and prediction error stability. However, due to its variational definition, CV@R is commonly believed to result in difficult optimization problems, even for smooth and strongly convex loss functions. In this talk, we present new results disproving this statement, establishing noisy (i.e., fixed accuracy) linear convergence of stochastic gradient descent for sequential CV@R learning, for a large class of not necessarily strongly-convex (or even convex) loss functions satisfying a set-restricted Polyak-Lojasiewicz inequality. This class contains all smooth and strongly convex losses as special cases, confirming that classical problems, such as linear least squares regression, can be solved efficiently under the CV@R criterion, just as their risk-neutral versions. We also illustrate our results numerically on indicative risk-aware learning tasks, also verifying their empirical validity.

Invited Session (Data Science and Information Theory): Random Graph Matching in Geometric Models: the Case of Complete Graphs

Jiaming Xu 2:40 PM-4:50 PM (online)

Duke University, USA

This talk focuses on the problem of matching two complete graphs with edge weights correlated through latent geometries, extending a recent line of research on random graph matching with independent edge weights to geometric models. We derive an approximate maximum likelihood estimator and characterize the sufficient conditions under which it achieves perfect recovery or almost perfect recovery. These conditions are further shown to be information-theoretically optimal even when the latent coordinates are directly observed. This work bridges several streams of literature including planted matching, feature matching, Procrustes matching, and graph matching. Based on joint work with Haoyu Wang, Yihong Wu, and Israel Yolou from Yale. Preprint available at https://arxiv.org/pdf/2202.10662.pdf.

Invited Session (Data Science and Information Theory): Collaborative and distributed learning for Healthcare: from Theory to Practice

Xiaoxiao Li 2:40 PM-4:50 PM (online)

University of British Columbia, Canada

With the development of artificial intelligence (AI) for healthcare, people started to pay more attention to the challenges and risks associated with AI models to be used in sensitive healthcare applications. Currently, there are still many practical barriers to the promotion of AI in healthcare applications, such as insufficient training samples, difficulties in data sharing and labeling, lack of transparency in AI models, etc. To overcome these barriers and accelerate the application of AI in healthcare, we must work on developing more accurate models while also improving AI's trustworthiness. Trusted AI has emerged as an important trend in AI research and industry. This presentation will discuss how to build a new generation of AI-powered healthcare systems and focus on the ongoing progress in both theories and practice towards advancing federated learning in healthcare data analysis.

Wednesday, 8 of June

Technical Session (Communication Systems): Probabilistic Shaping Using a Block-Based Bit-Level Distribution Matcher

***Maxim Goukhshtein*[1], *Stark Draper*[1], *Jeebak Mitra*[2]** 9:00 AM-10:20 AM

[1]University of Toronto, Canada; [2]Huawei Technologies, Canada

We present a distribution matching architecture aimed at low-complexity probabilistic shaping. The scheme operates by combining blocks of bits, generated in parallel by multiple binary distribution matchers, and mapping them to blocks of symbols from a non-binary alphabet. The proposed architecture constitutes a block-based generalization of the bit-level distribution matching (BL-DM) method. Namely, BL-DM corresponds to the particular case wherein single-bit blocks are used. While the computational complexity of the described scheme is effectively independent of the block size, larger block sizes can be used to realize a wider range of shaped output distributions, and in turn lead to an improved shaping performance. We demonstrate this benefit in our numerical simulations, which show that by using an increasingly larger block size, a lower per-shaped-symbol energy can be realized across all shaping rates and output blocklengths.

Paper URL: http://cwit.ca/2022/papers/1570794531.pdf

Technical Session (Communication Systems): A Novel Differential Decode and Forward Scheme for Channel-Unaware Two-Way Relay Networks

Salime Bameri*, *Ramy Gohary 9:00 AM-10:20 AM

Carleton University, Canada

We consider channel-unaware two-way relay networks in which two single-antenna nodes communicate through a single-antenna half-duplex decode-and-forward relay. To overcome the drawbacks of conventional signalling, we develop a novel differential signalling scheme. This scheme not only eliminates error propagation but also removes the unitarity restriction on the transmitted symbols in conventional differential signalling. Using non-unitary symbols in the differential signalling doubles the degrees of design freedom and yields better performance, which is confirmed by numerical results.

Paper URL: http://cwit.ca/2022/papers/1570796411.pdf

Technical Session (Communication Systems): Performance Evaluation of Media-based Modulation in Comparison with Spatial Modulations and Legacy SISO/MIMO

***Ehsan Seifi*[1], *Mehran Atamanesh*[2], *Amir K. Khandani*[2]** 9:00 AM-10:20 AM

[1]Ciena, Canada; [2]University of Waterloo, Canada

The idea of media-based modulation (MBM) is to embed information in the variations of the transmission media (channel states). This is in contrast to legacy wireless systems where data is embedded in a radio frequency (RF) source prior to the transmit antenna. MBM offers several advantages over legacy systems, including "additivity of information over multiple receive antennas", and "inherent diversity over a static fading channel". MBM is particularly suitable for transmitting high data rates using a single transmit and multiple receive antennas (single input multiple output MBM, or SIMO-MBM). Furthermore, to address complexity issues (hardware and decoding complexities, as well as the training overhead) that limit the amount of data that can be embedded in channel states using a single transmit unit, layered multiple input multiple output MBM (LMIMO-MBM) is introduced in a previous article. The current article compares the performance of MBM and LMIMO-MBM vs. legacy multiple input multiple output (MIMO), and emerging modulation techniques, spatial modulation (SM), and its variants, such as generalized SM (GSM) and quadrature SM (QSM). These comparisons demonstrate considerable performance gains for MBM and LMIMO-MBM vs. these notable schemes.

Paper URL: http://cwit.ca/2022/papers/1570796576.pdf

Technical Session (Communication Systems): Space-Time Interleaved OFDM Systems in Impulsive Noise and Mobile Fading Channels

Hen-Geul Yeh, Jun Zhou 9:00 AM-10:20 AM (online)

California State University, Long Beach, USA

A robust communication system in wireless propagation channels is desirable with an improved bit error rate (BER), specifically, in rapidly changing mobile channels with impulse noise (IN). In this paper, a 2x2 space-time conjugate cancellation (STCC) two-path transmission scheme combined with interleaved orthogonal frequency division multiplexing (IOFDM) system is proposed. Without coding, the interleave in IOFDM is for improving diversity. The STCC-IOFDM system features in the excellent inter-carrier interference (ICI) mitigation due to STCC in frequency selective mobile fading channels while the interleaving process introduces both time and frequency diversity to effectively combat IN. Simulations demonstrate that the proposed STCC-IOFDM systems are robust to various frequency selective environments, including when the IN exists in bad urban mobile channels.

Paper URL: http://cwit.ca/2022/papers/1570797509.pdf

Technical Session (Wireless Communications): Favorable Propagation for Wideband Massive MIMO with Non-Uniform Linear Arrays

Elhamsadat Anarakifirooz, Sergey Loyka 10:30 AM-11:50 AM

University of Ottawa, Canada

Favorable propagation (FP) for massive MIMO with uniform and non-uniform linear arrays is studied. A gap in the existing FP studies of uniform linear arrays is identified, which is related to the existence of grating lobes in the array pattern and which results in the FP condition being violated, even under distinct angles of arrival. A novel analysis and design of non-uniform linear arrays are proposed to cancel grating lobes and to restore favorable propagation for all distinct angles of arrival. This design is based on a subarray structure and fits well with efficient hybrid beamforming structures proposed for 5/6G systems. In addition, we show that the proposed design is robust in the frequency domain and can be used for wideband or ultra-wideband systems.

Paper URL: http://cwit.ca/2022/papers/1570796533.pdf

Technical Session (Wireless Communications): A Hybrid Random-Greedy Approach to User Selection for MU-MIMO Based on Pairwise Metrics

Omid Saatlou, Steven D Blostein 10:30 AM-11:50 AM

Queen's University, Canada

This paper proposes a hybrid user group selection method in multi-user multi-input multi-output (MU-MIMO) systems for downlink transmission. The proposed scheme provides additional trade offs between performance and complexity. In this method, initial groups of users are first randomly selected from a pool until a performance threshold of a simplified metric is satisfied. The proposed metric computes the minimum geometric angle among users' subspaces. Then, the user group is enlarged by maximizing sum rate among the users in a greedy fashion based on a subspace angle proposed performance metric. Monte Carlo simulation results comparing the performance of the proposed method with existing techniques as a function of initially chosen group sizes and selection pool sizes reveal potential for lowered complexity and/or improved performance.

Paper URL: http://cwit.ca/2022/papers/1570796574.pdf

Technical Session (Wireless Communications): Sum Rate Maximization of Full-Duplex MIMO Monostatic Backscatter Networks Under Residual Self-Interference

***Azar Hakimi*[1], *Shayan Zargari*[1], *Chintha Tellambura*[1], *Sanjeewa P. Herath*[2]** 10:30 AM-11:50 AM

[1]University of Alberta, Canada; [2]Huawei Technologies, Canada

Backscatter communication (BCS) devices have low cost, low power, and the ability to harvest energy, enabling ultragreen Internet of things (IoT) networks with energy autonomy. However, they achieve only low data rates and a limited communication range. A monostatic backscatter (MBS) network of multiple tags with a full-duplex (FD) multiple-input multipleoutput (MIMO) reader is subject to self-interference (SI), which exacerbates the aforementioned problems. Since SI cannot be removed ideally, the residual SI (RSI) degrades the system performance. Thus, the main goal of this study is to correct this problem. To this end, we formulate the maximization of the sum rate by optimizing the precoder and combiner filters of the reader and the reflection coefficients of the tags. The constraints are to limit the effects of the RSI and allow the energy harvested by the tags to exceed a minimum. Because the problem is nonconvex, we utilize alternating optimization (AO) to split it into three subproblems and develop iterative algorithms. The simulation results validate and quantify the achievable sum rate.

Paper URL: http://cwit.ca/2022/papers/1570797866.pdf

Technical Session (Wireless Communications): Intra C-RAN Two-Way Multi-Pair Computation under Total Power and Fronthaul Capacity Constraints

Mahmoud Hasabelnaby, Anas Chaaban 10:30 AM-11:50 AM

University of British Columbia, Canada

Most existing works on cloud radio-access networks (C-RANs) investigate the uplink or the downlink transmissions separately. However, joint uplink and downlink design can bring additional advantages, especially in intra-cloud C-RAN communications scenarios. In this paper, a two-way multi-pair computation strategy is proposed, where message source-destination information is taken into account in our design. The achievable end-to-end rate of this scheme is derived, optimized, and evaluated numerically under total power and fronthaul capacity constraints. Numerical results reveal that significant improvement in the achievable end-to-end sum-rate can be obtained using the proposed scheme compared to conventional ones.

Paper URL: http://cwit.ca/2022/papers/1570797661.pdf