Workshop on Sequential and Adaptive Information Theory

Sponsored by REPARTI

November 7-9, 2013

New Residence Hall
3625 Avenue du Parc
Montreal, QC.

Program

Thursday, November 7th, 2013	
10:00 am – 11:00am	Warren Gross, McGill University
11:00 am – 11:45am	Yücel Altuğ, Cornell University
Lunch	
1:15pm – 2:15pm	Stark Draper, University of Toronto
2:15pm – 3:00pm	Besma Smida, Purdue University
Break	
3:30pm – 4:30pm	Ashish Khisti, University of Toronto
4:30pm – 5:30pm	Jan Bajsy, McGill University
5:30pm – 6:30pm	Anant Sahai, University of California, Berkeley

Friday, November 8th, 2013	
9:00am–10:00am	Sekhar Tatikonda, Yale University
10:00am–11:00am	Tsachy Weissman, Stanford
11:00am–12:00pm	Charalambous D. Charalambous, University of Cyprus
Lunch	
1:30pm – 2:30pm	Young Han Kim, UCSD
2:30pm – 3:15pm	Natasha Devroye, University of Illinois, Chicago
Break	
3:45pm–4:45pm	Daniela Tuninetti, University of Illinois, Chicago
4:45pm–5:30pm	Patrick Mitran, University of Waterloo
5:30pm–6:15pm	Nevroz Şen, McGill University

Saturday, November 10th, 2013	
9:00am–10:00am	Maxim Raginsky, UIUC
10:00am–11:00am	Tamás Linder, Queen's University
11:00am–11:45am	Tara Javidi, UCSD

Thursday, November 7th, 2013

Warren Gross, *McGill University*: ***Implementation of Polar Decoders***

Polar codes are a new class of error-correcting codes that provably achieve the capacity of memoryless channels with low complexity encoding and decoding algorithms. However, there remain several important practical issues to be solved before they can see widespread use. In this talk I will review the main issues in designing decoders for polar codes and present recent results that show promise for low-complexity and high-throughput implementations.

Yücel Altuğ, *Cornell University*: ***Exact Asymptotics in Channel Coding***

The recent work on the sub-exponential term of the exponentially decaying bounds on the error probability will be overviewed. Specifically, we summarize our refinement of the sphere-packing and random-coding bounds. The order of the sub-exponential factors of these refinements almost coincide in general, and are equal for symmetric channels. For these channels, the latter finding unveils a dichotomy of the optimal order of the sub-exponential term. Notably, the defining property of this dichotomy also defines a phase transition of the third-order term of the normal approximation for symmetric channels. This is joint work with Aaron Wagner

Stark Draper, *University of Toronto*: ***The Streaming-DMT of Fading Channels***

We study sequential transmission of a stream of messages over a block-fading multi-input-multi-output (MIMO) channel. A new message arrives in each coherence block and the decoder is required to output each message after a delay of T coherence blocks. We establish the optimal diversity-multiplexing tradeoff (DMT) and show that it can be achieved using a simple interleaving of messages. The converse is based on an outage amplification technique which appears to be new. We also discuss another coding scheme based on a sequential tree-code. This coding scheme only requires the knowledge of delay at the decoder and yet realizes the optimal DMT. We finally discuss some extensions when multiple messages at uniform intervals arrive within each coherence period. This is joint work with Ashish Khisti

Besma Smida, *Purdue University*: ***Network coded HARQ***

In this work, we analyze the combination of network coding (NC) and Hybrid- Automatic Retransmission request (HARQ) feedback in the context of networks, without Channel State Information at the Transmitter (CSIT), where re-transmissions are prevalent. In particular, we consider the broadcast channel where a base node wishes to transmit different messages to multi-terminal nodes. The proposed scheme judiciously combines retransmissions to several users in a single resource block using NC. If the combinations are correctly chosen, the end users may exploit knowledge of the previously decoded packets to recover their designated packets from the combined ones. We derived throughput expressions with an arbitrary number of users and symmetric Rayleigh channels. We obtain an expression that captures the gain of combining NC and HARQ for different SNR regimes and receiver feedback protocols. We also introduce novel re-transmission strategies that make network coding more efficient at low SNR.

Ashish Khisti, *University of Toronto*: ***Layered Error-Correction Codes for Real-Time Streaming over Erasure Channels***

Error correction codes for real-time streaming are fundamentally different from classical block codes. The transmitter must encode the source stream sequentially, and the receiver must also decode the source symbols in a sequential fashion. In this talk we present both, the fundamental limits, and explicit constructions of such streaming codes over erasure channels. In establishing these limits, we introduce a class of channels where the erasure patterns are locally constrained in each sliding window. Such channels are found to be both analytically tractable, and provide useful approximations to the Gilbert-Elliott and related channels. As our main result, we show that any feasible streaming code must have a certain minimum column-distance, and column-span, and propose a new class of codes — MiDAS Codes — that attain a near optimal tradeoff between these metrics. The proposed codes are based on a certain layering principle, which is also found to be useful in a number of generalizations. Simulation results over the Gilbert-Elliott and related channels suggest that the proposed codes can significantly outperform other baseline codes, such as the Random Linear Codes, over a wide range of channel parameters.

Anant Sahai, *University of California, Berkeley*: ***TBA***

Jan Bajsy, *McGill University*: ***Faster-than-Nyquist Transmission over Continuous-Time Channels: Single and Multi-user Scenarios***

Faster-than-Nyquist (FTN) transmission has been explored initially at the Bell Labs as a means to increase data rates for communication over band-limited channels. However, severeintersymbol interference, caused by exceeding channel Nyquist rate signaling, has prevented any practical implementations or benefits from this technology. In this talk, we will present our recent results on channel capacity and coding for Faster-than-Nyquist communication. Specific uplink (multi-access), downlink (broadcast) and-point-to-point FTN channels will be discussed, making an argument that Faster-than-Nyquist technology may the "next big thing" in wireless communications.

Friday, November 8th, 2013

Sekhar Tatikonda, *Yale University*: ***The Directed Information Approach to Feedback Capacity***

It is well known that directed information can be used to prove coding theorems for a variety of channels with feedback. The capacity is typically characterized by an optimization of the directed information over a suitably chosen class of input distributions that respect causality. Much less is known about computing this directed information optimization. In this talk I will give an overview of the directed information approach and along the way I will spotlight open technical challenges.

Tsachy Weissman, *Stanford University*: ***Directed Information Optimization and Capacity of the POST Channel with and without Feedback***

We review the significance of directed information in communication and statistical inference. We also review some of its properties, which allow to approximate the capacity of any finite state channel with feedback to arbitrary precision. We then focus on the family of finite state channels where the state of the channel is its previous output. We refer to these as POST (Previous Output is the STate) channels. While the feedback capacity of these channels is easy to characterize, capacity in the absence of feedback is elusive. We identify a family of POST channels for which the two capacities coincide (surprisingly, in our humble opinion), and conjecture regarding conditions for the two capacities to coincide more generally. Based primarily on joint work with Haim Permuter and Himanshu Asnani.

Charalambos D. Charalambous, *University of Cyprus*: ***Source-Channel Matching for Sources with Memory***

In this talk we analyze probabilistic matching of sources to channels that symbol-by-symbol code transmissions with memory without anticipation are optimal, with respect to an average distortion and excess distortion probability. The presentation will recall some functional and topological properties of directed information using weak convergence of probability spaces on Polish spaces. Then it address existence, solutions, and properties of nonanticipative information Rate Distortion Function for sources with memory, and capacity achieving distribution of channels with memory and feedback.Finally, it will utilize the previous findings to address the joint source-channel matching for sources with memory, and discuss matching of the Binary Symmetric Markov source over a first-order symmetric channel with a power constraint, and the vector Gaussian source over additive Gaussian channels.

Young-Han Kim, *UCSD*: ***Relaying beyond *-forward***

Cooperative relaying is an important component in future wireless networks. Since Cover and El Gamal's 1979 paper on relay channels, several information theoretic coding techniques have been proposed, among which the three most basic are decode-forward (digital-to-digital interface), compress-forward (analog-to-digital interface), and amplify-forward (analog-to-analog interface). In this talk, we review these techniques and discuss how these schemes can be unified and improved. In particular, we demonstrate that interactive relaying can outperform these one-way noninteractive relaying techniques for general networks.

Natasha Devroye, *University of Illinois, Chicago*: ***A few examples (and open problems) of when adaptation is useless in two-way networks***

Finding the capacity region of two-way networks is in general very challenging. We first show a few examples of when adaptation is useless in networks, and pose two open problems: 1) what are general conditions for adaptation being useless in networks, and 2) does perfect feedback being useless in a one-way sub-network imply adaptation is useless in its two-way counterpart?

Daniela Tuninetti, *University of Illinois, Chicago*: ***Cooperative Interference Channels in the Mixed and Weak Interference Regimes***

The capacity of the classical non-coopertaive interference channel with two source-destination pairs is open in general. In Gaussian noise, the capacity is known exactly in the strong interference regime, and to within 1 bit in the mixed and weak interference regimes [ETW]. The key result of [ETW] is the derivation of novel outer bounds that quantify the amount of ???resource holes??? [ST], due to the decentralized processing in interference channels, when one of the users is transmitting at maximum rate. These novel rate bounds are of the form 2R1+R2 / R1+2R2. In [ST] it was shown that when output feedback from a destination to its source is present, there are no more ???resource holes??? in the system. In this talk we survey work done in the context of interference channels with cooperation and/or feedback, with particular emphasis on the amount of cooperation / feedback needed in the mixed and weak interference regimes to eliminate the ???resource holes??? problem. We also point out open problems, i.e., parameter regimes where an approximate characterization of the capacity in Gaussian noise is not available, and discuss what could be missing.

[ETW] R. Etkin, D. Tse, and H. Wang, "Gaussian interference channel capacity to within one bit," IEEE Trans. Info. Theory, vol. 54, no. 12, pp. 5534–562, Dec. 2008.

[ST] C.Suh and D.Tse,"Feedback capacity of the Gaussian interference channel to within 2 bits," IEEE Trans. Info.Theory, vol. 57, no. 5, pp. 2667–2685, 2011.

Patrick Mitran, *University of Waterloo*: ***Some Results and Issues in Online Energy Harvesting***

We consider the problem adaptive transmission power control for a continuous-time energy harvesting system where energy arrivals occur at random times in random amounts. We do not assume that the energy arrivals are known non-causally and consider the online setting. Here, there is a tradeoff between the dynamics of increasing instantaneous transmission power, which increases instantaneous transmission rate and can reduce battery overflow, and decreasing transmission power, which increases battery life and energy efficiency.

We present a series of structural results based on a formulation that maximizes the average transmission rate or throughput. Specifically, we show that it is sufficient to consider memoryless policies (which reduces the problem to the study of a compound Poisson dam, where the release rate is to be optimized), that the resulting optimization problem is concave, and derive Euler-Lagrange equations using a calculus of variation approach. We also discuss extensions to channels with state and the multiple access channel. Finally, we discuss open problems in online energy harvesting.

Nevroz Şen, *McGill University*: ***Multiple access channel with asymmetric noisy state information at the encoders***

We consider memoryless state-dependent multiple access channel where the encoders and the decoder are provided with various degrees of asymmetric noisy channel state information (CSI) and present capacity results for different scenarios depending on the availability of side information at the decision makers. Focusing on the causal setup, we next discuss the most general condition under which Shannon strategies are optimal in terms of sum-rate capacity when the CSIT at the encoders are correlated. This consists of the characterization of the information at the receiver and we then investigate the minimum rate required to transmit such information to the receiver when there is no CSI at the receiver. This is joint work with Fady Alajaji, Serdar Yüksel and Giacomo Como.

Saturday, November 9th, 2013

Maxim Raginsky, *UIUC*: ***Rational inattention, stochastic control and rate-distortion theory***

The framework of rational inattention, proposed by the economist Christopher Sims, studies decision-making by agents who minimize expected cost given available information (hence ???rational???), but are capable of handling only a limited amount of information (hence ???inattention???). Quantitatively, this information-processing constraint is stated in terms of an upper bound on the Shannon mutual information between the state of the system and the observation available to the agent. However, most of existing work on rational inattention has been relying on heuristic arguments and various simplifying assumptions on the structure of observation channels.

In this talk, based on joint work with Ehsan Shafieepoorfard and Sean Meyn, I will present a general theory of dynamic decision-making subject to information constraints in the context of average-cost optimal control of Markov processes. The underlying optimization problem can be reduced to an infinite-dimensional convex program fundamentally related to rate-distortion theory. In particular, it will be shown that the optimal information-constrained controller is the solution of a certain Shannon rate-distortion problem where the distortion function is given by the Bellman error, a quantity that naturally arises in approximate dynamic programming. The usual solution of the average-cost control problem, given by the Average-Cost Optimality Equation, is recovered in the information-unconstrained limit. The general theory will be illustrated through the example of scalar linear-quadratic-Gaussian (LQG) control in the rational inattention regime.

Tamás Linder, *Queen's University*: ***Optimal Zero-Delay Coding of Vector Markov Sources***

The traditional information theory of data compression allows asymptotically large decoding delays, but in many applications real-time operation is essential and even moderate delays may not be tolerated. In this talk we will focus on real-time (zero-delay) coding of continuous-alphabet Markov sources. We will first review some fundamental classic results on the structure of optimal schemes for real-time coding of Markov sources. We will then use a stochastic control formulation to study real-time coding of a vector-valued Markov source driven by an additive noise process, which also includes as a special case linear systems under a quadratic distortion measure. We will assume that the quantizers allowed are ones with convex codecells, and under this assumption construct a controlled Markov process that facilitates the treatment of this problem. For the finite-horizon problem we will show the existence of an optimal zero-delay coding scheme. For the infinite-horizon (average cost and discounted) problem we will establish the existence of optimal (deterministic or randomized) stationary Markov quantization policies. The new results in this talk are based on joint work with Serdar Yüksel.

Tara Javidi, *UCSD*: ***The Expected Drift of the Average-log-likelihood***

The main focus of the talk is to reexamine the problem of real-time coding over a discrete memoryless channel, in light of its connection to a generalization of Blackwell's sequential design of experiment (SDE). Relying on DeGroot's interpretation of information utility as the guiding design principle in an SDE, we relate the achievable rate (and reliability) of a feedback code to that of the expected drift in the average log-likelihood. We discuss success stories as well as open problems and unresolved challenges.