The Elisha Yegal Bar-Ness

Center for Wireless Information Processing

(CWiP)

Activity Report

February 2022

About the Center

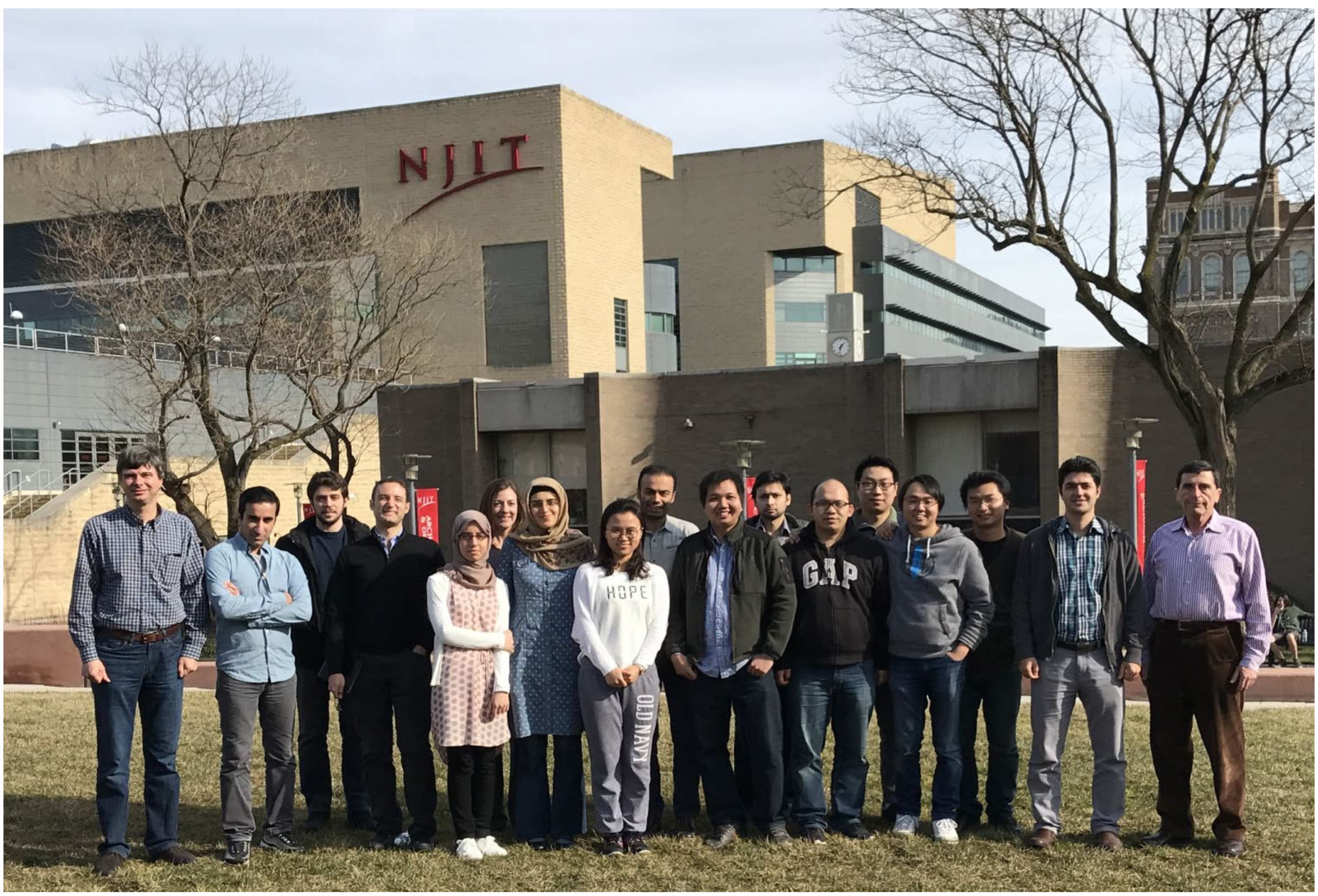
The Elisha Yegal Bar-Ness Center for Wireless Information Processing (CWiP) engages in a broad range of research areas ranging from wireless communications, radar, sensor networks, cloud radio, information theory and signal processing. A unifying theme of the Center's research is that of 5G wireless mobile networks.

There are five faculty members associated with the Center and over 20 graduate students, most of them pursuing their Doctor of Philosophy degree.

The Center routinely hosts visiting researchers, post-docs and students from overseas. Several students pursue double Ph.D. programs according to agreements between NJIT and other universities.

The Center seeks new collaborations with the wireless communications industry.

For more information, please contact Alexander Haimovich, Center Director, 973-596-3534 or alexander.m.haimovich@njit.edu.



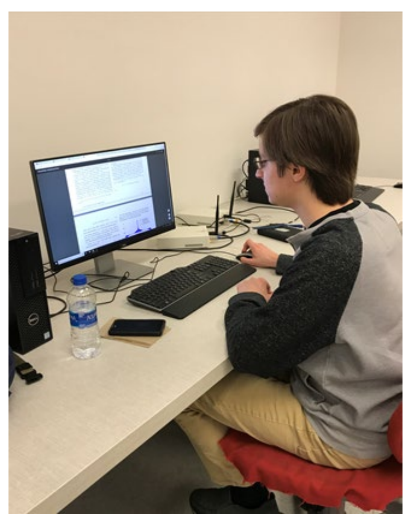
Vision of the Center

Primary Goal:

Serve as a focal point in the Department of Electrical and Computer Engineering for research on wireless, communications and signal processing.

Activities carried out by participants:

- Initiate and pursue research in the fields of wireless, communications and signal processing.
- Search, collectively as well as individually, for possible sources of financial research support for themselves and their affiliates (graduate students or visiting faculty).
- Establish contacts in the electronics industry in the Newark-metropolitan area and New Jersey as a whole, learn about their needs and suggest methods of collaboration.
- Assume responsibility for teaching graduate courses in the fields of communications and signal processing, propose and plan new courses, and monitor graduate courses taught by adjunct faculty.
- Undertake initiatives to recruit highly qualified graduate students, research associates and visiting
- faculty members and support the efforts of the department chairman to recruit new faculty.
- Suggest, design, prepare and deliver short courses as part of the New Jersey Institute of
- Technology's continuing education program.
- Organize seminars on topics of interest to Center members, the Department of Electrical and
- Computer Engineering and local industry.



Faculty

	**Alexander Haimovich, Center Director, Ying Wu Endowed Chair and Distinguished Professor** **Research Interests:** multi-sensor radar systems, localization, MIMO communications, blind signal processing.
	**Ali Abdi, Professor** **Research Interests:** Digital communication and propagation modeling in wireless channels (underwater, terrestrial, satellite), channel and parameter estimation techniques, space-time processing and interference cancellation, blind modulation recognition, systems biology and molecular networks.
	**Alex Dytso, Assistant Professor** Research Interests: Information theory, Wireless communications, Signal processing, Estimation theory, Nonparametric statistics, Statistical machine learning
	**Hongya Ge, Associate Professor** **Research Interests:** Statistical and Array Signal Processing. Wireless Communications. Space-Time Multiuser Detection. MIMO for Broadband Wireless Access.
	**Joerg Kliewer, Professor** **Research Interests**: LDPC codes, physical layer security, network coding, network error correction, network information theory, information theory and neuroscience

Center Staff

Kathy Bosco	Administrative Assistant
Changshi (James) Zhou	Staff Engineer
Erjian (Eric) Zhang	Research Associate

Visiting Post Doc

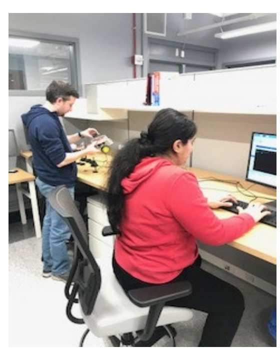
Allison Beemer	Post Doctoral Research Associate

Center Ph.D. Students

Rami Albughdar	Professor Abdi
Ali Emadi	Professor Abdi
Ian Zieder	Professor Dytso
Enlong Hu	Professor Ge
Anushreya (Anne) Ghosh	Professor Haimovich
Wei Jiang	Professor Haimovich
Kyle Wensell	Professor Haimovich
Zareen Khan	Professor Haimovich
Salman Habib	Professor Kliewer
Yusuf Ozkan	Professor Kliewer
Sarah Obead	Professor Kliewer
Sara Ghasvarianjahrom	Professor Kliewer

Masters & Undergrad Students

Yuan Zhao	Professor Abdi



Vector Acoustic Communication for High Speed Underwater Modems

Faculty: Ali Abdi
Graduate Student: Rami Rashid
Sponsor: National Science Foundation (NSF)

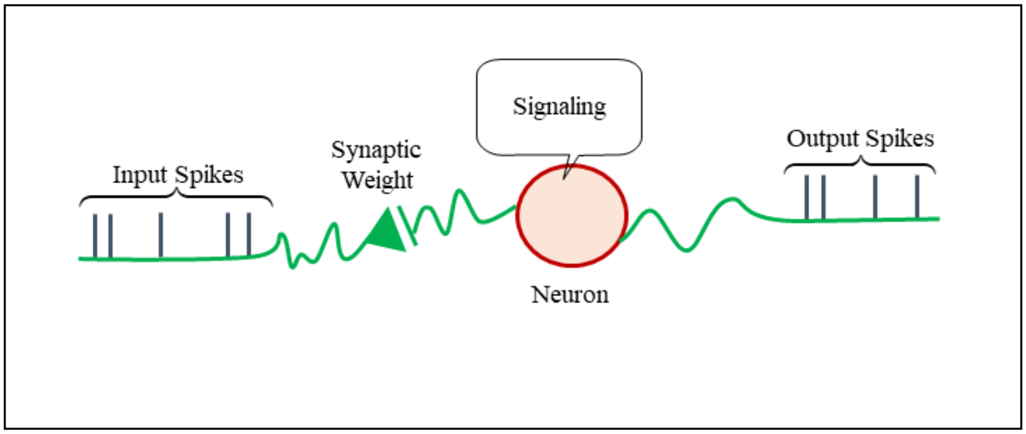
advanced Communication and Signal Processing (aCASP) Lab setup at NJIT for underwater communication research and development

Over 75% of the earth's surface is covered with water that overlays many resources upon which our lives depend. High speed wireless underwater data communication between underwater sensors, deepwater moored instruments, autonomous underwater vehicles, and surface vessels is of crucial importance in many applications of national interest. However, the achievable data rates by the conventional technologies are much smaller than what is needed for effective communication and management. To have high speed communication links in underwater environments, the transformative concept of communication via the vector components of the acoustic field was proposed and developed by A. Abdi in a prior NSF supported project.

In this project, a prototype modem is going to be developed, based on the vector field concept. The key difference between the new modem and other existing modems is that it uses vector transducers, which are compact multichannel devices, to transmit several data streams via multiple particle velocity vector channels. This is while other modems use scalar transducers, which can modulate the data only on the scalar acoustic pressure.

Systems Biology of Neuronal Signaling and Memory

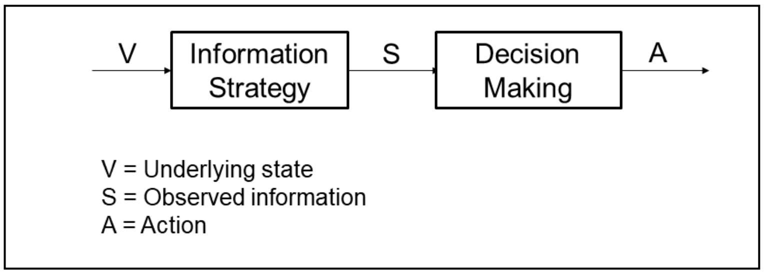
Faculty: Ali Abdi
Graduate Student: Ali Emadi
Sponsor: National Science Foundation (NSF)



Systems biology analysis of intracellular signaling networks has tremendously expanded our understanding of normal and diseased cell behaviors, and has revealed paths to finding proper therapeutic molecular targets. When it comes to neurons in human brain, analysis of intraneuronal signaling networks provides invaluable information on learning, memory and cognition related disorders, as well as potential therapeutic targets. However, neurons in human brain form a highly complex neural network that among its many roles, is also responsible for learning, memory formation and cognition. Given the impairment of these processes in mental and psychiatric disorders, one can envision that analyzing interneuronal processes, together with analyzing intraneuronal signaling networks, can result in a better understanding of the pathology, and subsequently, more effective target discovery. This hybrid analysis is the focus of this research.

Decision Making with Rational Inattention and Its Applications

Faculty: Ali Abdi
Graduate Student: Yuan Zhao
Sponsor: National Science Foundation (NSF)

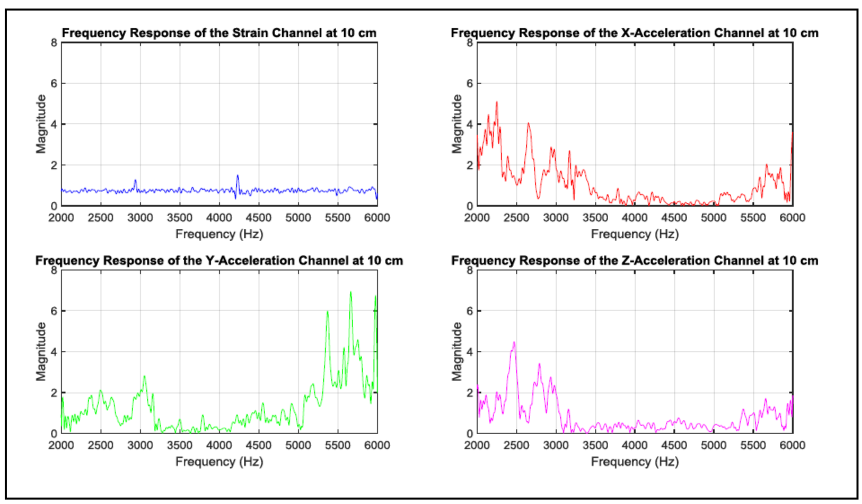


Economists, financial analysts, psychologists, etc., are interested in understanding how decision makers utilize scarce resources to make choices. In the rational inattention (RI) model, a decision maker tries to use limited amount of attention to optimize the utility net of information cost. In other words, a rationally inattentive decision maker uses the information that he/she finds to be useful, and discards the information considered not to be helpful. To quantify RI, Sims modeled the process of acquiring information as a channel, where input is the underlying state and output is the observed information. He used mutual information to measure the amount of attention. In this research, we investigate new optimal strategies for acquiring information to make more accurate decisions.

Communication via Pipelines

Faculty: Ali Abdi
Research Associate: Erjian Zhang
Sponsor: National Science Foundation (NSF)

Wireless data communication and telemetry via pipelines have different applications. However, given the limited available bandwidth, transmission rates are typically smaller than what is needed. In this research, a new method is proposed to increase the transmission rate over the same bandwidth, by deploying more than one actuator. Upon using multiple actuators and using various strain and acceleration channels, several data streams can be transmitted simultaneously. This increases the data rate without the need for additional bandwidth.

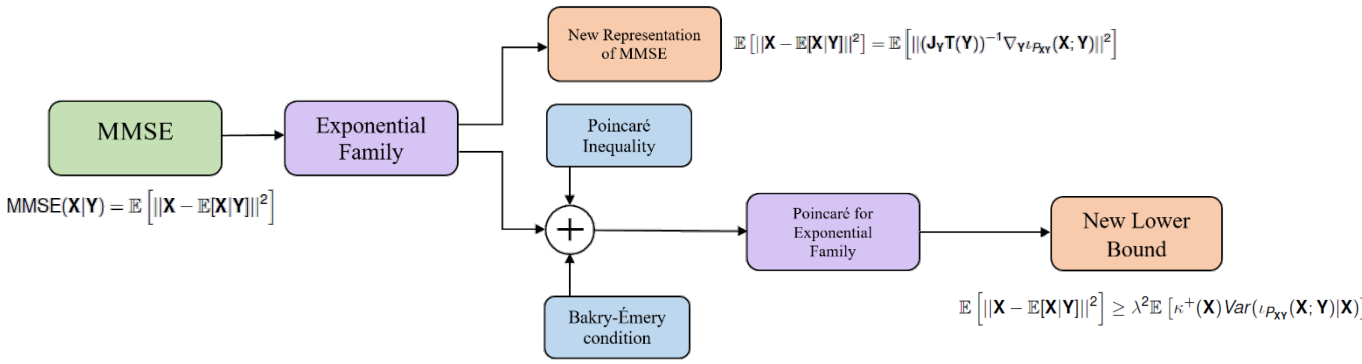


Bayesian Lower Bound on the Estimation Error via Poincarè Inequality

Faculty: Dr. Alex Dytso

Graduate Student: Ian Zieder

Collaborator: Dr. Martina Cardone (University of Minnesota, Minneapolis, MN)



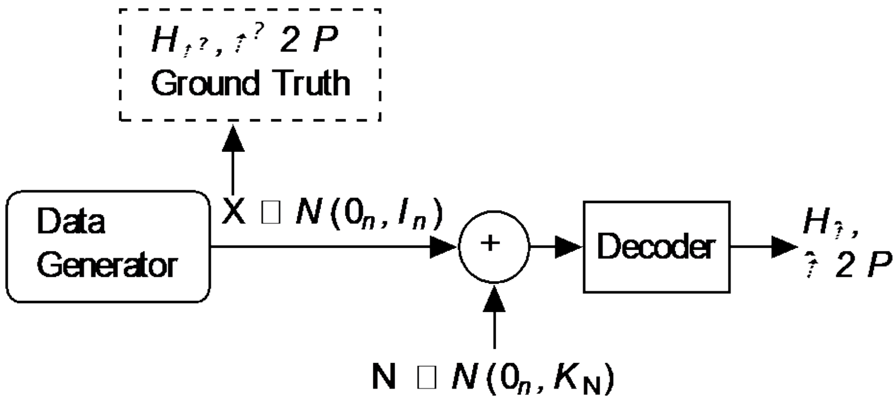
The minimum mean squared error (MMSE) is an essential and ubiquitous fidelity criterion in statistical signal processing. However, the MMSE is often difficult to compute in closed form, and we often need to rely on bounds. In terms of bounds, the attention typically falls on lower bounds as deriving a tight lower bound can often be a difficult task. In this work, we derive a novel lower bound on the MMSE. Towards this end, we present and study an alternative representation of the MMSE, mmse(X|Y). This new representation provides a new line of attack for direct computation of the MMSE and, together with the Poincarè inequality, allows us to derive a new lower bound on the MMSE.

Permutation Recovery from Noisy Observations

Faculty: Dr. Alex Dytso

Graduate Student: Minoh Jeong

Collaborators: Dr. Martina Cardone (University of Minnesota, Minneapolis, MN), Dr. H. Vincent Poor (Princeton University, Princeton, NJ)



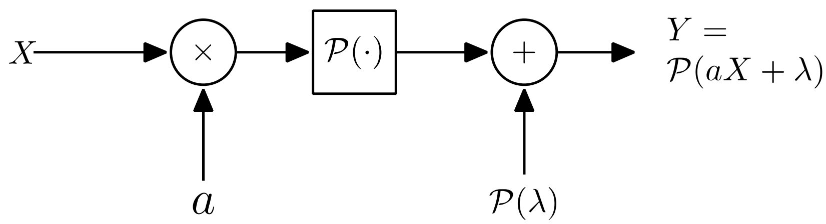
A noisy data structure recovery problem is considered. The goal is to investigate the following question: Given a noisy data observation, according to which permutation was the original data sorted? The focus is on scenarios where data is generated according to an isotropic Gaussian distribution, and the perturbation consists of adding Gaussian noise with an arbitrary covariance matrix. This problem is posed within a hypothesis testing framework. The objective is to study the *linear* regime in which the optimal decoder has a polynomial complexity in the data size, and it declares the permutation by simply computing a linear function of the noisy observation.

The main result of the work is a complete characterization of the linear regime in terms of the noise covariance matrix. Specifically, it is shown that this matrix must have a very flat spectrum with at most three distinct eigenvalues to induce the linear regime. Several practically relevant implications of this result are discussed, and the error probability incurred by the decision criterion in the linear regime is also characterized. A core technical component consists of using linear algebraic and geometric tools, such as Steiner symmetrization.

Communications Over Poisson Noise Channel

Faculty: Dr. Alex Dytso

Collaborators: Dr. Luca Barletta (Politecnico di Milano, Milano Italy), Dr. Shlomo Shamai (Technion – Israel Institute of Technology, Haifa, Israel)



(a) The Poisson noise channel with the input X, the scaling factor a and the dark current parameter λ.

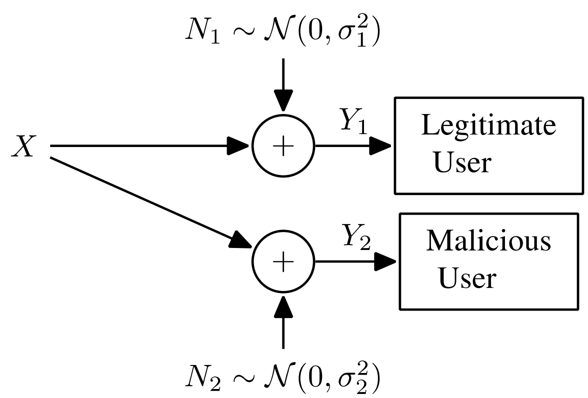
This work considers a Poisson noise channel with an amplitude constraint. It is well-known that the capacity-achieving input distribution for this channel is discrete with finitely many points. We sharpen this result by introducing upper and lower bounds on the number of mass points. Concretely, an upper bound of order $A log(A)$ and a lower bound of order square-root of A are established where A is the constraint on the input amplitude. In addition, along the way, we show several other properties of the capacity and capacity-achieving distribution. For example, a compact expression for the capacity is demonstrated. Moreover, an upper bound on the values of the probability masses of the capacity-achieving distribution and a lower bound on the probability of the largest mass point are established. Furthermore, on the per-symbol basis, a nonvanishing lower bound on the probability of error for detecting the capacity-achieving distribution is established under the maximum a posteriori rule.

Physical Layer Security: Vector Gaussian Wiretap Channel

Faculty: Dr. Alex Dytso

Student: Antonino Favano (Politecnico di Milano, Milan, Italy)

Collaborators: Dr. Luca Barletta (Politecnico di Milano, Milan, Italy)

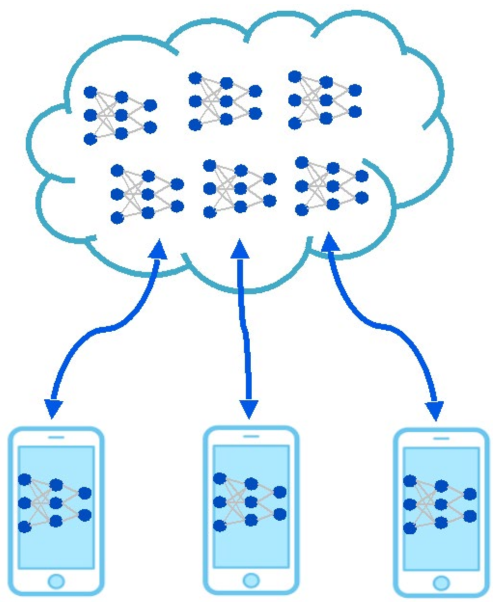


This project studies secrecy-capacity of an *n*-dimensional Gaussian wiretap channel under the peak-power constraint. This work determines the largest peak-power constraint R such that an input distribution uniformly distributed on a single sphere is optimal; this regime is termed the small- amplitude regime. The asymptotic of R as the dimension *n* goes to infinity is completely characterized as a function of noise variance at both receivers. Moreover, the secrecy-capacity is also characterized in a form amenable for computation. Furthermore, several numerical examples are provided, such as the example of the secrecy- capacity achieving distribution outside of the small amplitude regime.

Information Theoretic Generalization Bounds for Distributed and Federated Learning

Faculty: Dr. Alex Dytso

Collaborators: Dr. Leighton P. Barnes (Princeton University, NJ), Dr. H. Vincent Poor (Princeton University, NJ)



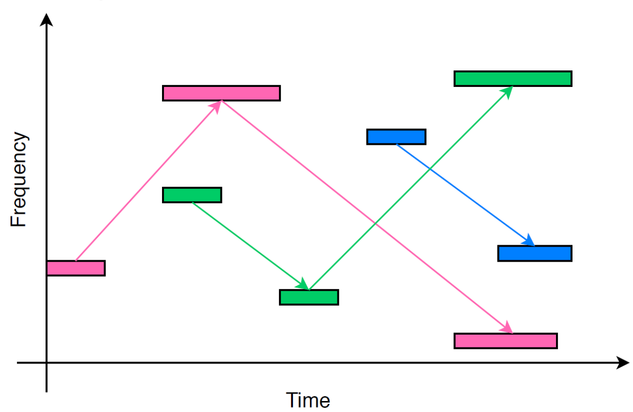
We consider information-theoretic bounds on expected generalization error for statistical learning problems in a networked setting. In this setting, there are *K* nodes, each with its own independent dataset, and the models from each node have to be aggregated into a final centralized model. We consider both simple averaging of the models as well as more complicated multi-round algorithms. We give upper bounds on the expected generalization error for a variety of problems, such as those with Bregman divergence or Lipschitz continuous losses, that demonstrate an improved dependence of *1/K* on the number of nodes. These "per node" bounds are in terms of the mutual information between the training dataset and the trained weights at each node, and are therefore useful in describing the generalization properties inherent to having communication or privacy constraints at each node.

Blind Multi-User Detection of Frequency Hopping Spread Spectrum Signals

Faculty: Alexander Haimovich
Graduate Student: Anushreya (Anne) Ghosh
Collaborator: Jason Dabin (US Navy)
Sponsor: US Department of Defense (Navy – Naval Information Warfare Center)

The separation and estimation of unknown signals received though unknown channels is referred to as blind source separation (BSS). BSS of radio frequency (RF) signals is an important Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) capability. In a typical scenario, the RF signals are measured by distributed sensors and the information is provided to a fusion center for processing. Classical methods for BSS, such as Independent Component Analysis (ICA) make certain assumptions, which are limiting and not suitable for some C4ISR applications, in which sources may operate intermittently and the number of sensors may be different and even smaller than the number of latent sources. To capture these properties, source activity is modeled with the aid of a hidden Markov model (HMM).

Frequency hopping spread spectrum (FHSS) communication signals are a form of covert communications with low-probability of intercept (LPI) properties in order to prevent reception by an unintended receiver. In FHSS, multiple users share a block of spectrum and transmit on carrier frequencies that change pseudo-randomly requiring a receiver to know the frequency hopping pattern a priori, as shown in the figure below. However, in BSS problems, such information cannot be known a priori.

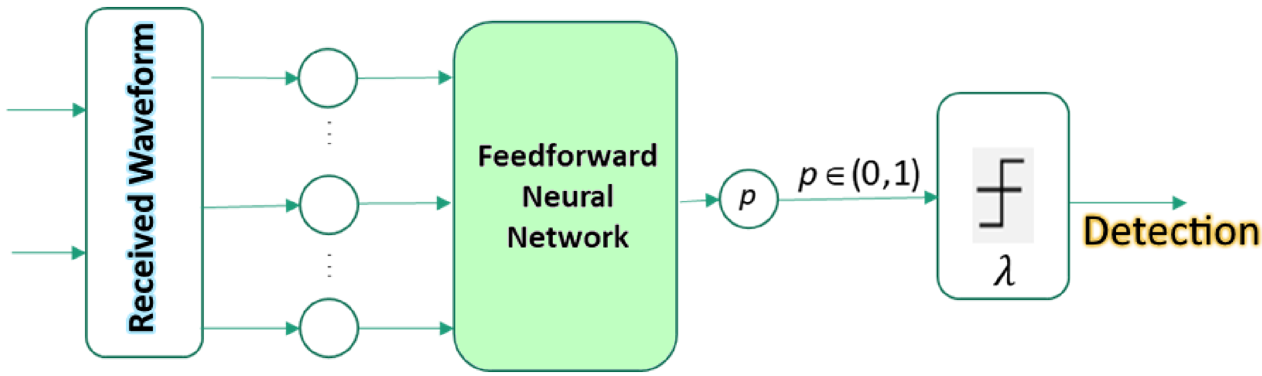


Frequency hopping spread spectrum signals

To fill this gap, we have developed methods for BSS of FHSS RF sources. These methods rely on the sparsity of the number of instantaneous sources, the time invariance of channels during a frequency hop, and exploit features that are not affected by frequency hopping, such as direction of arrival (DOA). Our set-up considers FHSS signals with aperiodic hops; a wireless network operating over slow flat-fading channels, and all sensors synchronized to the same clock. The goal is to separate multiple such FHSS sources with sparse and intermittent activity and assign source labels with the aid of DOA estimation.

Radar Signal Detection and Processing via Neural Network

Faculty: Alexander Haimovich
Graduate Students: Kyle Wensell, James Zhou
Sponsor: US Army

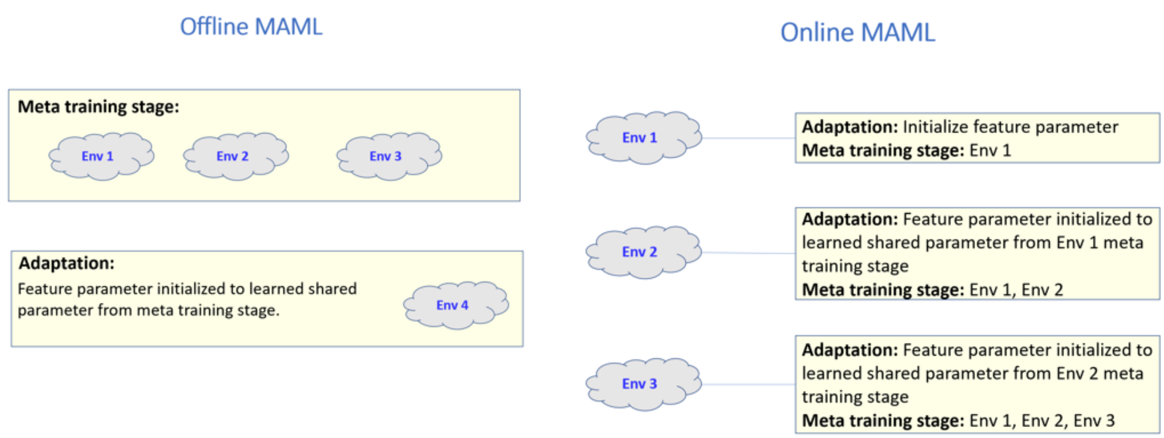


Traditional radar systems must be designed to handle many different operation environments. These environments are comprised of performance-reducing situations involving interference, clutter, and Doppler considerations. Generally, adverse situations such as these are handled by designing the receiver using some a priori knowledge of the environments. However, in some cases, the ideal receiver is non-trivial to find mathematically and therefore too difficult or complicated to use in real world scenarios.

Through the use of deep learning techniques, a neural network (NN) can be trained to perform waveform detection in all of these adverse environments, yielding improved detection performance and allowing for a more robust radar system. Because of this, NN-based detectors are a hot topic in the field of radar and communications. Our research involves making further improvements to these systems, including quantization of the data to one bit (which relaxes hardware requirements and computation time), and simultaneous training of the receiver and transmitter (which allows the radar system to show adaptive resistance against clutter and interference). The network is designed and trained using theoretical data generated from statistical target and environment models. After the network is trained, the NN performance is tested using software-defined radio (SDR) devices to analyze waveform propagation and real-time processing capabilities. Successful real-time operation of the network then allows for transmitter optimization depending on the statistics of the received data.

Fast Learning of Radar Systems Via Meta Learning

Faculty: Alexander Haimovich
Graduate Student: Zareen Khan
Collaborator: Osvaldo Simeone (King's College London, UK)
Sponsor: Army Research Laboratory



Fast learning of radar systems is proposed via alternating Model Agnostic Meta Learning (MAML) of detector and joint Reinforcement Learning (RL) of the radar waveform for target detection in an unknown environment. MAML consists of two stages, meta-training and adaptation. The radar is trained with data from multiple environments during meta training stage to learn a shared initial parameter. The weights of the neural network is initialized by a learnt shared parameter, which enables the fast learning from few data samples during the adaptation stage. We have developed MAML via offline and online meta learning, both of which enable fast learning with limited amount of data. Alternating learning of detector and waveform is carried out during adaptation stage of online MAML, while it is carried out during meta training stage of offline MAML. Numerical results show that alternating meta learning of detector and waveform reinforcement learning outperforms meta learning of detector only.

RELDEC: Reinforcement Learning-Based Decoding of Moderate Length LDPC Codes

Faculty: Joerg Kliewer
Graduate Student: Salman Habib
Collaborator: Allison Beemer (University of Wisconsin)
Sponsor: National Science Foundation (NSF)

Binary low-density parity-check (LDPC) codes are sparse graph-based channel codes. Due to their excellent error correcting performance for symmetric binary input channels, they have recently been standardized for data communication in the 5G cellular new radio standard. Tanner graphs of LDPC codes are sparse bipartite graphs whose vertex sets are partitioned into check nodes (CNs) and variable nodes (VNs). Typically, iterative decoding on an LDPC Tanner graph is carried out via flooding: all CNs and VNs are updated simultaneously in each iteration. In comparison, sequential decoding updates the nodes serially based on the latest messages propagated by their neighbors. Sequential scheduling problems seek to optimize the order of all CN (or VN) updates to improve the convergence speed and/or the decoding performance with respect to the flooding scheme. In this work, we improve the sequential decoding performance of LDPC codes using a novel reinforcement learning based scheme termed RELDEC (reinforcement learning-based decoding of moderate length LDPC codes), and its meta learning based variants, namely, agile meta-RELDEC (AM-RELDEC) and meta-RELDEC (M- RELDEC). These decoding schemes schedule groups (clusters) of CNs sequentially based on the learned scheduling order. In each scheduling instant, a cluster's neighbors are updated via flooding based on the latest messages propagated by its neighboring clusters.

In this project, a sequential LDPC decoding algorithm is modeled as a finite Markov decision prcess (MDP), where the code's Tanner graph is viewed as an environment with $\lceil m/z \rceil$ possible actions (cluster selections), where z is the cluster size and m is the number of CNs in the Tanner graph. Then, we apply RELDEC, AM-RELDEC and M-RELDEC, which all employ Q-learning, to learn an action-value function that determines how beneficial a particular choice of cluster is for optimizing the cluster scheduling policy. The learned policy is then incorporated in our sequential LDPC decoding algorithm for inference. Note that the state space size of the MDP, and hence the complexity of the RELDEC and meta-RELDEC schemes, can grow exponentially with the number of CNs, which can range in the hundreds for practical LDPC codes. Creating clusters of CNs reduces the state space cardinality of the MDP and significantly reduces the learning complexity. Given a cluster in the Tanner graph, let the *output* of that cluster at a particular iteration be the binary sequence resulting from hard-decisions on the posterior log-likelihood ratios (LLRs) computed by the (ordered) neighboring VNs. The state of the MDP in both our RELDEC and meta-RELDEC schemes are then given by the collection of all possible (cluster, cluster state) pairs.

Figs 1. and 2 compare the performances of our learning-based sequential decoding schemes with flooding (*i.e.*, all clusters are updated simultaneously per iteration), and a random sequential decoding scheme where the cluster scheduling order is randomly generated. We utilize each scheme for decoding a [384, 256]-WRAN irregular LDPC code and a 5G-NR LDPC code. In the case of 5G-NR, the code is constructed by lifting the BG2 base matrix with dimensions 42 × 52 using an optimized lifting matrix obtained from the literature with lifting factor 10, resulting in a 5G- NR LDPC code with block length 520 and a rate of approximately 1/5. We observe that in both cases the RELDEC schemes outperform the state-of-the-art flooding scheme by a significant amount.

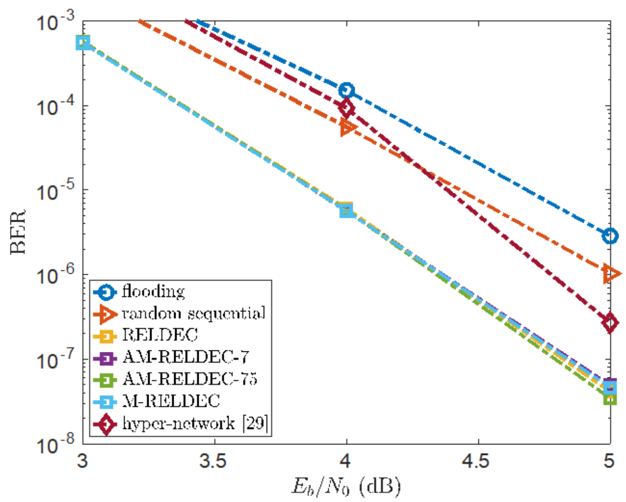


Figure 1: BER results using different BP decoding schemes for a [384,256] WRAN LDPC code (IEEE 802.22) and –5 decoder iterations for an AWGN channel. The hyper-network code results are taken from [Nachmani, Wolf 2019]

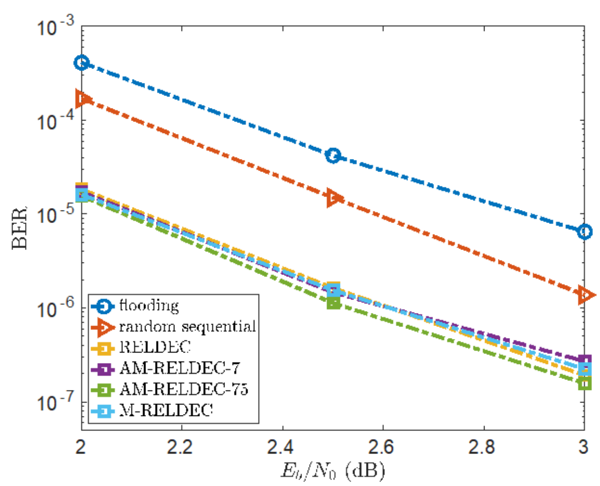


Figure 2: BER results using different BP decoding schemes for a [520,420] 5G-NR LDPC code and 50 decoder iterations for an AWGN channel.

[1] S. Habib, A. Beemer, and J. Kliewer. “RELDEC: Reinforcement learning-based decoding of moderate length LDPC codes”, submitted, arXiv:2112.13934

[2] S. Habib, A. Beemer, and J. Kliewer. “Belief propagation decoding of short graph-based channel codes via reinforcement learning”, In IEEE Journal on Selected Areas in Information Theory, 2021.

[3] S. Habib, A. Beemer, and J. Kliewer. “Decoding of moderate length LDPC codes via learned clustered check node scheduling”, In 17th International Symposium on Wireless Communication Systems, 2021.

[4] S. Habib, A. Beemer, and J. Kliewer. “Learning to decode: Reinforcement learning for decoding of sparse graph-based channel codes”, In Advances in Neural Information Processing Systems, 2020.

[5] S. Habib, A. Beemer, and J. Kliewer. “Learned scheduling of LDPC decoders based on multi-armed bandits”, In Proceedings IEEE Intl. Symp. on Inf. Theory, 2020.

Private Computation Over Coded Non-colluding Databases

Faculty: Joerg Kliewer
Graduate Student: Sarah Obead
Collaborator: Hsuan-Yin Lin, Eirik Rosnes (Simula UiB, Bergen, Norway)
Sponsor: National Science Foundation (NSF)

The problem of private information retrieval (PIR) from public databases has been the focus of attention for several decades in the computer science. The goal of PIR is to allow a user to privately access an arbitrary message stored in a set of databases, i.e., without revealing any information of the identity of the requested message to each database. Private computation (PC) is a recently proposed generalization of the PIR problem that addresses the private computation of functions of the stored messages, also denoted as private function retrieval. In PC a user has access to a given number of databases and intends to compute a function of messages stored in these databases. This function is kept private from the databases, as they may be under the control of an adversary.

We focus on the study and design of efficient PC protocols over distributed storage systems (DSSs) where the data is encoded by an $[n, k]$ linear code and then distributed and stored across n storage nodes referred to as coded DSSs. Using coding techniques, coded DSSs possess many practical features and benefits such as high reliability, efficient repairability, robustness, and security. We consider the problem of private polynomial computation (PPC) over noncolluding coded DSSs. In PPC, a user wishes to compute a multivariate polynomial out of a μ candidate polynomial functions of degree at most g over f variables (or messages) stored in n noncolluding coded databases.

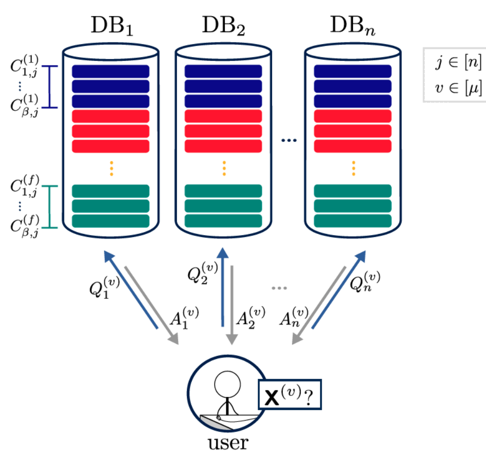


Figure 1: System Model for PC from Noncolluding Coded Databases

We first consider the private computation of polynomials of degree $g = 1$, i.e., private linear computation (PLC) for coded databases [1]. In PLC, a user wishes to compute a linear combination, over the f messages while keeping the coefficients of the desired linear combination hidden from the database. For a linearly encoded DSS, we present a capacity-achieving PLC scheme and show that the PLC capacity, which is the ratio of the desired amount of information and the total amount of downloaded information, matches the maximum distance separable (MDS) coded capacity of PIR for a large class of linear storage codes. Then, we consider private computation of higher degree polynomials, i.e., $g > 1$. For this setup, we construct two novel PPC schemes. In the first scheme [2] we consider Reed-Solomon coded databases with Lagrange encoding, which leverages ideas from recently proposed star-product PIR and Lagrange coded computation. The second scheme [3] considers the special case of coded databases with systematic Lagrange encoding. Both schemes yield improved rates, while asymptotically, as $f \rightarrow \infty$, the systematic scheme gives a significantly better computation retrieval rate compared to all known schemes up to some storage code rate that depends on the maximum degree of the candidate polynomials. Figure 2, shows the rates of our PPC schemes compared to the best known PPC schemes from the literature ([Karpuk, 2018], [Raviv & Karpuk, 2019]) for various values of the storage code rate $\alpha = k/n$, fixed k, $g = 2$, $f = 2$, $\mu = \mathrm{M}_2(f)$. For a small number of files ($f = 2$), our proposed schemes show improved performance for all code rates, while for a relatively large number of files ($f = 10$), our systematic scheme shows improved performance over all schemes up to some code rate.

1. S. A. Obead, H.-Y. Lin, E. Rosnes, and J. Kliewer, "Private Linear Computation for Noncolluding Coded Databases" in *IEEE Journal on Selected Areas in Communications*, vol. 40, no. 3, pp. 847-861, March 2022

2. S. A. Obead, H.-Y Lin, E. Rosnes and J. Kliewer, "Private polynomial computation for noncolluding coded databases," *in Proc. IEEE International Symposium on Information Theory (ISIT)*, Paris, France, July 2019, pp. 1677–1681.

3. S. A. Obead, H.-Y. Lin, E. Rosnes, and J. Kliewer, "Private polynomial computation for noncolluding coded databases" Submitted for possible publication at the *IEEE Transactions on Information Forensics and Security.* August 6, 2022.

List of Projects and Funding

Abdi, Ali (PI) “PFI: AIR – TT: A Novel Vector Acoustic Communication Technology for High Speed Underwater Modems”, US NSF, (August 2015 – April 2022)

Abdi, Ali (PI) “An Emergency Electro-Mechanical Communication System for Underground Tunnels and Mines”, US NSF, (March 2021 – August 2022)

Haimovich, Alexander M. “End-to-End Machine Learning (E2EML) Fuze”, Sponsored by US Army/Advanced Technology International (June 2020 – August 2023)

Haimovich, Alexander M. “End-to-End Deep Learning Radar System”, Sponsored by US Army (August 2020 – August 2022)

Haimovich, Alexander M. “Blind Frequency Hopping Spread Spectrum (FHSS) Signal Detection in Line of Sight and Non-Line of Sight Environments”, US Department of Navy, (September 2021 – September 2022)

Haimovich, Alexander M. “Blind Source Separation (BSS) of Frequency Hopping Spread Spectrum”, US Department of Navy, (January 2020 – December 2021)

Kliewer, Joerg (PI), Collaborative Research: CIF: Medium “Do you trust me? Practical Approaches and Fundamental Limits for Keyless Authentication”, National Science Foundation (October 2021 – September 2025)

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Kliewer, Joerg (PI), Collaborative Research: CCSS: Coding for 5G and Beyond: Limits and Efficient Algorithms, National Science Foundation (September 2017 – August 2022)

Kliewer, Joerg (PI), SaTC: CORE: Small: Collaborative: Covert/Secret and Efficient Message Transfer in Mobile Multi Agent Environments (September 2018 – August 2022)

Kliewer, Joerg (PI), CIF: Small: Collaborative Research: When Small Changes Have Big Impact: Improving Network Reliability and Security via Low-Rate Coordination (October 2019 – September 2022)

Total Center Project Funding: $2,900,000

Sample List of Refereed Journal Articles Published

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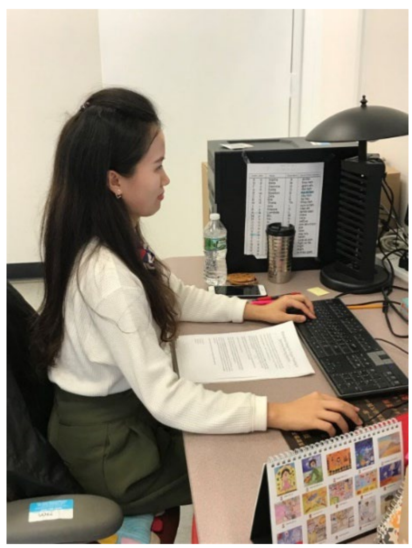


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PATENTS AWARDED/FILED

Wireless Mobile Station Receiver Structure With Smart Antenna - 6,137,785
Yeheskel Bar-Ness (Inventor), Alexander Haimovich (Inventor), Wei Chen Ye (Inventor)
New Jersey Institute of Technology

Turbo space-time coding with time varying linear transformations
Alexander Haimovich (Inventor), Hangjun Chen (Inventor)
New Jersey Institute of Technology

Clipping Distortion Canceller for OFDM Signals
Alexander Haimovich (Inventor), Hangjun Chen (Inventor)
New Jersey Institute of Technology

Method for Wireless Communications from Source Nodes to Infrastructure and then from Infrastructure to Destination Nodes, respectively.
Alexander Haimovich (Inventor), Shengshan Cui (Inventor)
New Jersey Institute of Technology

Asymmetric Error Correction and Flash-Memory Rewriting Using Polar Codes
Patent Number: US 10,379,945 B2   Issued: 8/13/2019
Inventors: Eyal En Gad; Yue Li; Anxiao Jiang; Jehoshua Bruck; Joerg Kliewer; Michael Langberg

PUBLISHED BOOKS

In A. De Maio, Y. Eldar, & A. Haimovich (Eds.), *Compressed Sensing in Radar Signal Processing* (pp. Xi-Xiii). Cambridge: Cambridge University Press. September 2019

NEWS

IEEE Board of Directors elevated Ali Abdi to IEEE Fellow, effective 1 January 2019, with the following citation: *For Contributions to Wireless Channel Modeling and Underwater Communications.*

Four students from the center received their degrees and walked in commencement.