Title: 基于代数几何的新一代 Shannon 理论

Speaker: 程帆 (上海交通大学 副教授)

Date: 2023 年 10 月 21 (星期六)

Time: 14:00—14:40

Tencent Meeting ID: 645-920-189

Inviter: Dr. Tao Guo

主办单位：东南大学网络空间安全学院

承办单位：江苏省网络空间安全学会

Abstract:
在过去十年中，高斯分布完全单调猜想的研究经历了从提出到突破、验证、以及最近和代数几何 Hodge 理论建立起了联系，这给我们提供了从根本上重新构建 Shannon 在 1948 年所奠基的理论的机遇。报告总结了过去 70 年的历史以及最近 10 年的进展，主要分为三个部分。
在高斯分布(机器学习的高斯混合模型、数学物理的热传导方程)的理论研究中，于 2013 年首次在数学上严格证明了高斯分布的完全单调指数至少为 3。以此为基础，提出了高斯分布的完全单调猜想(Gaussian Completely Monotone Conjecture, 简称 GCMC)。该工作解决了 2010 年 Fields 奖得主 C. Villani 教科书中的问题，取得了自 1966 年以来的技术性突破。
在 2019 年提出了 GCMC 所蕴含的 Fisher 信息分解原理，并提出了利用完全单调性解决高斯信息干扰模型的新思路。该思路于 2021 年被 M. Ledoux(2014 ICM Invited Speaker)研究团队所验证。
在 2022 年证明了 GCMC 与 J. Huh 的 Hodge 理论的联系，有望带来信息理论的代数几何化，诞生新一代信息理论。

Short Bio:
程帆，博士，长聘教轨副教授、博士生导师，密码与信息安全研究所，计算机科学与工程系，上海交通大学
2007 年本科毕业于上海交通大学计算机科学与工程系，2012 年于香港中文大学信息工程系获博士学位，师从 Shannon 奖得主 Raymond Yeung 教授。在香港中文大学、新加坡国立大学从事博士后工作。2016 年起任上海交通大学计算机科学与工程系特别研究员。
主要研究信息科学中的基础理论问题，包括且不限于信息论、机器学习与信息安全。在 IEEE Transactions on Information Theory, CVPR, ACL, EMNLP 等国际主流期刊会议发表论文 20 多篇，研究工作获得国家重点研发计划课题，国家自然基金、科技委 H863 课题、华为 2012 gift funding 支持。入选上海市科委扬帆计划(2017-2019)，上海市教委东方学者特聘教授(2018-2020)，2019 年获中国电子学会信息论分会青年新星奖，2020 年获得上海交通大学杨元庆优秀青年教师奖。2017、2018 分别获得上海市教学成果奖特等奖，国家教学成果奖二等奖。

Title: **Matroidal Entropy Functions: A Quartet of Theories of Information, Matroid, Design, and Coding**

Speaker: 陈琦 **(西安电子科技大学 副教授)**

Date: **2023 年 10 月 21 (星期六)**

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Inviter: Dr. Tao Guo

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Abstract:

A matroidal entropy function is an entropy function in the form log v · rM , where v is an integer exceeding one and rM is the rank function of a matroid M. For a matroid M, the characterization of matroidal entropy function induced by M is to determine its probabilistic-characteristic set χM, i.e., the set of integers v such that log v · rM is entropic. To characterize matroidal entropy functions, we introduce variable strength orthogonal arrays(VOA), which can be considered as special cases of classic combinatorial structure orthogonal arrays(OA). We prove that whether log v · rM is entropic depends on whether a VOA(M, v) is constructible. Leveraging the correspondences between matroidal entropy functions and VOAs, we characterize the matroidal entropy functions induced by matroids obtained from matroid operations such as deletion, contraction, minor, series and parallel connection and 2-sum. Utilizing these results, we characterize two classes of matroidal entropy functions, i.e., those induced by regular matroids and matroids with the same p-characteristic set as uniform matroid U2,4. As the support of characterizing random vector of a matroidal entropy function, i.e., the set of rows of the corresponding VOA is equivalent to the code book of an almost affine code, they can be applied to solve coding problems in secret sharing, network coding, index coding and locally repairable code.

Short Bio:

陈琦，西安电子科技大学副教授。2014 年毕业于香港中文大学，获博士学位，之后留校从事博士后研究至 2017 年。2015 年 9 月-2016 年 1 月，他同时也是美国 Drexel 大学博士后。他于 2018 年加入西安电子科技大学空天地一体化国家重点实验室以及通信工程学院。他是中国电子学会 2018 年信息论学术年会最佳报告奖获得者。他的研究兴趣为信息论及其相关领域，特别是信息不等式及熵区域的刻画问题。

Title: **Proving Information Inequalities and Identities with Symbolic Computation**

Speaker: **郭来刚 (北京师范大学 助理教授)**

Date: **2023 年 10 月 21 (星期六)**

Time: **15:40—16:20**

Tencent Meeting ID: 645-920-189

Inviter: Dr. Tao Guo

主办单位：东南大学网络空间安全学院

承办单位：江苏省网络空间安全学会

Abstract:

Proving linear inequalities and identities of Shannon's information measures, possibly with linear constraints on the information measures, is an important problem in information theory. For this purpose, ITIP and other variant algorithms have been developed and implemented, which are all based on solving a linear program (LP). In particular, an identity $f = 0$ is verified by solving two LPs, one for $f \ge 0$ and one for $f \le 0$.

In this paper, we develop a set of algorithms that can be implemented by symbolic computation. Based on these algorithms, procedures for verifying linear information inequalities and identities are devised. Compared with LP-based algorithms, our procedures can produce analytical proofs that are both human-verifiable and free of numerical errors. Our procedures are also more efficient computationally. For constrained inequalities, by taking advantage of the algebraic structure of the problem, the size of the LP that needs to be solved can be significantly reduced. For identities, instead of solving two LPs, the identity can be verified directly with very little computation.

This is a joint work with Raymond W. Yeung and Xiao-Shan Gao.

Short Bio:

郭来刚，北师大数学科学学院讲师，中国数学会计算机数学专业委员会委员。2019 年博士毕业于中国科学院大学，2016-2018 年曾在加拿大西安大略大学联合培养。2019 年和 2021 年曾分别加入中科院数学与系统科学研究院国家数学与交叉科学中心和香港中文大学网络编码实验室做博士后，合作导师分别为符号计算与信息论领域顶尖学者高小山研究员和 Raymond Yeung 教授。目前研究领域属于交叉学科，符号计算的交叉应用，具体方向为：符号计算在信息论中的应用，包括：香农不等式、熵幂不等式等问题；符号计算在非线性系统中的应用，包括：稳定性分析、分岔分析等问题。目前研究成果已发表在信息论领域顶刊 IEEE Transactions on Information Theory、信息论领域顶会 IEEE International Symposium on Information Theory、微分方程定性分析领域顶刊 Journal of Differential Equations 等。曾获得中国科学院院长奖、中国博士后基金特别资助、面上资助、国自然基金青年基金。

Title: **Online Multi-User Scheduling for Extended Reality (XR) Transmissions with Hard-Latency Constraint**

Speaker: **赵霄宇 (香港中文大学 博士后研究员)**

Date: **2023 年 10 月 21 (星期六)**

Time: **16:20—17:00**

Tencent Meeting ID: 645-920-189

Inviter: Dr. Tao Guo

主办单位：东南大学网络空间安全学院

承办单位：江苏省网络空间安全学会

Abstract:

In the forthcoming 6G era, Extended reality (XR) is an emerging application with unique traffic characteristics requirements, calling for innovative Ultra-Reliable and Low-Latency Communication (URLLC) technologies. In this talk, we present a multi-user scheduling scheme to meet hard-latency constraints for XR services. Specifically, we focus on a periodical XR traffic model, where the latency constraint for transmitting each XR frame is less than the inter-arrival time. To find an optimal multi-user scheduling scheme, we first describe the system as a periodic Markov Decision Process (MDP), where the scheduling performance is expressed as the probability of successful transmission within the latency constraint. Then, we obtain the maximum success probability and the optimal scheduling based on the optimal value function. Inspired by the properties of the optimal value function, we construct a lower bound of it and propose an online multi-user scheduling scheme. This way, scheduling decisions under the proposed scheme are determined by solving a series of nonlinear Knapsack Problem (KP) in polynomial time. Finally, rigorous analysis and simulation results show that the proposed scheduler achieves nearly optimal performance and outperforms other benchmark schedulers.

Short Bio:

Dr. Xiaoyu Zhao received the B.S. degree from Tianjin University in 2016, and the Ph.D. degree from Tsinghua University in 2021. In 2019, he was a Visiting Ph.D. Student with Princeton University. He is currently a postdoctoral fellow with the Chinese University of Hong Kong. His research interests include low-latency cross-layer design, delay-power tradeoff, and probabilistic scheduling.

Title: **Generalized Group Testing**

Speaker: 周桥桥 **(重庆大学 副研究员)**

Date: **2023 年 10 月 21 (星期六)**

Time: **17:00—17:40**

Tencent Meeting ID: 645-920-189

Inviter: Dr. Tao Guo

主办单位：东南大学网络空间安全学院

承办单位：江苏省网络空间安全学会

Abstract:

In the problem of classical group testing one aims to identify a small subset (of size d) diseased individuals/defective items in a large population (of size n). This process is based on a minimal number of suitably-designed group tests on subsets of items, where the test outcome is positive iff the given test contains at least one defective item.

Motivated by physical considerations, such as scenarios with imperfect test apparatus, we consider a generalized setting that includes as special cases multiple other group-testing-like models in the literature. In our setting the test outcome is governed by an arbitrary monotonically increasing (stochastic) test function $f(\cdot)$, with the test outcome being positive with probability $f(x)$, where x is the number of defectives tested in that pool.

For this generalized group testing, we derive upper and lower bounds on the number of tests required to identify all defective items. We also prove that ourkl sample-complexity bounds are information-theoretically near-optimal for a variety of sparse-recovery group-testing models in the literature.

Short Bio:

Qiaoqiao Zhou received the B.B.A. degree in business administration and the M.S. degree in electrical engineering from the Beijing University of Posts and Telecommunication in 2011 and 2014, respectively, and the Ph.D. degree in information engineering from The Chinese University of Hong Kong in 2020. He was a Research Fellow at the Department of Computer Science, National University of Singapore. His research interests include information theory and machine learning.