QuanTalks

IISc Quantum Technologies Initiative (IQTI) Seminar Series

Title

Local Message-Passing Decoding of Quantum LDPC Codes and Quantum Trapping Sets

Date & Time

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6 30 PM (IST)

Speakers

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Abstract: Quantum low-density parity-check (QLDPC) codes have been studied in quantum literature for about two decades, but the last two years witnessed their renaissance as several breakthroughs were made. These breakthroughs include a discovery of several new stabilizer code families constructed from classical codes and proving the existence of codes with minimum distance that increases linearly with the codeword length as opposed to the square root increase that was believed to be maximum possible. However, compared to classical codes, Tanner graphs of quantum LDPC codes are additionally constrained by the stabilizer generator constraints, and perform poorly when decoded using local message passing algorithms such as Belief Propagation. So poorly that they exhibit shallow error floors much worse than the classical counterparts. Lowering error floor is further hampered by degenerate errors - distinct errors that result in the same syndrome. It was observed by many research groups, but no systematic explanation of it existed. Researchers therefore relied on post-processing techniques to reduce error floor - the Ordered Statistics Decoding (OSD) being the dominant one. However, the OSD is not a local algorithm, and its complexity increases cubically with the code dimension (in addition to the BP complexity). In my research group, couple of years ago we have started investigating if QLDPC codes can be decoded using only local decoding algorithms, and this talk is about the status of this research. We have identified that similarly to classical codes, QLDPC also have trapping sets - dense configurations in their Tanner graphs that affect decoder convergence and are behind the error floor phenomenon. We established a framework for studying trapping sets in QLDPC codes that include unique features of "quantumness" of QLDPC codes such as degeneracy and syndrome decoding flavor of the "quantum" BP algorithm. In this talk, we establish a systematic methodology by which one can identify and classify quantum trapping sets according to their topological structure and decoder used. We show that the knowledge of quantum trapping sets can be used to design better QLDPC codes and decoders. Decoding probability improvements of two orders of magnitude in the error floor regime are demonstrated for some practical finite-length QLDPC codes without requiring any post-processing. The talk is intended to classical coding theory researchers, and no background of quantum error correction is needed.

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Biography: Dr. Bane Vasic is a Professor of Electrical and Computer Engineering and Mathematics at the University of Arizona and a Director of the Error Correction Laboratory. He is an inventor of the soft error-event decoding algorithm for intersymbol interference channels with correlated noise, and the key architect of a detector/decoder for Bell Labs data storage read channel chips which were regarded as the best in industry. His pioneering work on structured low-density parity check (LDPC) error correcting codes based on combinatorial designs has enabled low-complexity iterative decoder implementations. Structured LDPC codes are today adopted in a number of communications standards and data storage systems. Dr. Vasic's work on codes on graphs, trapping sets and error floor of iterative decoding algorithms has led to decoders for the binary symmetric channel with best error-floor performance known today. He is a founder of Codelucida, a company developing advanced error correction solutions for communications and data storage. Recently, Codelucida has received numerous innovation awards including 2017 Arizona Innovation Challenge Award from Arizona Commerce Authority, 2018 I-Squared Startup of the Year from Tech Launch Arizona, and Best of Show Award for the Most Innovative Flash Memory Technology at the 2019 Flash Memory Summit, the World largest exhibition of flash memory technologies. Codelucida is a Xilinx Partner providing LDPC Codec IP cores for flash memory controllers. He is an IEEE Fellow, Fulbright Scholar, da Vinci Fellow, and a past Chair of IEEE Data Storage Technical Committee. Currently, he is in the Workforce Technical Advisory Committee within the Quantum Economic Development Consortium (QED-C), established with support from the National Institute of Standards and Technology (NIST) as part of the Federal strategy for advancing quantum information science called for by the National Quantum Initiative Act in 2018. Dr. Vasic is also a PI on a Department of Energy multi-university project led by Fermi National Laboratory to establish a Center for Superconducting Materials and Systems. He is also involved in University of Arizona Quantum Hub, a group of researchers leading effort to establish a graduate program in quantum information science and engineering at the UArizona.

Biography: Dr. Nithin Raveendran is a postdoctoral research associate at the Department of Electrical and Computer Engineering, the University of Arizona, Tucson. His current area of research is broadly on quantum computation and communication, with a focus on quantum error correction on developing improved quantum error correction codes and best-performing iterative decoders. He earned his Ph.D. degree on the topic of trapping sets of classical and quantum low-density parity-check codes under the guidance of Prof. Bane Vasic and Prof. Saikat Guha at the University of Arizona. Prior to his Ph.D., he earned his master's degree at the Department of Electronic Systems Engineering (DESE), Indian Institute of Science (IISc), Bangalore, and his undergraduate degree in Electrical and Electronics Engineering at BITS Pilani. His area of expertise is on classical and quantum error correction codes, inference algorithms, and quantum computing. His recent journal and conference publications can be accessed on Google Scholar link - https://scholar.google.com/citations?hl=en&user=FBrIdeAAAAAJ.

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