領域論壇：量子計算
Session: Quantum Computing

Venue: 數學館 M212

Time	Speaker	Title of the Talk	Chair
13:50–14:15	賴青沂	Quantum error correction from the perspective of coding theory	游至仕
14:15–14:40	謝明修	Good Quantum LDPC Codes with Linear Time Decoders	游至仕
14:40–15:05	陳建隆	On the Generating Quantum Feature Maps for SVM Classifier	游至仕
15:05–15:30	林家祥	HyperQUEEN: Hyperspectral Quantum Deep Network for Satellite Image Restoration	游至仕

Quantum error correction from the perspective of coding theory

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Abstract

Quantum states are vulnerable and quantum operations are imperfect. Quantum error correction techniques are necessary for reliable quantum computation and communication. This talk begins with a tutorial on quantum error correction from coding theory. Then I will introduce recent developments in fundamental theories, code constructions, and decoding techniques.

Good Quantum LDPC Codes with Linear Time Decoders

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Abstract

We construct a new explicit family of good quantum low-density parity-check codes which additionally have linear time decoders. Our codes are based on a three-term chain $(\mathbb{F}2^{m\times m})^V \xrightarrow{\delta^0} (\mathbb{F}2^m)^E \xrightarrow{\delta^1} \mathbb{F}2^F$ where V (X-checks) are the vertices, E (qubits) are the edges, and F (Z-checks) are the squares of a left-right Cayley complex, and where the maps are defined based on a pair of constant-size random codes $C_A, C_B : \mathbb{F}2^m \to \mathbb{F}2^\Delta$ where Δ is the regularity of the underlying Cayley graphs.

One of the main ingredients in the analysis is a proof of an essentially-optimal robustness property for the tensor product of two random codes.

References

[1] I. Dinur, M.-H. Hsieh, T.-C. Lin, and T. Vidick, *Good Quantum LDPC Codes with Linear Time Decoders*, arXiv:2206.07750, 2022.

On the Generating Quantum Feature Maps for SVM Classifier

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Abstract

In this talk, we compare two techniques for generating quantum feature maps that can be used in quantum-enhanced support vector machines, which rely on kernel methods to access high dimensional Hilbert spaces efficiently. The first approach involves using a genetic algorithm with a multi-objective fitness function, which employs a penalty method to maximize classification accuracy while minimizing the gate cost of the quantum feature map's circuit. The second method employs a variational quantum circuit and focuses on constructing an ansatz based on unitary matrix decomposition. We present numerical results and comparisons that demonstrate how the fitness function can reduce gate cost while maintaining high accuracy. We also show that conducting the circuit through unitary matrix decomposition leads to even better performance. Additionally, we propose some ideas for reducing and optimizing circuit gate cost while maintaining perfect accuracy. This is a joint work with Bang-Shien Chen.

HyperQUEEN: Hyperspectral Quantum Deep Network for Satellite Image Restoration

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Abstract

Quantum science just winning the 2022 Nobel Prize in Physics is of high potential to lead future development of remote sensing technologies. Given the very limited number of entangled quantum bits (qubits) even in the most advanced quantum computers, processing remotely sensed hyperspectral image (featured by its large data volume) using current quantum computer does not seem to be technically feasible. Even if the quantum image state can be well processed to the quantum state of the target image (QSTI), it cannot be perfectly retrieved/output as the QSTI will collapse to some eigenstate once it is measured. Owing to these challenges, current quantum image processing technologies can only achieve classification-level applications requiring just a few output qubits. We design a hyperspectral quantum deep network (HyperQUEEN) to encode the hyperspectral information using very few qubits, as well as to learn the mapping from some measuring statistics (associated with the collapsed-QSTI) to the target image (instead of directly retrieving the unobservable QSTI), thereby solving the challenges. HyperQUEEN is the first quantum architecture that makes a breakthrough to blindly reconstruct NASA's damaged hyperspectral images, which means a lot for the upcoming space era. As the immature quantum facility nowadays does not yet allow us to fully exhibit its high potential, we are not aiming at developing state-of-the-art methods, but are demonstrating the feasibility of quantum hyperspectral remote sensing. Mathematical analysis guiding our design toward the low-rank quantum deep network, together with comprehensive experiments, will also be presented.