Opportunity Title: Tailoring Quantum Error Correcting Codes to Error Models
Opportunity Reference Code: ICPD-2021-08

Organization	Office of the Director of National Intelligence (ODNI)
Reference Code	ICPD-2021-08
How to Apply	**Create and release your Profile on Zintellect** – Postdoctoral applicants must create an account and complete a profile in the on-line application system. **Please note: your resume/CV may not exceed 2 pages.**

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If you have questions, send an email to ICPostdoc@orau.org. Please include the reference code for this opportunity in your email.

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Application Deadline	2/26/2021 6:00:00 PM Eastern Time Zone
Description	**Research Topic Description, including Problem Statement:**

From a theoretical perspective, the development of quantum error correcting codes (QECCs) has been a resounding success, much of which has been built on the underlying theory of classical error correcting codes. However, the underlying error model for most QECCs has been that of independent identically distributed (IID) errors, and that model is known to inaccurately represent the errors that arise in the true noise environment of a quantum computer. The goal here is to develop a theory of quantum error correction that takes into account correlated coherent errors and, in particular to deal with errors that are temporally correlated, such as those that might arise in a non-white noise environment.

It is important to deal with abstract parameterized error models in this project, rather than tie the error models to specific quantum computing architectures or specific types of qubits. The first order of business should be to create general abstract parameterized error models with a clear understanding of what all the parameters are and their interrelations, if any. Based on these abstract error parameters, the main goal will be to create parameterized families of quantum error correcting codes and tie the code parameters to error parameters.

It will be very important to include autocorrelation functions in the error model, and hopefully ask the question of how to deal with an arbitrary (parametrized) autocorrelation function. Normally autocorrelation functions refer to noise in the system, so an important question will be how to turn a noise autocorrelation function into an error autocorrelation function.

Example Approaches:

Current QECCs can be built from pairs of classical error correcting codes, as can
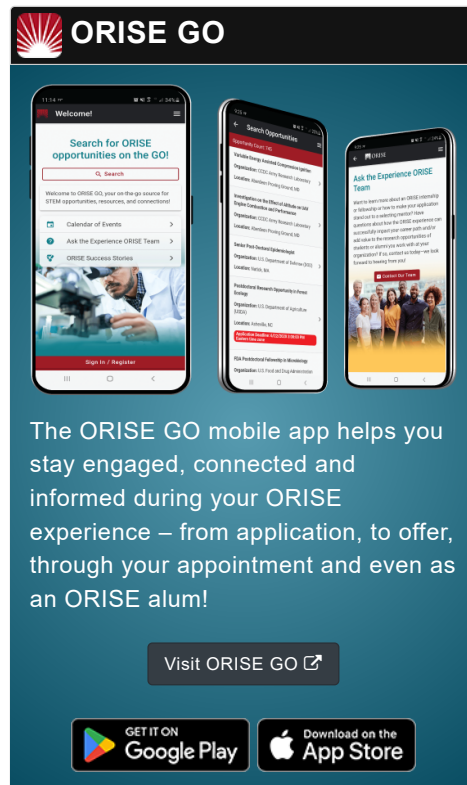
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current independent sigma-x and sigma-z errors with different error rates. Extending this theory to spatially correlated multi-qubit error models with different rates, for say all 15 types of two-qubit errors, might be possible using tensor product structures from classical error correcting codes. Dealing with time-correlated error seems more difficult, but a starting point could be to look at how classical error correction deals with this problem (e.g. burst errors). Classically, certain types of interleaving schemes for independent codes can create immunity from noise at specific frequencies, and the question is whether such techniques are extendible to the quantum domain.

In terms of dealing with parameterized error models, a possible starting point could be autoregressive moving average (ARMA) models for weakly stochastic time series, which are well studied in the classical domain, and ask how they can be translated into the quantum domain. Imposing a quantum error correcting code on top of such a model should then lead to a corresponding ARMA model for logical qubits. An important question will be how to accomplish this transformation computationally. Once that is done, theoretical experimentation with different kinds of quantum error correcting codes can begin in earnest.

Relevance to the Intelligence Community:

Current methods of quantum error correction are unlikely to suffice as the number of qubits increases in quantum computing systems and longer algorithms are implemented. New QECCs will have to be developed that take into account spatial-temporal correlations in the underlying noise environment that give rise to spatial-temporal correlated errors. Without such new types of QECCs, progress toward larger-scale quantum computation will be severely impeded.

Approaching this in a parameterized abstract way, rather than tying the results to a specific type of physical qubit or a specific underlying computing architecture, will be of broad use in understanding how quantum computers can come to grips with a wide range of qubit error models.

Key Words: Quantum Computing, Error Analysis, QECC

Qualifications

Postdoc Eligibility

- U.S. citizens only
- Ph.D. in a relevant field must be completed before beginning the appointment and within five years of the application deadline
- Proposal must be associated with an accredited U.S. university, college, or U.S. government laboratory
- Eligible candidates may only receive one award from the IC Postdoctoral Research Fellowship Program

Research Advisor Eligibility

- Must be an employee of an accredited U.S. university, college or U.S. government laboratory
- Are not required to be U.S. citizens

Eligibility Requirements

- **Citizenship:** U.S. Citizen Only
- **Degree:** Doctoral Degree.

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- **Discipline(s):**
  - **Chemistry and Materials Sciences** (12 👁)
  - **Communications and Graphics Design** (2 👁)
  - **Computer, Information, and Data Sciences** (17 👁)
  - **Earth and Geosciences** (21 👁)
  - **Engineering** (27 👁)
  - **Environmental and Marine Sciences** (14 👁)
  - **Life Health and Medical Sciences** (45 👁)
  - **Mathematics and Statistics** (10 👁)
  - **Other Non-Science & Engineering** (2 👁)
  - **Physics** (16 👁)
  - **Science & Engineering-related** (1 👁)
  - **Social and Behavioral Sciences** (27 👁)