Quantum Code Zoo

ZWL*

(Dated: January 19, 2021 **quantum-code-zoo**)

A zoo of quantum codes, inspired by the quantum algorithm zoo. This zoo includes a classification of all known codes and an one-liner description with construction reference. This is an ongoing project, contributions, pull requests and comments are welcome.

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I. INTRODUCTION

Since the discovery of Shor's codes in 1995 [cite], quantum error correction has experienced fast development in the past two decades. Still, new codes comes out week by week, with starling progress. It is a non-trivial task to give a proper name for a new class of code. A good name gives pictural description of the code, providing no confusion and receiving no complain.

One can find a discussion of names used for physics quantities and theorems here [cite]

II. QUANTUM CODE ZOO

Each code is classified into one or more categories in this list.

Whatever code you find, let's find a place for it in this list

- fermion codes
- bosonic codes
  - GKP codes
  - cat codes
- CWS
  - Stabilizer codes
    - CSS codes
      - QHP codes
        - toric codes
        - HQHP codes
          - toric codes in higher-Dimension
      - Quantum bicycle codes
      - Homological product codes
      - Lifted product codes
      - Fiber bundle codes
      - Quantum pin codes
      -
    - non-CSS codes
      - rotated surface codes
      - Quantum XYZ product codes
  - Subsystem codes
    - Subsystem product codes
      - Subsystem hypergraph product codes
        - Bacon Shor codes
  - Concatenated codes
    - Shor's codes

unclassified
- quantum hyperbicycle codes[1]

III. GLOSSARY AND REFERENCES IN ALPHABET ORDER

This section has a one-liner explanation for each codes, plus necessary notes, in alphabet order

Format

code name [cite]: description + necessary notes

Augmented surface code [2]: A homological product codes of a surface code and a $[[4,2,2]]$ code.

Bacon Shor codes

BCH codes

Binomial codes

Bosonic codes

Cat codes

CSS codes: Two classical codes that one contains the other; A stabilizer code with X-type and Z-type check operators.

Concatenated cat codes: Concatenated codes with cat code as the inner code and another qubit code as the outer code

Concatenated codes: A multi-layer structure where the logical qubits of one code are used as the physical qubits of another code.

Color codes:

Cubic codes: toric codes in 3D

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Data syndrome codes: when measurement error are considered, it adds extra bits to the code, hence called data syndrome codes. It is similar to space-time codes.

Fiber bundle codes

Gottesman-Kitaev-Preskill (GKP) codes [3]: encode a qubit into an oscillator, that is, continuous variable. It could be a qudit as well.

Higher-dimensional quantum hypergraph product codes:

Homological product codes

Hypercubic codes: toric codes in 4D

Lifted product codes [4]

Stabilizer codes: A subspace stabilized by an abelian subgroup of the Pauli group.

Quantum bicycle codes:

Quantum convolutional codes:

Quantum fractional codes [5, 6]

Quantum Hamming codes: A $[[7, 1, 3]]$ CSS code.

Quantum Hypergraph Product (QHP) codes: A CSS code defined by the hypergraph product of two graphs, which corresponds to two classical codes.

Quantum pin codes

Quantum XYZ product codes

Rotated surface codes

Semi-topological codes [7]

Shor's codes

Space-time codes: Multiple measurements will add a temporal dimension to the code.

Steane codes: A $[[5, 1, 3]]$ code

Subsystem codes

Subsystem product codes

Subsystem hypergraph product codes

Surface codes: constructed from any tessellation of an arbitrary surface or a higher-dimensional manifold. Generalization of the toric codes.

Surface-GKP codes: A concatenated code with GKP code as the inner code, and surface code as the outer code.

Tensor network codes [8]: Define stabilizer code using a tensor, which maps the physical qubits to logical qubits.

Toric codes: The code is defined on a periodic square lattice, that is, a torus. The check operators are weight-4 vertex operators and plaquette operators. The logical operators are nontrivial cycles on the torus.

IV. DECODERS

Cellular automaton decoders [9] and more references.
Maximum likelihood decoder
Minimum weight/energy decoder
Quantum Viterbi decoder

V. CLASSICAL CODE

This is not the main part of the project. Just give some intuition of the origins of some quantum codes.
Branching MERA code [10]
linear code
convolutional code
polar code

VI. CONTRIBUTION GUIDE

Contributions are welcome!

- add codes
- add reference, original paper for construction is prefered
- add one liner explanation, to let the general audience know what is it. We don't intend to teach the detail of the codes here. We suppose the audience are familiar with it, otherwise they can learn from the references.
- classify the codes into categories
- polish this latex document

VII. SIMILAR PROJECTS

Quantum Algorithm Zoo `https://quantumalgorithmzoo.org/`
Quantum protocol Zoo `https://wiki.veriqloud.fr/index.php?title=Protocol_Library`

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