Quantum error correction: Hamming code and Cyclic code

Quantum error correction is of crucial importance in all of communication theory.
Classically, the Hamming code is built as a block linear code which can correct up to N errors in a 2N+1 codebook. It saturates the Hamming bound and therefore it is a perfect code. Does the quantum analogue provide protection against quantum noise? To answer this question, we want to build a general (N,k) quantum Hamming code in Qiskit.
The same holds for Cyclic codes, for which a theoretical model is already developed based on weakly self-dual binary codes. It is natural to consider the possibility of implementing it practically, starting from quantum shift register circuits.

1	1	0	1
0	1	1	0
1	1	0	1
1	0	1	1

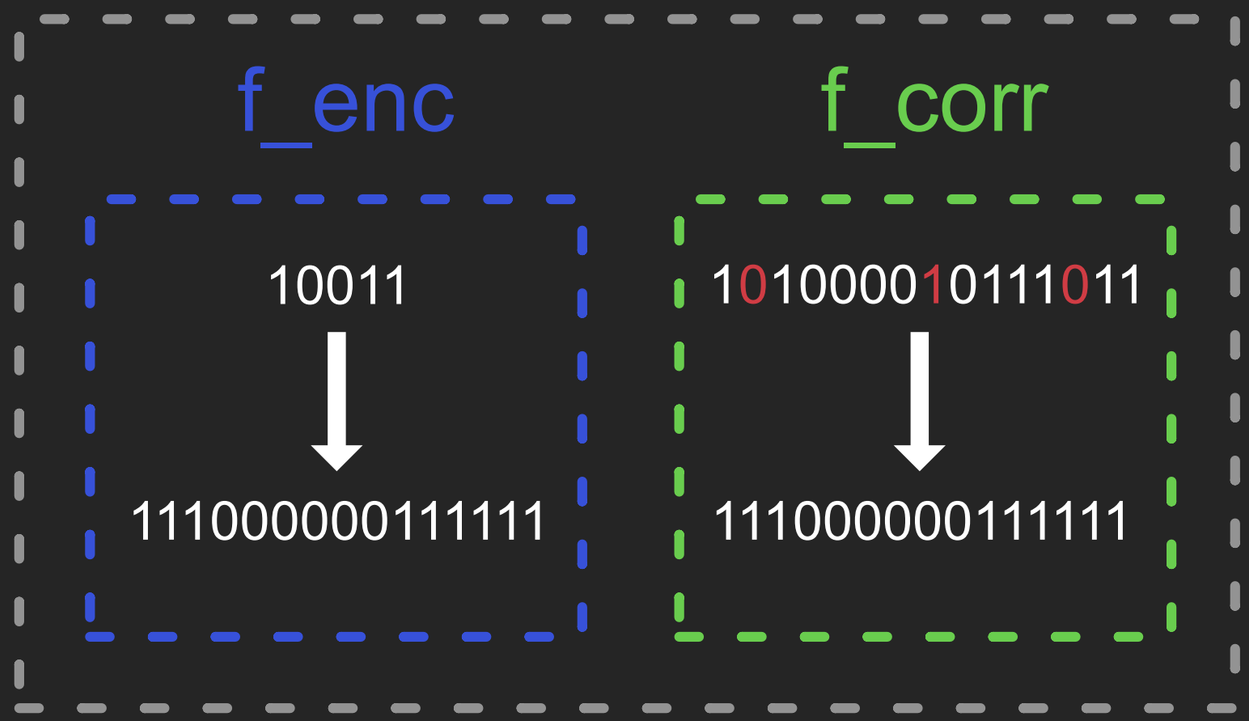
Impact and goals

Achieving a functional implementation of Hamming and Cyclic codes could prove useful for many reasons, from better communication between quantum computers to the possibility of making a realiable memory. Up until now there is no general Qiskit implementation of both codes, this could also provide new ideas in cryptography as well as in the area of optical signals.
The goal is also to study how effective both codes are when dealing with a high number of Qbits, using noise models to simulate the interaction with the enviroment.
Furthermore, with our code we‘ll likely be able to contribute toward Qiskit library.

Each E.C.C is made up of 2 functions:

f_enc takes an input message and makes it redundant

f_corr takes a compromised message and restores it



The Timeline

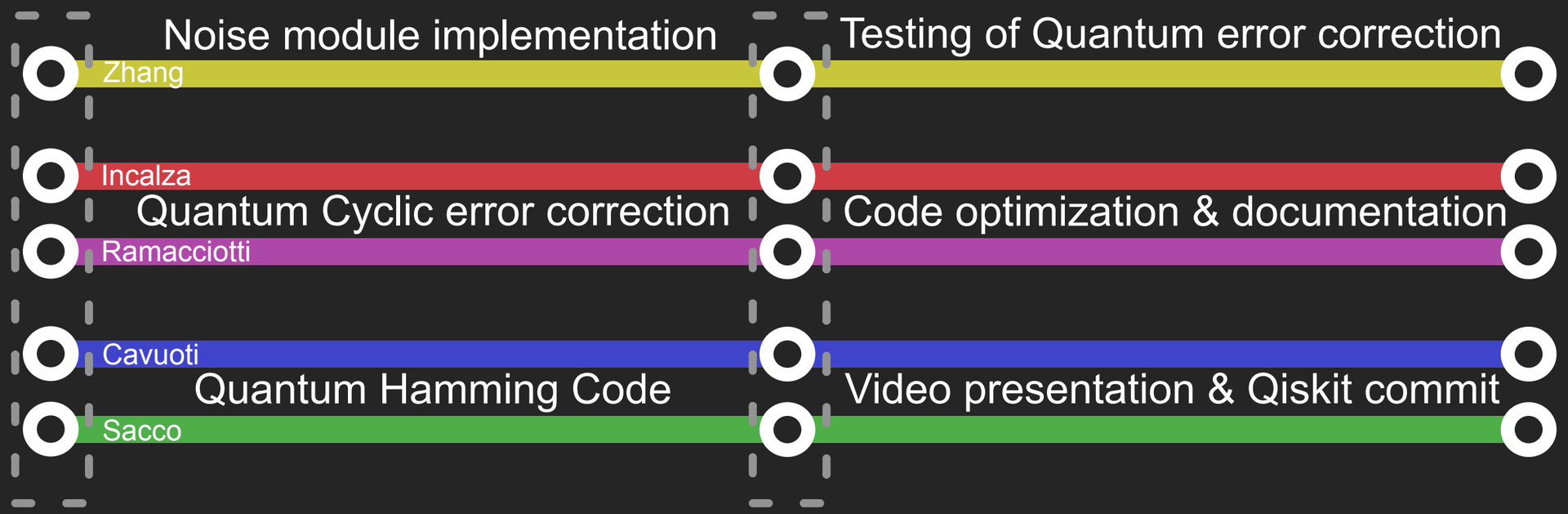
Each phase will take about two weeks

Phase 1

Writing both of the E.C.C. algorithms, each one based on two encoding/ decoding functions

Phase 2

Testing of the algorithms efficency and runtime, building of a noise model, study of decoherence of out states, optimization of the software



Team Skills:

Zhang: Quantum Chemistry and Qiskit
Incalza: Quantum Information and Theoretical Physics
Ramacciotti: Quantum Information and Quantum Computing
Cavuoti: Machine Learning and Data Science
Sacco: Machine Learning and Quantum Computing

Sources

- H.Naruma, B.K. Behera and P.K. Panigrahi, Designing a Quantum Hamming Code Generator, Detector and Error Corrector Using IBM Quantum Experience , 2020;
- M.Grassl and T.Beth, Cyclic Quantum Error-Correcting Codes and Quantum Shift Registers, 1999
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- Qiskit noise module: qiskit.providers.aer.noise