



Mestrado em Engenharia Física

Perfil em Física da Informação
Universidade do Minho

A crash course on quantum error correction

Bruno Coutinho

Bruno Coutinho obtained his PhD in 2016 and worked at the Instituto de Telecomunicações (IT) from 2016 to 2025 on quantum computation, communication, and error correction. He is currently a senior researcher at the German Aerospace Center (DLR), working on quantum error correction and the design of logical operations on qLDPC codes.

Course Plan

Lec 1 - Mon, 12 Oct, 11:00-13:00 (DI 0.05)

The three-qubit code, the Shor code, and the stabilizer formalism.

Lec 2 - Mon, 12 Oct, 16:00-18:00 (DI 0.08)

CSS construction, surface codes, degeneracy.

Lec 3 - Wed, 14 Oct, 9:00-11:00 (Ed1 1.22)

Brief description of fault tolerance, error models, and decoders.

Sem - Fri, 16 Oct, 14:00-16:00 (DI 0.09)

Seminar on recent topics in quantum error correction.

Abstract

This course provides an introduction to quantum error correction, starting with the first quantum error correcting codes, the three-qubit code and the Shor code, followed by the stabilizer formalism, which allows the construction of generic codes, such as the CSS construction, of which the surface code is an example. The module finishes with more advanced concepts in quantum error correction, such as fault tolerance, noise modeling, and the need for decoders.

Although formally planned as a module for the Quantum Computation Curricular Unit in the Physics Engineering MSc, this crash course is offered to all interested students and researchers at UMinho, INESC TEC, and INL.

Project (for Quantum Computation students only)

For Quantum Computation students, the module will be evaluated through a project consisting of a noise simulation of small codes and a comparison of different decoders, testing at least two different decoders through BLER curves and computational times. An essential part of the project is that students independently study the decoders they use: they are expected to select them, understand how they work, and explain both the decoders and the methodology used to simulate and compute the BLER curves. Preparation for the project will be done through individual one-hour sessions with each group to answer questions.

References

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Fowler, A. G., Mariantoni, M., Martinis, J. M., and Cleland, A. N., Surface codes: Towards practical large-scale quantum computation, Phys. Rev. A 86, 032324 (2012)

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Terhal, B. M., Quantum error correction for quantum memories, Rev. Mod. Phys. 87, 307 (2015)

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