Final project

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1 Work description

The fundamental objectives of this work are the analysis of quantum computing tools and the implementation of quantum programs, using techniques learned in the practical classes. The projects should be carried out in groups of two students. Each group may choose a topic from the list in Section 2, or propose one, and when applicable implement corresponding algorithms. Each group should write an essay on the topic chosen and when applicable a Qiskit script (or a script in another quantum programming language). The essay should preferably be in English and follow the structure of an article/experimental report

Each work should contain (and will be evaluated on) the following elements:

1. *Introduction* - each work should start by describing the problem to be addressed and any known quantum techniques/subroutines involved.

2. *Materials and methods* - for instance, any algorithm should be described rigorously, in mathematical terms.

3. *Implementation* - the work should provide a coded implementation of the algorithms or programs, with distinct examples when possible.

    - This element will be evaluated for code presentation and documentation. Points will be awarded for the implementation's ease-of-use and scalability.

4. *Results and discussion* - whenever applicable the implementation should be simulated and its results discussed.

    - Are the results as expected? If not, point to possible faults in the implementation, algorithm or hardware limitations.
    - What future work may be developed from the implementation?

2 Suggested topics

1. Quantum chemistry
2. Quantum machine learning
3. Quantum computing for finances
4. Measurement-based quantum computing
5. Quantum error correction (e.g. surface codes)
6. Variational methods
7. Game theory (e.g. Quantum Prisoner's Dilemma)
8. Quantum walks
9. Graph problem (e.g. graph colouring)
10. Optimisation problem (e.g. finding the best route in a map)
11. Compilation tools (e.g transpiling, optimising circuits)
12. Quantum programming languages (e.g. a survey on the existing languages, their strengths, their weaknesses, etc)

The following list of references may be used as inspiration:

- A Full Quantum Eigensolver for Quantum Chemistry Simulations
- Image Classification via Quantum Machine Learning
- Reinforcement Learning with Quantum Variational Circuits
- Dynamic portfolio optimization with real datasets using quantum processors and quantum-inspired tensor networks
- Quantum risk analysis
- Implementation of single-qubit measurement-based t-designs using IBM processors
- Scalable Quantum Circuit and Control for a Superconducting Surface Code
- Automated error correction in IBM quantum computer and explicit generalization
- Variational Quantum Circuits to Prepare Low Energy Symmetry States
- Solving diner's dilemma game, circuit implementation and verification on the IBM quantum simulator
- Checking and Coloring of Graphs Through Quantum Circuits: An IBM Quantum Experience
- Physical realization of topological quantum walks on IBM-Q and beyond
- Quantum Minimum Searching Algorithm and Circuit Implementation

3 Submission instructions and defence

Submit the **report and the jupyter notebook/scripts** until **Monday, January 16, 2023, at 23:59** to ana.i.neri@inesctec.pt.

You will have **15 min for your work defence**, this includes your presentation and questions. It will happen on **Friday, January 20, 2023**.

Any questions contact: ana.i.neri@inesctec.pt