Experimenting with Quantum Neural Networks

Project proposal

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1 Goals

One of the future trends in computation is the use of quantum computers. These machines will allow for a tremedous improvement in our capacity to solve specific types of problems. For instance, Shor's algorithm [7] can factorize prime numbers in polynomial time and Grover's algorithm [1] can search an unsorted database in $O(\sqrt{N})$ time.

Neural Networks (NNs) have emerged as the current top method in artificial intelligent systems, and are the central focus of deep learning where they are applied to solve many different problems with excellent results [2, 4, 5].

With this project we want to study the possibility of using quantum computation principles to build better NNs [6]: Quantum Neural Networks (QNNs). These QNNs can perform tasks that would require exponentially many resources if they were to be done on a conventional (non-quantum) computer [3].

We will study several examples of QNNs that can be used for regression and classification and implement new ones. As we don't have a quantum computer yet :-) , we will use a simulator to study the many possibilities that arise when considering QNNs.

2 Work plan

The project has the following tasks:

T1 Introduction to quantum computation (3 weeks).

T2 Study the quantum simulator and existing samples (3 weeks).

T3 Implement new code to run QNNs on new problems (7 weeks).

T4 Write the project's report (2 weeks).

3 Technical and Academic Requirements

Be able to program using Python on Linux, use a source code repository and produce documentation (using doxygen, sphinx or other similar tool).

It is desirable that the student has grades above 13 on the following courses: Estruturas de Dados, Probabilidades e Estatística, Inteligência Artificial.

4 Expected Results

- Source code and documentation of all code developed.
- Project report.

5 References

[1] L.K. Grover. A fast quantum mechanical algorithm for database search. In *Proceedings of the 28th Annual ACM Symposium on the Theory of Computation*, pages 212–219, 1996.

[2] Chetak Kandaswamy, Luís M. Silva, Luís A. Alexandre, and Jorge Santos. High-content analysis of breast cancer using single-cell deep transfer learning. *Journal of Biomolecular Screening*, 21(3), 2016.

[3] Nathan Killoran, Thomas R. Bromley, Juan Miguel Arrazola, Maria Schuld, Nicolás Quesada, and Seth Lloyd. Continuous-variable quantum neural networks. *arXiv e-prints*, page arXiv:1806.06871, June 2018.

[4] Jose Marques, Gabriel Falcao, and Luís A. Alexandre. Distributed learning of CNNs on heterogeneous CPU/GPU architectures. *Applied Artificial Intelligence*, 32(9-10):822–844, 2018.

[5] Ana C. Perre, Luís A. Alexandre, and Luís C. Freire. Lesion classification in mammograms using convolutional neural networks and transfer learning. *Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization*, 0(0):1–7, 2018.

[6] M. Schuld, I. Sinayskiy, and F. Petruccione. The quest for a quantum neural network. *Quantum Inf Process*, 13(11):2567–2586, 2014.

[7] P.W. Shor. Polynomial-time algorithm for prime factorization and discrete logarithms on a quantum computer. *SIAM Journal on Computing*, 1997.

[8] Abel Zacarias and Luís A. Alexandre. Application of lifelong learning with CNNs to visual robotic classification tasks. In *24th Portuguese Conference on Pattern Recognition, RECPAD 2018*, Coimbra, Portugal, October 2018.