Ph.D. in Information Technology
Thesis Defense

December 19th, 2025
at 11:30
Seminar Room "Alessandra Alario" – building 21

Costantino CARUGNO – XXXVI Cycle

Evaluating challenges and prospects of quantum annealing in selected applications

Supervisor: Prof. Paolo Cremonesi

Abstract:

Quantum annealers are specialized devices designed to solve optimization problems by leveraging quantum effects. In this thesis, we first investigate the capabilities of current hardware on standard real-world problem formulations, addressing the complex translation into Quadratic Unconstrained Binary Optimization (QUBO) models. It explores technical hurdles such as limited qubit counts, sparse connectivity, noise, and the heuristic nature of hardware embedding. To address identified limitations, we subsequently propose novel problem reformulations and encoding strategies. Finally, we explore hybrid quantum-classical architectures, combining both paradigms to mitigate topological and size constraints. These methodologies are validated through experiments on job shop scheduling, linear regression, and community detection benchmarks.

Riccardo NEMBRINI – XXXVI Cycle

Developing the Synergies Between Quantum Annealing and Machine Learning

Supervisor: Prof. Paolo Cremonesi

Abstract:

Quantum Computing has attracted increasing interest in recent years due to its potential for addressing problems that are difficult to solve with classical methods. Among the available technologies, Quantum Annealing provides a way to approach optimization problems by exploiting the physical evolution of a quantum system towards a low-energy state. While current hardware remains limited by noise and connectivity constraints, access to quantum annealers has become more widespread, enabling experimentation on practical tasks. Therefore, this thesis explores possible synergies between current Quantum Annealing and Machine Learning, in both directions. First, Quantum Annealing is applied to tasks commonly found in the Machine Learning field, such as Community Detection for recommendation and Feature Selection for recommendation, classification and ranking. These problems are reformulated for the quantum hardware, and the effectiveness of these approaches is evaluated through empirical studies. The formulation is versatile enough to represent both established and specifically designed problems. Quantum Annealing proves to be applicable to problems of around a hundred variables, requiring hybrid solutions for larger ones. Results are comparable or better than classical methods, but some drawbacks such as latency and problem programming time still remain. Then, Machine Learning methods are used to address limitations in the use of Quantum Annealing. A Reinforcement Learning model is developed to tackle the process of Minor Embedding, a necessary step for programming problems on current quantum annealers. Both feed-forward and graph-based neural network models are trained for this purpose, and their performance is analysed. Results show that a learning-based approach is feasible, and applying the right architectural and training choices also makes it more effective. The overall goal of this thesis is thus to evaluate the applicability of current Quantum Annealing hardware to Machine Learning problems and to explore how Machine Learning techniques can assist in improving Quantum Annealing workflows, paving the way for novel research and improvements on both fronts.

PhD Committee

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