ARTIFICIAL INTELLIGENCE

DM 630/Fondazione Links - Leveraging Quantum Machine Learning and Error Correction in Quantum Computing with novel technological platforms

Funded By	FONDAZIONE LINKS - LEADING INNOVATION & KNOWLEDGE FOR SOCIETY [P.iva/CF:11904960017] MINISTERO DELL'UNIVERSITA' E DELLA RICERCA [P.iva/CF:97429780584] Politecnico di TORINO [P.iva/CF:00518460019]

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Context of the research activity	Complex Computational Systems needed for AI require reliable and efficient technologies and architectures. Quantum Machine Learning (QML) algorithms based on matrices of qubis are an advantageous solution provided that reliable Error Correction methods based on physical qubits models and their architectures and control systems are adopted. A new methodology focused on E.C algorithms, control methods, physical models and hardware acceleration platforms will be explored for neutral atoms, trapped ions, solid state and superconducting quantum technologies. Progetto finanziato dal PNRR a valere sul DM 630/2024 - CUP: E14D24002330004

	The research program places emphasis on development and innovation in the field of AI models applied to quantum computers, in particular in the domain of Quantum Machine Learning (QML), underlining the crucial importance of error correction for technological progress and the practical applicability of these methods. The approach adopted involves the use of cutting-edge error correction methods, such as Steane codes and surface codes, which have proven to be fundamental for integrating logical qubits into concrete QML applications and algorithms, such as Quantum Neural Networks and Quantum Support Vector Machines among others. In terms of technological platforms, the most significant advances in this field are research involving neutral atoms, solid state, superconducting

Objectives	technologies and trapped ions, characterized by the use of techniques such as mid-circuit measurements and syndrome extraction. Furthermore, it also offers a specific focus on the development of algorithms implemented on FPGAs (Field-Programmable Gate Arrays). This direction not only facilitates the rapid prototyping and flexibility required in quantum, but also promotes the integration of advanced physics simulations and specialized manufacturing techniques, both of which are expected to produce substantial innovations in the creation of quantum hardware. These tools not only improve prototyping and device manufacturing, but also contribute to the creation of hybrid solutions that tightly integrates classical and quantum elements, optimizing the performance and effectiveness of error corrected QML algorithms for scientific and industrial uses. In fact, the underlying technologies heavily affect the implementation requirements of these methodologies, representing an emerging field of study of crucial importance for the practical application of quantum algorithms. An attention to the development of practical experiments based on platforms available through collaborations or blocks to be fabricated and characterized and controlled via the developed QML algorithms on available technologies will give value to the whole project. This strategically integrated orientation highlights the transformative potential of advanced electronics in shaping the future of quantum computing and AI in general.

Skills and competencies for the development of the activity	Understanding of the fundamental principles of physics and quantum mechanics. Knowledge of AI models and applications. Experience with FPGAs (Field-Programmable Gate Arrays). Ability to design and develop electronic circuits. Experience with programming languages relevant to quantum computing, such as Python, C, C++, Qiskit. Experience integrating advanced physics simulations. Knowledge of manufacturing and characterization techniques. Experience in working in research projects. Skill in data analysis and interpretation of experimental results. Ability to work in multidisciplinary teams. Ability to solve complex problems and develop innovative solutions. Critical and analytical thinking skills. Skill in writing scientific reports and papers and presenting research results.