Politecnico di Torino

COMPUTER AND CONTROL ENGINEERING

DAUIN - Algorithms and methods for bridging the gap between NISQ and fault tolerant quantum computing

Funded By	Dipartimento DAUIN
Supervisor	MONTRUCCHIO BARTOLOMEO - bartolomeo.montrucchio@polito.it
Contact	SONZA REORDA MATTEO - matteo.sonzareorda@polito.it MONTRUCCHIO BARTOLOMEO - bartolomeo.montrucchio@polito.it
Context of the research activity	Actual quantum computers are in the Noisy Intermediate Scale Quantum phase. New fault tolerant computers are on the horizon, and in 2025 in PoliTO the first industrial full stack quantum computer in Italy has been bought, from IQM. The main target will be the analysis and development of new algorithms for bridging the gap between NISQ and early fault tolerant quantum computers. Satisfiability (SAT) in Electronic Design Automation (EDA) will be an important example.
	Being a totally new paradigm, quantum computing is going to be a challenge for engineers, who would have not only to re-implement classical algorithms in a quantum way, but also explore uncharted paths of the new way of representing and elaborating information and its processing. In the last years, QC companies and research institutes have come up with different software stacks, appealing to a wide spectrum of possible users, from Machine Learning to Optimization to Material simulation. However actual QCs have to be considered NISQ and not really fault tolerant computers. Analysis and possibly development of new algorithms to cover the gap between NISQ and early fault tolerant quantum computers (FTQC) will therefore be the final research objective of this research activity. Satisfiability (SAT) in Electronic Design Automation (EDA) will be a first important example, since efficient quantum based solutions can be performed. Industrial applications will be seen with particular attention, since industries will be the first to be involved in QC revolution. In particular, domains like finance, chemistry, combinatorial optimization (QUBO) as well as image processing techniques are of particular interest.

Objectives	Since QC has a very fast evolution, the most interesting research problems will be identified together among the cited domains, also including new domains that could become relevant during the PhD period. The work plan is structured in the three years of the Ph.D. program: 1 - in the first year the Ph.D. student should improve his/her knowledge of quantum computing and technology, in particular since quantum mechanics and quantum computing are not usually seen in the previous curriculum; he/she should also follow in the first year most of the required courses in Politecnico. At least one or two conference papers will be submitted during the first year. The conference works will be presented by the Ph.D. student and they will be carried out based on the preliminary study of algorithms working on envisioned platforms. 2 - In the second year the work will be both on designing and implementing new algorithms and on preparing a first work for a journal, together with another conference. Interdisciplinary aspects will be also considered. Teaching credits will be also finalized. 3 - In the third year, the work will be completed with at least a publication in a selected journal summarizing the results of the implementation of the algorithms on platforms and technologies that will be selected as the most promising. The participation to the preparation of proposals for funded projects will be taken in consideration. The target publications will be main conferences and journals related to quantum computing, if possible. Since at the moment there are only a very few of them in the computing engineering field, the choice will be done selecting, if possible, those linked to IEEE and ACM, that already started publishing specifically on QC. An example could be the IEEE Quantum Week (QCE). It is important to note that interdisciplinary aspects will be considered as fundamental, since QC is now very useful for solving problems that can come from many research fields. Several projects with companies have been funded in the previous years, e.g. with TIM, and also European projects (EQUO and QUBIP). Collaboration with Fondazione Links will be important for this research work.

Skills and competencies for the development of the activity	The Ph.D. candidate will be required to use a strong interdisciplinary approach for working on different applications and on methods for error correction/detection and/or noise resilient algorithms. Since the QC landscape is in continuous evolution thanks to hardware improvements, the Ph.D. student should be able to quickly adapt to these changes, carefully studying and comparing APIs for a certain application domain. Knowledge of Python and quantum mechanics is useful, but not mandatory.