



PhD in INGEGNERIA DELL'INFORMAZIONE / INFORMATION TECHNOLOGY - 38th cycle

Research Area n. 1 - Computer Science and Engineering

**PARTENARIATO PNRR Research Field: SOFTWARE ENGINEERING FOR CLOUD
COMPUTING**

Monthly net income of PhDscholarship (max 36 months)

€ 1400.0

In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity

**Motivation and objectives of the research
in this field**

This research project is in the framework of
CENTRO NAZIONALE PER HPC, BIG DATA E
QUANTUM COMPUTING
CUP D43C22001240001
Decreto di Concessione D.D. 1031 del 17/06/2022

Quantum computing is reaching significant and promising advancements and represents one of the ground-breaking initiatives that are expected to change the way we conceive programming today. However, the research on quantum computing today is still focusing mostly on addressing technical problems at the physical and hardware level. For instance, an important issue that is being considered is how to deal with interferences in the hardware that cause significant noise in the results obtained by a quantum computer. Programming a quantum computer still means combining low level quantum logic gates in a quantum circuit or formulating a problem in terms of a specific mathematical structure. A crucial issue from the software engineering standpoint is the identification of effective design and programming abstractions that allow people skilled in computer science to take advantage of the enormous power of quantum computing still keeping the complexity of design and



	<p>programming activities under control and enabling analysis and testing of the developed code. The objective of this PhD work is to provide a contribution in this context. The work will start with a systematic analysis of the state of the art. It will then proceed with the development of various classes of algorithms using the two low level programming models currently proposed in the quantum computing context, the gate model and the quantum annealing model (preliminary experiments have been developed by the research group and published in [Piro 2020, Olivieri 2021 and Piro 2021]). This will allow us to compare the two approaches, to identify commonalities and differences and to define some preliminary design abstractions. The extensive validation and refinement of the defined abstractions will be the focus of the core part of the work. To start addressing the problem of how to validate quantum software, the usage of model-checking techniques will be experimented.</p> <p>[Piro 2020] Francesco Piro, Mehrnoosh Askarpour, Elisabetta Di Nitto. Generalizing an Exactly-1 SAT Solver for Arbitrary Numbers of Variables, Clauses, and K. In the proceedings of 1st Quantum Software Engineering and Technology Workshop 2020 http://ceur-ws.org/Vol-2705/paper1.pdf</p> <p>[Olivieri 2021] Pierriccardo Olivieri, Mehrnoosh Askarpour, Elisabetta di Nitto. Experimental Implementation of Discrete Time Quantum Walk with the IBM Qiskit Library. 2021 IEEE/ACM 2nd International Workshop on Quantum Software Engineering (Q-SE), 2021. https://ieeexplore.ieee.org/document/9474567</p> <p>[Piro 2021] Francesco Piro. Applying quantum annealing to an extension of the Traveling Salesperson Problem: implementation and resulting methodology. Master Thesis Politecnico di Milano, Dec 2021.</p>
<p>Methods and techniques that will be developed and used to carry out the research</p>	<p>The work will be highly experimental and will include:</p> <ul style="list-style-type: none"> •the development of programming examples to derive lessons learnt; •the definition of proper abstractions and their validation in multiple cases to demonstrate their generality; •the implementation of development and verification



	frameworks to support quantum computing programmers; The research will be mainly carried out at Politecnico di Milano, but visits to other internationally recognized research centers will be pursued.
Educational objectives	<ul style="list-style-type: none"> • Learn about the research methods (both sperimental and theoretical) adopted in software engineering • Learn about quantum computing • Advance the state of the art on approaches to simplify the development of quantum computing programs and to increase their quality • Learn how to conduct a case study-based evaluation • Learn how to write scientific papers in the area of software engineering
Job opportunities	Considering the significant interest quantum computing is raising and the need to have people able to develop software according to this paradigm, we expect PhD graduates in this area to be very successful in finding multiple job opportunities both in industry and academia
Composition of the research group	8 Full Professors 3 Associated Professors 2 Assistant Professors 12 PhD Students
Name of the research directors	Elisabetta Di Nitto

Contacts
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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6



Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information

EDUCATIONAL ACTIVITIES (purchase of study books and material, including computers, funding for participation in courses, summer schools, workshops and conferences): financial aid per PhD student
5.707,13 Euro

TEACHING ASSISTANTSHIP: (availability of funding in recognition of supporting teaching activities by the PhD student)

There are various forms of financial aid for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.

COMPUTER AVAILABILITY: individual use

DESK AVAILABILITY: individual use

D. D. 3138 del 16/12/2021 rettificato con D.D. 3175 del 18/12/2021 "Avviso pubblico per presentazione Proposte di intervento per il Potenziamento di strutture di ricerca e creazione di "campioni nazionali" di R&S su alcune Key Enabling Technologies da finanziare nell'ambito del Piano Nazionale di Ripresa e Resilienza, Missione 4 Componente 2 Investimento 1.4 "Potenziamento strutture di ricerca e creazione di "campioni nazionali di R&S" su alcune Key Enabling Technologies" finanziato dall'Unione europea - NextGenerationEU"