PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Alessandro Di Bernardo

Cycle: XXXVII

Training and Research Activities Report

Academic year: 2022-2023 - PhD Year: Second

Tutor: prof. Leopoldo Angrisani

Co-Tutor: prof. Egidio De Benedetto

Date: October 23, 2023

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle: **Author:**

1. Information:

- **PhD student:** Alessandro Di Bernardo **PhD Cycle:** XXXVII
- **DR number:** 995867
- **Date of birth:** 03/03/1996
- **Master Science degree:** Biomedical Engineering (bionic and biorobotic field)
  University: Università degli studi di Napoli Federico II
- **Scholarship type:** no scholarship
- **Tutor: prof.** Leopoldo Angrisani
- **Co-tutor: prof.** Egidio De Benedetto

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Data mining the output of quantum simulators – from critical behavior to algorithmic complexity	Seminar	1	0.2	11/11/22	Marcello Dalmonte	Y
Crash course on data excellence – parte 1	Seminar	1.5	0.3	14/11/22	Giuseppe Longo	Y
Automated Offensive Security: Intelligence is all you need	Seminar	1.5	0.3	28/11/22	Giuseppe Longo	Y
Durability of Fuel Cell Systems	Seminar	1.5	0.3	30/11/22	Elodie Pahon	Y
Muscle-based Human-Machine Interfaces	Course	13	2.6	06/12/22	Daniele Esposito	Y
Open digital framework-crash course	Seminar	3	0.6	17/01/23	Alessandra Baldi	Y
ITIL-Crash course	Seminar	3	0.6	24/01/23	Alessandra Baldi	Y
Blockchain and 5G in business	Seminar	3	0.6	13/02/23	Alessandra Baldi	Y
Analysis and control of functional brain networks	Seminar	1	0.2	09/03/23	Simone Mancini, Giacomo Ascione, Francesco Bajardi	Y
The state of the art of AI and Physics-Based Simulations in drug discovery	Seminar	1	0.2	17/03/23	Michele Ceccarelli	Y

Learning gene association networks using single-cell RNA-seq data: a graphical approach	Seminar	1.5	0.3	31/03/23	Michele Ceccarelli	Y
Crash course on data excellence – part III	Seminar	1	0.2	22/05/23	Giuseppe Longo	Y
Symbiotic Control of Wearable Soft Suits for human motion assistance and augmentation	Seminar	2	0.4	26/05/23	Fanny Ficuciello	Y
Quantum communications with continuous variables of light	Seminar	1.5	0.3	20/06/23	Angela Sara Cacciapuoti	Y
Exploring Advanced Aerial Robotics: A Journey into Cutting-Edge Projects and Neural Control	Seminar	1	0.2	29/06/23	Julien Mellet	Y
Using Deep Learning Properly	Course	10	4	13/07/23	Andrea Apicella	Y
Big Data Architecture and Analysis	Course	20	5	26/07/23	Giancarlo Sperlì	Y
Fondi Europei e programmazione 2021/2027	Seminar	2	0.4	14/09/23	Sara Di Cunzolo	Y
Panoramica delle opportunità di finanziamento	Seminar	3	0.6	28/09/23	Sara Di Cunzolo	Y
Tecniche e metodi per la redazione dei progetti – 1^ modulo	Seminar	3	0.6	12/10/23	Sara Di Cunzolo	Y

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	**2.6**	**1.1**	**8**		**11.7**
Bimonth 2		**1.8**	**8**		**9.8**
Bimonth 3		**0.7**	**8**		**8.7**
Bimonth 4		**1.1**	**8**		**9.1**
Bimonth 5	**9**		**7**		**16**
Bimonth 6		**1.6**	**6**		**7.6**
Total	**11.6**	**6.3**	**45**	**0**	**62.9**

Expected	**10 - 20**	**5 - 10**	**30 - 45**	**0 – 1.6**	

3. Research activity:

After the introduction of concepts related to the field of quantum technology, the research went on to deepen the various facets both hardware and software. In more detail, an analysis was carried out in terms of communication, simulation, sensing, imaging and control, elements that are of great interest. All these elements were considered to define a prototype of quantum applications on Cyber Physical Measurement System (CPMS) systems [1], in order to exploit the potential of quantum technology.

In detail, given a real system (infrastructure, vehicles, building, people), measurements are taken through quantum sensors and then processed and provided as input to a quantum artificial intelligence system based on Quantum Machine Learning (QML). This system will provide a decision output that can improve and manage the CPMS system.

The second year of research was focused on the development of the skills needed to implement the prototype, starting from a set of available data from the EEG signals research team, the goal was the integration of an artificial intelligence solution based on quantum computing techniques.
This year, a collaboration was born between the research teams of Prof. Giuseppe Acampora and Leopoldo Angrisani, with the aim, starting from the same dataset, to compare the efficiency and effectiveness of today's machine learning system with a quantum one. This required a processing of the EEG signals so that could be used by both AI systems and allow a peer comparison.
The data set consists of data acquired by Brain Computer Interface (BCI) [2] systems collected by electrodes placed on the scalp. EEG signals are related to a series of visual stimuli to which the subject is exposed, using augmented reality tools [3]. Once captured, the signal is sampled, filtered and the spectral power density is calculated. All the collected power spectral densities are then divided according to the frequency of the light stimulus and each of them is defined as class 1 or 0 based on whether the subject observes one stimulus instead of another.

The acquisition time of the EEG signal lasts 10 seconds, in the study [4] it is observed that in the calculation of the spectral power density given the indirect proportionality, when the time window for signal acquisition is reduced, there is a loss of information resulting in a reduction in accuracy for the traditional machine learning system. It is highlighted by considering the accuracy values which is 98.9% with an acquisition window of 10 seconds and is reduced to 81% with a window of 2 seconds. From this consideration we are analyzing the possibility of improving the accuracy with a lower EEG signal acquisition time through the Quantum Machine Learning.
Starting from the same experimental setup, the goal is to derive a series of similar kernels between classic ML case and quantum case in order to compare them equally, moreover the experiment will be replicated on the different time windows of the EEG signal.
The comparison will then be enhanced from a statistical point of view, giving greater attention to the accuracy and training time of the system.

New pre-processing techniques and the introduction of new programming techniques were explored during the year. Referring to the latter was deepened the language Q#, a high-level language with special

libraries and a cloud platform, made available by Microsoft. Microsoft's in-depth tools are: Azure Quantum and Quantum Development Kit [5].

[1] *Angrisani, Leopoldo, et al. "A ML-based Approach to Enhance Metrological Performance of Wearable Brain-Computer Interfaces." 2022 IEEE International Instrumentation and Measurement Technology Conference (I2MTC). IEEE, 2022.*

[2] *Arpaia, Pasquale, et al. "Metrological characterization of consumer-grade equipment for wearable brain–computer interfaces and extended reality." IEEE Transactions on Instrumentation and Measurement 71 (2021): 1-9.*

[3] *Cultrera, Alessandro, et al. "Smart Glasses for Visually Evoked Potential Applications: Characterisation of the Optical Output for Different Display Technologies." Engineering Proceedings 10.1 (2021): 33.*

[4] *Arpaia, Pasquale, et al. "Metrological characterization of a low-cost electroencephalograph for wearable neural interfaces in industry 4.0 applications." 2021 IEEE International Workshop on Metrology for Industry 4.0 & IoT (MetroInd4. 0&IoT). IEEE, 2021.*

[5] *https://azure.microsoft.com/it-it/products/quantum/*

4. Research products:

PROTOTYPES:

An artificial intelligence (AI) system based on Quantum Machine Learning (QML) techniques is ongoing implemented. Specifically, a Machine Learning model is being compared with a QML model showing the main differences.

The dataset used for this prototype consists of EEG signals that have been managed according to technical requirements.

This activity is in collaboration with the research team of prof. Giovanni Acampora.

5. Conferences and seminars attended

None.

6. Periods abroad and/or in international research institutions

None.

7. Tutorship

20/02/23: Lesson for Quantum Computing Academy
Title: "*Quantum Technology in metrology field and Quantum Computing*"

8. Plan for year three

The research for next year will focus on the study of QML in terms of implementation from a coding point of view, focusing on the analysis of the main libraries, kernels, languages, techniques, quantum optimizers

and simulators that can allow the use in a pragmatic way and exploit the potential of quantum computing techniques to the state of the art.

This study will continue in practical terms with the continuous prototype that is being worked on in collaboration with the research team of Prof. Acampora, which aims to find the conjunction of quantum computing in the context of measurement.

In fact, as the final output of the thesis work of the doctorate, the aim is to tell at first the importance of quantum technology in the measurement context and then deepen the implementation aspect on CPMS systems. The main focus will be on the use of big data (of various nature linked to a physical system) collected that manipulated with quantum computing techniques can provide a detailed representation and implement an artificial intelligence within the physical system.