UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

itee PhD information technology electrical engineering

DIETI UNINA

PhD student Alessandro Di Bernardo

# Exploring the potential of Quantum Machine Learning to improve analysis and classification of EEG signals: a comparative study with Machine Learning

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co-Tutor: Prof. Egidio De Benedetto

itee PhD information technology electrical engineering

Cycle: XXXVII

Year: Third

# Background information

- MSc in **Biomedical Engineering**
- Research group: Electric and Electronic Measurements, CeSMA
- PhD started on **1/11/2021** – ended **31/10/2024**
- Scholarship type: **without scholarship**

# Summary of study activities

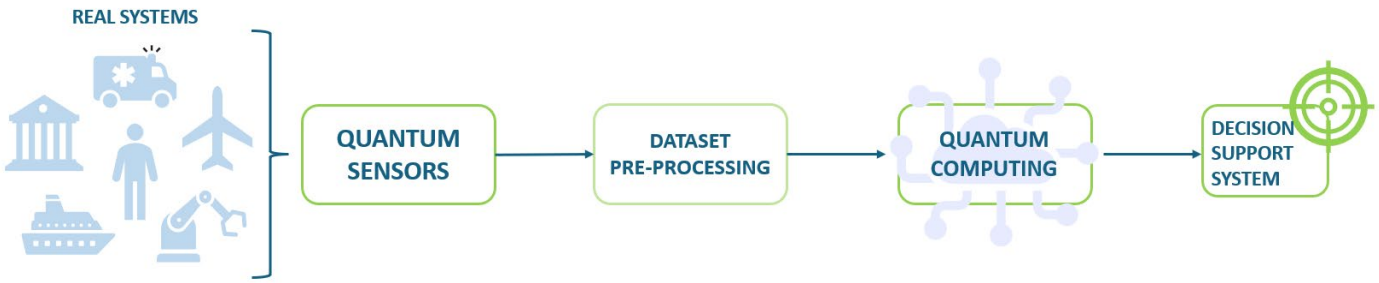
- **8 Courses**. Topics covered include concepts of: virtualisation technologies, statistics, data science, Machine and Deep Learning, Big Data.

- **50 Seminars**. The topics of discussion cover a variety of topics, the most important of which relate to: AI, quantum algorithms, diagnostic techniques in healtcare, data minning.

- **2 Main Conferences**.
  - Quantum horizons for industry. Florence, May 2022.
  - IEEE Metrology for eXtended Reality, Artificial Intelligence and Neural Engineering. St Albans, London, UK, Oct. 2024

# Research area

- The research focuses on a branch of quantum computing, namely **Quantum Machine Learning** (QML).
- A proposal was defined on which to focus research efforts:




- Prior knowledge on AI defined a comparison from a case study between Machine Learning (ML) and QML.
- Development of a QML algorithm based on a dataset of **EEG signals**.

# Research results

- The results obtained from the developed QML algorithm provided an insight into the state of the art in this area of quantum technology research for this particular application context relating to a dataset of EEG signals.
- It was found that for this application, *ML offers better performance in terms of classification accuracy in decision support*, highlighting the technical limitations of QML.

# Research products

| | |
|---|---|
| [J1] | P. Arpaia, U. Bracale, F. Corcione, E. De Benedetto, **A. Di Bernardo**, V. Di Capua, L. Duraccio, R. Peltrini, R. Prevete,<br>*Assessment of blood perfusion quality in laparoscopic colorectal surgery by means of Machine Learning,*<br>**International Journal of Nature, scientific reports,**<br>Scientific Reports, 2022, 12.1: 14682. |
| [C2] | L. Angrisani, E. De Benedetto, **A. Di Bernardo**, R. Prevete, A. Tedesco,<br>*A Comparative Analysis Between Quantum Machine Learning and Machine Learning on EEG Dataset,*<br>**International Conference IEEE on Metrology for eXtended Reality, Artificial Intelligence and Neural Engineering,**<br>St Albans, London, UK, Oct. 2024, IEEE. |
| [C3] | R. De Santis, A. Fresa, P. Calzone, G. Guida, A. Panza, F. Adinolfi, M. Imbò, **A. Di Bernardo**, R. Sibilia,<br>*Blockchain in Healthcare: Building a Secure Foundation for Digital Medicine,,*<br>**Conference on I-CITIES 2024, ICT for smart cities,**<br>Messina, Italy, Sept. 2024, https://icities24.unime.it/papers/9.pdf. |
| [J4] | L. Angrisani, E. De Benedetto, A. Di Bernardo, R. Prevete,<br>*Quantum Machine Learning compared withMachine Learning application on EEG Dataset*,<br>Under preparation. |

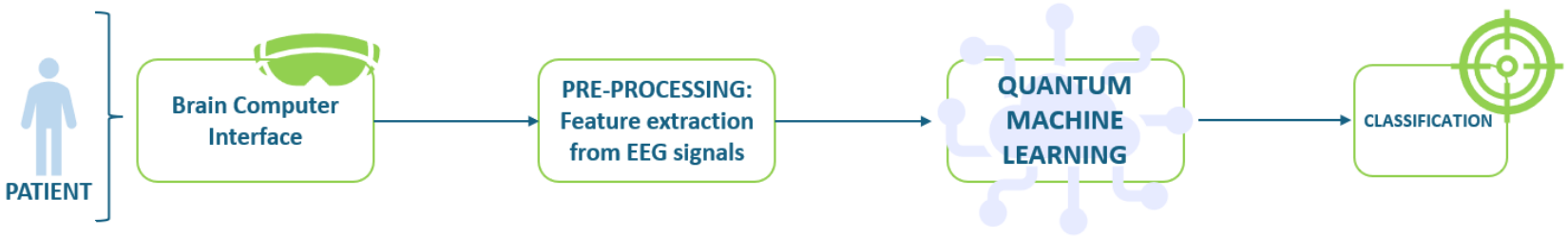
# Research products

- Development of algorithms for quantum machine learning applications with frameworks/languages: **Q#** Microsoft, **Qiskit** IBM.

- **Code development of a QSVC** (Quantum Support Vector Classifier) quantum machine learning algorithm to perform classifications on a dataset of EEG signals.

# PhD thesis overview

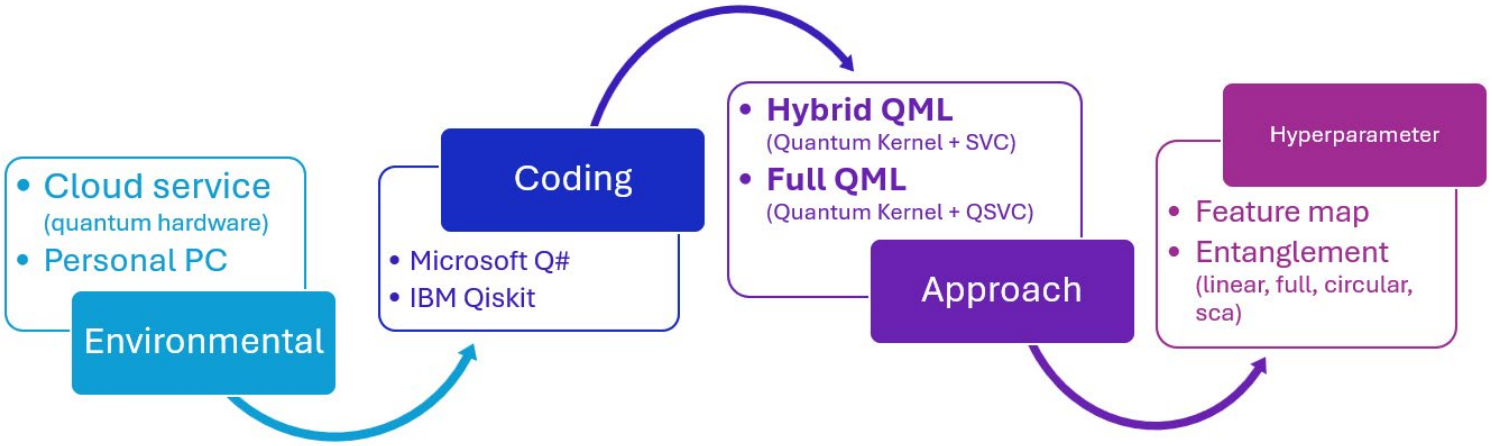
The proposal on the previous slide focused on a specific application related to Brain Computer Interfaces (**BCI**) and the classification of **EEG** signals obtained from these systems using a **QML** algorithm.




In this comparison between ML and QML, with the same dataset, the aim is to identify limitations and advantages of QML, including *problems with the generalisation of quantum algorithms*.

# PhD thesis: introduction

Taking a private dataset [1], it is defined a QML classifier  through a series of decision steps:



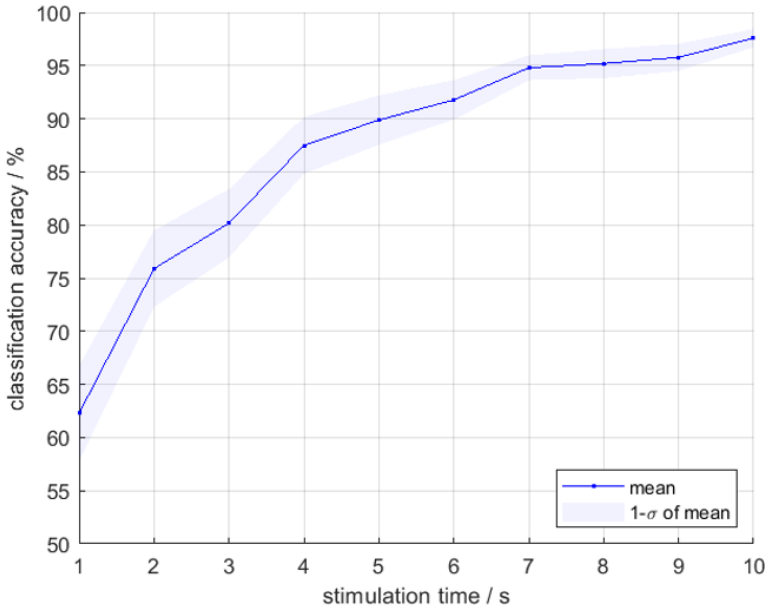



[1] Angrisani L., Arpaia P., Esposito A. and Moccaldi, N., 2019. A wearable brain–computer interface instrument for augmented reality-based inspection in industry 4.0. IEEE Transactions on Instrumentation and Measurement.

# PhD thesis: methodology

The different implementation solutions of artificial intelligence on the EEG signal dataset, two quantum approaches have been identified: the hybrid and the full quantum approach.

# PhD thesis: results



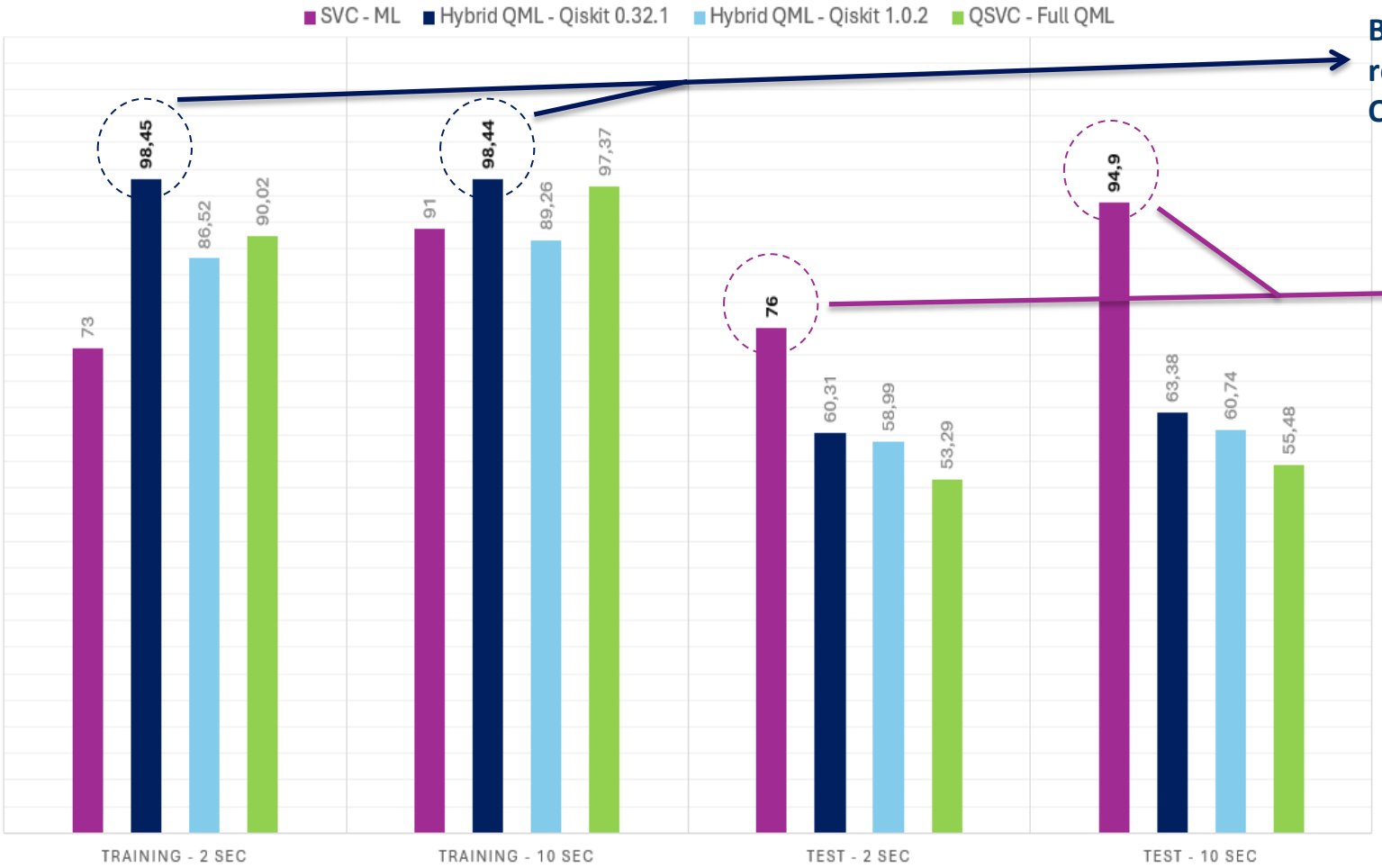

From the results obtained in the case of ML with a classical Support Vector Classifier (SVC), it can be seen from the graph that the classification accuracy increases as the EEG signal acquisition window increases.

# PhD thesis: results

The analysis was chosen for the 2-second and 10-second window. Comparing the results for training and testing in the cases of:

- **SVC**, Machine Learning
- **Hybrid** Quantum Machine Learning with **Qiskit 0.32.1**
- **Hybrid** Quantum Machine Learning with **Qiskit 1.0.2**
- **QSVC**, Full Quantum Machine Learning

# PhD thesis: results

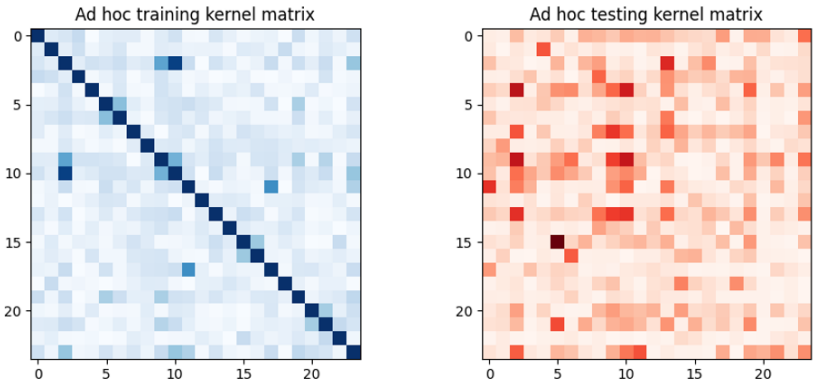



**Best training results: Hybrid QML – Qiskit 0.32.1**

**Best test results: ML**

# PhD thesis: conclusion

The results show that all quantum approaches are affected by the ***problem of overfitting***. Analysing the matrix of the quantum kernel calculation shows the difficulty of generalisation in testing phase.




This highlights that QML does not perform better than ML to date, one of the causes of overfitting for QML:

- quantum noise
- model complexity
- limited dataset

# Thanks for the attention