SCUOLA NORMALE SUPERIORE

RELAZIONE ATTIVITA' ANNUALE DEI PERFEZIONANDI/DOTTORANDI – TERZO/QUARTO ANNO
REPORT ON THE PHD ACTIVITY – THIRD/FORTH YEAR

NOME E COGNOME NAME AND SURNAME	Marco Fanizza
DISCIPLINA PHD COURSE	Nanosciences

CORSI FREQUENTATI CON SOSTENIMENTO DI ESAME FINALE ATTENDED COURSES (WITH FINAL EXAM)	VOTAZIONE RIPORTATA MARK	NUMERO DI ORE HOURS

CORSI FREQUENTATI SENZA SOSTENIMENTO DI ESAME FINALE ATTENDED COURSES (ATTENDANCE ONLY)	NUMERO DI ORE HOURS

ALTRE ATTIVITÀ FORMATIVE (SEMINARI, WORKSHOP, SCUOLE ESTIVE, ECC.) – DESCRIZIONE OTHER PHD ORIENTED ACTIVITIES (SEMINARS, WORKSHOPS, SUMMER SCHOOLS, ETC) – DESCRIPTION	NUMERO DI ORE HOURS
Quantum Techniques in Machine Learning 2019, 20-24 October	20
Mathematical and computational aspects of machine learning, workshop at SNS, 7- 11 October 2019	30
Quantum Information Processing 2020, Shenzhen (conference)	32

SCUOLA
NORMALE
SUPERIORE

Theory of Quantum Computation, Communication and Cryptography 2020, online (conference),	20
International Symposium on Information Theory 2020, online (conference), 21-26 July	r e c o r d e d sessions

SCUOLA
NORMALE
SUPERIORE

ATTIVITÀ DI RICERCA SVOLTA (MAX. 8.000 CARATTERI)*
RESEARCH ACTIVITY (MAX. 8000 CHARACTERS)

My research activity has explored different theoretical problems in the context of quantum statistical inference, with two main focuses: learning properties of quantum states and communicating with quantum systems in presence of noise.

The first topic deals with the problem of understanding how to measure copies of an unknown state in order to learn the desired property using the least amount of copies. The critical difference with inference in classical probability is that in the quantum case the measurement has to be carefully chosen. In this context, during my first two years of PhD I worked on two fundamental problems:

1) Characterize optimal learning machine for quantum state discrimination, which is a quantum generalization of supervised learning, and evaluate the scaling of the error probability with the size of the learning set.
2) Characterize the optimal measurement for learning the overlap between two unknown pure states, evaluating the optimal mean square error.

During this year I have worked on two other problems in this area, for which I have partial results. The first is extending the results of 2) to general distances between mixed states, and to testing identity between collections of distributions. The second is about finding sufficient conditions for efficient testing of membership to a set of pure states: solving this problem would open a way for generalizing several results in the classical statistical learning literature to their quantum analogue. These two problems will be the focus of my last year of PhD, completing the thesis project.

About the topic of communication over quantum channels, during this year I have worked on two problems, reaching important results in both:

3) Classical communication in absence of a reference frame with continuous variable systems: we argue that communicating with sources producing squeezed light can give better communication rates than just using coherent (classical) light. When the receiver's measurement is photodetection, we prove an unconditional advantage of squeezed light. It is interesting to notice

that this advantage does not come from quantum enhanced sharing of phase reference, a strategy which is suboptimal with respect to communicating with coherent states alone.

4) Quantum and private communication: together with my colleague Farzad Kianvash we have improved the method used last year to get a state-of-the-art bound on the quantum capacity of the depolarizing channel, based on considering extensions of channels with non-orthogonal flags. We derived a very general set of sufficient conditions for degradability of flagged extensions, which give us state-of-the-art bounds on the quantum and private capacity of all the main finite dimensional quantum channels. In other words, our techniques provide the best quantitative understanding of the fundamental limits in protecting quantum states from the most common model of errors in quantum computers and quantum memories.

Kianvash and I are currently exploring several other developments on the approach 4) , for example on continuous variable quantum and private communication.

From November to February I have been hosted by the Quantum Information Group at the Autonomous University of Barcelona, supported by the Erasmus Traineeship program, where I collaborated with experts in the topic of my thesis. This opportunity greatly improved my knowledge of the field and of the technical skills required for recent crucial developments.

Some of the results obtained during my PhD have been accepted as contributed talks held by me or the other authors at top conferences in quantum information theory, such as TQC 2020, ISIT 2020, Beyond IID 2020, and presented at two invited seminars (Autonomous University of Barcelona and Heriot-Watt University)

*se si intende sottoporre una relazione di ricerca più estesa, utilizzare il campo per una descrizione sintetica e allegare il documento in formato .pdf

If you are going to submit a longer report, please fill the box with a synthetic abstract and attach a document in pdf format

SCUOLA NORMALE SUPERIORE

EVENTUALI PUBBLICAZIONI PUBLICATIONS (IF AVAILABLE)
Donà, Fanizza, Sarno, Speziale, *SU(2) graph invariants, Regge actions and polytopes* Classical and Quantum Gravity 35 (4), 045011, (2018)
Fanizza, Mari, Giovannetti, O*ptimal learning machines for quantum state discrimination* IEEE Transactions on Information Theory Volume 65 Issue 9 • Sept.-2019
Donà, Fanizza, Sarno, Speziale, *Numerical study of the Lorentzian EPRL spin foam amplitude,* Physical Review D 100 (10), 106003, (2019)
Kianvash, Fanizza, Giovannetti, *Optimal quantum subtracting machine* Physical Review A 99 (5), 052319, (2019)
Chessa, Fanizza, Giovannetti, *Quantum-capacity bounds in spin-network communication channels* Physical Review A 100 (3), 032311, (2019)
Fanizza, Rosati, Skotiniotis, Calsamiglia, Giovannetti, *Beyond the swap test: optimal estimation of quantum state overlap,* Physical Review Letters 124 (6), 060503, (2020)
Fanizza, Kianvash, Giovannetti, *Quantum Flags and New Bounds on the Quantum Capacity of the Depolarizing Channel.* Physical Review Letters 125.2, 020503, (2020)
Fanizza, Rosati, Skotiniotis, Calsamiglia, Giovannetti, *Classical capacity of quantum Gaussian codes without a phase reference: when squeezing helps,* arXiv preprint arXiv:2006.06522
Kianvash, Fanizza, Giovannetti, *Bounding the quantum capacity with flagged extensions,* arXiv preprint arXiv:2008.02461

NOME DEL RELATORE THESIS ADVISOR
Vittorio Giovannetti

DATA DATE	18/10/2020	FIRMA SIGNATURE	Marco Fanizza