THE COMPUTER AND THE BRAIN

In 1957 John von Neumann wrote a monumental book entitled "The computer and the brain" in an effort to understand the similarities between a then emerging computer and the human brain. The brain can be thought of as nature's information processing machine, i.e. nature's computer. The desire to understand the human brain architecture and to improve the computing machines has always attracted attention and it seems that each can benefit from the other. Today, Artificial Intelligence is perhaps one of the fastest growing fields of science and its applications are pervasive in our daily lifes, ranging from single user oriented applications (e.g. AI in smartphones, self-driving cars, etc.) to those for more structured users (e.g. AI for health care in hospitals, AI for autonomous weapons in military industries, etc.). Not surprisingly, the growth of AI has prompted the mathematical study of neural networks, as a simultaneously emerging field. Given that nature works in a quantum way, improved understanding of how the brain functions warrants using quantum methods. Through isolating, manipulating and measuring quantum observables in a controlled way in a laboratory, as it is done in quantum computers, we will not only gain insight into how our brains work, but also create and train new generation of computers which work in the same fashion.

This bundle is composed by three courses:

- *Machine Learrning*, course taught by Prof. Elena Agliari (Sapienza, Italy)
- *Neural Networks*, course taught by Prof. Adriano Barra (Salento, Italy)
- *Quantum Computing*, course taught by Prof. George Androulakis (S. Carolina, USA)

The main tools behind all these courses will be borrowed from statistical and quantum mechanics, two hegemon disciplines in Mathematical and Theoretical Physics. The perspective audience in these courses will be advanced undergraduates and graduate students or even faculty majored in Mathematics, Physics, Computer Science, Electrical Engineering, Bioengineering, or Neuroscience.

The bundle itself is thought of as a whole hence the students are encouraged to register in all three courses. For registration and more information see
http://unboundprometheus.com/program-two/

An intellectual retreat in the picturesque island of Crete Greece, from July 14th to July 21st, 2019.

1. Machine learning

In the course of "Machine Learning" the following topics will be covered:

- A short introduction to the general state of the art in machine learning
- The perceptron and related models (e.g. multi-layers feed-forward nets)
- An introduction to stochastic dynamics
- A general theory for constructing learning rules
- The (restricted) Boltzmann machine learning and its equivalence to Hebbian learning

All of these topics can be found in the book *Theory of neural information processing systems*, by A.C.C. Coolen, R. Khuen, P. Sollich. The participants of the course are recommended to obtain a copy of this book prior to participating.

For a detailed description of the course see http://unboundprometheus.com/machine-learning

The instructor of the course is **Elena Agliari**. Elena obtained a master degree in Condensed Matter Physics (2004) and a Ph.D. degree in Theoretical Physics (2007) at the University of Parma, Italy. She has been working at the Albert-Ludwigs-Universitaet of Freiburg (Germany) and at the Laboratoire de Physique Théorique de la Matière Condensée, Université Pierre et Marie Curie, Paris (France); she is currently researcher in Applied Mathematics in Sapienza University of Rome, Italy. Her research interests include complex systems, statistical mechanics, -with particular focus on neural networks, machine learning and biological complexity- but she is also active in the fields of graph theory and in stochastic processes. She has got the Italian scientific qualification as professor for both Theoretical and Mathematical Physics. She is (co-)author of about 80 publications on international scientific journals (edited by Nature Publishing Group, American Physical Society, Institute of Physics Publishing, etc.). An extended CV, with all the details and all the produced papers, is available at her website: http://elenaagliari.weebly.com
Perspective participants can email her directly if they have any questions about the course.

2. Neural networks

In the course of "Neural Networks" the following topics will be covered:

- An introductory perspective on biological aspects of neural networks with elementary mathematics
- A short introduction to Statistical Mechanics of simple & complex systems
- The application of these two points above to the formalization of neural networks
- An inspection of modern networks able to show multitasking capabilities (i.e. parallel processing) and NP-skills
- A one-to-one mapping among the subjects focused via statistical mechanics and the corresponding electronic counterparts

All of these topics can be found in the book *Theory of neural information processing systems*, by A.C.C. Coolen, R. Khuen, P. Sollich. The participants of the course are recommended to obtain a copy of this book prior to participating.

For a detailed description of the course see http://unboundprometheus.com/neural-networks

The instructor of the course is **Adriano Barra**. Adriano has a master in Theoretical Physics from Sapienza (Rome) and a Ph.D. in Applied Mathematics from King's College (London) and, at present, teaches as Associate Professor in Mathematical Physics in Salento University (Italy) three courses: *Probability & Statistics*, *Neural Networks* and *Complex Systems*. Since his early post-doc he always worked in the statistical mechanics of complex systems, with particular care on Artificial Intelligence and Biological Complexity. In Italy he is enabled Professor of Mathematical Physics, Theoretical Physics and Experimental Physics (Biophysics). His scientific production counts more than 80 scientific articles on the relevant Journals (Physical Review Letters, Neural Networks, Journal of Statistical Physics, etc.): an extended CV, with all the details and all the produced papers, is available at his website: https://www.adrianobarra.com

Perspective participants can email him directly if they have any questions about the course.

3. Quantum computing

In the course of "Quantum computing" the following topics will be covered:

- A short introduction to logic
- An introduction to quantum mechanics
- An introduction to quantum information theory
- Presentation of some quantum algorithms
- Descriptions of some physical realizations of quantum computers

All of these topics can be found in the book *Quantum computation and quantum information*, by Michael A. Nielsen and Isaac L. Chuang. The participants of the course are recommended to obtain a copy of this book prior to participating.

For a detailed description of the course see http://unboundprometheus.com/quantum-computing

The instructor of the course is **George Androulakis**. George obtained his Ph.D. from the Mathematics Department of the University of Texas at Austin in 1996. He has held postdoctoral positions at the University of Missouri-Columbia, and Texas A&M University and a visiting position at Georgia Tech. He is an Associate Professor at the University of South Carolina. He has worked in several areas of mathematics and he enjoys working with graduate students. His current research interests include quantum mechanics and quantum information theory. His detailed curriculum vitae, research activities and contact information can be viewed in http://people.math.sc.edu/androula/

Perspective participants can email him directly if they have any questions about the course.