International Doctoral Program in Science Position

Machine learning applications to physics research

Background and motivation

This research project lays in the flourishing intersection between Computer Science and Physics. In last years it has been observed that machine learning is coming to hold a crucial position in fields of physical science ranging from particle physics to cosmology, quantum many-body physics, quantum computing, and chemical and material physics [1].

Examples of successful applications of machine learning techniques to physics research include, among others: discovering gravitational lenses [2], constructing effective variational many-body wavefunctions in interacting systems with long-range entanglement [3], identifying phase transitions from entanglement spectra [4], characterizing dynamical phases in closed quantum systems where statistical mechanics is not applicable [5], etc.

On the other hand, machine learning development can benefit from physics research, in particular for the understanding of internal operations. In fact, one of the major open problems in machine learning is related to explainability, in particular with deep neural networks: these algorithms can perform very well in some tasks (e.g., classification) but it's difficult to understand exactly why, both in theory and in practice. Examples of how machine learning theoretical development can exploit physical research are the recent proposal of an explanation for the performance of deep learning based on renormalization group theory [6], and an approach to clustering based on statistical physics [7].

The goals of the present project are: exploring the connections between physics and computer science, developing ad hoc machine learning models for physics research, and proposing new techniques for explainable machine learning.

References

1. Carleo G. et al. Machine learning and the physical sciences. Rev. Mod. Phys. 91, 045002 (2019)
2. Huang, X. et al. Finding Strong Gravitational Lenses in the DESI DECam Legacy Survey. ApJ 894 78 (2020)
3. Carleo, G. and Troyer, M. Solving the quantum many-body problem with artificial neural networks. Science 355, 602 (2017).
4. van Nieuwenburg, E., Liu, YH. & Huber, S. Learning phase transitions by confusion. Nature Phys 13, 435–439 (2017).
5. Hsu, Y.-T., et al. Machine learning many-body localization: Search for the elusive nonergodic metal. Phys. Rev. Lett. 121, 245701 (2018)
6. E. De Mello Koch, et al. Is Deep Learning a Renormalization Group Flow?, IEEE Access, vol. 8, pp. 106487-106505, (2020)
7. Rose K, Gurewitz E, Fox GC. Statistical mechanics and phase transitions in clustering. Phys. Rev. Lett. 65, 945 (1990)

Profile

- Master's degree or comparable qualification in Computer Science, Computer Engineering, Physics, Mathematics or adjacent fields. The title must be obtained before OCTOBER 31ST 2021.
- A strong interest for multidisciplinary research is required.
- Good knowledge of the English language, both spoken and written, is essential.
- Strong commitment, ability to work in a team, and eagerness for international mobility is desired.

Opportunities

- Experimental research participating to the international collaboration between Università Cattolica del Sacro Cuore (UCSC) and University of Notre Dame (ND), USA, with at least one year spent in both institutions.
- **Double degree opportunity (European title from UCSC and American title from ND)**

Supervisors

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