ARTIFICIAL INTELLIGENCE

PNRR - Topological and geometric methods in AI

Funded By	MINISTERO DELL'UNIVERSITA' E DELLA RICERCA [P.iva/CF:97429780584] Politecnico di TORINO [P.iva/CF:00518460019]

Supervisor	VACCARINO FRANCESCO - francesco.vaccarino@polito.it

Contact	Giovanni Petri, Northeastern University London, giovanni.petri@nulondon.ac.uk

Context of the research activity	A trained (deep) learning model is a sequence of maps and spaces. Data, old and new, are mapped through the model strata from input to output. The main ingredients are a training set of samples from an unknown distribution, a suitable loss function, and an algorithm for empirical loss minimization. Our aim is to extract topological and geometric information, either from data as represented internally by trained models or from the space of parameters learned during the training process.In particular, we are interested in understanding how topology and geometry intertwine with the process of learning via Morse theory, Geometric Invariant Theory and Discrete Exterior Calculus. Progetto finanziato nell'ambito del PNRR: PNRR M4C2, Investimento 1.3 - Avviso n. 341 del 15/03/2022 - PE0000013 Future Artificial Intelligence Research (FAIR) - CUP E13C22001800001

Objectives	Our aim is to extract topological and geometric information, either from data as represented internally by trained models, or from the space of parameters learned during the training process. Understanding how models work, from a geometrical and topological perspective, would enable the design of better architectures, with improved model performance and training. The first question we want to study is what happens to data during the journey from input to output. We will define techniques grounded on TDA and Morse Theory to study how the topology of a point cloud representing data is changing when it is feed-forwarded through different existing networks. This is expected to shed light on the intrinsic dimension of the data and the learning systems as well, on the relevance of different features, and on which geometric and topological properties of the data are preserved in the sequence of representations as data flows through the networks. We will address similar questions on the space of model parameters. Again, we are interested in how topology and geometry intertwine with the process of learning. For different architectures, we will study the sublevel sets of the

	Gradient or of other functional via Morse Theory. Indeed, Morse theory relate the topology of the domain of a (Morse) function with the nature of its critical points. The space of parameters aforementioned is the domain of the loss (together with the space of data) and training is seeking for critical points, hence, understanding via Morse Theory (and Persistent Homology as well) the nature of this landscape will give a new way to develop more efficient algorithms for training and new insight on this aspect of ML/AI.

Skills and competencies for the development of the activity	The ideal candidate is a fellow with a formal education in algebra, topology, algebraic topology, algebraic geometry and or differential geometry which has also a documented experience in computer programming/data science. Skills and competences in machine learning and deep learning will be considered a plus.