Tsinghua Workshop on Machine Learning in Geometry and Physics 2018

Report of Contributions

Contribution ID: **8**   Type: **not specified**

Learning and Lie Groups

Monday, June 11, 2018 9:00 AM (1 hour)

Machine learning methods are mostly based on calculus and probability and statistics on Euclidean spaces.
However, many interesting problems can be articulated as learning in lower dimensional embedded manifolds
and on Lie groups. This talk reviews how learning and Lie groups fit together, and how the machine learning community can benefit from modern mathematical developments. The topics include:

•Introduction to Calculus on Lie Groups (Differential Operators, Integration)
•Probability on Lie Groups (Convolution, Fourier Analysis, Diffusion Equations)
•Application 1: Workspace Generation and Inverse Kinematics of Highly Articulated Robotic Manipulators
•Application 2: Pose Distributions for Mobile Robots
•Application 2: Lie-Theoretic Invariances in Image Processing and Computer Vision
•Application 3: Coset-Spaces of Lie Groups by Discrete Subgroups in Crystallography
•Prospects for the Future

Presenter: CHIRIKJIAN, Gregory S. (Johns Hopkins University)

Contribution ID: **9**

Type: **not specified**

A Generalized Construction of Calabi-Yau Manifolds and Mirror Symmetry

Monday, June 11, 2018 10:30 AM (45 minutes)

We extend the construction of Calabi-Yau manifolds to hypersurfaces in non-Fano toric varieties. The associated non-reflexive polytopes provide a generalization of Batyrev's original work, allowing us to construct new pairs of mirror manifolds. In particular, this allows us to find new K3-fibered Calabi-Yau manifolds, relevant for string compactifications.

Presenter: BERGLUND, Per (New Hampshire)

Contribution ID: **10** Type: **not specified**

Patterns in Calabi-Yau Threefolds

Monday, June 11, 2018 11:15 AM (45 minutes)

TBA

Presenter: JEJJALA, Vishnu (Witwatersrand)

Contribution ID: **11**   Type: **not specified**

Neural Program Synthesis and Neural Automated Theorem Proving, via Curry-Howard Correspondence

Monday, June 11, 2018 2:00 PM (45 minutes)

Curry-Howard correspondence is, roughly speaking, the observation that proving a theorem is equivalent to writing a program. Using this principle, I will present a unified survey of recent trends in the application of deep learning in program synthesis and automated theorem proving, with commentary on their applicability to the working mathematician and physicists.

Presenter: YANG, Greg (Microsoft Research)

Contribution ID: **12**   Type: **not specified**

Quantum Computers and Machine Learning

Monday, June 11, 2018 2:45 PM (45 minutes)

I will discuss the two-fold relation between Quantum Computers and Machine Learning. On one hand Quantum Computers offer new algorithms to perform training tasks on classical or Quantum data. On the other hand, Machine Learning offers new tools to study Quantum Matter, and to control Quantum experiments.

Presenter: GARCIA SAEZ, Artur (Barcelona SC Center)

Contribution ID: **13**   Type: **not specified**

Renormalization and hierarchical knowledge representations

Tuesday, June 12, 2018 9:00 AM (1 hour)

Our understanding of any given complex physical system is made of not just one, but many theories which capture different aspects of the system. These theories are often stitched together only in informal ways. An exception is given by renormalization group techniques, which provide formal ways of hierarchically connecting descriptions at different scales.

In machine learning, the various layers of a deep neural network seem to represent different levels of abstraction. How does this compare to scale in renormalization? Can one build a common information-theoretic framework underlying those techniques?

To approach these questions, I compare two different renormalization techniques (which emerged from quantum information theory), and attempt to adapt them to unsupervised learning tasks. One approach, MERA, superficially resembles a deep convolutional neural net, while another approach based on dimensional reduction yields something similar to principal component analysis.

Presenter: BENY, Cedric (Hanyang University)

Contribution ID: **14**   Type: **not specified**

Real-space renormalization group

Tuesday, June 12, 2018 10:30 AM (45 minutes)

Physical systems differing in their microscopic details often display strikingly similar behaviour when probed at macroscopic scales. Those universal properties, largely determining their physical characteristics, are revealed by the renormalization group (RG) procedure, which systematically retains 'slow' degrees of freedom and integrates out the rest. We demonstrate a machine-learning algorithm based on a model-independent, information-theoretic characterization of a real-space RG capable of identifying the relevant degrees of freedom and executing RG steps iteratively without any prior knowledge about the system. We apply it to classical statistical physics problems in 1 and 2D: we demonstrate RG flow and extract critical exponents. We also discuss the optimality of the procedure.

Presenter: KOCH-JANUSZ, Maciej (ETH Zurich)

Contribution ID: 15 Type: **not specified**

Topological Data Analysis for Cosmology and String Theory

Tuesday, June 12, 2018 11:15 AM (45 minutes)

Topological data analysis (TDA) is a multi-scale approach in computational topology used to analyze the "shape" of large datasets by identifying which homological characteristics persist over a range of scales. In this talk, I will discuss how TDA can be used to extract physics from cosmological datasets (e.g., primordial non-Gaussianities generated by cosmic inflation) and to explore the structure of the string landscape.

Presenter: SHIU, Gary (University of Wisconsin-Madison)

Contribution ID: **16** Type: **not specified**

Algebraic geometry of the restricted Boltzmann machine

Wednesday, June 13, 2018 9:00 AM (1 hour)

TBA

Presenter: MORTON, Jason (Pennsylvania State University)

Contribution ID: **17** Type: **not specified**

Reinforcement learning in the string landscape

Wednesday, June 13, 2018 10:30 AM (45 minutes)

In studying the string landscape, we often want to find vacua with specific properties, but do not know how to select the string geometry that gives rise to such vacua. For this reason, we apply reinforcement learning, a semi-supervised approach to machine learning in which the algorithm explores the landscape autonomously while being guided towards models with given properties. We illustrate the approach using examples from heterotic, type II, and F-theory.

Presenter: RUEHLE, Fabian (Oxford)

Contribution ID: 18   Type: **not specified**

On Finding Small Cosmological Constants with Deep Reinforcement Learning

Wednesday, June 13, 2018 11:15 AM (45 minutes)

I will review the Bousso-Polchinski model and aspects of its computational complexity. An asynchronous advantage actor-critic will be used to find small cosmological constants.

Presenter: HALVERSON, Jim (Northeastern)

Contribution ID: **19**   Type: **not specified**

Faster exploration of parameter space in supersymmetry and string theory using machine learning

Wednesday, June 13, 2018 2:00 PM (45 minutes)

TBA

Presenter: KRIPPENDORF, Sven (LMU Munich)

Contribution ID: **20** Type: **not specified**

The Nelson-Seiberg theorem, its extensions, string realizations, and possible machine learning applications

Wednesday, June 13, 2018 2:45 PM (45 minutes)

The Nelson-Seiberg theorem relates F-term SUSY breaking and R-symmetries in N=1 SUSY field theories. I will talk its several extensions including a revision to a necessary and sufficient condition, discrete R-symmetries and non-Abelian R-symmetries, relation to SUSY and W=0 vacua in the string landscape, and some possible machine learning applications in the searching for SUSY vacua.

Presenter: SUN, Zheng (Sichuan University)

Contribution ID: **21**   Type: **not specified**

Tensor network from quantum simulations to machine learning

Thursday, June 14, 2018 9:00 AM (1 hour)

Tensor network is both a theoretical and numerical tool, which has achieved great success in many body physics from calculating he thermodynamic property and quantum phase transition to simulations of black holes. As a general form of high dimensional data structure, tensors have been adopted in diverse branches of data analysis, such as in signal and image processing, psychometric, quantum chemistry, biometric, quantum information, back holes, and brain science. Tensor network simulates the interactions between tensors and becomes a developing powerful in these new fields. During recent years, tensor network numerical methods such as matrix product state (MPS) and projected entangled pair state (PEPS) has also finds its way to machine learning. Besides, the physical concept of entanglement offers a new theoretical approach to the design of different neural networks.

For example, we find that graphic models, such as restricted Boltzmann machine (RBM) is equivalent to a specific tensor network and we can study the expression power of the RBM.

Presenter: CHEN, Jing (Flatiron Institute)

Contribution ID: **22**   Type: **not specified**

Tensor Network Holography and Deep Learning

Thursday, June 14, 2018 10:30 AM (45 minutes)

Motivated by the close relations of the renormalization group with both the holography duality and the deep learning, we propose that the holographic geometry can emerge from deep learning the entanglement feature of a quantum many-body state. We develop a concrete algorithm, call the entanglement feature learning (EFL), based on the random tensor network (RTN) model for the tensor network holography. We show that each RTN can be mapped to a Boltzmann machine, trained by the entanglement entropies over all subregions of a given quantum many-body state. The goal is to construct the optimal RTN that best reproduce the entanglement feature. The RTN geometry can then be interpreted as the emergent holographic geometry. We demonstrate the EFL algorithm on 1D free fermion system and observe the emergence of the hyperbolic geometry (AdS_3 spatial geometry) as we tune the fermion system towards the gapless critical point (CFT_2 point).

Presenter: YOU, Yi-Zhuang (UCSD & Harvard)

Contribution ID: **23**   Type: **not specified**

Reverse engineering Hamiltonian from spectrum

Thursday, June 14, 2018 11:15 AM (45 minutes)

Handling the large number of degrees of freedom with proper approximations, namely the construction of the effective Hamiltonian is at the heart of the (condensed matter) physics. Here we propose a simple scheme of constructing Hamiltonians from given energy spectrum. The sparse nature of the physical Hamiltonians allows us to formulate this as a solvable supervised learning problem. Taking a simple model of correlated electron systems, we demonstrate the data-driven construction of its low-energy effective model. Moreover, we find that the same approach works for the construction of the entanglement Hamiltonian of a given quantum many-body state from its entanglement spectrum. Compared to the known approach based on the full diagonalization of the reduced density matrix, our one is computationally much cheeper thus offering a way of studying the entanglement nature of large (sub)systems under various boundary conditions.

Presenter: FUJITA, Hiroyu (University of Tokyo)

Contribution ID: **24**   Type: **not specified**

Toward reduction of autocorrelation in HMC by machine learning

Thursday, June 14, 2018 2:00 PM (45 minutes)

Recent development of machine learning (ML), especially deep learning is remarkable. It has been applied to image recognition, image generation and so on with very good precision. From a mathematical point of view, images are just real matrices, so it would be a natural idea to replace this matrices with the configurations of the physical system created by numerical simulation and see what happens. In this talk, I will review our attempt to reduce autocorrelation of Hamiltonian Monte Carlo (HMC) algorithm. In addition, I would like to discuss a possibility of using recent sophisticated generative models like VAE, GAN to improve HMC. (work in collaboration with A. Tomiya, arXiv:1712.03893)

Presenter: TANAKA, Akinori (Riken)

Contribution ID: **25**   Type: **not specified**

Machine learning for parton distribution determination

Thursday, June 14, 2018 2:45 PM (45 minutes)

Parton Distribution Functions (PDFs) are a crucial ingredient for accurate and reliable theoretical predictions for precision phenomenology at the LHC. The NNPDF approach to the extraction of Parton Distribution Functions relies on Monte Carlo techniques and Artificial Neural Networks to provide an unbiased determination of parton densities with a reliable determination of their uncertainties. I will discuss the NNPDF methodology in general, the latest NNPDF global fit (NNPDF3.1) and then present ideas to improve the training methodology used in the NNPDF fits and related PDFs.

Presenter: CARRAZZA, Stefano (CERN)

Contribution ID: **26**   Type: **not specified**

Deep Learning and AdS/CFT

Friday, June 15, 2018 9:00 AM (1 hour)

We present a deep neural network representation of the AdS/CFT correspondence, and demonstrate the emergence of the bulk metric function via the learning process for given data sets of response in boundary quantum field theories. The emergent radial direction of the bulk is identified with the depth of the layers, and the network itself is interpreted as a bulk geometry. Our network provides a data-driven holographic modeling of strongly coupled systems. With a scalar $\phi 4$ theory with unknown mass and coupling, in unknown curved spacetime with a black hole horizon, we demonstrate our deep learning (DL) framework can determine them which fit given response data. First, we show that, from boundary data generated by the AdS Schwarzschild spacetime, our network can reproduce the metric. Second, we demonstrate that our network with experimental data as an input can determine the bulk metric, the mass and the quadratic coupling of the holographic model. As an example we use the experimental data of magnetic response of a strongly correlated material Sm0.6Sr0.4MnO3. This AdS/DL correspondence not only enables gravity modeling of strongly correlated systems, but also sheds light on a hidden mechanism of the emerging space in both AdS and DL.
(Work in collaboration with A.Tanaka, A.Tomiya and S.Sugishita, arXiv:1802.08313)

Presenter: HASHIMOTO, Koji (Osaka University)

Contribution ID: 27   Type: **not specified**

Detection of phase transition via convolutional neural networks

Friday, June 15, 2018 10:30 AM (45 minutes)

A Convolutional Neural Network (CNN) is designed to study correlation between the temperature and the spin configuration of the 2 dimensional Ising model.
Our CNN is able to find the characteristic feature of the phase transition without prior knowledge. Also a novel order parameter on the basis of the CNN is introduced to identify the location of the critical temperature; the result is found to be consistent with the exact value. This talk is based on following paper,
Journal of the Physical Society of Japan 86 (6), 063001 (arXiv:1609.09087).

Presenter: TOMIYA, Akio (Central China Normal University)

Contribution ID: **28**   Type: **not specified**

The Machine Learning Role on High Energy Physics: A theoretical view

Friday, June 15, 2018 11:15 AM (45 minutes)

In this talk, I show some concepts in computing, Physics and Mathematics focusing on High Energy Physics. I share some programming languages and tools implemented for computing the amplitudes, decays and cross sections. In particular, I explore the Two-Higgs Doublet Model and Extended Gauge Group Model and some results using Artificial Inteligence.

Presenter: ORDUZ DUCUARA, Javier Andres (UNAM)