



## Machine Learning in Geometry and Physics workshop

几何与物理中的机器学习研讨会

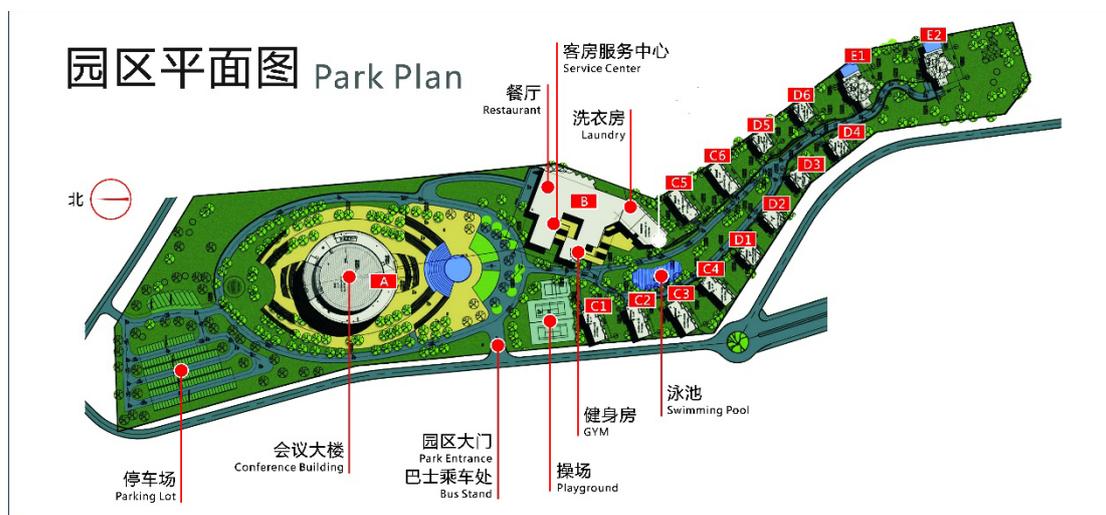
June 11-15, 2018

**Welcome to TSIMF**

The facilities of TSIMF are built on a 23-acre land surrounded by pristine environment at Phoenix Hill of Phoenix Township. The total square footage of all the facilities is over 29,000 square meter that includes state-of-the-art conference facilities (over 10,000 square meter) to hold many international workshops simultaneously, two libraries, a guest house (over 10,000 square meter) and the associated catering facilities, a large swimming pool, gym and sports court and other recreational facilities.

Mathematical Sciences Center (MSC) of Tsinghua University, assisted by TSIMF's International Advisory Committee and Scientific Committee, will take charge of the academic and administrative operation of TSIMF. The mission of TSIMF is to become a base for scientific innovations, and for nurturing of innovative human resource; through the interaction between leading mathematicians and core research groups in pure mathematics, applied mathematics, statistics, theoretical physics, applied physics, theoretical biology and other relating disciplines, TSIMF will provide a platform for exploring new directions, developing new methods, nurturing mathematical talents, and working to raise the level of mathematical research in China.

## About Facilities



## Registration

Conference booklets, room keys and name badges for all participants will be distributed at the Registry. Please take good care of your name badge. It is also your meal card and entrance ticket for all events.



## Guest Room



Conference Center can receive about 378 people having both single and double rooms, and 42 family rooms.

All the rooms are equipped with: free Wi-Fi, TV, air conditioning and other utilities.

Family rooms are also equipped with kitchen and refrigerator.

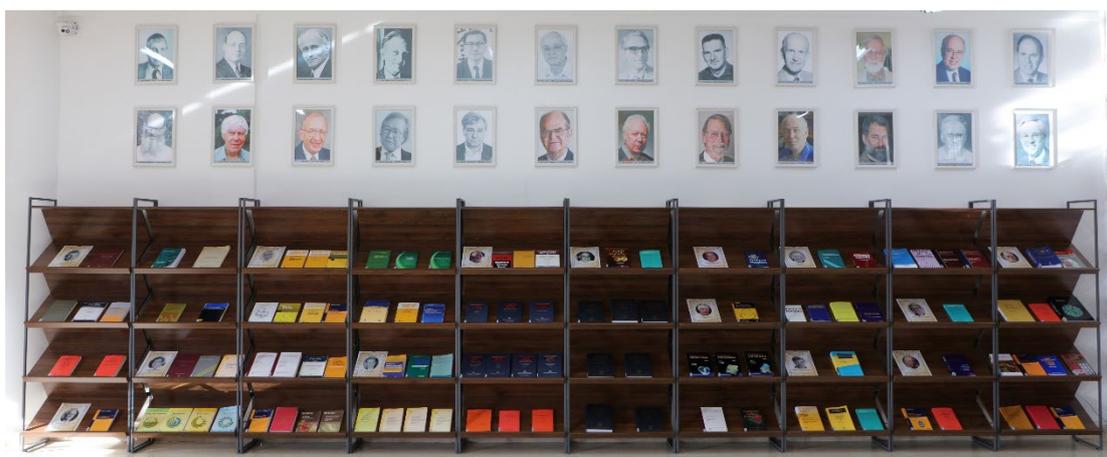


## Library



**Opening Hours: 09:00am-22:00pm**

TSIMF library is available during the conference and can be accessed by using your room card. There is no need to sign out books but we ask that you kindly return any borrowed books to the book cart in library before your departure.



In order to give readers a better understanding of the contributions made by the Fields Medalists, the library of Tsinghua Sanya International Mathematics Forum (TSIMF) instituted the Special Collection of Fields Medalists as permanent collection of the library to serve the mathematical researchers and readers.

So far, there are 210 books from 43 authors in the Special Collection of Fields Medalists of TSIMF library. They are on display in room A220. The participants are welcome to visit.

## Restaurant



All the meals are provided in the Chinese Restaurant (Building B1) according to the time schedule.



<b>Breakfast</b>	<b>07:30-08:30</b>
<b>Lunch</b>	<b>12:00-13:30</b>
<b>Dinner</b>	<b>17:30-19:00</b>



## Laundry

**Opening Hours: 24 hours**

The self-service laundry room is located in the Building 1 (B1).

## Gym

The gym is located in the Building 1 (B1), opposite to the reception hall. The gym provides various fitness equipment, as well as pool tables, tennis tables etc.

## Playground



Playground is located on the east of the central gate. There you can play basketball, tennis and badminton. Meanwhile, you can borrow table tennis, basketball, tennis balls and badminton at the reception desk.

## Swimming Pool

Please note that there are no lifeguards. We will not be responsible for any accidents or injuries. In case of any injury or any other emergency, please call the reception hall at +86-898-38882828.



## Outside Shuttle Service

We have shuttle bus to take participants to the airport for your departure service. Also, we would provide transportation at the Haihong Square (海虹广场) of Howard Johnson for the participants who will stay outside TSIMF. If you have any questions about transportation arrangement, please feel free to contact Ms. Li Ye (叶莉), her cell phone number is (0086)139-7679-8300.

## Free Shuttle Bus Service at TSIMF

We provide free shuttle bus for participants and you are always welcome to take our shuttle bus, all you need to do is wave your hands to stop the bus.



Destinations: Conference Building, Reception Room, Restaurant, Swimming Pool, Hotel etc.



## Contact Information of Administration Staffs

**Location of Conference Affair Office: Room 104, Building A**

Tel: 0086-898-38263896

Technical Support: Mr.Shouxi,HE 何守喜

Tel: 0086-186-8980-2225

Email: hesx@tsimf.cn

Administrator: Ms. Xianying, WU 吴显英

Tel:0086-186-8962-3393

Email: wuxy@tsimf.cn

**Location of Accommodation Affair Office: Room 200, Building B1**

Tel: 0086-898-38882828

Accommodation Manager: Ms. Li YE 叶莉

Tel: 0086-139-7679-8300

Email: yeli@tsimf.cn

**Office Director**

Kai CUI 崔凯

Tel/Wechat: 0086- 136-1120-7077

Email :cuikai@tsimf.cn

**Director of TSIMF**

Prof.Xuan GAO 高瑄

Email: gaoxuan@tsinghua.edu.cn

<b>Schedule for the Workshop on Machine Learning            in Geometry and Physics            June 11-15, 2018</b>					
Time&Date	Monday (Jun 11)	Tuesday (Jun 12)	Wednesday (Jun 13)	Thursday (June 14)	Friday (June 15)
7:30-8:30	<i>Breakfast</i>				
Chair					
8:40-9:00	Opening Ceremony				
9:00-10:00	Gregory Chirikjian	Cedric Beny	Jason Morton	Jing Chen	Koji Hashimoto
10:00-10:30	<i>Tea Break</i>				
Chair					
10:30-11:15	Per Berglund	Maciej Koch-Janusz	Fabian Ruehle	Yi-Zhuang You	Akio Tomiya
11:15-12:00	Vishnu Jejjala	Gary Shiu	Jim Halverson	Hiroyuki Fujita	J.A. Orduz-Ducua
12:00-13:30	<i>Lunch</i>				
Chair					--
14:00-14:45	Greg Yang	<i>Excursion: Nanshan temple 13:30— 17:00</i>	Sven Krippendorf	Akinori Tanaka	<i>Departure</i>
14:45-15:30	Artur Garcia Saez		Zheng Sun	Stefano Carrazza	
15:30-16:00	<i>Tea Break</i>		<i>Tea Break</i>		
16:00-17:30	Free Discussion	Free Discussion	Free Discussion		
17:30-19:00	<i>Dinner</i>	<i>Banquet 18:00- 20:00</i>	<i>Dinner</i>		

\* MONDAY

Gregory S. Chirikjian

Title:

Learning and Lie Groups

Abstract:

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

Per Berglund

Title:

A Generalized Construction of Calabi-Yau Manifolds and Mirror Symmetry

Abstract:

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.

Vishnu Jejjala

Title:

Patterns in Calabi-Yau Threefolds

Abstract:

TBA

Greg Yang

Title:

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

Abstract:

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

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application of deep learning in program synthesis and automated theorem proving, with commentary on their applicability to the working mathematician and physicists.

Artur Garcia Saez

Title:

Quantum Computers and Machine Learning

Abstract:

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.

\* TUESDAY

Cedric Beny

Title:

Renormalization and hierarchical knowledge representations

Abstract:

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.

Maciej Koch-Janusz

Title:

Real-space renormalization group

Abstract:

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.

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Gary Shiu

Title:

Topological Data Analysis for Cosmology and String Theory

Abstract:

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.

\* WEDNESDAY

Jason Morton

Title:

Algebraic geometry of the restricted Boltzmann machine

Abstract:

TBA

Fabian Ruehle

Title:

Reinforcement learning in the string landscape

Abstract:

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.

Jim Halverson

Title:

On Finding Small Cosmological Constants with Deep Reinforcement Learning

Abstract:

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

Sven Krippendorf

Title:

file:///C:/Users/YMSC-staff/Desktop/0611-0615%20Machine%20Learning%20in%20Geometry%20and%20Physics/abstracts.txt[2018/6/5 14:10:55]

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

Abstract:

TBA

Zheng Sun

Title:

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

Abstract:

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.

\* THURSDAY

Jing Chen

Title:

Tensor network from quantum simulations to machine learning

Abstract:

Tensor network is both a theoretical and numerical tool, which has achieved great success in many body physics from calculating the 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, black 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.

Phys. Rev. B 97, 085104 (2018)  
arXiv: 1712.04144

Yi-Zhuang You

Title:

Tensor Network Holography and Deep Learning

Abstract:

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

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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<sub>3</sub> spatial geometry) as we tune the fermion system towards the gapless critical point (CFT<sub>2</sub> point).

Hiroyu Fujita

Title:

Reverse engineering Hamiltonian from spectrum

Abstract:

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 cheaper thus offering a way of studying the entanglement nature of large (sub)systems under various boundary conditions.

Akinori Tanaka

Title:

Toward reduction of autocorrelation in HMC by machine learning

Abstract:

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)

Stefano Carrazza

Title:

Machine learning for parton distribution determination

Abstract:

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.

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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.

\* FRIDAY

Koji Hashimoto

Title:

Deep Learning and AdS/CFT

Abstract:

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  $\text{Sm}_{0.6}\text{Sr}_{0.4}\text{MnO}_3$ . 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)

Akio Tomiya

Title:

Detection of phase transition via convolutional neural networks

Abstract:

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).

Javier Andres Orduz Ducuara

Title:

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

Abstract:

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 Intelligence.

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## Group Photo

