BRIDGING THE GAP BETWEEN PRACTICE AND THEORY IN DEEP LEARNING

ABSTRACT

The success of deep learning practices has driven the rapid development of learning theory. However, recent studies have pointed out that contrasting scenarios and conclusions exist between many existing theories and their corresponding real-world applications, leading to a significant gap. This workshop aims to bridge this gap by (i) spotting unnoticed gaps between learning theory and practice and (ii) narrowing the existing ones by developing new analyses. We hope that this workshop will not only raise awareness of the challenges in bridging the gap between theory and practice in deep learning but also inspire new solutions and insights that contribute to the advancement of deep learning. **The workshop website:** https://sites.google.com/view/bgpt-iclr24.

1 WORKSHOP SUMMARY

The rapid development and tremendous success of deep learning in practice are well-known. As the technological advancements in deep learning are primarily driven by heuristics, a large body of work has emerged to provide theoretical guarantees for this practical discipline, aiming to make models based on deep learning more stable and reliable.

Existing theoretical work on deep learning often builds upon established methodologies from other fields, such as numerical optimization and statistics. However, recent research has pointed out that the assumptions and conclusions of these analyses may differ significantly, or even contradict, the practical implementation of deep learning. A notable example is the classic optimizer iteration complexity analysis, which assumes bounded smoothness of the target function and selects the learning rate based on the upper bound of smoothness. However, the recently observed "Edge of Stability" phenomenon suggests that the smoothness of neural networks is actually determined by the learning rate. In other words, there is a considerable gap between current theory and practice. This gap hinders our ability to accurately describe practice through theory, thus impeding our understanding and guidance of practical applications.

This workshop aims to identify the existing gaps and explore ways to narrow them. Specifically, we welcome submissions that meet one of the following criteria:

- Works that highlights a discrepancy between existing theoretical analyses and practice.
- Works that proposes new experimental observations that can help advance our understanding of the underlying mechanisms of deep learning.
- Works that offer theoretical insights that match existing experimental observations.
- Works that propose algorithms based on theoretical derivations which perform well in practice.

On the other hand, this workshop will **not** cover works that only prove tighter bounds without offering new insights for practice, works that propose new empirical tricks or use existing ones without providing theoretical insights (even if these tricks achieve SOTA performance), works that neither lead to practical applications nor provide explanations for practical phenomenons. The detailed topics of this workshop include (but are not limited to) the following:

Optimization theory for deep learning. Several subareas may include: Edge of Stability (EoS) phenomenon, adaptive optimizers, non-smoothness of neural network landscape, the role of initialization, architectural design, and optimization tricks in influencing the convergence.

Generalization theory for deep learning. Several subareas may include: the implicit bias of gradient-based optimizers, effects of overparameterization, loss landscape flatness, and more gen-

erally, how neural network architectures, data distribution, optimizers, and initialization impact the generalization performance.

Theory of large language models. Several subareas may include: understanding the scaling law and emergence, theory of in-context learning, theory of chain-of-thought, the expressive power of autoregressive Transformers, and more fundamentally, what the key reasons behind the success of large language models are.

We hope that by providing a venue to discuss the current dichotomy between empirical results and theoretical guarantees in modern machine learning, our workshop will bring more visibility not only to the gaps in our understanding but also to promising techniques in reducing the gaps. Most importantly, we hope that our workshop will help foster a diverse, vibrant community of researchers with the curiosity to tackle the important work of ensuring we understand the ML tools of the upcoming decades.

2 Modality and accessibility

This workshop is designed as a hybrid event, offering participants the flexibility to engage in-person or virtually. It mainly contains three types of events: invited talks, contributed talks, and poster sessions. We will share abstracts for accepted papers and talks at least a week in advance of the workshop. Accepted papers will be published on OpenReview.

1. **Invited talks.** All invited talks will be recorded, captioned, and made accessible to ICLR attendees to accommodate all time zones.

2. **Contributed talks.** The Program Committee will work together to select several submissions as orals and invite them to give contributed talks. Previously published paper will NOT be selected as orals.

3. **Poster Session.** All accepted papers should provide a poster. Our schedule includes a poster session to facilitate participation from attendees.

For the remote attendees, we will live-stream the whole workshop (invited talks and contributed talks) via zoom, and provide support for remote Q&A. Besides, we will host the accepted posters and papers on our website.

Finally, we will organize a slack channel for all potential attendees to encourage broad discussions during the whole workshop.

3 Invited Speakers

Name:	Sanjeev Arora (confirmed)
Email:	arora@cs.princeton.edu
Website:	https://www.cs.princeton.edu/ arora/
Experience:	Sanjeev Arora is the Charles C. Fitzmorris Professor in Computer Science. He joined Princeton in 1994 after earning his PhD from the UC Berkeley. Professor Arora won the Fulkerson Prize in Discrete Mathematics in 2012, the ACM Prize in Computing in 2011, EATCS-SIGACT Gödel Prize (cowinner) twice, in 2001 and 2010, the Packard Fellowship (1997) and the ACM Doctoral Dissertation Award (1995). He was a plenary lecturer at International Congress of Mathematicians in 2018. He was appointed a Simons Foundation investigator in 2012, and also won best paper awards in IEEE FOCS 2010 and ACM STOC 2004. Professor Arora was the founding director and lead PI at the NSF-funded Center for Computational Intractability in 2008-13.

Name:	Ali Jadbabaie (confirmed)
Email:	jadbabai@mit.edu
Website:	https://jadbabaie.mit.edu/
Experience:	Ali Jadbabaie is the JR East Professor and Head of the Department of Civil and Environmental Engineering at Massachusetts Institute of Technology (MIT), where he is also a core faculty in the Institute for Data, Systems, and Society (IDSS) and a Principal Investigator with the Laboratory for Information and Decision Systems. Previously, he served as the Director of the Sociotechnical Systems Research Center and as the Associate Director of IDSS which he helped found in 2015. He received a B.S. degree with High Honors in electrical engineering with a focus on control systems from the Sharif University of Technology, an M.S. degree in electrical and computer engineering from the University of New Mexico, and a Ph.D. degree in control and dynamical systems from the California Institute of Technology. He was a Postdoctoral Scholar at Yale University before joining the faculty at the University of Pennsylvania, where he was subsequently promoted through the ranks and held the Alfred Fitler Moore Professorship in network science in the Department of Electrical and Systems Engineering. He is a recipient of a National Science Foundation Career Development Award, an US Office of Naval Research Young Investigator Award, the O. Hugo Schuck Best Paper Award from the American Automatic Control Council, and the George S.Axelby Best Paper Award from the IEEE Control Systems Society. He has been a senior author of several student best paper awards, in several conference including ACC, IEEE CDC and IEEE ICASSP. He is an IEEE fellow, and the recipient of a Vannevar Bush Fellowship from the Office of Secretary of Defense. His research interests are broadly in systems theory, decision theory, optimization and and control, in particular optimization for Machine Learning.

Name:	Gitta Kutyniok (unconfirmed)
Email:	kutyniok@math.lmu.de
Website:	https://www.ai.math.uni-muenchen.de/members/professor/kutyniok
Experience:	Gitta Kutyniok currently is a Bavarian AI Chair for Mathematical Foundations of Artificial Intelligence at the Ludwig-Maximilians Universität München. She received her Diploma in Mathematics and Computer Science as well as her Ph.D. degree from the Universität Paderborn in Germany, and her Habilitation in Mathematics in 2006 at the Justus-Liebig Universität Gießen. Gitta Kutyniok has received various awards for her research such as an award from the Universität Paderborn in 2003, the Research Prize of the Justus-Liebig Universität Gießen and a Heisenberg-Fellowship in 2006, and the von Kaven Prize by the DFG in 2007. Gitta Kutyniok's research work covers, in particular, the areas of applied and computational harmonic analysis, artificial intelligence, compressed sensing, deep learning, imaging sciences, inverse problems, and applications to life sciences, robotics, and telecommunication.

Name:	Lester Mackey (confirmed)
Email:	lmackey@stanford.edu
Website:	https://web.stanford.edu/ lmackey/
Experience:	Lester Mackey is a statistical machine learning researcher at Microsoft Research New England and an adjunct professor at Stanford University. He received his Ph.D. in Computer Science (2012) and his M.A. in Statistics (2011) from UC Berkeley and his B.S.E. in Computer Science (2007) from Princeton University. Before joining Microsoft, He spent three wonderful years as an assistant professor of Statistics and, by courtesy, Computer Science at Stanford and one as a Simons Math+X postdoctoral fellow, working with Emmanuel Candes. His Ph.D. advisor was Mike Jordan, and his undergraduate research advisors were Maria Klawe and David Walker. He got his first taste of research at the Research Science Institute and learned to think deeply of simple things at the Ross Program.

Name:	Suvrit Sra (confirmed)
Email:	suvrit@mit.edu
Website:	https://optml.mit.edu/
Experience:	Suvrit Sra is a Alexander von Humboldt Professor of Artificial Intelligence at the Technical University of Munich (Germany), and and Associate Professor in the EECS Department at MIT (USA), where he is also a member of the Laboratory for Information and Decision Systems (LIDS) and the Institute for Data, Systems, and Society (IDSS). He obtained his PhD in Computer Science from the University of Texas at Austin. Before TUM & MIT, he was a Senior Research Scientist at the Max Planck Institute for Intelligent Systems, Tübingen, Germany. He has held visiting positions at UC Berkeley (EECS) and Carnegie Mellon University (Machine Learning Department) during 2013-2014. His research bridges mathematical topics such as differential geometry, matrix analysis, convex analysis, probability theory, and optimization with machine learning. He founded the OPT (Optimization for Machine Learning) series of workshops, held from OPT2008–2017 at the NeurIPS (erstwhile NIPS) conference. He has co-edited a book with the same name (MIT Press, 2011). He is also a co-founder and chief scientist of Pendulum, a global AI+logistics startup.

Name:	Mengdi Wang (confirmed)
Email:	mengdiw@princeton.edu
Website:	https://ece.princeton.edu/people/mengdi-wang
Experience:	Mengdi Wang received her Ph.D. in Electrical Engineering and Computer Science from Massachusetts Institute of Technology in 2013. At MIT, Mengdi was affiliated with the Laboratory for Information and Decision Systems and was advised by Dimitri P. Bertsekas. Mengdi joined Princeton University in 2014. She received the Young Researcher Prize in Continuous Optimization of the Mathematical Optimization Society in 2016 (awarded once every three years), the Princeton SEAS Innovation Award in 2016, the NSF Career Award in 2017, the Google Faculty Award in 2017, and the MIT Tech Review 35-Under-35 Innovation Award (China region) in 2018. She is currently serving as an associate editor for Operations Research.

4 ORGANIZERS AND BIOGRAPHIES

Name:	Wei Chen
Email:	chenwei2022@ict.ac.cn
Website:	https://weichen-cas.github.io/
Experience:	Wei Chen is a professor at Institute of Computing Technology, Chinese Academy of Sciences. Before she joined CAS in 2022, she was the leader of computing and learning theory group and the co-director of theory center in Microsoft Research Asia. She is now focusing on how to make machine learning trustworthy via "causality" and mathematics. Her current research interests include deep learning theory and causal machine learning, such as the convergence and implicit regularization of deep learning optimizers, causality-inspired models and o.o.d. prediction, robust learning and its applications in AI tasks. In 2021, she was named by Forbes as one of the 50 Top Women in Tech in China.

Name:	Christa Cuchiero
Email:	christa.cuchiero@univie.ac.at
Website:	https://homepage.univie.ac.at/christa.cuchiero/
Experience:	Christa Cuchiero is a professor at the University of Vienna. She earned her doctorate in Mathematics from ETH Zurich in 2011. Her research centers around mathematical finance, stochastic analysis and machine learning. She is particularly interested in classes of universal stochastic processes, approximation theory in dynamic situations, data-driven risk inference and AI in finance. Christa Cuchiero has received numerous prizes and fellowships, including the prestigious START award of the Austrian Science Fund (FWF). She has given a number of keynote speeches and serves on the editorial board of several academic journals. She has also co-organised international conferences and workshops and a world online seminar series on machine learning in finance.

Name:	Hadi Daneshmand
Email:	hdanesh@mit.edu
Website:	https://www.mit.edu/~hdanesh/index.html
Experience:	Hadi Daneshmand holds a postdoctoral fellowship at the Foundation of Data Science Institute (FODSI) hosted by MIT. Before, he was a Swiss National Science Foundation (SNSF) postdoctoral at Princeton University and a postdoctoral researcher at INRIA Paris. Hadi completed his Ph.D. at the Machine Learning Institute at ETH Zurich. His research focus is artificial intelligence and machine learning with a specific focus on the notion of over-parameterization in deep neural networks.

Name:	Stefanie Jegelka
Email:	stefje@mit.edu
Website:	http://people.csail.mit.edu/stefje/
Experience:	Stefanie Jegelka is a Humboldt professor at TU Munich, and an associate professor (on leave) at MIT. Her research interests include understanding and improving deep learning, in particular for structured data, robustness to distribution shifts, and learning with symmetries. Her work has received several awards, including an Alexander von Humboldt Professorship, an invited sectional lecture at the International Congress for Mathematicians, a Sloan Research Fellowship, a DARPA Young Faculty Award, an NSF CAREER award, and a Best paper award at ICML. She has co-organized more than 14 workshops, many of them at NeurIPS or ICML, and she has served as a program chair for ICML 2022.

Name:	Zelda Mariet
Email:	zmariet@google.com
Website:	http://www.zelda.lids.mit.edu
Experience:	Zelda Mariet is a senior research scientist at Google DeepMind. She obtained her PhD in machine learning at MIT in 2019. Her research focuses on the rigorous modeling of diversity and similarity in machine learning applications. Most recently, she has worked on generalizing the theory of ensembling, relying deeply upon the theory of Fenchel conjugates and duality. She has co-organized the 2019 and 2020 ICML "Negative Dependence in Machine Learning" workshops, as well as the 2023 "Duality Principles for Modern ML" ICML workshop .

Name:	Andre Niyongabo Rubungo
Email:	rn3004@princeton.edu
Website:	https://andrews2017.github.io/
Experience:	Andre Niyongabo Rubungo is second-year Ph.D. student at Princeton University, advised by Professor Adji Bousso Dieng. He is mainly interested in artificial intelligence for science, specifically focusing on leveraging large language models to solve challenging problems in materials science. He was the co-organizer of the first GEM workshop at ACL 2021 and has been serving as a reviewer for top ML and NLP conferences including ICLR, ICML, NeurIPS, and EAMT. He is the recipient of the ACL 2022 Best Linguistic Insight Paper Award.

Name:	Jiaye Teng
Email:	tjy20@mails.tsinghua.edu
Website:	www.tengjiaye.com
Experience:	Jiaye Teng is a fourth-year Ph.D. candidate at Tsinghua University, advised by Professor Yang Yuan. His research primarily centers around the field of theoretical machine learning, with a particular emphasis on statistical learning and generalization analysis. He is among the organizers of the FAI-Seminar, a highly regarded academic seminar featuring 20 talks and garnering over 90,000 views.

Name:	Bohan Wang
Email:	bhwangfy@gmail.com
Website:	bhwangfy.github.io
Experience:	Bohan Wang is a third-year joint Ph.D. candidate of Microsoft Research Asia and University of Science and Technology of China, advised by Professor Wei Chen and Professor Zhi-Ming Ma. He is mainly interested in optimization in deep learning, with a focus on understanding the underlying mechanisms of deep learning optimizers. His first-author works have been accepted by flagship conferences such as ICML, NeurIPS, ICLR, COLT, including several oral and spotlight.

Name:	Bohang Zhang
Email:	zhangbohang@pku.edu.cn
Website:	https://zbh2047.github.io
Experience:	Bohang Zhang is a fifth-year Ph.D. candidate at Peking University, advised by Professor Liwei Wang. His research centers around fundamental topics of machine learning, especially the expressive power of neural networks, with connections to robustness, graph learning, and reasoning in language models. He is one of the recipients of ICLR 2023 Outstanding Paper Award.

Name:	Jingzhao Zhang
Email:	jingzhaoz@mail.tsinghua.edu.cn
Website:	https://sites.google.com/view/jingzhao/home
Experience:	Jingzhao Zhang is an assistant professor at Tsinghua, IIIS. He graduated in 2022 from MIT EECS PhD program under the supervision of Prof. Ali Jadbabaie and Prof. Suvrit Sra. Before that, he received B.S. degree from UC Berkeley and was advised by Prof. Laura Waller. His research focuses on providing theoretical justifications and analyses to practical large-scale optimization algorithms. He is also interested in machine learning applications, especially those involving dynamical system formulations. He received Ernst A. Guillemin SM Thesis Award and George M. Sprowls PhD Thesis Award.

5 Program Committee

Confirmed:

- Wei Chen (CAS)
- Hadi Daneshmand (MIT)
- Guhao Feng (Peking)
- Thien Le (MIT)
- Zelda Mariet (Google DeepMind)
- Jiaye Teng (Tsinghua)
- Runzhe Wang (Princeton)
- Tianle Cai (Princeton)
- Xingyu Dang (Tsinghua)
- Kaixuan Huang (Princeton)
- Shengjie Luo (Peking)
- Sadhika Malladi (Princeton)
- Kaiyue Wen (Tsinghua)
- Bohang Zhang (Peking)
- Christa Cuchiero (univie)
- Yuxin Dong (Xi'an Jiaotong)
- Stefanie Jegelka (MIT)
- Jianhao Ma (UMich)
- Andre Niyongabo Rubungo (Princeton)
- Bohan Wang (USTC)
- Jingzhao Zhang (Tsinghua)

Unconfirmed:

- Neha Gupta
- Omar Montasser
- Kwangjun Ahn
- Kavya Ravichandran
- Christina Baek
- Surbhi Goel
- Gene Li
- Abhishek Panigrahi
- Alex Atanasov
- Micah Goldblum
- Rohith Kuditipudi
- Jeremy Cohen
- Ahmed Khaled
- Jikai Jin
- Hong Liu
- Kumar Kshitij Patel
- Frederik Kunstner
- Elan Rosenfeld
- Eshaan Nichani
- Margalit Glasgow
- Tianhao Wang

6 AUDIENCE: REACH-OUT AND ANTICIPATED SIZE

We are committed to reaching a diverse and engaged audience for the workshop. We will provide a dedicated website and landing page for the workshop, providing detailed information about the event, speakers, and registration instructions. Our workshop will be advertised via popular social media platforms (X / Twitter, r/MachineLearning, Facebook) and traditional avenues (e.g., WikiCFP, speaker and organizer academic/professional networks). To ensure we reach a broad audience, we will also be reaching out for participants via popular affinity mailing lists, including LXAI, Black in AI, MusIML, and Queer in AI.

Based on previous workshops on similar topics (e.g., Duality principles for modern machine learning, ICML 2023), we anticipate over 100 in-person attendees and over 1000 virtual attendees.

7 DIVERSITY COMMITMENT

Workshop organizers include researchers from n different nationalities (Rwandan, Chinese, German, Japanese, Austrian, Iranian), and at different stages of their careers in academia (professors, postdocs, PhD students) and industry. The 6 men and 4 women also hail from different geographic regions (Europe, North America, and East Asia), and are committed to fostering collaborations among researchers across the globe who are working on this topic. Several organizers have experiences in co-organizing workshops before.

Similarly, our invited speakers reflect a broad spectrum of gender, ethnicity, and professional backgrounds. The collective research interests of the organizers and speakers encompass algorithmic regularization, generalization theory, distribution shift and reliability in ML, self-supervised learning, and generative modeling, reflecting the interdisciplinary nature of the workshop.

As mentioned above, we will be advertising our workshop and soliciting submissions via different affinity groups. Submissions to our workshop will go through a double-blind review, and contributed talks will be selected based on review scores while maintaining a diversity of covered topics. Finally, we hope that our hybrid format will broaden the reach of our workshop beyond those able to physically travel to Vienna.

8 PREVIOUS RELATED WORKSHOPS

This workshop does not have any earlier versions. Below, we list previous workshops that are related to this one. The following workshops also targets on theory of general machine learning:

- NeurIPS 2023. Mathematics of Modern Machine Learning (M3L)
- ICLR 2023. Mathematical and Empirical Understanding of Foundation Models (ME-FoMo)
- ICLR 2022. GroundedML: Anchoring Machine Learning in Classical Algorithmic Theory

Distinguishing itself from preceding workshops, we take a special focus on the gap between existing theory and practice, aiming at narrowing the gap, developing better theory that align with experimental findings, and designing theoretical-inspired algorithms that work in practice.

In addition to the above workshop, the following one has a seemingly similar title to ours but is actually different:

- NeurIPS 2022. I Can't Believe It's Not Better: Understanding Deep Learning Through Empirical Falsification

There are also several workshops targeting specific theoretical topics in machine learning, such as optimization, self-supervised learning, optimal transport, sampling, etc.

- NeurIPS 2023. Optimization for Machine Learning (OPT 2023)
- ICLR 2022. Workshop on Self-Supervised Learning: Theory and Practice

- NeurIPS 2023. Optimal Transport and Machine Learning
- NeurIPS 2023. Heavy Tails in ML: Structure, Stability, Dynamics
- NeurIPS 2023. Sampling and Optimization in Discrete Space
- ICML 2023. Duality Principles for Modern Machine Learning

Here, we welcome submissions in any general machine learning topic, as long as it suits the requirements as stated in Section 1.

9 TENTATIVE SCHEDULE

The workshop aims to foster engaging and interactive discussions among participants. The agenda features an array of engaging sessions, including:

1. **Invited Talks (6 sessions)**: Each of these sessions will comprise a 25-minute talk followed by a 5-minute question and answer period. This format allows us to explore critical topics in-depth while encouraging active engagement.
2. **Contributed Talks (5 sessions)**: Authors of submitted works will have the opportunity to present their research during these sessions. These talks provide a platform for showcasing the latest developments and insights within the field.
3. **Poster Sessions (4 sessions)**: To maximize the exchange of ideas and promote networking, we have planned four poster sessions. These provide an excellent platform for in-depth discussions and sharing of research findings.

In addition to these in-person activities, we aim to enhance interaction further by accommodating remote participants. Our online viewers and the live audience will have the opportunity to pose questions and engage with the speakers and paper authors through Slack, fostering a dynamic and inclusive experience.

The workshop's lunch and coffee breaks will be integrated with the official conference schedule. We believe this approach will allow participants to make the most of their time at the event and maximize their engagement.

Our tentative schedule for the workshop is as follows:

Time	Event
09:00 - 09:10	Introduction and opening remarks
09:10 - 09:40	Invited Talk 1
09:40 - 10:10	Invited Talk 2
10:10 - 11:00	Poster Session 1 and Coffee Break
11:00 - 11:30	Invited Talk 3
11:30 - 11:45	Contributed Talk 1
11:45 - 12:00	Contributed Talk 2
12:00 - 14:00	Poster Session 2 and Lunch Break
14:00 - 14:30	Invited Talk 4
14:30 - 15:00	Invited Talk 5
15:00 - 15:15	Contributed Talk 3
15:15 - 15:30	Contributed Talk 4
15:30 - 16:20	Poster Session 3 and Coffee Break
16:20 - 16:50	Invited Talk 6
16:50 - 17:05	Contributed Talk 5
17:05 - 17:55	Poster Session 4