

Minhak Song

Undergraduate Student, KAIST

Personal website: songminhak.github.io Contact: minhaksong@kaist.ac.kr

Research Interests

I am interested in the theoretical foundations of modern machine learning, with the goal of **bridging theory and practice**. My current research focuses on the **training dynamics of optimization algorithms**, particularly in the pretraining and fine-tuning of language models, leveraging these insights to design principled and efficient methods.

Education

Korea Advanced Institute of Science and Technology (KAIST) , Daejeon, South Korea	03/2020 – Present
B.S. in Mathematical Sciences (Minor in Industrial and Systems Engineering)	GPA: 4.19/4.3 (Graduation: 08/2026)
> Tuition and stipend fully covered by National Presidential Science Scholarship.	
> Leave of absence for 2 years of mandatory alternative military service (02/2023 – 11/2024).	
University of Washington (UW) , Seattle, WA	01/2025 – 06/2025
Exchange Student	
> Tuition and stipend fully covered by Korea-U.S. Student Exchange Program Scholarship.	
University of California, Berkeley , Berkeley, CA	06/2022 – 08/2022
Summer School	
> Tuition and stipend fully covered by KAIST Presidential Fellowship.	
Korea Science Academy of KAIST , Busan, South Korea	03/2017 – 02/2020
Science High School for Gifted Students	

Research Experience

Paul G. Allen School of Computer Science & Engineering @ UW , Seattle, WA	06/2025 – 08/2025
Undergraduate Researcher with Prof. Sewoong Oh	
> Focus: Zeroth-Order Optimization for Language Model Training	
Paul G. Allen School of Computer Science & Engineering @ UW , Seattle, WA	01/2025 – 06/2025
Undergraduate Researcher with Prof. Simon Du	
> Focus: Reinforcement Learning for Human Feedback (RLHF) from an Optimization Perspective [5]	
Optimization & Machine Learning Laboratory @ KAIST , Seoul, South Korea	03/2022 – 12/2024
Undergraduate Researcher with Prof. Chulhee Yun	
> Focus: Training Dynamics of Optimization Algorithms in Deep Learning [1, 2, 3, 4, 6]	

Publications

(* denotes equal contribution)

- [6] **Through the River: Understanding the Benefit of Schedule-Free Methods for Language Model Training**
Minhak Song*, Beomhan Baek*, Kwangjun Ahn, Chulhee Yun [\[Paper\]](#)
ICML 2025 Workshop on High-dimensional Learning Dynamics [ICMLW 2025]
- [5] **Understanding the Performance Gap in Preference Learning: A Dichotomy of RLHF and DPO**
Ruizhe Shi*, Minhak Song*, Runlong Zhou, Zihan Zhang, Maryam Fazel, Simon Du [\[arXiv:2505.19770\]](#)
Under Review [Manuscript]
- [4] **Understanding Sharpness Dynamics in NN Training with a Minimalist Example: The Effects of Dataset Difficulty, Depth, Stochasticity, and More**
Geonhui Yoo, Minhak Song, Chulhee Yun [\[Paper\]](#) [\[arXiv:2506.06940\]](#)
International Conference on Machine Learning [ICML 2025]
- [3] **Does SGD really happen in tiny subspaces?**
Minhak Song, Kwangjun Ahn, Chulhee Yun [\[Paper\]](#) [\[arXiv:2405.16002\]](#)
International Conference on Learning Representations [ICLR 2025]
- [2] **Linear attention is (maybe) all you need (to understand Transformer optimization)**
Kwangjun Ahn*, Xiang Cheng*, Minhak Song*, Chulhee Yun, Ali Jadbabaie, Suvrit Sra [\[Paper\]](#) [\[arXiv:2310.01082\]](#)
International Conference on Learning Representations [ICLR 2024]

Talks

“Does SGD really happen in tiny subspaces?”

- > Prof. Yaoqing Yang’s Group Meeting @ Dartmouth CS. Invited Talk (60min).
> Prof. Sewoong Oh’s Group Meeting @ UW CSE. Invited Talk (60min).
- Remote, 05/2025
Seattle, WA, 04/2025

“Trajectory Alignment: Understanding the Edge of Stability Phenomenon via Bifurcation Theory”

- > Prof. Chulhee Yun’s Group Meeting @ KAIST AI. Invited Talk (60min).
- Seoul, South Korea, 07/2023

Industry Experience

- Upstage, Seoul, South Korea
AI Research Engineer Intern
- 09/2022 – 12/2022
- > AI startup led by Prof. Sung Kim @ HKUST.
> Designed personalized recommendation models using contextual bandit algorithms for e-commerce service.

Selected Honors and Awards

- National Presidential Science Scholarship (45,000 USD), Korea Student Aid Foundation.2020 – 2026
- KAIST Presidential Fellowship (30,000 USD), KAIST.2020 – 2026
- KAIST Alumni Academic Scholarship (15,000 USD), KAIST Alumni Scholarship Foundation.2021 – 2026
- Korea-U.S. Student Exchange Program Scholarship (9,000 USD), Minister of Trade, Industry and Energy.2025
- Travel Award, ICLR 2024. Vienna, Austria2024
- Travel Award, NeurIPS 2023. New Orleans, LA2023
- Top Student Award (rank #1 at department), KAIST ISE.Spring 2021, Fall 2021, Spring 2022
- Dean’s List (top 2%), KAIST.Spring 2021, Fall 2021, Spring 2022
- Talent Award of Korea (50 high school students in Korea), Deputy Prime Minister and Minister of Education.2019
- Hanseong Scholarship for Gifted Students (10,000 USD), Hanseong Sonjaehan Scholarship Foundation.2018 – 2019
- Grand Prize, Korean Young Physicists’ Tournament.2018

Teaching and Academic Activities

- Participant, Deep Learning Theory Workshop and Summer School, Simons Institute. Berkeley, CA
> Part of “Summer Cluster: Deep Learning Theory” program at Simons Institute for the Theory of Computing.
- Summer 2022
- Academic Tutor, KAIST. Daejeon, South Korea
> Courses: Calculus I (Spring 2021), Calculus II (Fall 2021).
- 2021
- Conference Reviewer: NeurIPS 2024–2025, ICML 2025, ICLR 2025, AISTATS 2025
- Workshop Reviewer: ICML 2025 Workshop on High-dimensional Learning Dynamics

Selected Coursework

- KAIST: Real Analysis, Probability Theory, Convex Optimization, Statistical Learning Theory, Deep Learning Theory
- University of Washington: Advanced Machine Learning, Interactive Learning, Optimization: Fundamentals and Applications, Toolkit for Modern Algorithms

Skills

- Languages: Korean (native), English (fluent) — TOEFL iBT: 108 (R29/L25/S28/W26)
- Computer Languages & Software: Python, \LaTeX , MATLAB