Hyemin Gu

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Research interest

dynamical transport, gradient flows, particle transport, Wasserstein proximal regularization, entropic regularization, generative modeling

Projects

Generative Particles Algorithm Link to Demo

Developed a generative model for high-dimensional scarce data (28×28 MNIST 200 samples) which is mathematically formulated by gradient flows of probability distributions and corresponding particle dynamics. A choice of learning loss as **Wasserstein-1 proximal regularized f-divergence** leads to stabilizing the dynamics and helps finding low-dimensional data manifolds.

Wasserstein-1/Wasserstein-2 proximal generative flow Link to Demo

Formulated and implemented a generative model with **continuous-time adversarial flow** architecture for learning distributions that are supported on low-dimensional manifolds. Our formulation is analyzed via Mean Field Game theory and ensures good properties of the learned flow such as **uniqueness** of solution and **optimal (linear) paths**.

Wasserstein proximal generative models Link to Demo

Learning objectives for generative models such as generative adversarial networks and normalizing flows have their Wasserstein-p proximal regularized counterparts with $p = 1, 2$ which can be finitely evaluated even for comparing distributions with disjoint supports and therefore stabilizes their training processes. In addition, learning objectives for the state-of-art score-based generative models contain a type of Wasserstein-2 proximal regularization. We compared the **influences of Wasserstein-p proximal regularizations with** $p = 1, 2$ on these generative models for learning **polynomially-tailed distributions**.

Publications

Chen, Ziyu et al. (2024). *Learning heavy-tailed distributions with Wasserstein-proximal-regularized α-divergences*. arXiv: 2405.13962 [stat.ML]. URL: https://arxiv.org/abs/2405.13962.

Gu, Hyemin, Panagiota Birmpa, et al. (2024). "Lipschitz-Regularized Gradient Flows and Generative Particle Algorithms for High-Dimensional Scarce Data". In: *SIAM J.Data Science, to appear*. URL: https://arxiv.org/abs/2210.17230.

Gu, Hyemin, Markos A. Katsoulakis, et al. (2024). *Combining Wasserstein-1 and Wasserstein-2 proximals: robust manifold learning via well-posed generative flows*. arXiv: 2407.11901 [stat.ML]. URL: https://arxiv.org/abs/2407.11901.

Conferences

Poster Presentation at Optimal Transport in Data Science – ICERM, Brown university May 2023
– H. Gu et al., *Lipschitz Regularized Gradient Flows and Latent Generative Particles* Link to File

Poster Presentation at Joint Mathematics Meetings, Mathematical Association of America Jan 2018
– H. Gu, *Training a 2 layer Neural Network using SVD-generated weights* Link to File

Poster Presentation at Joint Mathematics Meetings, Mathematical Association of America Jan 2017
– J. Park et al., *Necessary and sufficient conditions for shortest vectors in lattices of dimension 2 and 3* Link to File

Education

2020 - present PhD candidate (Mathematics) at University of Massachusetts - Amherst, MA, USA

2018 - 2020 Master (Mathematics)'s degree at Ewha Womans University, Seoul, South Korea
Thesis: *Convolutional Neural Network for 2D Flow Estimation Problem*

2014 - 2018 Bachelor's degree at Ewha Womans University, Seoul, South Korea
Major in *Mathematics* and *Computational science*, minor in *Statistics*
Dean's list 5 semesters
Thesis: *Low cost training of a classification Neural Network with respect to Weight Selection*

Teaching experience

Graduate teaching assistant at University of Massachusetts - Amherst, MA, USA Feb 2021 - Dec 2021

- (MATH532H) Nonlinear dynamics and chaos with applications: graded assignments and conducted **tutorial sessions for Python ODE solving**
- (MATH545) Linear algebra for applied mathematics: graded assignments, conducted discussion sessions and arranged offie hours
- (MATH235) Linear algebra, (MATH545) Linear algebra for applied mathematics: graded assignments

Graduate teaching assistant at Ewha Womans Universiy, Seoul, South Korea Mar 2018 - Dec 2019

- Numerical differential equations (**numerics for ODE/PDE, Monte-Carlo, optimization**): graded assignments and arranged office hours
- Finite mathematics and programming (**Matlab programming, mathematical logic, combinatorics**): graded assignments and arranged office hours
- Calculus 2 (**multivariate calculus**): graded assignments and arranged office hours
- Numerical analysis (**linear system solving, power method, numerical integration/differentiation**): graded assignments and arranged office hours

Work Experience

Statistics specialist at Ewha Womans University Seoul Hospital, Seoul, South Korea Jul 2020 - Dec 2020

- Developed a **pipeline for acquiring, analyzing, and visualizing** gene expression data from open repositories using R; authored a **tutorial book** on the process.
- Conducted **training sessions on statistical analysis using R** for colleagues.

Training

Industrial Mathematics Academy from National Institute for Mathematical Sciences, South Korea Jun 2018

- Presented a final result of a group project for solving industrial problem.
- Proposed a **Convolutional Neural Network for classifying** infected individual from images.
- Coordinated team efforts for the group project.
- Attended tutorials on **Python data analysis and Keras**, lectures on **matrix based data analysis, linear programming theory and practice**.

Industrial Mathematics Academy from National Institute for Mathematical Sciences, South Korea Dec 2017

- Proposed a **model for assessing safe driving scores** from On-board diagnostic data based on Poisson process.
- Attended tutorials on **basics to neural networks**.

Leadership

Department seminar organizer as a part of *Graduate Student Advisory Committee* Sep 2022 - present
Department of Mathematics and Statistics, University of Massachusetts - Amherst, MA, USA

– **Invited speakers** among faculties in the department for introducing their research interests to early-career graduate students and **hosted talks**.
– **Participated in regular Graduate Student Advisory Committees meetings**, reported the progress, and discussed future directions.

Honors and awards

Anne and Peter Costa Graduate Prize in Applied Mathematics April 2024