Mohsen Karkheiran

GitHub — LinkedIn — Streamlit — Publications

Summary

Ph.D. in Mathematical Physics with 4 years of research experience, offering a strong foundation in mathematical modeling, computational physics and problem solving, with extensive knowledge in deep learning. My portfolio of work showcases a broad array of AI concepts, with a strong emphasis on application and value-add (including simple RNN/ANN/CNN), reinforcement learning (Q-learning, DQN, Actions-Critic, REINFORCE) and physics-informed neural networks (PINNs). Currently leading a major Quantum AI project, developing a tensor network package to implement many algorithms in Tensor-Trains and DMRG optimization. Bridging my deep understanding of physics with AI methodologies to contribute effectively in interdisciplinary roles.

Skills

Deep Learning: Reinforcement Learning, Recurrent Neural Networks, Convolutional Neural Networks, Artificial Neural Networks, Physics informed Neural Networks, NLP, LLM(basic)

Tools: Excel, Tableau, Github, Streamlit, AWS (S3, Lambda, IAM, EC2, SageMaker, RDS, DynamoDB, Glue), DataBricks

Machine Learnng: Linear Regression, Logistic Regression, Decision Trees, Random Forest, KNN, k-means, PCA, Association Rule Learning, Causal Impact Analysis , NetworkX, NLTK

Programming: Python(Base, Pandas, Numpy, Matplotlib, seaborn, Scikit-Learn, SciPy, NetowrokX, NLTK, Keras, PyTorch), Julia, SQL, MongoDB , Mathematica , SageMath, MAGMA

Mathematics: Differential Equations, Linear Algebra, Statistics (Hypothesis Testing, AB Testing, Central Limit Theorem, Distributions), Algebraic Geometry/Topology, Differential Geometry, Category Theory

Physics: Classical/Statistical/Quantum Physics and Field Theory

Quantum Computing: PennyLane, Qiskit

Work Experience

Postdoctoral fellow *Mathematical Physics*, University of Alberta, Edmonton, Alberta 01/2023 - Now
Visiting researcher at University of Waterloo.

- Novel connections were derived between geometries and physical models using MAGMA and SageMath.
- Classified symmetries of geometrical spaces by CNNs and ANNs with an accuracy close to 98%.

Postdoctoral fellow *High Energy Physics*, Institute for Basic Sciences, 10/2020 - 11/2022
Daejeon, South Korea

- Used numerical algebraic geometry in Mathematica to link polynomial rings' linear algebra with space geometry.

AI related Projects

PINNs in Finance: Applied **PINNs** (written from scratch) to solve the differential equation of option pricing in the famous **Black-Sholes-Merton** model. PINNs are much faster and more precise than traditional finite element methods. In addition, with PINNs inverse problem method it is possible to find the parameters of the underlying market.

Parameter finding with DeepXDE: Used the PINNs package, DeepXDE, to solve differential equations in physical models. Simulated a noisy environment, applied PINNs inverse problem method to find the physical paramters of the system from data.

Q-Learning in Finance: Simulated stock market prices and used Q-Learning to find fair option prices based on the Black-Scholes-Merton model.

Optimization with RL: An off-policy RL technique (Q-learning) based on **PyTorch** is used to find the shortest path in a field with arbitrary obstacles (complete, on-policy versions are being developed, will be deployed soon).

RNN for Time Series: Applied RNN architectures to time series to forecast future values. This was used in the context of stock market prices, and compared with the traditional time series approach ARIMA. In the context of weather forecasting, we apply LSTM models to predict the hurricanes' paths.

Grocery Image Classification: In order to help groceries to enhance their delivery and sorting systems, we build and optimize a Convolutional Neural Network to classify images of fruits.

AI in Algebraic Geometry: With deep learning techniques such as **ANNs** and **CNNs** we classified the symmetries of six dimensional spaces commonly used in string theory model buildings. These spaces are characterized by matrices; **image processing** algorithms are used (Finished to be published soon).

Image Search Engine: By transferring **VGG16** architecture, we built a Deep Learning based Image Search Engine that will help customers find similar products to ones they want.

Quantum AI: A Python-based package is written to analyze **Tensor Networks**, find **MPO, MPS, PEPS** states, apply compression, and **DMRG**. It has can map tensor networks into **quantum circuits** to be used quantum machine learning problems (to appear soon).

GitHub Portfolio: Many projects that use **ML** techniques such as **RandomForrests, DecisonTrees, SVM, SGD** in combination with **NLP**, **NetworkX**, and unsupervised learning techniques such as **PCA, t-SNE** (Visit Github and Streamlit pages for updates).

Education

PhD *Mathematical Physics/String Theory*, Virginia Tech, Blacksburg, USA, 05/2020

Certifications

- Data Science Certificate, University of Waterloo (WatSpeed): Data Science, Statistics in Data Science, Machine leanrning, Big Data Management
- PINNs course University of Alberta (Prof. V. Putkaradze)
- Data Science Certificate, University of Michigan: Machine learning, NLP, Network Analysis.

Special Mention

- Rank 2 in national entrance exam for Ph.D program in physics between 5000 applicants, Iran, 2013
- Rank 6 in national national entrance exam for M.Sc program in physics between 6000 applicants, Iran, 2011
- Rank 368 in national national entrance exam for B.Sc programs between 10^5 applicants, Iran, 2007