KAN based Autoencoders for Factor models

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Introduction

- Factor models describe relationships between asset returns and factors.
- Standard form: $r = \boldsymbol{\beta}\, factor + \boldsymbol{\epsilon}$
- Some popular models: Fama French, CAPM, etc.

What’s the problem?

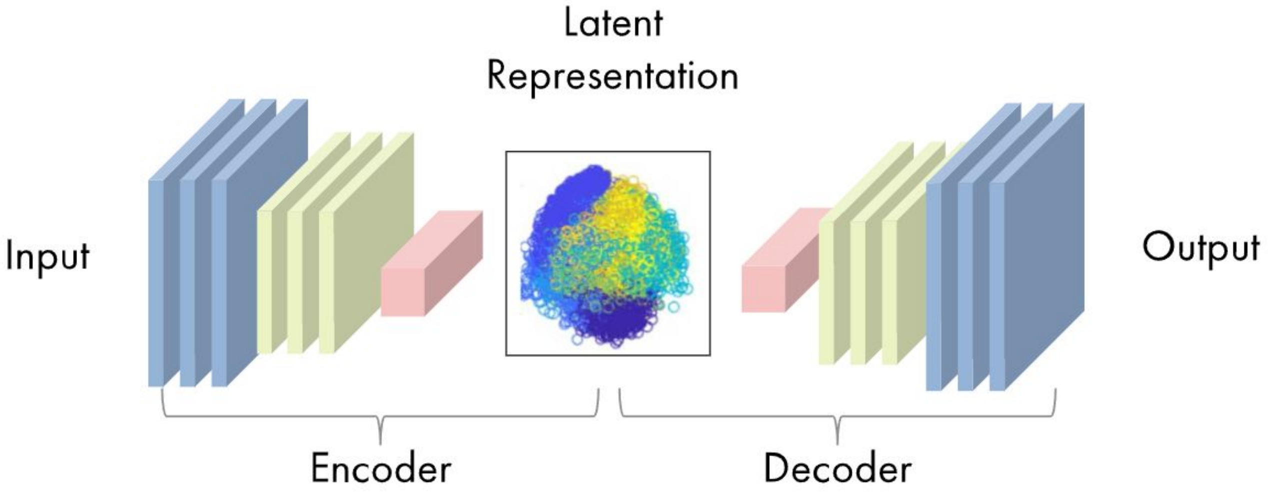
- Real world data isn’t linear or independent.
- It is:
  1. Collinearity - Gram Schmidt Process, PCA
  2. Multidimensional representation - Feature engineering
  3. Noise - PCA
- Factors aren’t enough, PCA can’t go back

Experiment Setup

- Risk Weighted Portfolio Construction of Russell 3000 dataset
- Winsorized Outliers
- OLS for getting factor weights, $r = \boldsymbol{\beta}\, factor + \boldsymbol{\epsilon}$
- One reason to do this, faster and efficient, however entire dataset **could be** better (However, [1.5 million * 26 factors] v/s [15120 * 26 factors]).

Autoencoders

- Neural networks that learn to compress and reconstruct data
- Goal: Learn efficient representations while preserving important information



https://www.mathworks.com/discovery/autoencoder.html

Kolmogorov Arnold Networks

Based on Kolmogorov-Arnold Representation theorem, any continuous function of several variables can be constructed using only:

- Addition, Composition, Functions of a single variable

It showed complex multivariate functions could be built from simple building blocks.

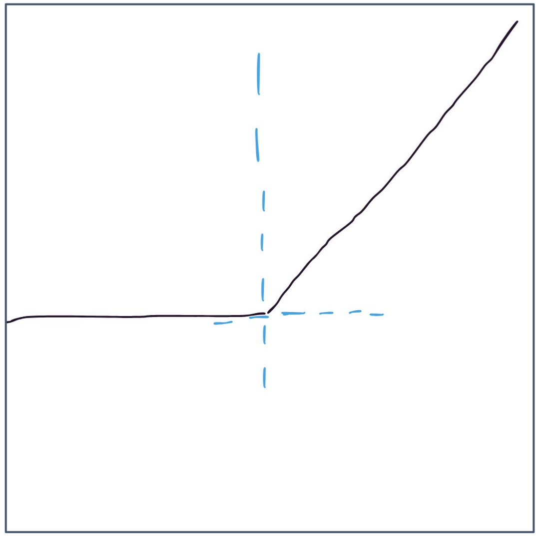
Neural nets are black-box equation solvers, Researchers at MIT thought why not use the kolmogorov's work in neural nets.

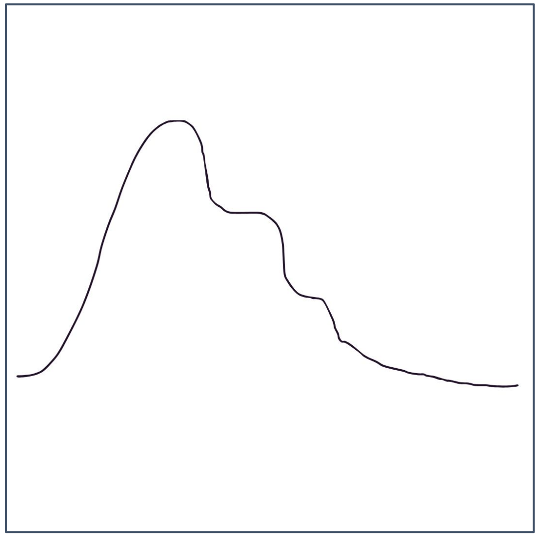
Liu, Ziming, Yixuan Wang, Sachin Vaidya, Fabian Ruehle, James Halverson, Marin Soljačić, Thomas Y. Hou, and Max Tegmark. "Kan: Kolmogorov-arnold networks." *arXiv preprint arXiv:2404.19756* (2024).

Kolmogorov Arnold Networks

Activation functions in DL: ReLU, sigmoid, GeLU, etc.

KAN has flexible and learnable activation functions.





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Kolmogorov Arnold Networks

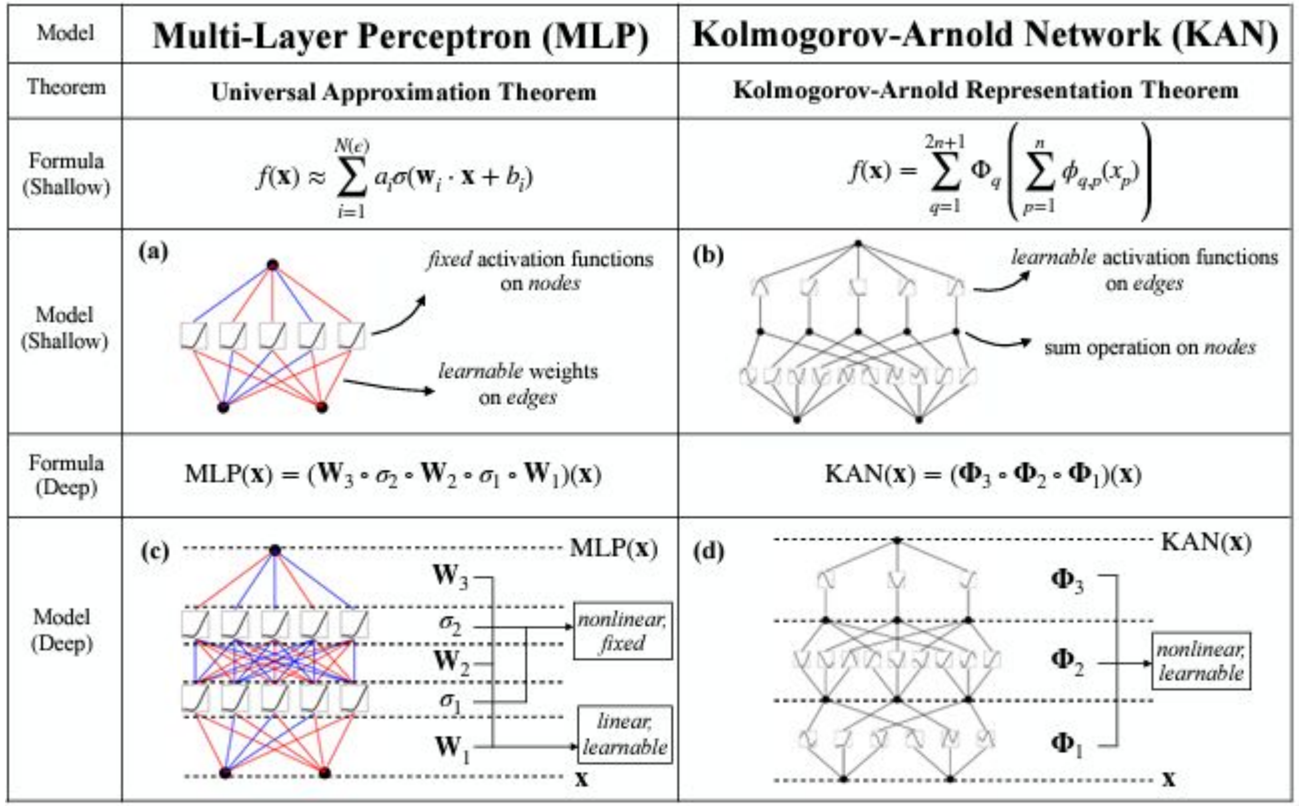

Figure 0.1: Multi-Layer Perceptrons (MLPs) vs. Kolmogorov-Arnold Networks (KANs)

KANs are flexible and interpretable, paper has examples.

Unfortunately, our work hasn't proved interpretability yet.

Liu, Ziming, Yixuan Wang, Sachin Vaidya, Fabian Ruehle, James Halverson, Marin Soljačić, Thomas Y. Hou, and Max Tegmark. "Kan: Kolmogorov-arnold networks." *arXiv preprint arXiv:2404.19756* (2024).

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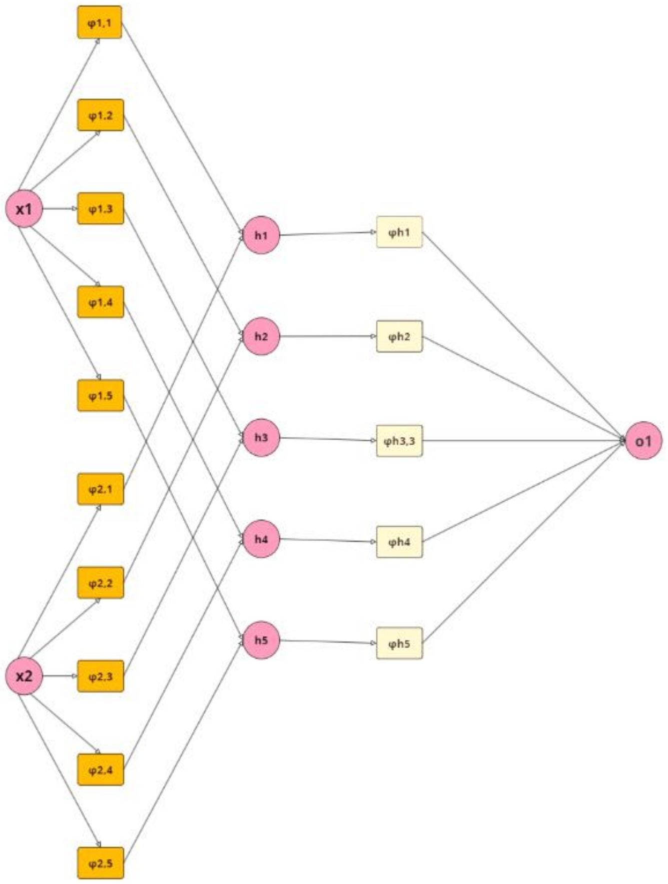
Model Design

- KAN based encoder for getting latent representations as model factors
- Use a simple decoder to reconstruct a factor model explaining returns
- Solve to minimize the loss function (Actual returns vs approximated returns)



Wang, Tianqi, and Shubham Singh. "KAN based Autoencoders for Factor Models." arXiv preprint arXiv:2408.02694 (2024).

Loss

Creating a loss function for factor model

- predicted return -> $r_{□}^{\text{predicted}} = \boldsymbol{\beta}_{□} factor_{□} + \boldsymbol{\epsilon}_{□}$

  Loss = $r_{□}^{\text{actual}} - r_{□}^{\text{predicted}}$

Results

Dataset: 60 years of stock data (1957-2016)

Training: 1957-1987 (30 yr) Validation: 1987-1999 (12 yr) Testing: 2000-2016 (16yr)

Table 1: R^2 Scores

Model	FF	CA	KAN-CA
1 factor	<0	11.06	11.02
3 factors	<0	11.39	11.26
6 factors	<0	11.29	11.32

Table 2: Predictive R^2 Scores

Model	FF	CA	KAN-CA
1 factor	<0	0.202	0.203
3 factors	<0	0.168	0.203
6 factors	<0	0.188	0.214

Table 3: Sharpe Ratio

Model	1 factor	3 factors	6 factors
CA	0.86	0.87	0.91
KAN-CA	0.84	0.86	0.96

Future Research Directions

- Demonstrate KAN's interpretability, so we have better interpretable factor models.
- Establish statistical significance of performance improvements through extended validation periods and comprehensive sensitivity analysis across market conditions.
- Optimize model architecture through systematic hyperparameter studies, adding more neurons and longer training periods, with standardized benchmarking against more state-of-the-art factor models.
- Add Mean Variance Portfolio, Random Portfolio Tests, Q-test

Feedback and questions

Paper link: https://www.arxiv.org/abs/2408.02694

Thank you!