Portfolio Optimization with Deep Learning

Erdȍs Institute Deep Learning Bootcamp
Spring 2024

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Introduction

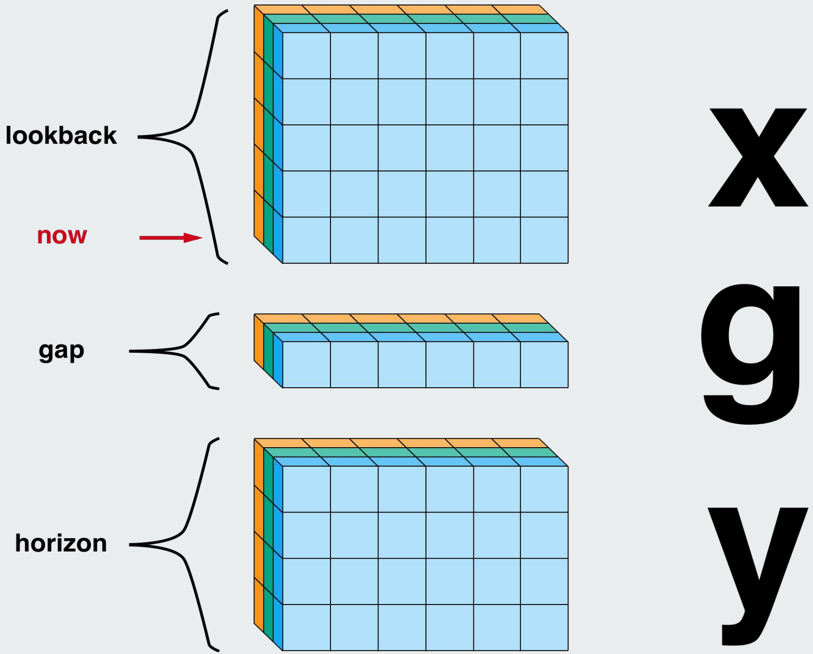
Portfolio optimization is a fundamental problem in finance.

Goal for an investor is to construct a portfolio of investments, that maximizes the returns and minimizes the risk.

A mathematical framework for this was introduced by Markowitz, known as the mean variance model, where an investor seeks a portfolio to maximize the expected total return for any given level of risk measured by variance.

Markowitz framework

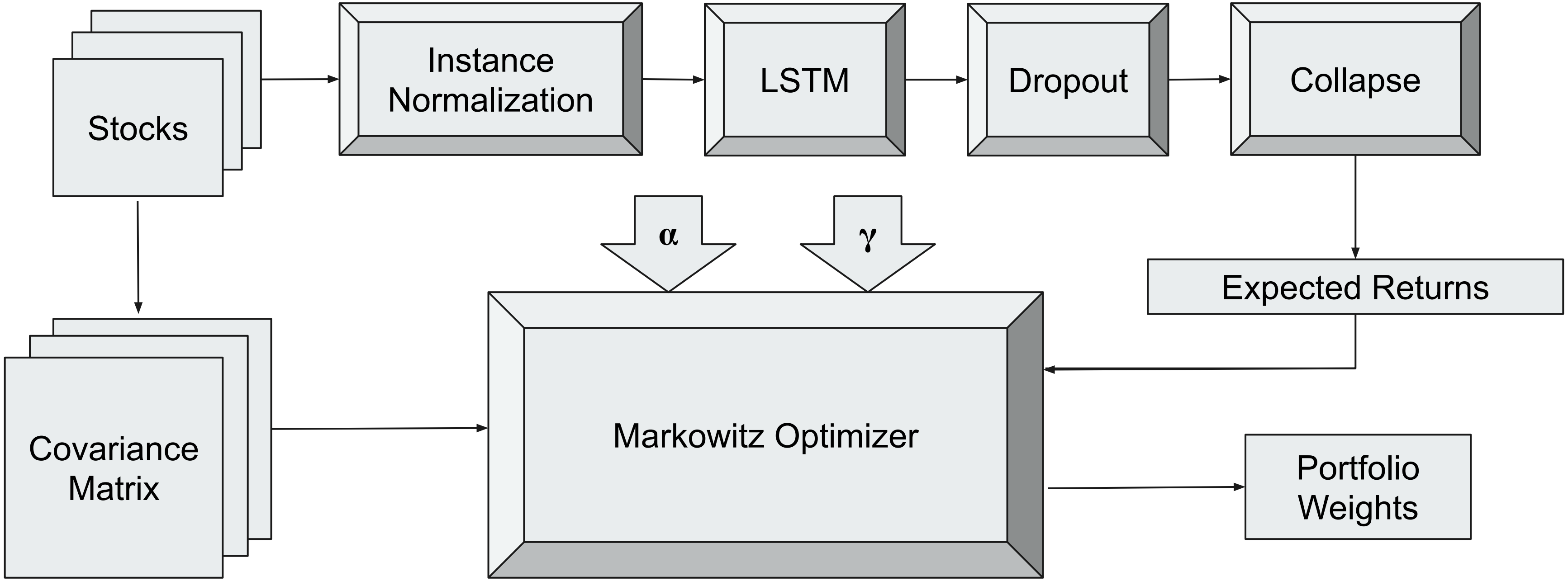
This can be implemented in the following way: (1) Estimation of the expected returns (μ) and the covariance matrix (Σ) and (2) Solving a convex optimization problem (max $\mu \cdot w - \gamma\, w \cdot (\Sigma\, w)$) such that w is a positive vector of weights and sum of weights is 1.



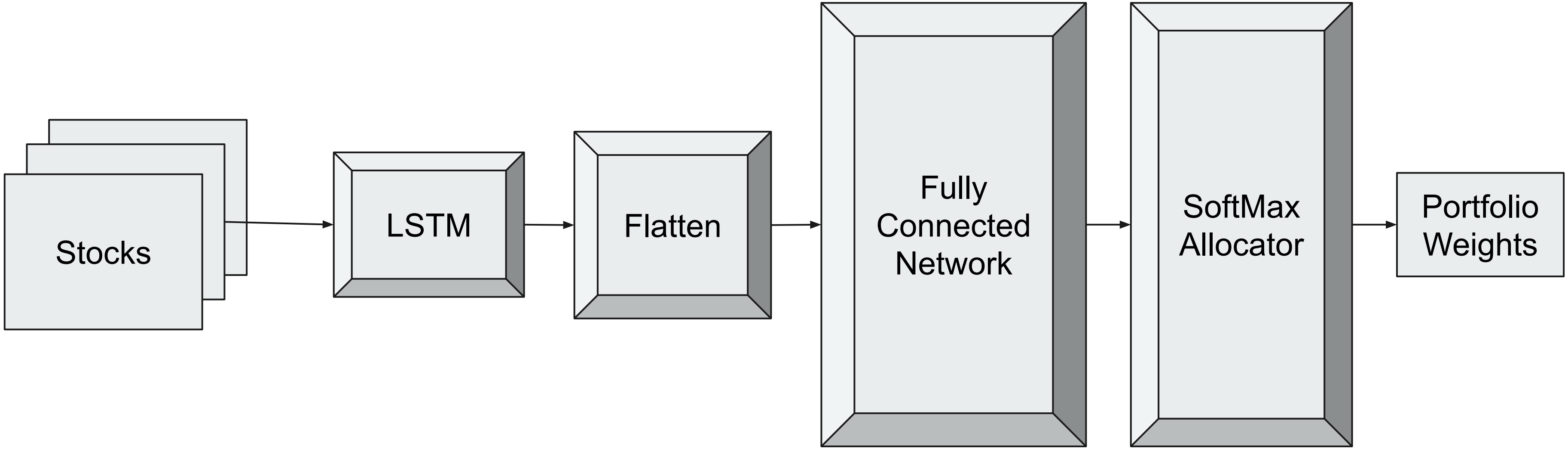
To perform portfolio optimization we used a deep learning library called DeepDow.The idea behind DeepDow is to create an end to end deep neural network that learns weightage of each stock in the portfolio from the historical price data.

To do this, think of a financial time series as 3D tensor consisting of time, assets values and channels.

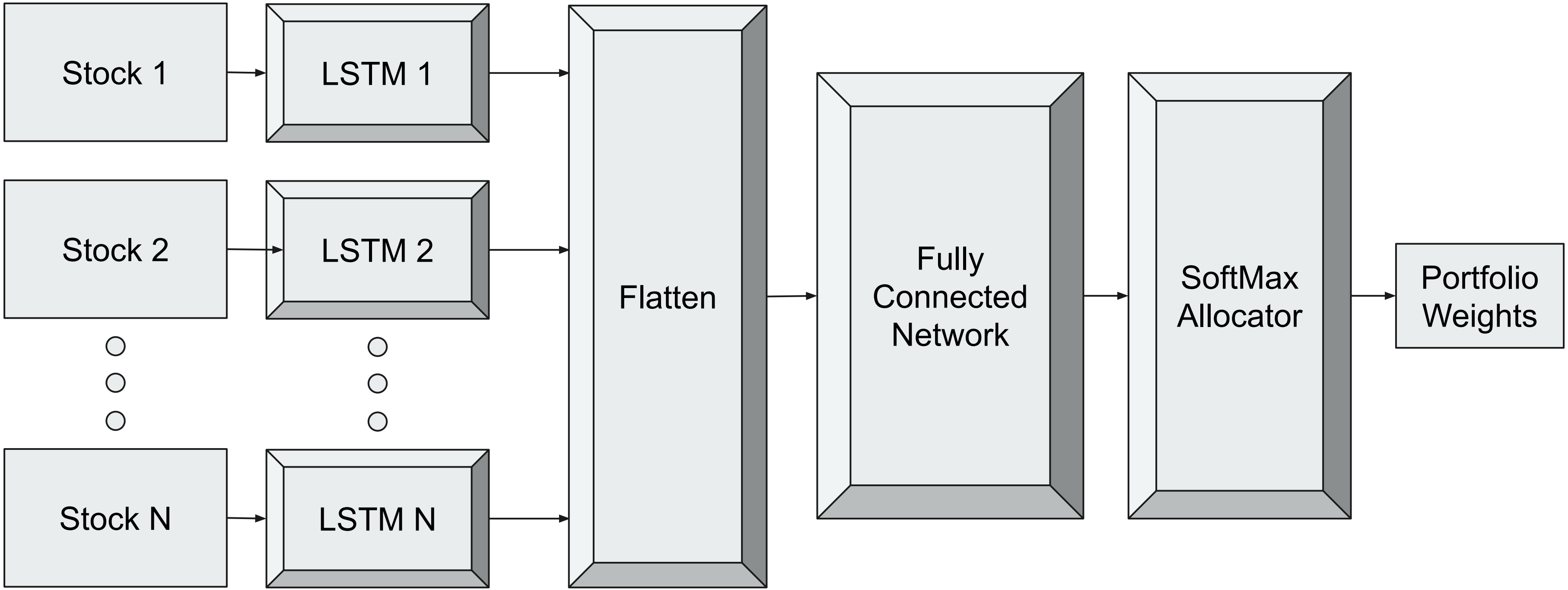
BachelierNet



SingleLSTMNet



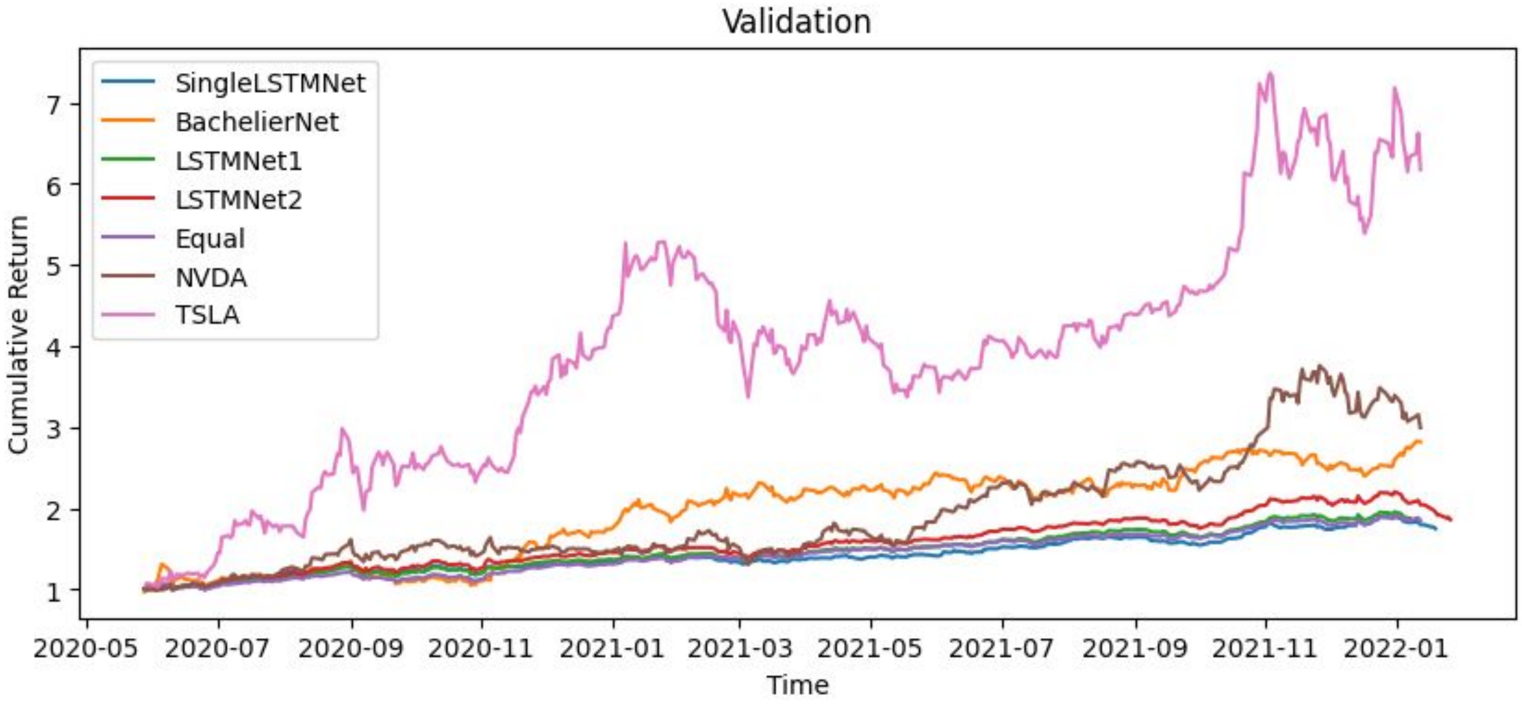
LSTMNet


Stock 1
Stock 2
Stock N
LSTM 1
LSTM 2
LSTM N
Flatten
Fully Connected Network
SoftMax Allocator
Portfolio Weights

Common Loss Functions (the lower, the better!)

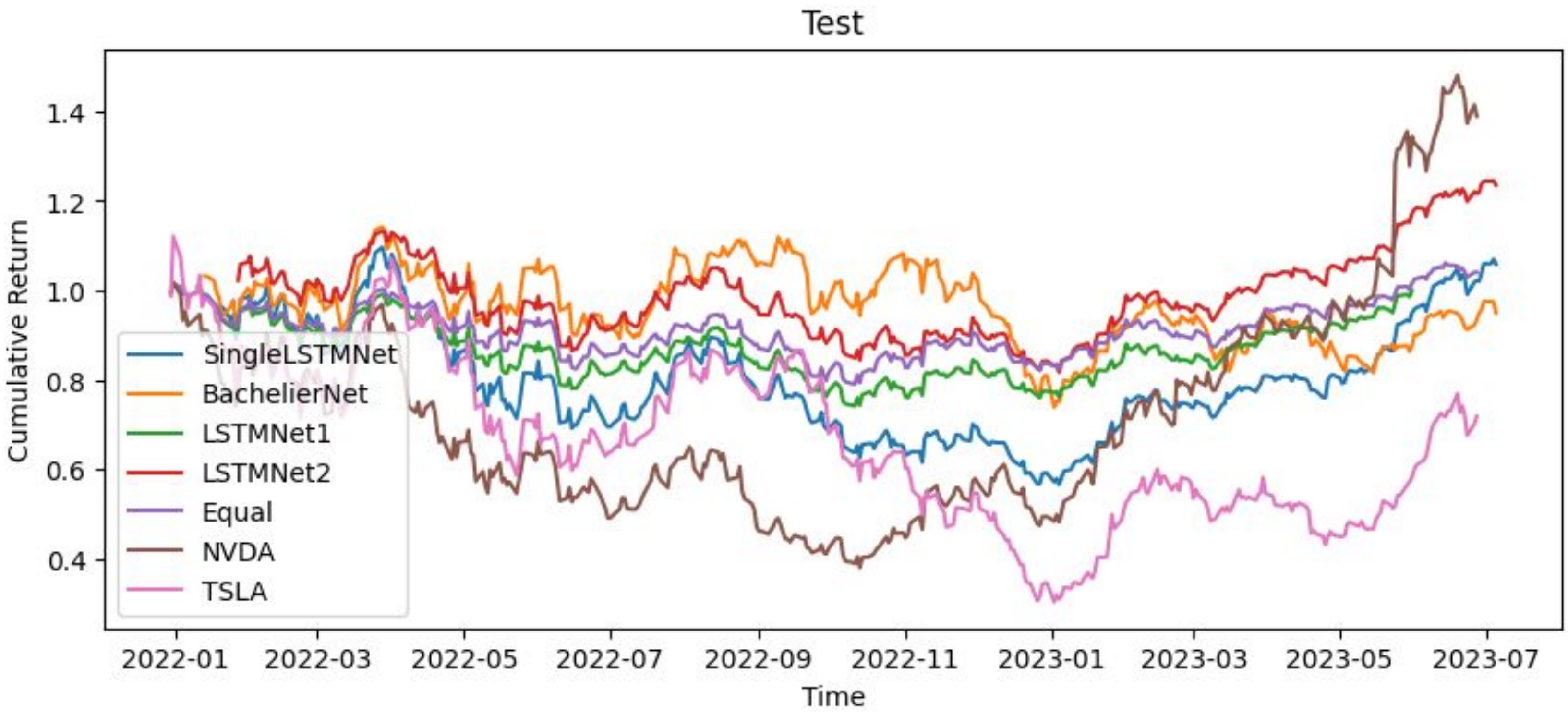
- Negative cumulative return (~ negative of the gain): $$\frac{p^{\mathbf{w}}_{t+\text{horizon}}}{p^{\mathbf{w}}_t} - 1$$
- Sharpe ratio (excess return relative to risk free return/ std.): $$\frac{\mu^{\mathbf{w}} - r_{\text{rf}}}{\sigma^{\mathbf{w}} + \epsilon}$$
- Largest weight or Squared weights (penalize biased portfolio): $max(\mathbf{w})$ or $\sum_{i=1}^{N} w_i^2$

Results on Validation Set



Remark: Tesla and NVIDIA outperformed in the validation period

Results on Test Set



Remark: Tesla crashed in the test period

Lessons Learnt and Conclusions

- Deep Learning provides valuable suggestions in portfolio optimization

    1. Usually perform better than a simple equal portfolio

- Possible Limitations:

    1. Stocks may outperform in a period of time but not afterwards
    2. Model may not perform well (generalizable) to later time
    3. Need to try different NN architecture to select the optimal network
    4. Require insightful hyperparameter selection

Experience and human factor are still important in finance!