Portfolio optimization using neural network

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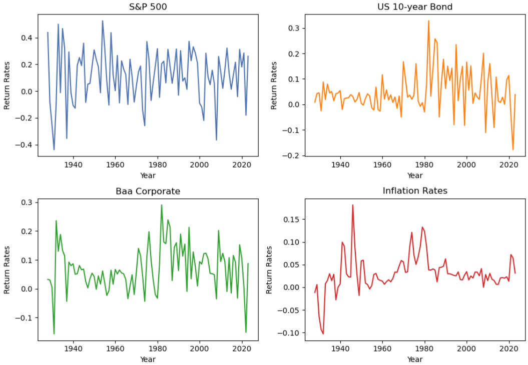
Problem

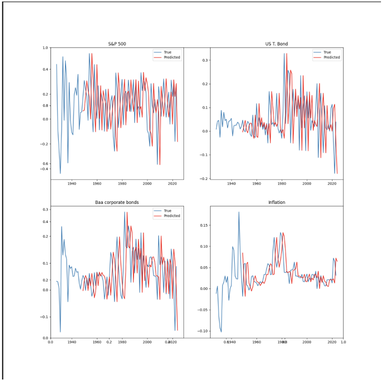
- Data: Annual historical interest rate from investing in S & P500, Baa Corporate bond, U.S Treasury Bond and inflation rate from 1928-2023
- Problem: Time series problem with less than 100 data points with 4 columns, very small dataset
- Objective: To output a ratio to invest in each option (S & P500, Baa Corporate bond, U.S Treasury Bond and common asset) to maximize our income.

Dataset: Historical Return Rates of Different Assets

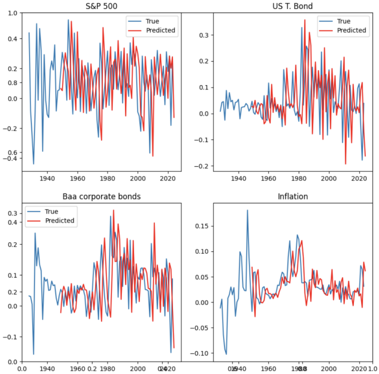


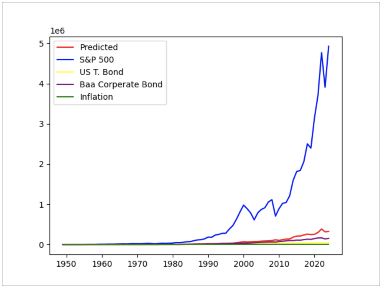
Feedforward neural network

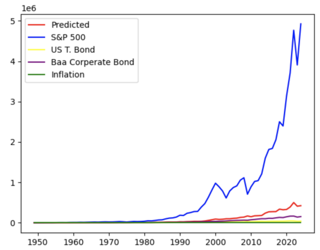
Fully connected neural network.



- Loss: MSE
- With 1 hidden layer of 4 neurons. Problem: Overfitting
- With no hidden layer


S&P 500
US T. Bond
Baa corporate bonds
Inflation
True
Predicted
1940
1960
1980
2000
2020


1e6
Predicted
S&P 500
US T. Bond
Baa Corperate Bond
Inflation
0
1
2
3
4
5
1950
1960
1970
1980
1990
2000
2010
2020


1e6
Predicted
S&P 500
US T. Bond
Baa Corperate Bond
Inflation
0
1
2
3
4
5
1950
1960
1970
1980
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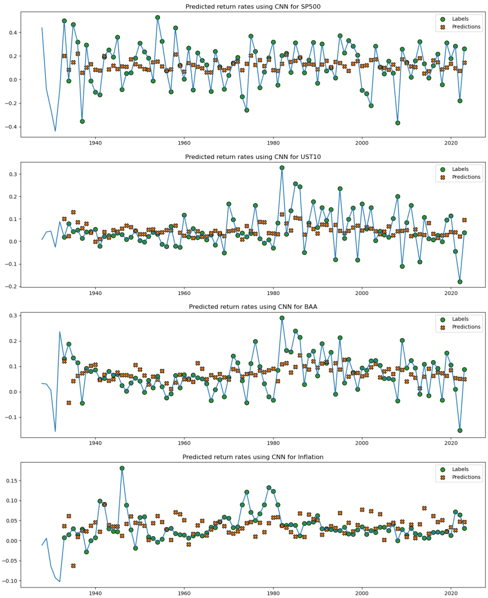
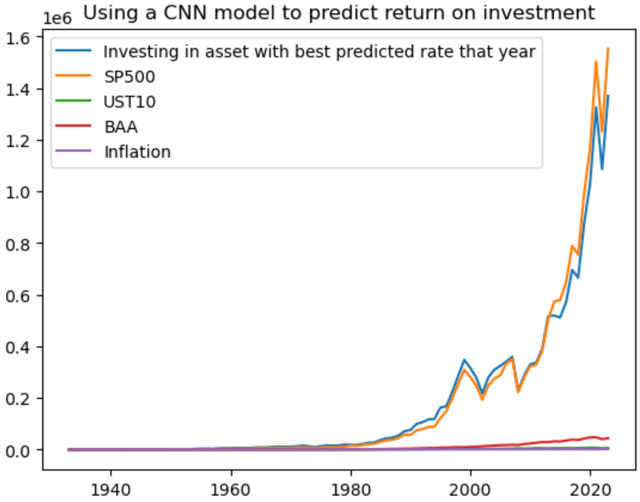
2000
2010
2020

CNN Architecture

- **1st layer**
  1D convolutional layer with 32 filters, kernel size 5, with a ReLU activation layer.
- **2nd layer**
  A dense layer with 32 units and a ReLU activation layer
- **3rd layer**
  Dense layer with 4 outputs (one for each prediction)



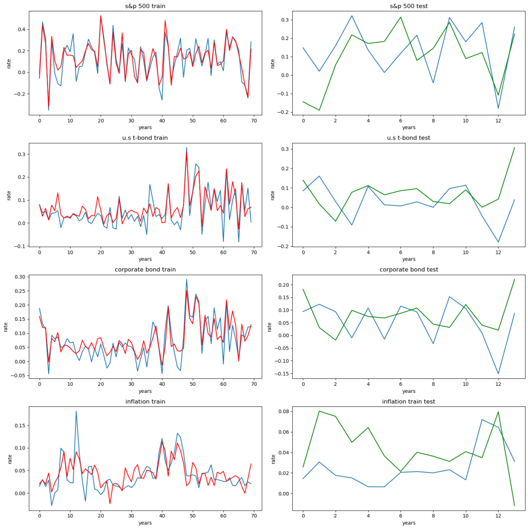
Predicted return rates using CNN for SP500
Labels
Predictions
0.4
0.2
0.0
−0.2
−0.4
1940
1960
1980
2000
2020
Predicted return rates using CNN for UST10
Labels
Predictions
0.3
0.2
0.1
0.0
−0.1
−0.2
1940
1960
1980
2000
2020
Predicted return rates using CNN for BAA
Labels
Predictions
0.3
0.2
0.1
0.0
−0.1
1940
1960
1980
2000
2020
Predicted return rates using CNN for Inflation
Labels
Predictions
0.15
0.10
0.05
0.00
−0.05
−0.10
1940
1960
1980
2000
2020


Using a CNN model to predict return on investment
1e6
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1940
1960
1980
2000
2020
Investing in asset with best predicted rate that year
SP500
UST10
BAA
Inflation

Predicting interest rate using LSTM-model 1

- Train/test split: 0.8/0.2, using past 6 years rates as input.
- Architecture: 2 Layer LSTM followed by a linear layer with Tanh activation and dropout to regularize, the loss function is Huber Loss.
- Train for 1000 epochs.

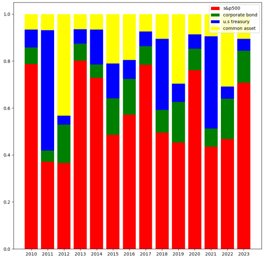
Predicting interest rate using LSTM-model 1

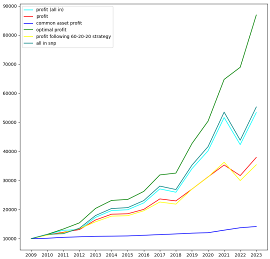


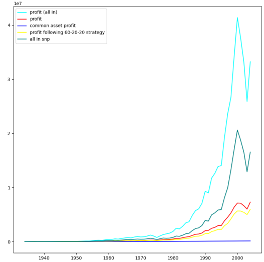
Ratio maximization using CNN

- Train/test split: 0.8, 0.2, using past 6 years as input
- Architecture: 1 convolution layer with kernel size (3,4) followed by sigmoid layer and then a dense layer with softmax output

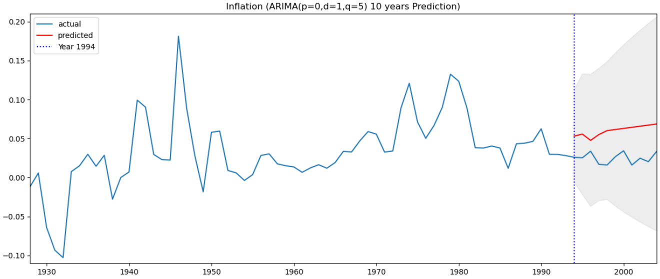
Ratio maximization using CNN





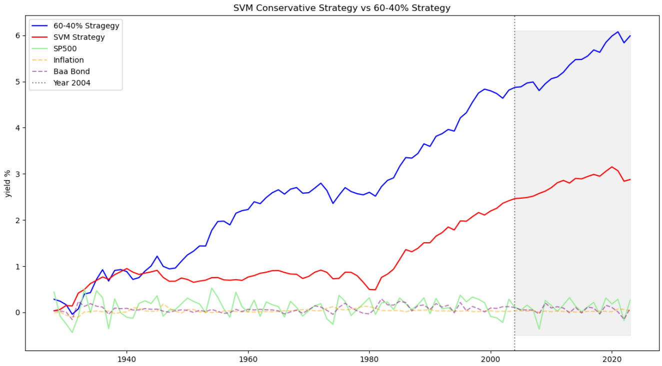


ARIMA model to model inflation



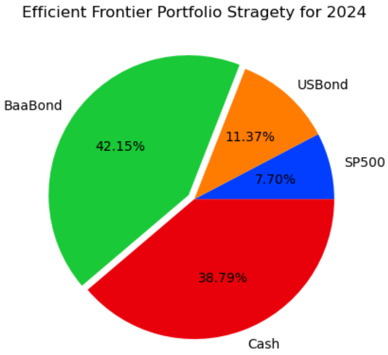
- p: number of past values included in the AR (auto-regressive) model
- d: number of the time in the time series is differenced
- q: number of past forecast errors included in the MA model

SVM strategy vs 60-40 comparison



- using the 60-40
- US 10-year Bond and Baa Bond check the Oscillation
- using SVM conservative strategy to decide the whether to buy stock, or bounds for the next year. train the model with last 70 years with fitted curve, the grey area is the predicted curve

Efficient frontier Portfolio

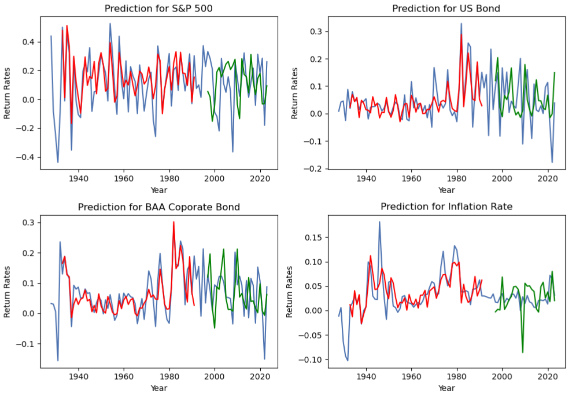


The efficient frontier investment portfolios maximizing expected return for a given level of risk, as measured by the standard deviation of returns. We use Mean-Variance Optimization to make the prediction for 2024.

LSTM Model Architcture

- One layer of LSTM with hidden size 32, followed by a linear layer and a dropout layer. Loss function is mean-squared error.

LSTM Model Results

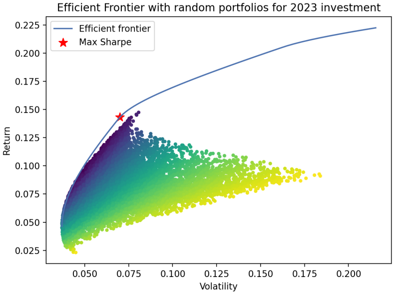


Use Mean-Variance Optimization to find Optimal Assets Allocation

- Use LSTM output as expected return
- Risk Model: described by the covariance matrix, estimated by Ledoit-Wolf shrinkage estimator
- Use Python PyPortfolioOpt library to perform the convex optimization task

Mean-Variance Optimization

- Sharpe Ratio: divides a portfolio's excess returns by a measure of its volatility to assess risk-adjusted performance – use 0.02 in our experiments
- Can change different constraints for different investment strategies (minimize volatility, high risk aversion parameter, set target volatility etc.)



Compare different asset allocation strategies over 12 year period