# Finance Time Series Modeling with Deep Learning

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## 1. Previous Work

The previous paper (Xiong et al., 2018) applies a deep reinforcement learning framework to train an agent to learn an adaptive learning strategy to maximize the investment return. They trained their agent on the 2009-2016 period.

## 2. Problem Statement

### 2.1. Problem position

As explained by (Xiong et al., 2018) they modeled the problem as a Markov Decision Process where we have states and actions:

- $S_t = [p_t, h_t, b_t]$ where $p_t \in \mathbb{R}_+^D$ represents the price of stocks, $h_t \in \mathbb{N}^D$ the holding cost of these stocks and $b_t \in \mathbb{R}_+^D$ the remaining balance.
- $A_t = [a_1, ..., a_D]$ a set of action like buying, selling or holding a stock.

### 2.2. Dataset

Following (Xiong et al., 2018), we track the daily close price of 30 stocks in the Dow Jones Index Average (DJIA) from 01/01/1995 to 12/31/2018.
The model will be trained on data from 01/01/1995 to 12/31/2013 and validated on data from 01/01/2014 to 12/31/2016. Then we will test our model on the stock price from 01/01/2017 to 12/31/2018. The dataset can be acquired from yahoo finance API[1] [2]. Some sampled statistics are displayed in table 1.
*Open* is a price at which a stock first trades upon the opening of an exchange on a trading day. *Close* is the last price during a trading day. *Volume* is the total amount of a stock that changes hands during a day. We mainly use the close price to test the model.

*Table 1.* Sample Data

| timestamp | open | close ($p_t$) | volume |
|---|---|---|---|
| 1995-01-03 | 1.38 | 1.370 | 25967200 |
| 1995-01-04 | 1.379 | 1.406 | 39670400 |
| 1995-01-05 | 1.401 | 1.388 | 18410000 |

*Source: Yahoo Finance*

## 3. Evaluation Criterion

The model we propose will be compared with the S&P 500 Index[3] in terms of average annual return and Sharpe ratio. The return of index, which is the baseline of the model, is calculated by equation (1). Sharpe ratio, defined by equation (2), represents the additional amount of return that an investor receives per unit of increase in risk and annual rate of return. Normally, any Sharpe ratio greater than 1.0 is good enough.(Hodges et al., 1997)

$$R_{Index} = \frac{Index_{end} - Index_{start}}{Index_{start}} \tag{1}$$

$$S = \frac{\mathbb{E}(R_a - R_{rf})}{\sigma_a} \tag{2}$$

where $R_a$ is the asset return, $R_{rf}$ is the risk-free return. and $\sigma_a$ is the standard deviation of the asset return.

## 4. Objectives for Milestone

Our ideas to explore more deeply this subject are two folds. First, we propose to explore the reinforcement learning strategy by extending the training period to the previous years and compare the strategy with the baseline S&P 500 Index. Especially we would like to catch and learn patterns from both before and during the recession.

A second idea is to focus on Time Series with in more deterministic way. Following some ideas presented by (Martin et al., 2014) build inputs of time series as a vector

$$X_t = [S_{t-p}, S_{t-p+1}, ..., S_t]^T$$

And predict an output $\hat{S}_{t+1}$ using 1 dimensional convolution to learn patterns such as increase, decrease, plateaus or any other interesting pattern.

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[1]One available Python API: https://pypi.org/project/yahoo-finance-api2/

[2]The code is available on https://github.com/Amelrich/W4995_DL_Project_Team23

[3]The return of index like S&P 500 and Dow Jones are commonly used as baseline of trading model.

## References

Hodges, C. W., Taylor, W. R., and Yoder, J. A. Stocks, bonds, the sharpe ratio, and the investment horizon. *Financial Analysts Journal*, 53(6):74–80, 1997.

Martin, L., Lars, K., and Amy, L. A review of unsupervised feature learning and deep learning for time-series modeling. *Pattern Recognition Letters 42*, 2014.

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