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Main supervisor	Marc Wildi
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Contents

Abstract

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1. Introduction

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3. Theory

The following chapter is intended to provide the theoretical foundations necessary for our work. It is divided into a part that provides an overview of artificial neural networks. Followed by section 2.3. that shows the background and the ecosystem of Bitcoin. This knowledge should be kept in mind, which should help in understanding the price formation of Bitcoin.

3.1. Neural network

In the context of this work, artificial neural networks are used to answer supervised learning questions that focus on classification of data. This means that a neural network finds a correlation between the data and their labels and optimizes its parameters in order to minimize the error for the next try. This process is called supervised training and is performed with a test data sample. An application example of classification is that a neural network is used for face recognition after it has learned the classification of different faces in the process of supervised training. Predictive analysis works similarly to the classification of labeled data. It estimates future values based on past events and can be trained with historical data. On the other hand, unsupervised learning (clustering) is applied to detect patterns from unlabeled data. Based on these patterns, for example, anomalies can be detected that are relevant in the fight against fraud (fraud detection). Unsupervised learning is not discussed further in this paper.

Section 3.1.1. will demonstrate the functioning of a neural network using a simple perceptron.

3.1.1. Perceptron

The construction of an artificial neural network is demonstrated using a perceptron. It is a simple algorithm for supervised learning of binary classification problems. This algorithm classifies patterns by performing a linear separation. Although this discovery was anticipated with great expectations in 1958, it became increasingly apparent that these binary classifiers are only applicable to linearly separable data inputs. This was only later addressed by the discovery of multiple layer perceptrons (MLP).

(Rosenblatt, 1958)

Basically, a perceptron is a single-layer neural network and consists of the following five components and can also be observed in 1.

1. Inputs
2. Weights
3. Bias
4. Weighted sum
5. Activation function

Inputs are the information that is fed into the model. In the case of econometric time series, it is mostly the current and historical log returns (lags). These are multiplied by the weights and added together with the bias term to form the weighted sum. This weighted sum is finally passed on to the non-linear activation function, which determines the output of the perceptron.

The perceptron can also be represented as a function. Analogous to the representation above, the inputs x_i are multiplied by the weights w_i in a linear combination. Then an error term is added so that the whole can be packed into the non-linear activation function $g(S)$. $\hat{y}$ is the binary output of this perceptron. With the aid of an activation function, a binary output is obtained. The Heaviside step function shown in figure 1 is usually only used in single layer perceptrons, which recognize linear separable patterns. For the multi layer neural networks presented later, step functions are not an option, because in the course of the backprogation algorithm the gradient descent has to be minimized. This requires derivatives of the activation function, which in the case of this Heaviside step function equals 0. Because the foundation for the optimization process is missing, functions like the sigmoid function or the hyperbolic tangent function are used. More about this topic is discussed in chapter 3.1.2..

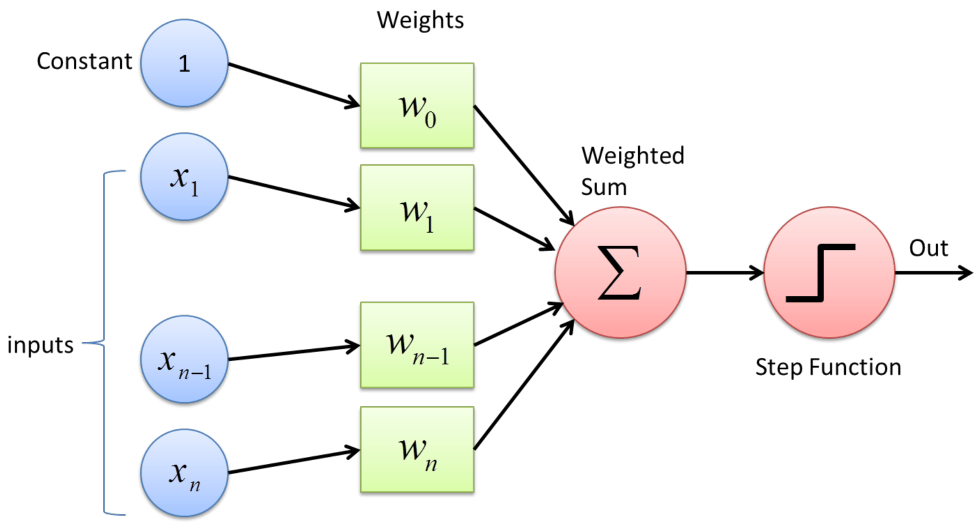


Figure 1: Schematic diagram of a perceptron.

$$\hat{y} = g(w_0 + \sum_{i=1}^{n} x_i w_i) \tag{1}$$

(Anthony and Bartlett, 1999)

As just mentioned, the aim is to feed the perceptron with the training set and change the weights w_i with each cycle so that the prediction becomes accurate. The output value is compared to the desired value. Finally, the sign of the difference $y - \hat{y}$ determines whether the inputs of that iteration are added to or subtracted from the weights. Ideally, the weights will gradually converge and provide us with an usable model.

3.1.2. Backprogation algorithm

- Backprogatation algo
- Gradient descent

3.1.3. Types of artificial neural networks

- MLP / DNN (explain nodes and layers)
- Recurrent neural networks (RNN)
- Long-short term memory (LSTM)

3.1.4. Challenges

- Early stopping required to avoid overfitting to in-sample data
- Gradient vanishing problem
- Dying Relu Problem (?)

3.2. Bitcoin

In this section bitcoin as a cryptocurreny is introduced. The historical data is analyzed and commentend. Further the technology in and around cryptocurrencies is briefly explained. A detailed explanation would requiere a paper itself, therefore the explanation is done as simple as possible.

In the following work bitcoin as a cryptocurreny is mentionend in its short term BTC, by the meaning of US Dollars per Bitcoin.

3.2.1. Historical analysis

2.3.1. historical analysis Bitcoin was first introduced in 2009 as the leader of a new era of cryptocurrencies. Firstly the recognition wasnt very high due to the fact of a non established technology. At the end of 2016 things began to change, more volume was flushed in the market and the price of BTC began to slowly ascend. in 2017 the real rally began and the BTC rose up to nearly 20k USD / BTC. In the following years until 2020 BTC had a lot of different phases from rising and falling to a price at the end in 2020 around 10000 USD per BTC. Most recent events topped everything before, as the BTC rose up to 58000 US Dollar after companies like Tesla and Signal bought in with high volume.

3.3.2. SHA256 Hash

- Block
- Blockchain
- Distributed Blockchain
- Token
- Coinbase Transaction
- Public/Private Key -> Signing
- Signature (sign, verify)
- Transaction

3.7. Reference

3.7.1. Figure Reference

As you can see in figure 2 -> GOOGLE

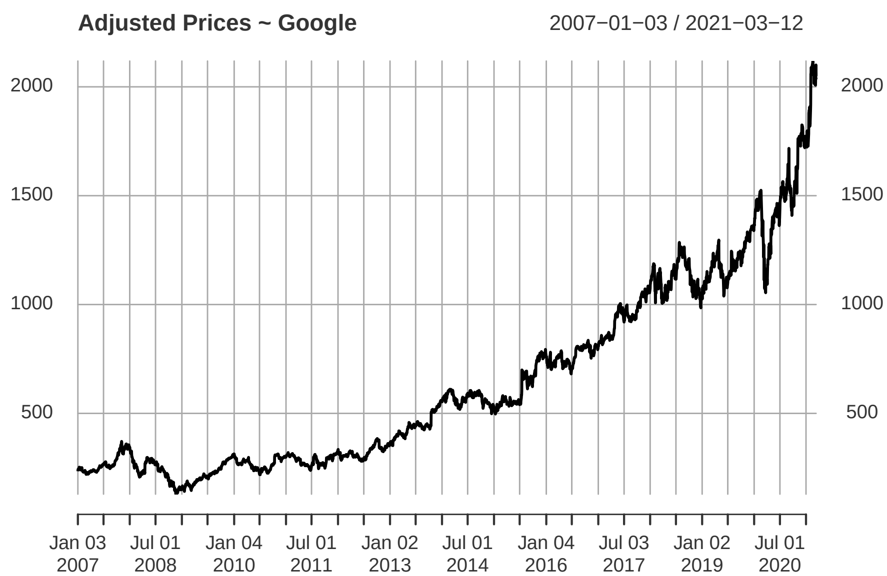


Figure 2: Visualization of the adjusted prices of the Alphabet Inc Class A Stock.

3.7.2. Equation Reference GARCH-formula can be seen in 2

$$
\begin{aligned}
\epsilon_t &= \log(x_t) - \log(x_{t-1}) \\
\epsilon_t &= \sigma_t u_t \\
\sigma_t^2 &= c\sigma^2 + \sum_{j=1}^{n} \alpha_j \sigma_{t-j}^2 + \sum_{k=1}^{m} \beta_k \epsilon_{t-k}^2
\end{aligned}
\tag{2}
$$

Table 1: Coefficients GARCH(1,1).

	Estimate	Std. Error	p-Value
ω	1.104964e-05	1.863816e-06	3.057113e-09
α_1	7.385350e-02	1.074870e-02	6.378675e-12
β_1	8.942916e-01	1.381726e-02	0.000000e+00

3.7.3. Table Reference In table 1 you can see the flexerino of the coefficients.

3.7.4. Section Reference

Here we can see a wild section, which will reference to itself: 2.7.4.

Or reference to the Bitcoin-section 2.3.

3.7.5. Literature Reference

Add bibliography reference in the `.bib`-file in the add folder.

Here I make a reference to the original bitcoinpaper [1] or to the specific page on the NN financial trading paper [2, pp. 6–8].

4. Methodology

The focus of this thesis is to predict historical prices of bitcoin using the models listed in Chapter XX. The predictive accuracy of these obtained predictions are compared using loss functions (Annualized Sharpe, Diebold Mariano Test, MAE, MSE, RMSE, Mincer-Zarnowitz Regressions). Then, based on the best models with the most accurate predictions, trading strategies are worked out to compare with a buy-and-hold strategy. Finally, we would like to venture into the topic of explainability and attempt to explain why the chosen models lead to these outcomes. The procedure of this quantitative study is described in this chapter.

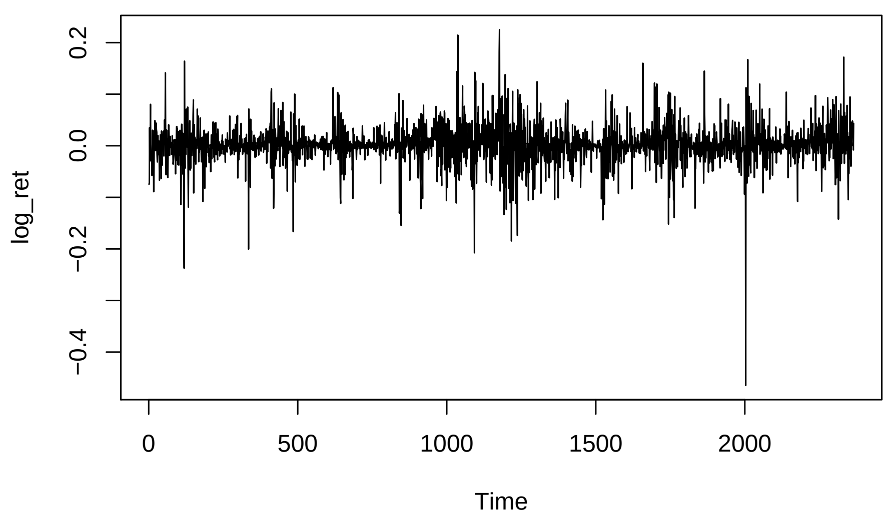
- Data and Analysis of Bitcoin (BTC/USD)
- Defining the train and test samples (including description about calm and volatile phases).
- Calculate predictions with the defined models (AR, NN, RNN, LSTM).
- Compare Predictions with Realized Data (Annualized Sharpe, Diebold Mariano Test, MAE, MSE, RMSE, Mincer-Zarnowitz Regressions)
- Explain trading strategies
- Explainability for the best models
- (Backup: Which models work well in which market phases?)

4.1. Data and analysis of Bitcoin

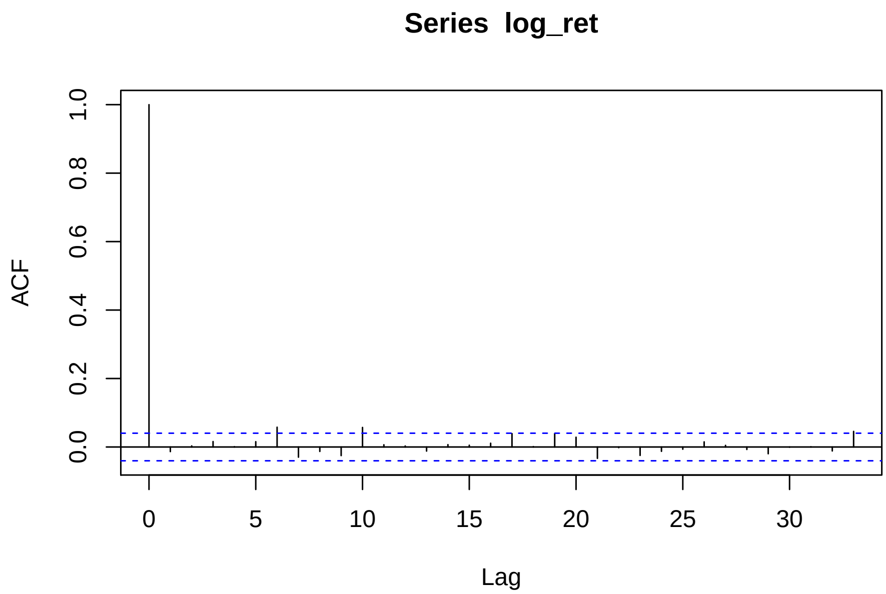
The data in this paper is accessed via yahoofinance provided by coinmarket https://coinmarketcap.com/. We use the daily "closing price" of bitcoin in US Dollars with the ticker BTC-USD. Cryptoassets are tradeble 24 hours a day 256 days a year, there is no real "closing price" for the bitcoin, therefore the "closing-Price" is just the last price of the day evaluated at last timestamp with timeformat UTC.

In chapter 3.3. the bitcoin price is visualized. For processing and analyzing the data in order to fullfill the weak stationarity assumptions we transform the data into logreturns

$$\text{LogReturn} = \log(x_t) - \log(x_{t-1})$$



By computing the autocorrelation oft the log_returns, there is still dependence visible in lag 6 and 10. This indicates dependency in volatility-cluster, to cancel out the effect an ARMA-GARCH model is fitted to the data and the residuals are standardized by the model standard-deviation.



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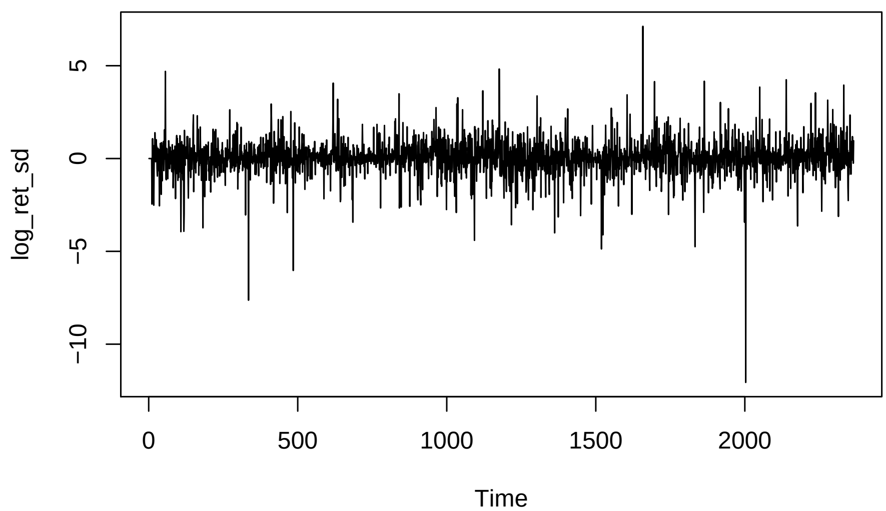

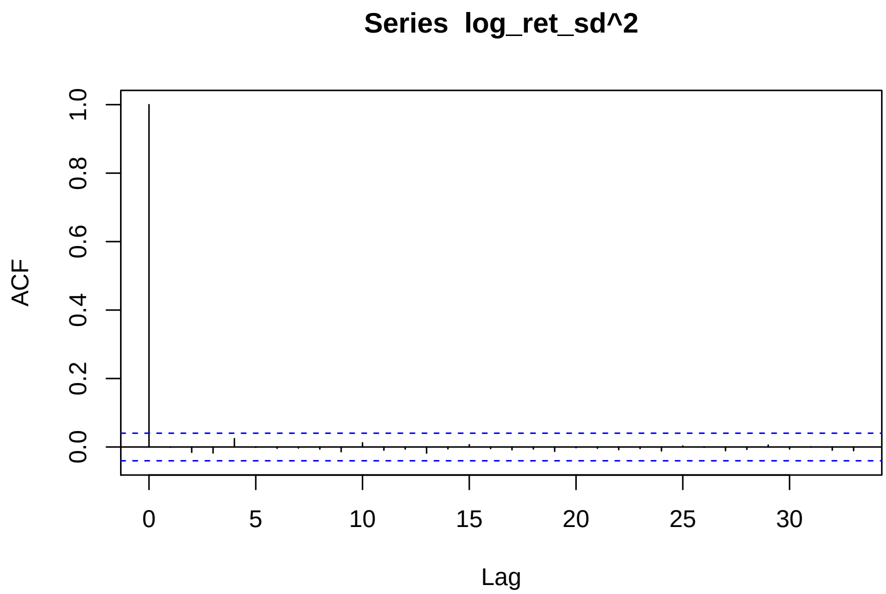

4.2. Defining train and test samples

- Describe different phases
- Explain why we set train and test sample like this
- Describe stable and volatile phases and why we should keep that in mind for predictions

4.3. Forecasting

- Autoregressive process (AR)
- Deep learning neural network / multi layer percepton
- Recurrent neural network (RNN)
- Long short-term memory (LSTM)

4.3.1. In-sample

- Compare Predictions with Realized Data (Annualized Sharpe, Diebold Mariano Test, MAE, MSE, RMSE, Mincer-Zarnowitz Regressions)

4.3.2. Out-of-sample

- Compare Predictions with Realized Data (Annualized Sharpe, Diebold Mariano Test, MAE, MSE, RMSE, Mincer-Zarnowitz Regressions)

4.4. Trading strategies

- Define trading strategies
- Define realistic fee structure for trading (Coinbase Pro, Binance, Kraken etc.)

4.5. Explainability

- Performing the predictions with the two (?) best models
- Include variations to find possible starting points for explainability (number of nodes, layers)

4.6. (Relationship between accuracy and market phase)

- Test

4. Results

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5. Conclusion

Best Trading Algorithm ever!

5.1. Get rich or die tryin

Neque volutpat ac tincidunt vitae semper quis. At elementum eu facilisis sed odio morbi quis commodo odio. Eget dolor

5.2. Be GME stock, or not to be GME stock

Tellus at urna condimentum mattis pellentesque id nibh. Morbi tempus iaculis urna id volutpat lacus laoreet. Sem fringilla

5. References

[1] S. Nakamoto, *Bitcoin: A peer-to-peer electronic cash system.* online: www.bitcoin.org, 2008, p. 9.

[2] R. R. Georgios Sermpinis Andreas Karathanasopoulos, *Neural networks in financial trading.* online: Springer Science+Business Media, 2019, p. 16.

6. Attachment

This project work is created with R-4.0.2 , RStudio Version 1.4.904 and RMarkdown in collaborative working via Git / Github