Math3004: Industrial Project

Title: A comparison of ARIMA and Neural Network models for NFLX daily price forecasting

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1. Introduction

1.1 Background

American entrepreneurs Reed Hasting and Marc Randolph established Netflix which have the creation original programming in 1997 and subscription service thorough the Internet was begun in 1999. Netflix gave 1 million dollar prize to people who can improve 10 percent its recommendation system in 2006. In 2010, there was just unlimited streaming service in streaming plan not including DVDS. House of Cards (drama series) was released and made people's attention in 2013 and Netflix continues to release new original programming. By the end of 2018, there are more than 1,000 original programmings in its platform (Encyclopedia Britannica, 2019). The original programmings are the important role to draw the attention of new subscribers and also keep the current users that make Netflix stock (NFLX) attractive to many investors.

Figure 1: Daily NFLX close Price versus Date from 1st January 2015 to 29th July 2021

In figure 1, it shows the trend of NFLX daily close price from 1st January 2015 to 29th July 2021. The data that are used in this project is come from yahoo finance website. In the picture, NFLX price climbed moderately from 2015 to the middle of 2015 and there was slight fluctuation from the middle 2015 to the end of 2016. In 2017 to the middle of 2018, the NFLX price grew significantly, especially in the first half of 2018 because of the number of net new subscribers and the earnings reported (Bylund, 2018). The NFLX price went down hugely in the second half of 2018 because of a project to enter the streaming space of Walt Disney; however Netflix's original contents was the important key to fend off Disney (Kline, 2018). The NFLX price increased 37.2 percent in the first half of 2019 as a result of a stellar fourth-quarter report (Bylund, 2019). New streaming subscription deals from Disney and Apple made NFLX price fall in the second half of the year (Gsmanessis, 2019). There was a rapid ascent in the price of NFLX from the end of 2019 to the middle of 2020 despite Covid-19 (Team, 2021). The NFLX price hit the peak at the beginning of 2021 and continued to fluctuate until the middle of 2021. The trend of NFLX price is quite complicated to use simple statistics to predict.

1.2 Objectives of research

The aims of this project are to:
1) explore the NFLX daily price data;
2) understand principles of Auto Regressive Integrated Moving Average (ARIMA) model and Neural Network (NN) model for non-stationary time series;
3) establish and develop Auto Regressive Integrated Moving Average (ARIMA) model and Neural Network (NN) model for forecasting;
4) evaluate and compare Neural Network (NN) and Auto Regressive Integrated Moving Average (ARIMA) models on NFLX daily close price.

1.3 Significance of the research

Netflix Inc. is America's most influential content platform which have 167 million paying subscribers all over the world (Netflix, 2020). Netflix is the important factor to disrupted cable companies by creating its own original programming, analyzing user data and having a good movies recommendation system (Team, 2021). Therefore, it is not surprising that NFLX daily price must be in the public eye. Investors' interest in buying NFLX stock is increasing gradually, which make many investors find tools to predict NFLX daily price. Autoregressive Integrated Moving Average (ARIMA) and Neural Network (NN) models are the famous models in financial forecasting. To obtain the accurate prediction on NFLX daily price, it is important to understand the principle of building the models and to be able to compare the results between Moving Average (ARIMA) and Neural Network (NN) models.

2. Literature Review

Khan and Alghulaiakh (2020) performed Auto Regressive Integrated Moving Average (ARIMA) models on NFLX price data from five years. They did three different customize parameters which are ARIMA(4,1,4), ARIMA(1,1,22) and ARIMA(1,2,33). They tried to reduce the noise of data by calculate moving average of different period in week month and year. The best one was weekly that not loss much the information of itself. MAPE was used to measure the performance of all three models and ARIMA(1,2,33) is the best performance.

Shamsuddin et al (2008) applied Artificial Neural Network Time Series Modeling for Revenue Forecasting. This research aimed to investigate the performance of Artificial Neural Network with different number of inputs node and activate functions. They also focused on the method on pre-processing data for the performance of backpropagation (BP) network. The result showed that the small number of inputs getting the better performance than large number of inputs, the best activated function was Sigmoid an and the method of pre-processing technique also effected the performance of Artificial Neural Network model. However, they did not use the comparison other financial time series models.

Oancea and Ciucu (2014) performed time series forcasting using Neural Network (NN) on the daily exchange rate EUR/RON and USD/RON from 2005 until 2013. This research showed the big advantage of Neural Network (NN) which is be able to estimate the nonlinear function that ARIMA or other financial time series can not.

Moyazzem et al (2017) applied Auto-Regressive Integrated Moving Average (ARIMA) and Neural Network (NN) on Jute Production in Bangladesh. They compared two financial time series which is Auto-Regressive Integrated Moving Average (ARIMA) and Neural Network (NN). In this research the best performance is selected by Box-Jenkin model and the best performance is ARIMA(1,1,1) which is the smallest AIRMA model.

Adebiyi et al (2014) also used the comparison between Autoregressive Integrated Moving Average (ARIMA) and Neural Network (NN) on New York Stock Exchange. For this paper Neural Network (NN) showed the performance over Autoregressive Integrated Moving Average (ARIMA). However, the trend of New York Stock Exchange and NFLX close price are not similar. Therefore, Auto-Regressive Integrated Moving Average (ARIMA) and Neural Network (NN) on NFLX price data should be investigated.

3. Methodology

3.1 Auto Regressive Integrated Moving Average (ARIMA) model

An Auto regressive Integrated Moving Average (ARIMA) model is the model that use regression analysis focusing on changing variables by relative of one dependent variable. The goal of model is to forecast the future financial market.

ARIMA model is notated as ARIMA(p,d,q) where

p: the number of lag observations in the model.

d: the number of times that the raw observations are differenced.

q: the size of the moving average window.

$$y_t = c + \phi_1 y_{t-1} + ... + \phi_p y_{t-p} + \theta_1 \epsilon_{t-1} + ... + \theta_q \epsilon_{t-q} + \epsilon_t$$

The method of building ARIMA model to forecasting the future stock start with exploration and model specification, it is the method that focus on exploration and statistic of data this includes data transformation, ACF and PACF. The next steps is to do model fitting which is the method that find the best parameter of model. After that is model diagnostic which is the method to check the assumption of model. Residual analysis such as plots of the residuals, normality of the residuals, autocorrelation of the residuals, histogram of residuals and the Ljung-Box test are used in this section. After checking the assumption of model. If it is satisfied , the process are finished and go to forecast method. If it is not satisfied, model specification are reprocess again and go in the same process.

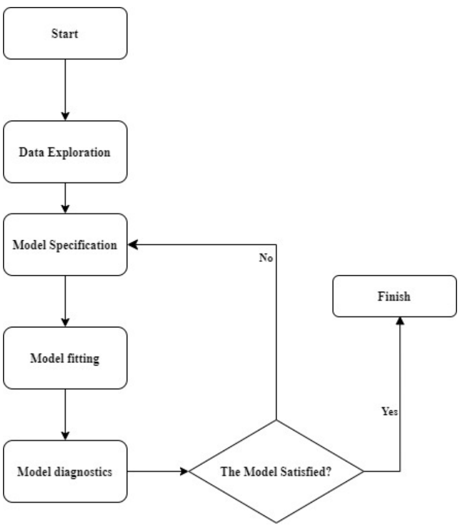

Figure 2: The process of ARIMA model.

Date exploration and model specification

Stationarity is the process of statistical properties (mean, variance and autocorrelation) not change over time. Augmented Dickey-Fuller test is used for checking stationarity The null hypothesis $H0$ is the data be non-stationary and the alternate hypothesis $H1$ is the data be stationary.

After cheeking stationarity,transformations are used for changing the data to be stationary and normal distribution. Differencing transformation is used for changing the data to be stationary. The formula is in the equation below. Where y' is transformations values and t is term in time series model.

$$y' = y_t - y_{t-1}$$

Log transformation, it can use to make highly skewed distributions less skewed.The formula is in the equation below. Where y' is transformations values.

$$y' = log(y)$$

Autocorrelation Function and Partial Autocorrelation Function are the coefficient of correlation between a time series and its lagged values and the function that explains the partial correlation between the series and lags of itself, respectiviely. ACF can find as the formula below.

$$\rho_k = corr(X_t, X_{t+k}) = \frac{cov(X_t, X_{t+k})}{\sqrt{var(X_t)var(X_{t+k})}}$$

Note $\sigma_{X_t} = \sigma_{X_{t+k}}$

PACF can be defined as the conditional correlation of

$$X_{t+1} \text{ with } X_t \text{ given } X_{t=1}..., X_{t+k-1}$$

The general method to choose the lag of p and q by ACF and PACF in tabel below.

	AR(p)	MA(q)	ARMA(p,q)
ACF	Tails off	Cuts off after lag q	Tails off
PACF	Cuts off after lag p	Tails off	Tails off

Model fitting

Maximum likelihood estimation (MLE), It is the technique to miximise probability of parameter. For ARIMA models, MLE is try to minimising.

$$\sum_{i=1}^{T} \epsilon_t^2$$

It will find the maximise logarithm of the probability that indicate p, d and q (Hyndman, 2021).

For writing Gaussian likelihood of ARMA model we assume that $u_t \sim i.i.d.N(0, \sigma^2)$.

The Gussian likelihood of $x = (x_1, x_2, ..., x_T)'$ equation is

$$L(\theta|x) = (2\pi)^{-T/2}|\Gamma(\theta)|^{\frac{1}{2}} e^{-\dfrac{1}{2}x'\Gamma(\theta)^{-1}x}$$

where $\Gamma(\theta) = E(xx')$ TxT covariance matrix of x depending on θ and the Gaussian likelihood of ARMA model is

$$l(\theta|x) = \tfrac{1}{2}[Tlog(2\pi) + log|\Gamma(\theta)| + x'\Gamma(\theta)^{-1}x]$$

Model diagnostics

In model diagnostics, plots of the residuals is the plot of residuals over time. It is expected the plot to have close to zero and no trend in horizontal level. Q-Q plot is a plot of two sets of quantiles in x-axis and y-axis when them are the same distribute it will be the straight line (University of Virginia Library Research Data Services + Sciences). Autocorrelation of the residuals will show that the variance of residual be the same of before plot or not. It should be constant(Hyndman, 2021). Histogram of residuals use to check the residuals are normally distributed. The Ljung-Box is the test for absence of serial autocorrelation to node k.The null hypothesis $H0$ is the model not showing lack of fit and the alternate hypothesis $H1$ is the model showing a lack of fit (Stephanie, 2021).

3.2 Neural Network (NN) model

Neural Network (NN) model is an algorithm that simulates the human brain operateswork for finding the relationship of data from changing input to get the best possible result (Chen,2021).

NNAR(p,k) notation and the parameters can be defined as:
p: lagged inputs.
k: nodes in the single hidden layer.

The method of building NN model to forecasting the future stock is similar with ARIMA model but it does not have model diagnostics method.

The NN model is the algorithm that connected between output of previous node and input of the next node layer. Weighted linear combination is used to combine input node. In the final layer, output is modified by nonlinear function to be final output.

Here is the equation of NN model.

$$Z_j = b_j + \textstyle\sum_{i=1}^{4} w_{i,j}x_i$$

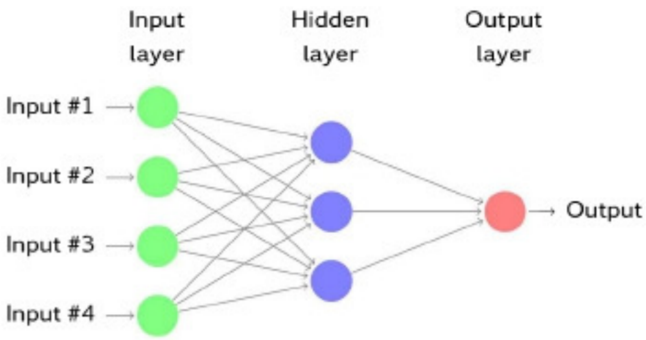

Figure 3: NN with four input and one hidden layer with three hidden neurons

The example of NN model with the input into hidden neuron j is in Figure 3. There are several nonlinear functions that can be used for NN model. In this project we used the famous nonlinear function which is sigmoid (Hyndman,2021), Here is the equation of sigmoid.

$$S(Z) = \frac{1}{1+e^{-z}}$$

This nonlinear functions can reduce the effect of extreme input values and robust to outlier.The stared weights is set by randomly then the parameters of NN are learned from data. Therefore NN model is trained in many time with different starting points and getting the result by averaged.

In NNAR(p,P,k) function, if p and P are not selected p values will choose automatic by AIC where $P = 0$ when it is non-seasonal time series and k is set to

$$k = \frac{(p + P + 1)}{2}$$

3.3 Comparison metric

The mean absolute percentage error (MAPE) is used for this project. It is a metric that use for measuring accuracy with percentage. Here is the formula of MAPE.

$$MAPE = \frac{1}{n} \sum_{t=1}^{n} |\frac{A_t - F_t}{A_t}|$$

Where n is the number of forecasting points.

A_t is actual value.

F_t is forecast value.

4. Results

4.1 Auto Regressive Integrated Moving Average (ARIMA) model

Date exploration and model specification

The data are transformed by taking log transformation and differencing transformation then use Augmented Dickey-Fuller test. The result is show that the log of differencing of data is stationary at 1% significant level.

Then the transformed data are plotted of ACF (Figure 2) and PACF (Figure 3) to choose the p and q values. The candidate model that all lag are significant are ARIMA(1,1,1) with σ^2 estimated equal 0.0006857 and ARIMA(2,1,2) with σ^2 estimated equal 0.0006816.

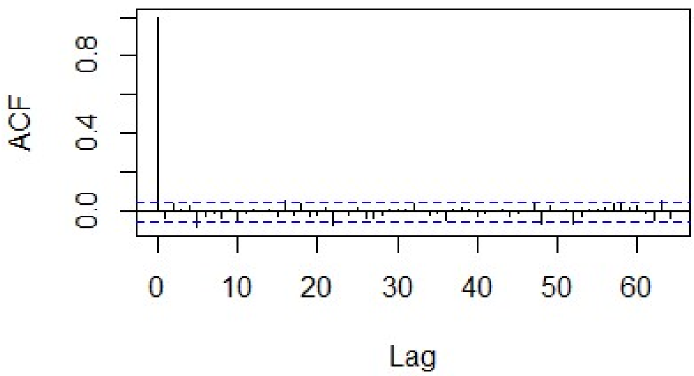

Figure 4: The ACF plot of diff(log(data))

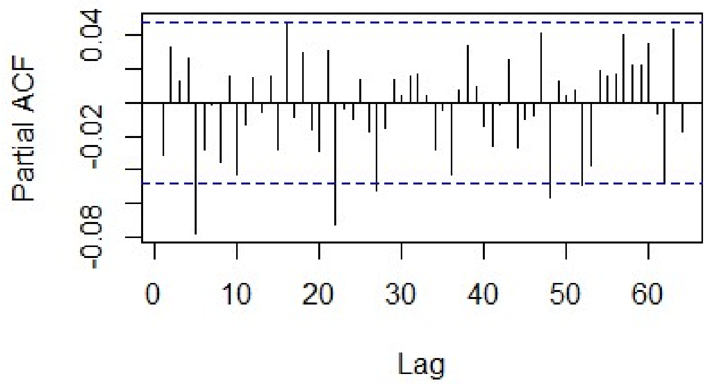

Figure 5: The PACF plot of diff(log(data))

Model fitting

The p-value of ARIMA (1,1,1) is in following table.

ARIMA(1,1,1)	$\hat{\phi}_1$	$\hat{\theta}_1$
p-values	4.399223e-06	0.0001091261

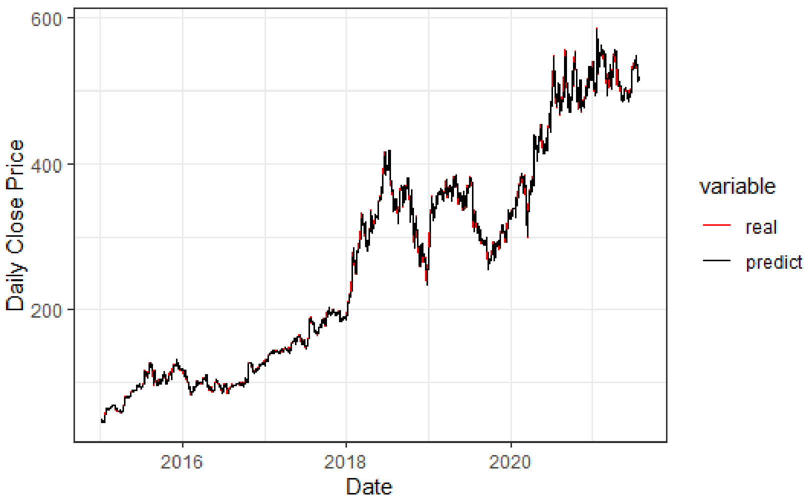

Figure 6: The fitted model of ARIMA(1,1,1) and the observed NFLX daily close price.

In the figure 6, it show that the ARIMA(1,1,1) model get good fit on the data. There are just some period that the different between real line and predict line is large.

The p-value of ARIMA(2,1,2) is in following table.

ARIMA(2,1,2)	$\hat{\phi}_1$	$\hat{\theta}_1$	$\hat{\phi}_2$	$\hat{\theta}_2$
p-values	0.0001250062	0.00000000	3.472350e-06	0.00000000

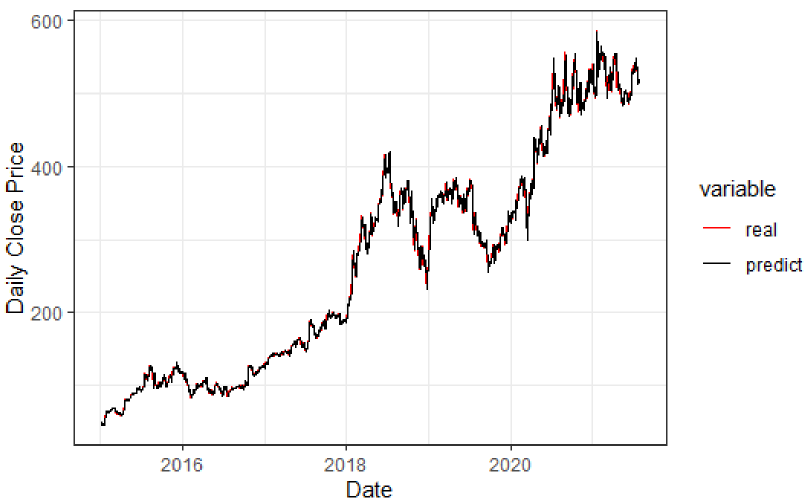

Figure 7: The fitted model of ARIMA(2,1,2) and the observed NFLX daily close price..

In the figure 7, it show that the ARIMA(2,1,2) model also get good fit on the data same as ARIMA(1,1,1). We can not concluded by eye that which one is better.

Model diagnostics

For ARIMA(1,1,1), the residual plot is close to zero with no trend and the histogram and Q-Q plot look normal. Autocorrelation of the residuals is close to zero and the p-value of Ljung-Box test equal 0.02178 that fail to reject null hypothesis at 1% significant.

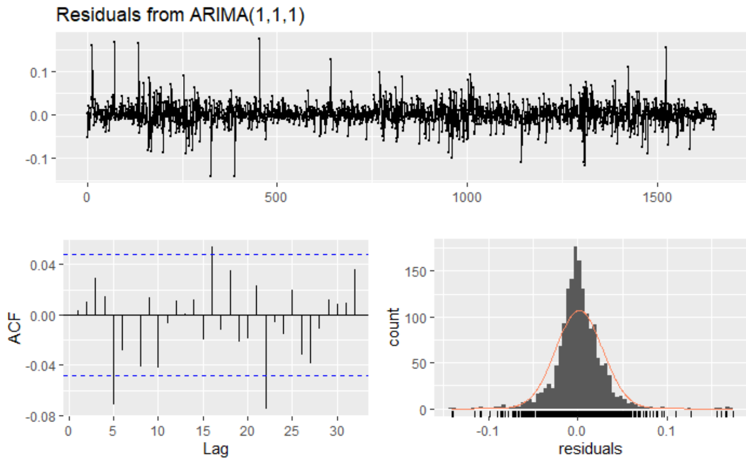

Figure 8: The Residual analysis part1 of ARIMA(1,1,1).

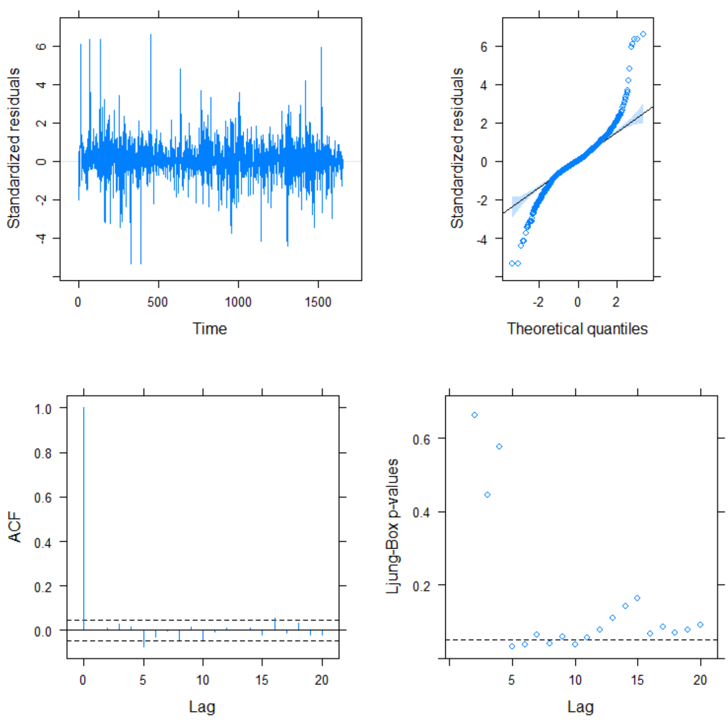

Figure 9: The Residual analysis part2 of ARIMA(1,1,1).

For ARIMA(2,1,2), the residual plot is close to zero with no trend and the histogram and Q-Q plot look normal. Autocorrelation of the residuals is close to zero and the p-value of Ljung-Box test equal 0.02926 that fail to reject null hypothesis at 1% significant.

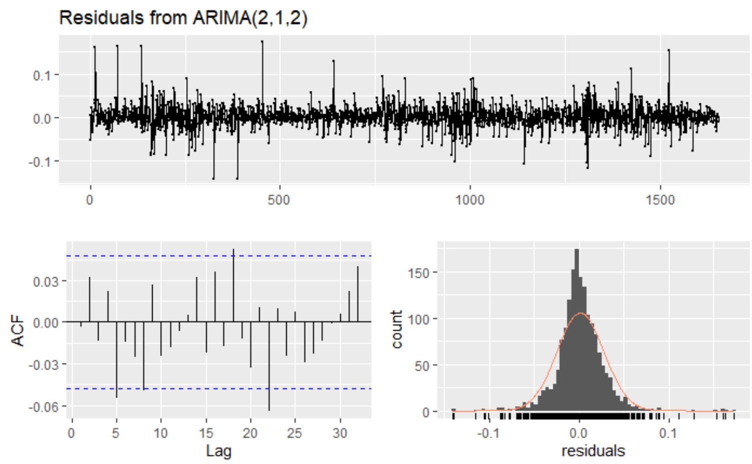

Figure 10: The Residual analysis part1 of ARIMA(2,1,2).

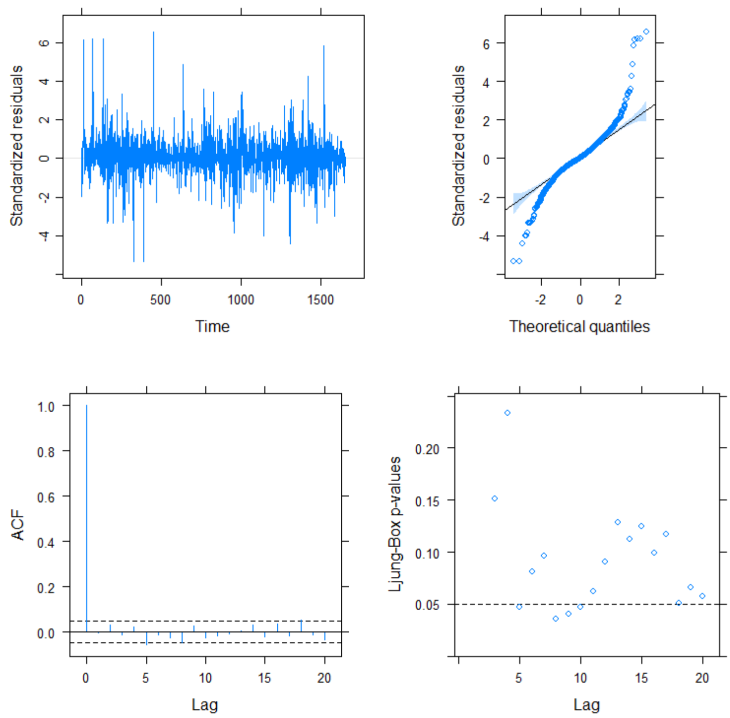

Figure 11: The Residual analysis part2 of ARIMA(2,1,2).

4.2. Neural Network (NN) model

The data are transformed by taking log transformation then best model at NNAR(1,1) and σ^2 estimated equal 0.0006896.

In the figure 12, it show that the NNAR(1,1) model get not goof fit on the data when combine with ARIMA model. The different between real line and predict line is large.

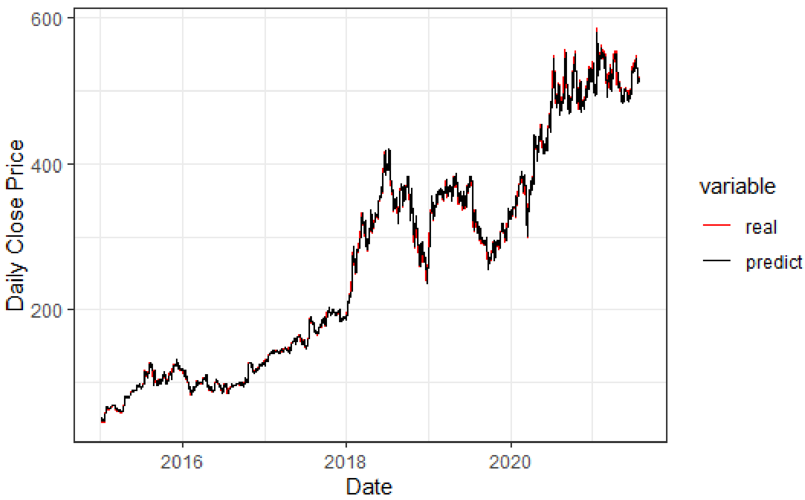

Figure 12: The fitted model of NNAR(1,1) and the observed NFLX daily close price.

4.3 Forecasting and model comparison

Forecasting data

For ARIMA(1,1,1) model, the equation for log(data) is

$$y_t = -0.7132346 y_{t-1} + 0.6807162 \epsilon_{t-1} + \epsilon_t$$

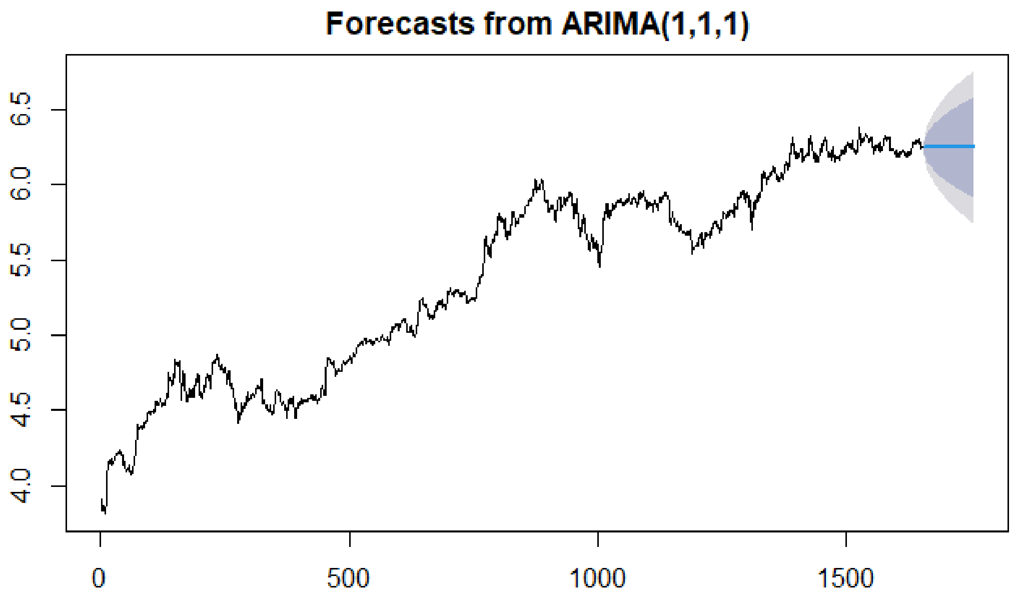

Figure 13: The forecasting of ARIMA(1,1,1) model for NFLX daily close price.

For ARIMA(2,1,2) model, the equation for log(data) is

$$y_t = 0.2242938 y_{t-1} - 0.9423746 y_{t-2} - 0.2525022 \epsilon_{t-1} + 0.9577389 \epsilon_{t-2} + \epsilon_t$$

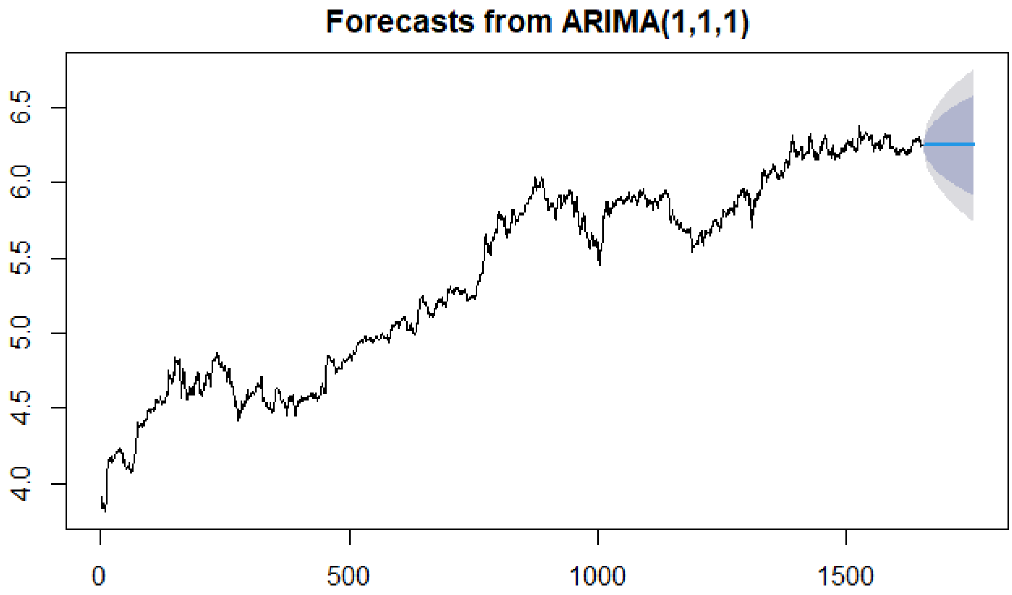

Figure 14: The forecasting of ARIMA(2,1,2) model for NFLX daily close price.

, and the forecasting of NNAR(1,1) model is in following graph.

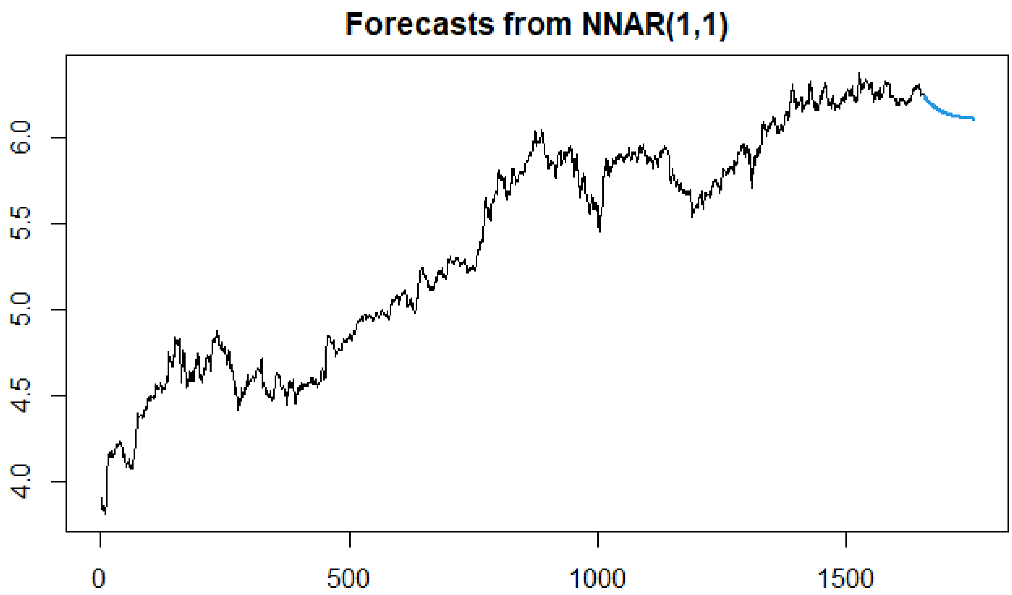

Figure 15: The forecasting of NNAR(1,1) model for NFLX daily close price.

Model comparison

We now summaries the finding by comparing the models that we fitted on NFLX daily close price. The MAPE is use to calculate between real values and forecast value in the next 10 days (working day) from 30th July 2021 to 12th October 2021.

Model	σ^2 estimated	MAPE
ARIMA(1,1,1)	0.0006857	0.04174586
ARIMA(2,1,2)	0.0006816	0.04137974
NNAR(1,1)	0.0006896	0.06420685

The ascending σ^2 estimated values are ARIMA(2,1,2), ARIMA(1,1,1) and NNAR(1,1) respectively.The result of MAPE of Auto Regressive Integrated Moving Average (ARIMA) and Neural Network (NN) are in the table above.

5. Conclusion

To sum up, this project focuses on build the best of Auto Regressive Integrated Moving Average (ARIMA) model and Neural Network (NN) model for predicting NFLX daily close price, and compare MAPE and σ^2 estimated between Auto Regressive Integrated Moving Average (ARIMA) model and Neural Network (NN) model.

Transformation data is the process to reduce the error of prediction. The results show that the least MAPE and σ^2 estimated is ARIMA(2,1,2), ARIMA(1,1,1) and NNAR(1,1), respectively. Auto Regressive Integrated Moving Average (ARIMA) model take more step than Neural Network (NN) model because Auto Regressive Integrated Moving Average (ARIMA) model have to check for model diagnostics before forecast the data. However, Auto Regressive Integrated Moving Average (ARIMA) model get MAPE lower than Neural Network (NN) model in this case.

For future application, other neural network that more suitable than neural network. For example, Recurrent Neural Network (RNN) model and Long Short-Term Memory (LSTM) model. Both Recurrent Neural Network (RNN) model and Long Short-Term Memory (LSTM) model is the neural network which have connected node in same level. This will make them more suitable with sequential data and time series data.

6. Reference

Adebiyi, A. A., Adewumi, A. O., & Ayo, C. K. (2014). Comparison of Arima and artificial neural networks models for stock price prediction. Journal of Applied Mathematics, 2014, 1-7. https://doi.org/10.1155/2014/614342

Bylund, A. (2018). Why Netflix Is Up 50% in 2018. The Motley Fool. https://www.fool.com/investing/2018/11/15/why-netflix-is-up-50-in-2018.aspx

Bylund, A. (2019). How Netflix SHARES Gained 37% in the first half of 2019. The Motley Fool. https://www.fool.com/investing/2019/07/11/how-netflix-shares-gained-37-in-the-first-half-of.aspx.

Chen, J. (2021, May 19). Neural network definition. Investopedia. https://www.investopedia.com/terms/n/neuralnetwork.asp.

Encyclopedia Britannica, inc. (2019). Netflix. Encyclopaedia Britannica. https://www.britannica.com/topic/Netflix-Inc.

Gsmanessis. (2019). When Netflix shares drop by this much, this fast, the next move is usually higher. CNBC. https://www.cnbc.com/2019/09/24/when-netflix-shares-drop-this-fast-the-next-move-is-usually-higher. html

Hossain, Md & Abdulla, Faruq & Hossain, Zakir. (2017). Comparison of ARIMA and Neural Networks to Forecast the Jute Production in Bangladesh. 40. 11-18.

Hyndman, R. J., & Athanasopoulos, G. (2021). Forecasting: Principles and practice. OTexts.

Kline, D. B. (2018). Why Did Netflix, Inc. Shares Drop 19% in October? The Motley Fool. https://www.fool.com/investing/2018/11/11/why-did-netflix-inc-shares-drop-19-in-october.aspx

Oancea, B., & Ciucu, T. C. (2014, January 7). Time Series forecasting using Neural Networks. arXiv.org. Retrieved October 24, 2021, from https://arxiv.org/abs/1401.1333.

Shakir Khan and Hela Alghulaiakh, "ARIMA Model for Accurate Time Series Stocks Forecasting" International Journal of Advanced Computer Science and Applications(IJACSA), 11(7), 2020. http://dx.doi.org/10.14569/IJACSA.2020.0110765

Shamsuddin, Siti Mariyam & Sallehuddin, Roselina & Mohd Yusof, Norfadzlia. (2008). Artificial Neural Network Time Series Modeling for Revenue Forecasting. Chiang Mai Journal of Science. 35.

Stephanie. (2020, June 8). Ljung box test: Definition. Statistics How To. Retrieved October 8, 2021, from https://www.statisticshowto.com/ljung-box-test/.

Team, T. (2021, April 21). Netflix stock up 14% in 2020 at $375 Despite COVID-19; is it sustainable? Forbes. https://www.forbes.com/sites/greatspeculations/2020/04/02/netflix-stock-up-14-in-2020-at-375-despite-covid-19-is-it-sustainable/ ?sh=740ed1a230e4

University of Virginia Library Research Data Services + Sciences. (n.d.). Retrieved October 8, 2021, from https://data.library.virginia.edu/understanding-q-q-plots/.