PREDICTING TESLA STOCK PRICE MOVEMENTS USING SELECTED MACHINE LEARNING TECHNIQUES, WITH A FOCUS ON INVESTORS SENTIMENT EXPRESSED IN COMMENTS SECTION OF YAHOO FINANCE

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Bern 08.11.2024

AGENDA

1) Why Tesla Stock
2) Data collection and sentiment scoring
3) Exploratory data analysis
4) Stock price prediction using:
    a) Logistic Regression
    b) Random Forest
    c) Long Short-Term Memory Model
5) From Prediction to Profit: Trading Simulation

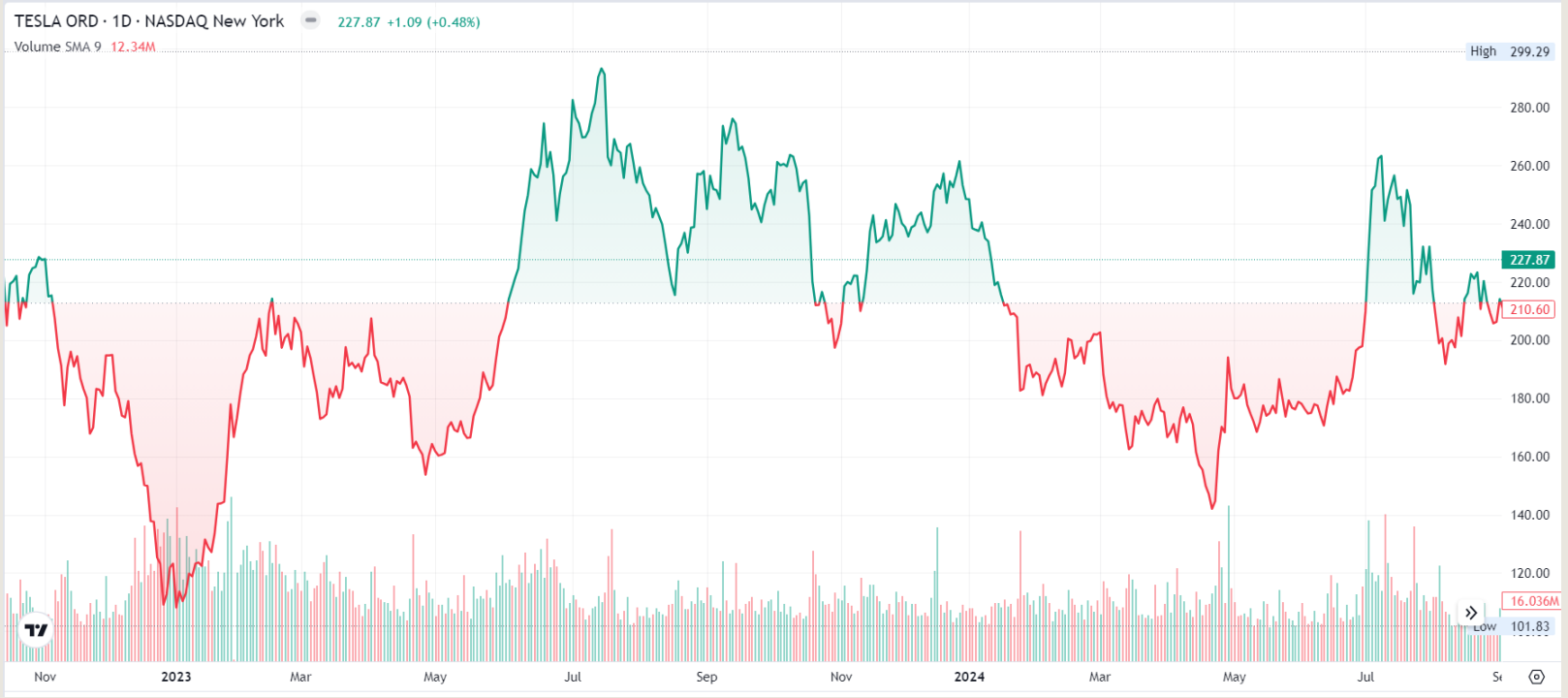
WHY TESLA?

The Magnificent 7 companies are among the seven dominant tech giants driving significant stock market growth through their innovation and influence, making them highly attractive to investors.

https://alaricsecurities.com/magnificent-7-stocks-from-nifty-fifty-to-market-dominance/

WHY WE PICKED TESLA?

- Characterized by frequent "bull runs" and sharp price drops
- Ideal for sentiment analysis due to its dynamic fluctuations which generate sentiment swings among the investors



DATA COLLECTION AND SENTIMENT SCORING

SENTIMENT DATA COLLECTION

- Web scrapped **648k** comments from Yahoo Finance: https://finance.yahoo.com/quote/TSLA/community/

yahoo!finance

THE #1 FINANCE SITE IN THE U.S.[1]

62% of adult Americans own stocks, reaching a 20-year high

Source: https://www.visualcapitalist.com/american-stock-ownership-by-share-of-financial-assets/

#1 platform for business news[1]

With 93M monthly unique visitors in the U.S.[1]

[1] Comscore Media Metrix Multi-Platform, Business/Finance News category, July 2022, U.S.

#1 video platform in finance category

With 6.2M monthly unique viewers.

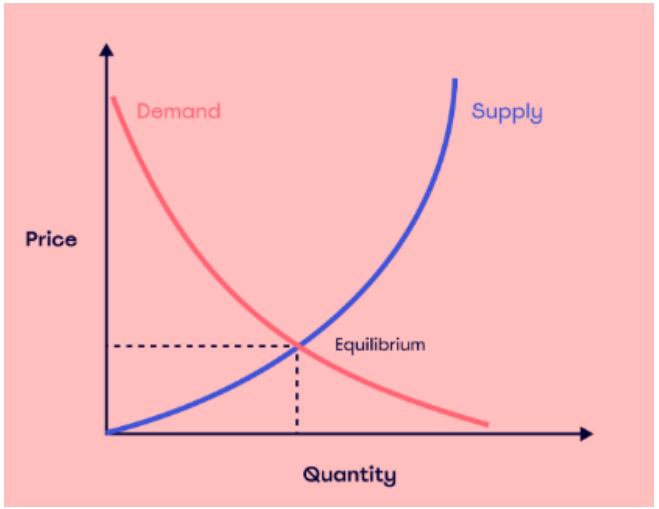
[2] Comscore Video Metrix, Desktop Content Only, July 2022, U.S.

Source: https://www.advertising.yahooinc.com/about/our-brands/yahoo-finance

SENTIMENT ASSUMPTIONS

Comment makers represent actual or potential TESLA stock owners and express the general sentiment of the market regarding the asset

- **Positive sentiment** drives **demand** for TSLA shares, as market participants anticipate price increases based on optimistic commentary. This increased demand **pushes the stock price higher.**
- **Negative sentiment** instills fear among market participants, creating the perception that the stock price will fall. This encourages shareholders to sell, increasing **supply** and **driving the price down.**



BULL AND BEAR MARKET

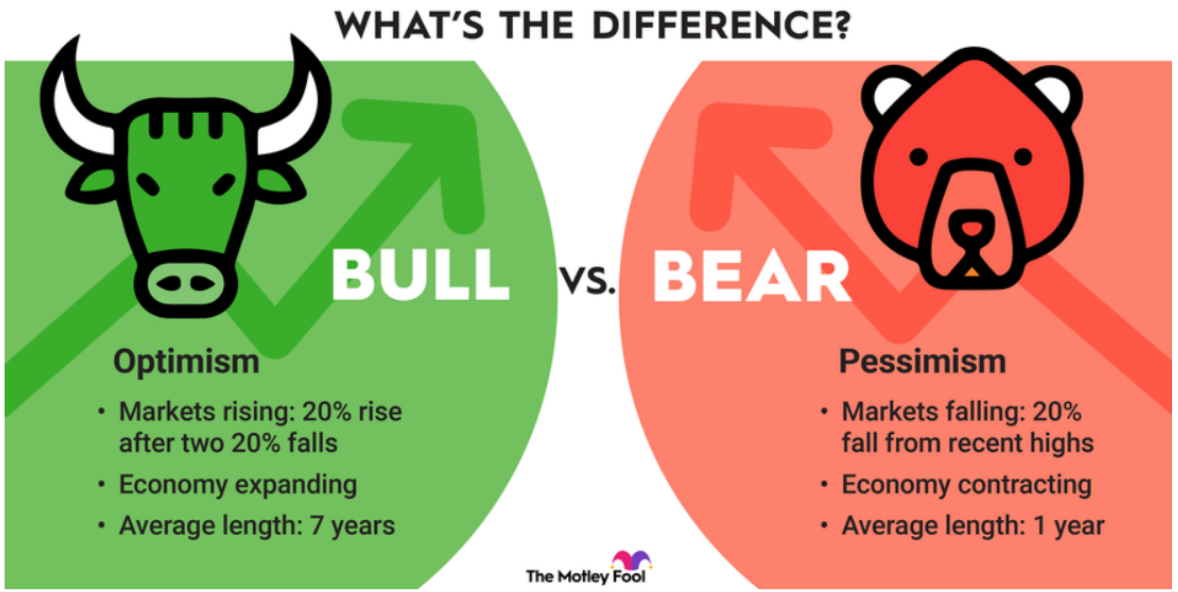
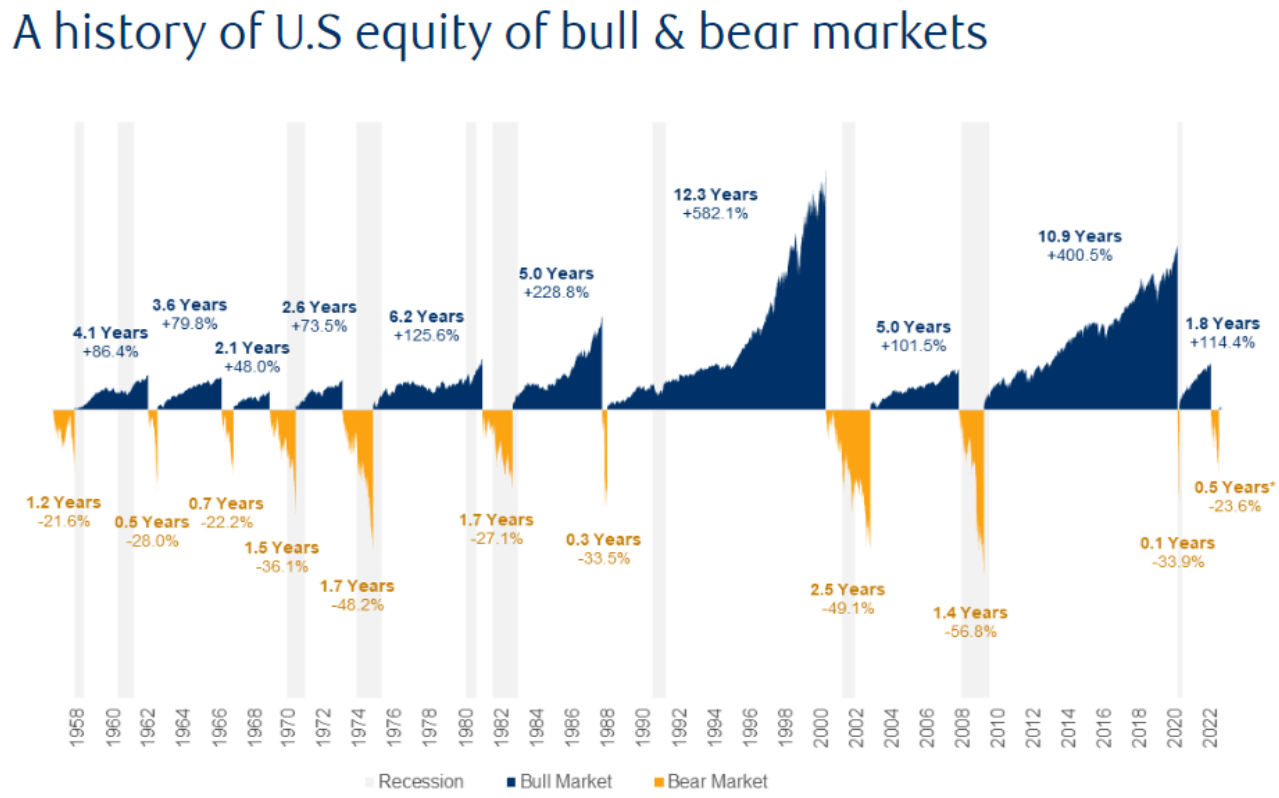


Image source: The Motley Fool



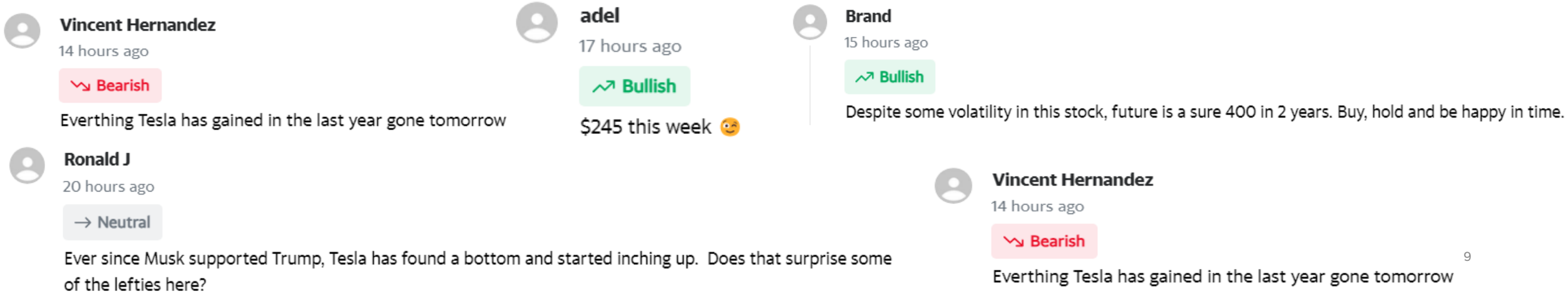
Source: https://www.rbcgam.com/en/ca/learn-plan/investment-basics/the-bulls-the-bears/detail

SENTIMENT SCORING

Each comment receives a sentiment score ranging from –1 (highly negative) to 1 (highly positive), based on a two-tier approach:

- **44.4% of comments** have a sentiment tag where users **explicitly** express their outlook on Tesla's future stock price, the score is assigned as follows:
  - **BULLISH** – "price will raise" - sentiment Score: **1**
  - **NEUTRAL** – "no change in price" - sentiment Score: **0**
  - **BEARISH** – "price will fall" - sentiment Score: **–1**

	# of comments	% of comments
BEARISH	126'007	19.4%
BULLISH	147'633	22.8%
NEUTRAL	14'370	2.2%
null	360'077	55.6%
TOTAL	**648'087**	**100.0%**



SENTIMENT SCORING

- For the remaining **55.6% of comments** without a sentiment tag, we assign a sentiment score using the **VADER** (Valence Aware Dictionary and sEntiment Reasoner) lexicon.
- **VADER** is a pre-trained sentiment analysis tool specifically designed for social media text.
- It uses a lexicon of words with pre-labeled sentiment scores and adjusts based on factors like punctuation, capitalization, and negation.
- The sentiment score range:
  - **-1**: Extremely Negative
  - **0**: Neutral
  - **1**: Extremely Positive

Mark

23 hours ago

It is difficult to believe that people are buying or even trading this stock anymore.

```
{'neg': 0.152, 'neu': 0.848, 'pos': 0.0, 'compound': -0.3612}
```

Henry Schneider

6 hours ago

Kamala harris knows what is AI and can support tech stocks

```
{'neg': 0.0, 'neu': 0.787, 'pos': 0.213, 'compound': 0.4019}
```

AlexD

1 day ago

Tesla holding strong today.

```
{'neg': 0.0, 'neu': 0.476, 'pos': 0.524, 'compound': 0.5106}
```

jc

22 hours ago

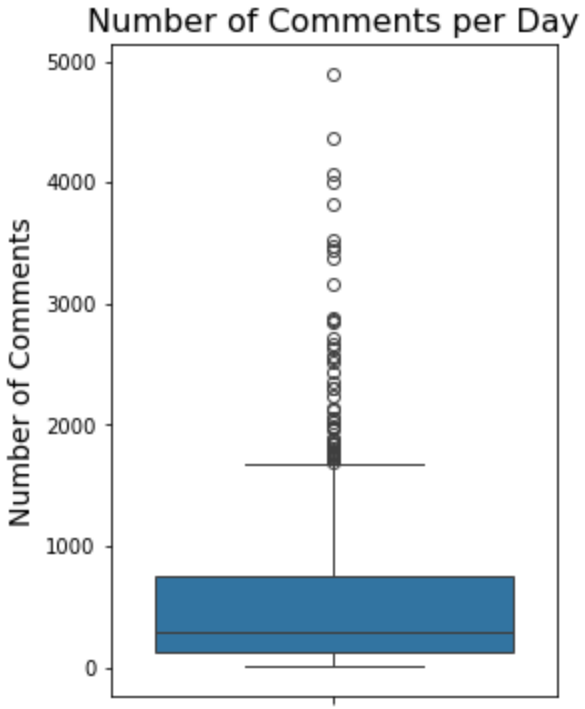
Cybertrucks are so ugly.

```
{'neg': 0.586, 'neu': 0.414, 'pos': 0.0, 'compound': -0.6418}
```

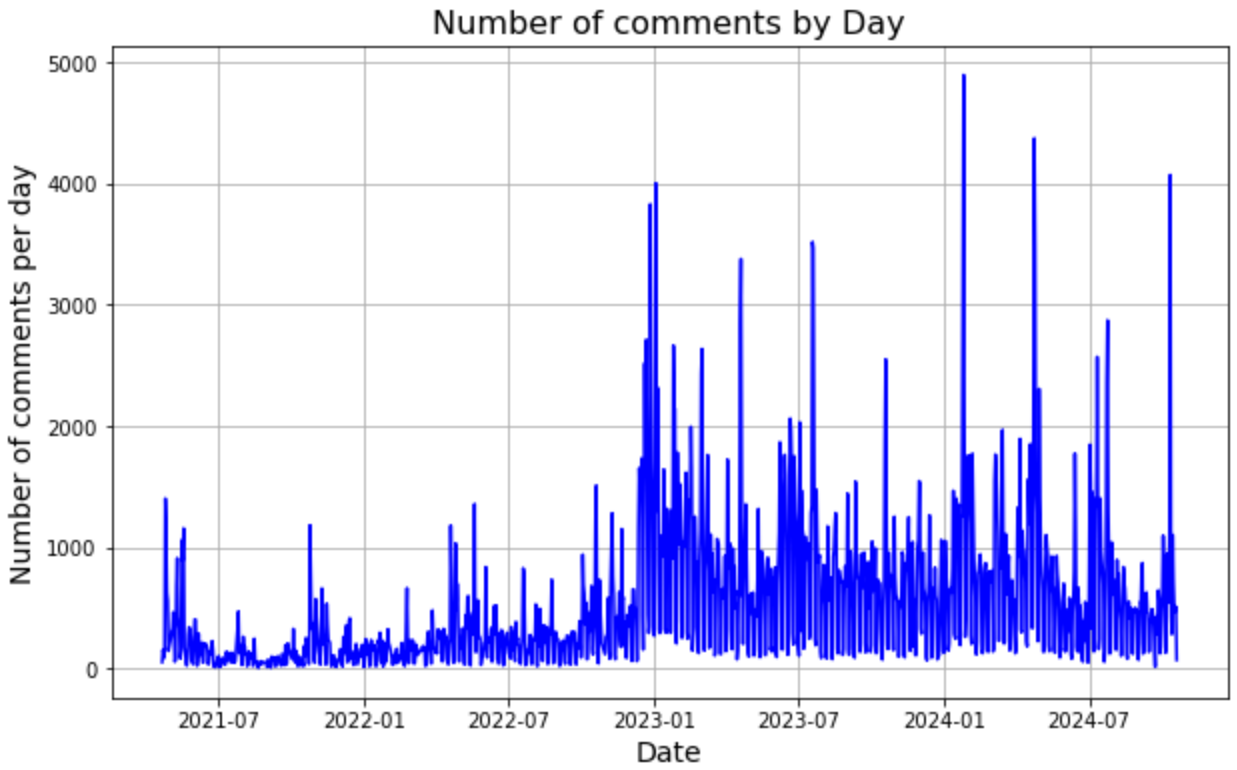
EXPLORATORY DATA ANALYSIS

COMMENTS DATA COLLECTION

- Analysis period: 01.05.2021 - 30.09.2024, 3 years and 5 months
- Web scrapped **648k** comments from Yahoo Finance: https://finance.yahoo.com/quote/TSLA/community/



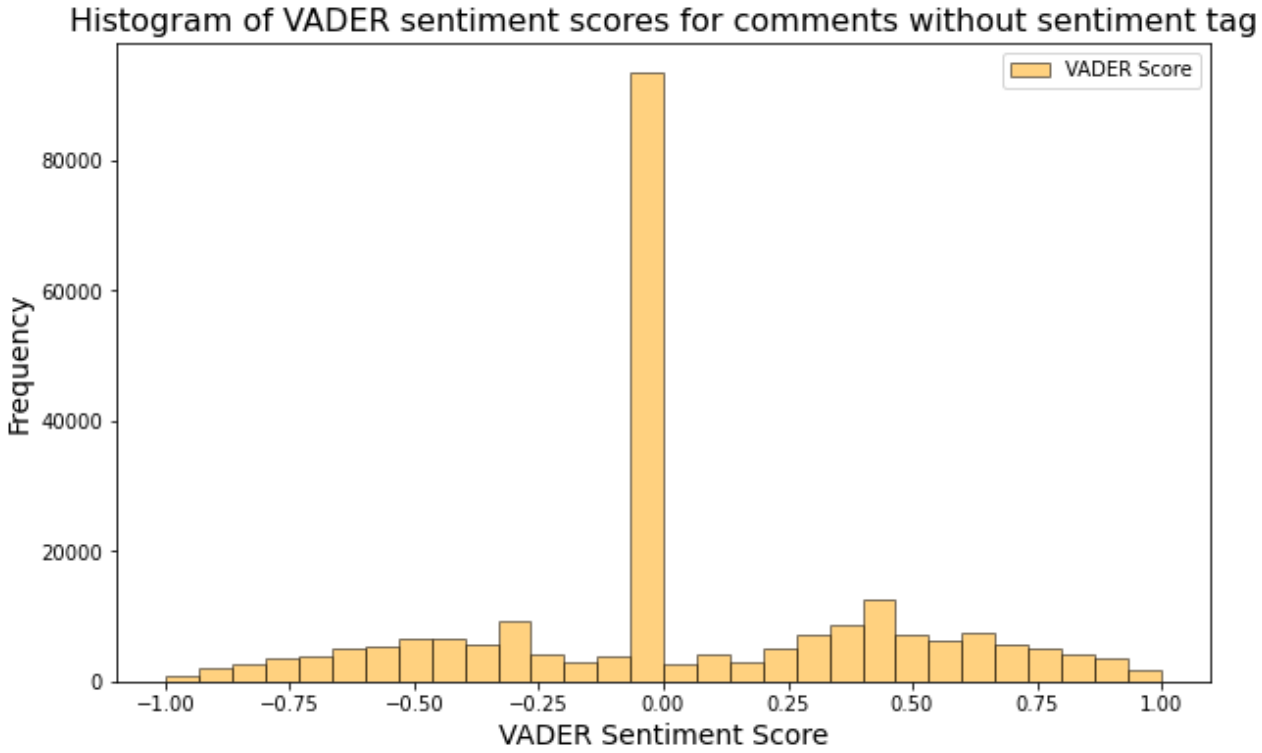
	comment_count
count	1240.000000
mean	522.650806
std	583.815412
min	1.000000
25%	128.000000
50%	293.500000
75%	749.500000
max	4900.000000

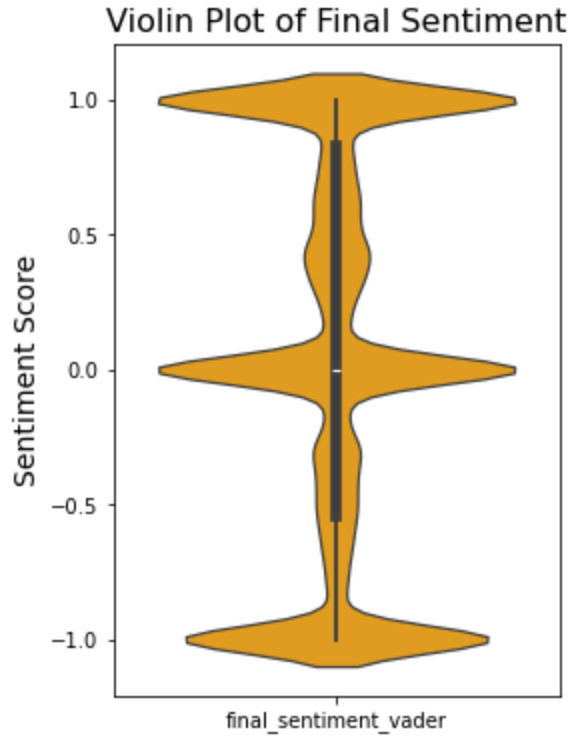


SENTIMENT SCORES

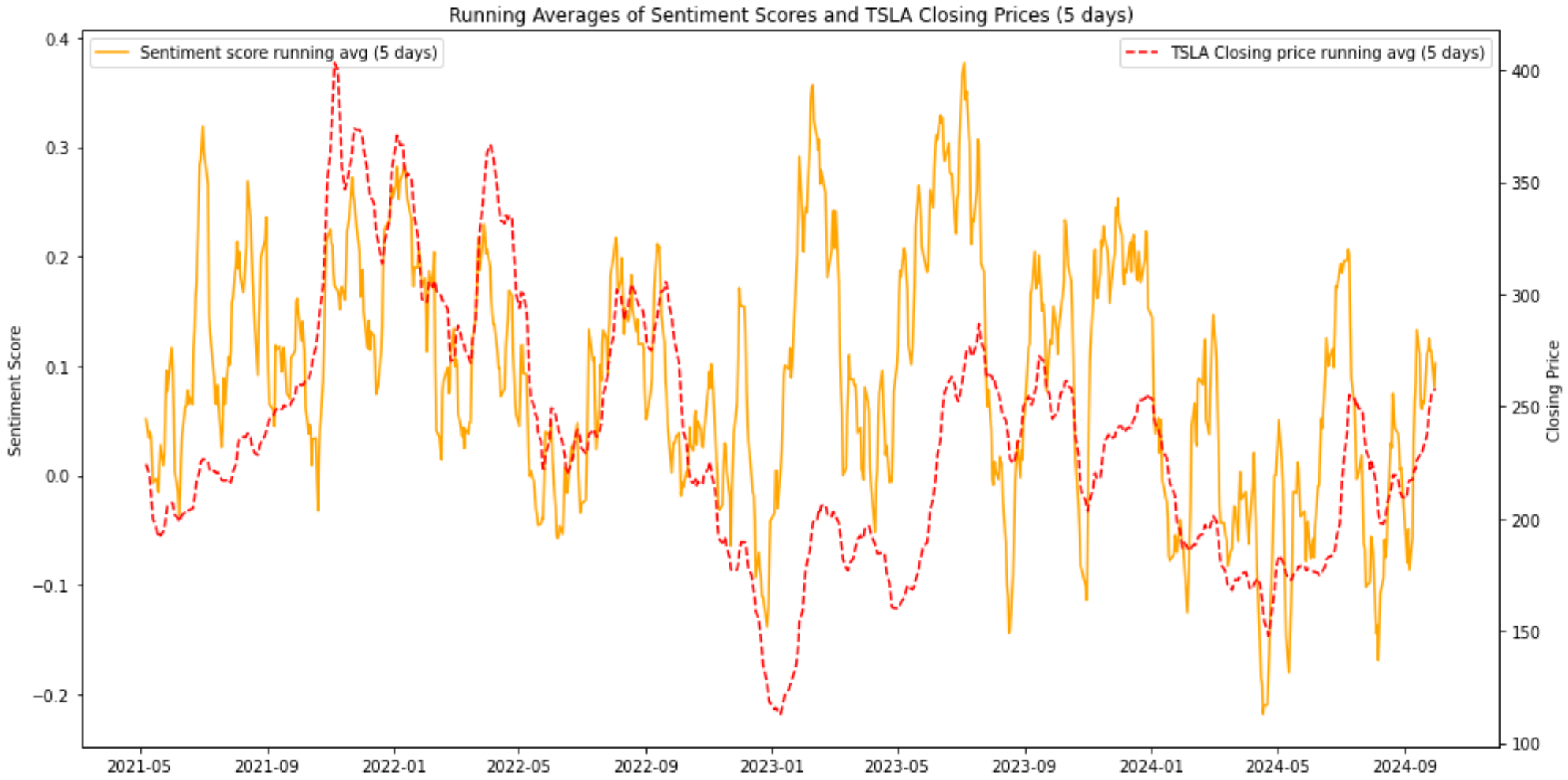
- For **44.4%** of comments with BULLISH/BEARISH/NEUTRAL sentiment tag we assign a value: –1, 0 or 1 based on the tag
- For the outstanding **55.6%** of comments without the tag we derive the sentiment score based on the VADER sentiment

	# of comments	% of comments
BEARISH	126'007	19.4%
BULLISH	147'633	22.8%
NEUTRAL	14'370	2.2%
null	360'077	55.6%
TOTAL	**648'087**	**100.0%**





SENTIMENT VS TSLA CLOSING PRICE



TSLA STOCK PRICE PREDICTION – LOGISTIC REGRESSION

LOGISTIC REGRESSION

- Logistic regression, despite its name, is a linear model for classification rather than regression
- ML technique used to predict the binary outcomes that are categorical and mutually exclusive.
- In this model, one class is assigned a target value of 1 (positive class), and the other class is assigned a target value of 0 (negative class).
- To predict the probability p of a point belonging to the positive class, logistic regression applies a *sigmoid function* to a linear combination of input features. The sigmoid function transforms this linear output into a probability range between 0 and 1, where:

$$p = \sigma(w_0 + w_1 x_1 + ... + w_p x_p)$$

Where $\sigma(x) = \frac{1}{1+e^{-x}}$.

- The model's parameters w are optimized to minimize a specific *loss function*, which, in binary classification, is the *log loss*. This loss function measures the difference between the predicted probabilities and the actual target values, helping adjust w to improve prediction accuracy.

LOGISTIC REGRESSION

Goal: Predict whether Tesla's closing price on the next trading day will be **higher** or **lower** than today's closing price.

Data Preprocessing

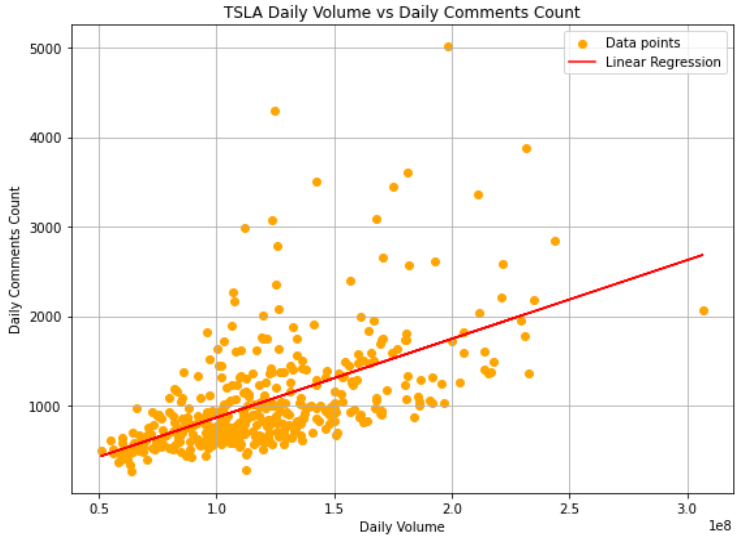
- Aggregate by day, add a column with T+1 closing price, and a target column: 1 if price went up or 0 if down

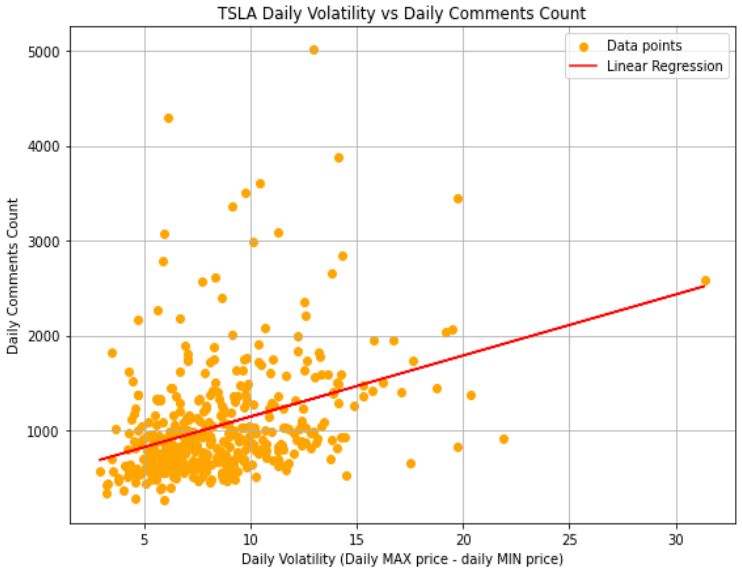
Features selection:

1) 5 days running average of the sentiment score
2) 5 days running average of the TSLA closing price
3) 5 days running average of TSLA daily volume
4) 5 days running average of TSLA daily volatility
5) Closing price today

Model Training

- Train/test split = 20%
- Random state = 1





LOGISTIC REGRESSION - EVALUATION

$$\text{Accuracy} = \frac{\text{True Positives} + \text{True Negatives}}{\text{Total Predictions}}$$

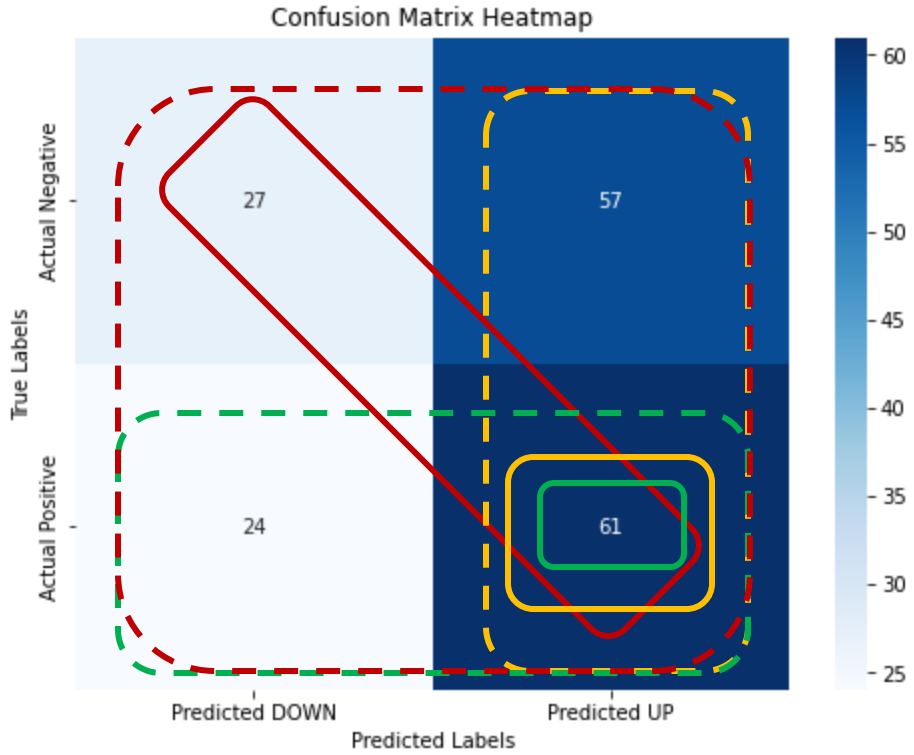
52,1%

$$\text{Precision} = \frac{\text{True Positives}}{\text{True Positives} + \text{False Positives}}$$

51,6%

$$\text{Recall} = \frac{\text{True Positives}}{\text{True Positives} + \text{False Negatives}}$$

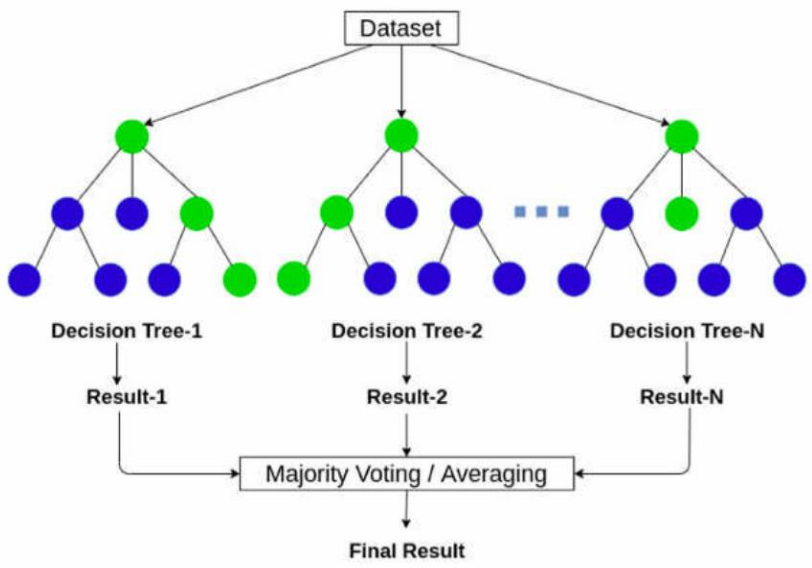
71,6%



TSLA STOCK PRICE PREDICTION – RANDOM FOREST

RANDOM FOREST

- Random Forest is an ensemble learning algorithm that combines multiple decision trees to improve prediction accuracy and reduce overfitting.
- It can be applied to classification or regression problems.
  .
- Instead of relying on a single decision tree, the Random Forest model combines the output of each tree, using the average of their predictions to produce a final, more reliable output.



Source: https://www.gofar.ai/p/predicting-market-risk-using-machine

RANDOM FOREST

Goal: Predict TSLA Closing price on T+1

Data Preprocessing

- Aggregate by day, add a target column with T+1 closing price

Features selection:

1) 5 days running average of the sentiment score
2) 5 days running average of the TSLA closing price
3) 5 days running average of TSLA daily volume
4) 5 days running average of TSLA daily volatility
5) Closing Price today

Model Training

- Train/test split = 20%
- Random state = 333
- Random Forest Regressor with n_estimators = 100 (# of decission trees)

RANDOM FOREST – EVALUATION

MSE - Mean Squared Error

- Measure accuracy of predictions in regression tasks
- Avg. Of the squared differences between actual and predicted values
- Squaring to emphasize larger errors, hard to interpret because the results are squared as well

MSE: 103

R^2 – R-squared

- a metric used in regression analysis to measure how well a model's predictions match the actual data.
- Specifically, it indicates the proportion of the variance in the dependent variable that is predictable from the independent variables
- **0** means the model explains none of the variance (no predictive power).
- **1** means the model explains all the variance (perfect predictive power).

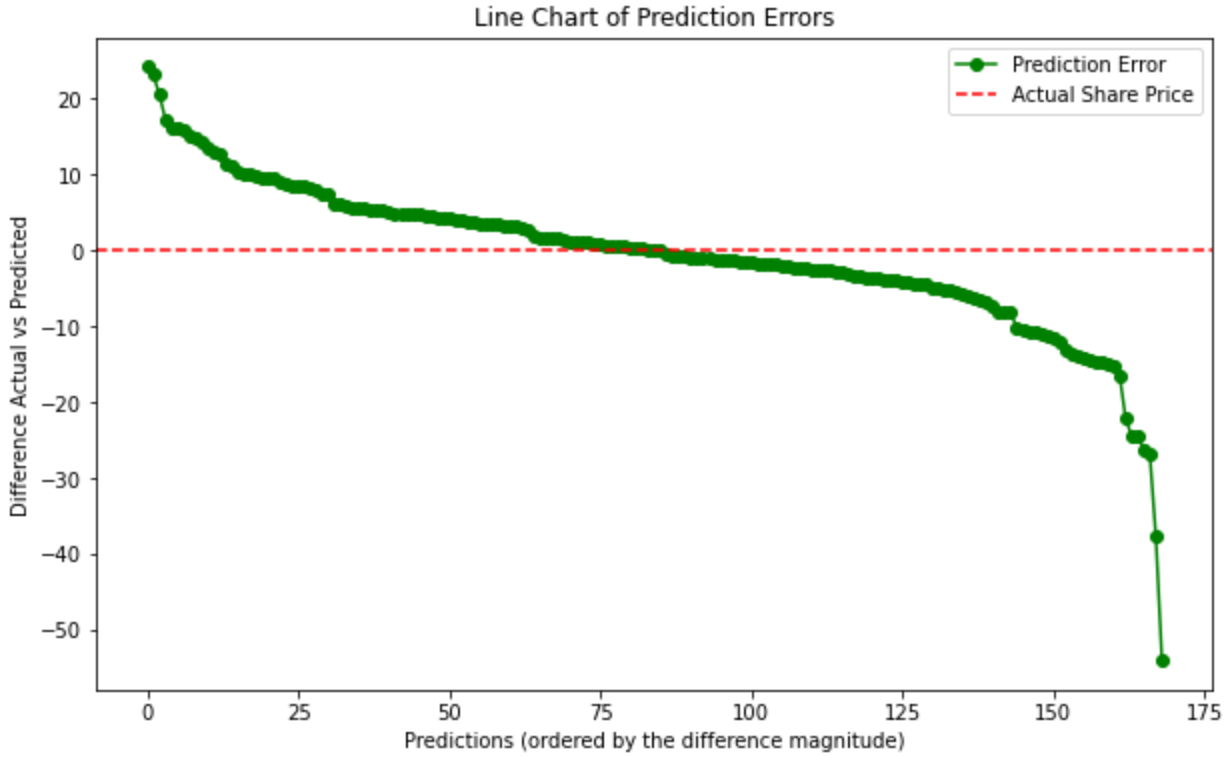
R^2: 0.95

RANDOM FOREST – EVALUATION

MAE - Mean Absolute Error

- a metric used to measure the accuracy of a model's predictions by calculating the average of the absolute differences between predicted and actual values.

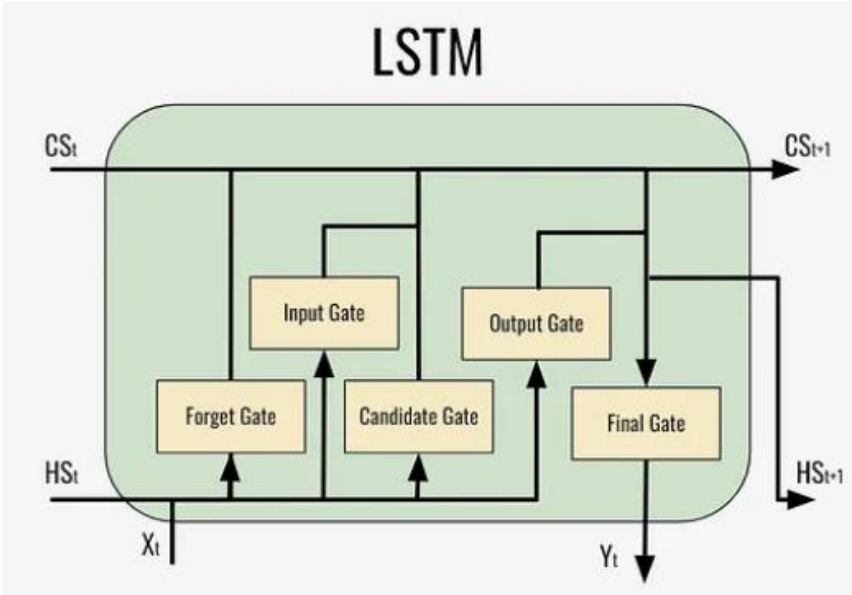
MAE: 7.05



TSLA STOCK PRICE PREDICTION – LONG SHORT-TERM MEMORY (LSTM) MODEL

LONG SHORT-TERM MEMORY MODEL

- **LSTM Overview**: Long Short-Term Memory (LSTM) models are a type of recurrent neural network specifically designed for learning from sequences of data, making them well-suited for time series predictions like TSLA share prices.
- **Memory Mechanism**: LSTMs use memory cells and gate mechanisms to retain relevant information over long periods, enabling them to capture how past investor sentiment influences future price movements.
- **Input Processing**: By processing sentiment scores as input sequences, LSTMs can effectively identify the relationship between investor sentiment and fluctuations in stock prices.



https://medium.com/@CallMeTwitch/building-a-neural-network-zoo-from-scratch-the-long-short-term-memory-network-1cec5cf31b7

LONG SHORT-TERM MEMORY MODEL

Goal: Predict TSLA Closing price on T+1

Data Preprocessing

- Aggregate by day, target is the Closing price on T+1
- Scale all the features to be in range 0 – 1
- Create sequences, for selected number of days (5 days)

Features selection:

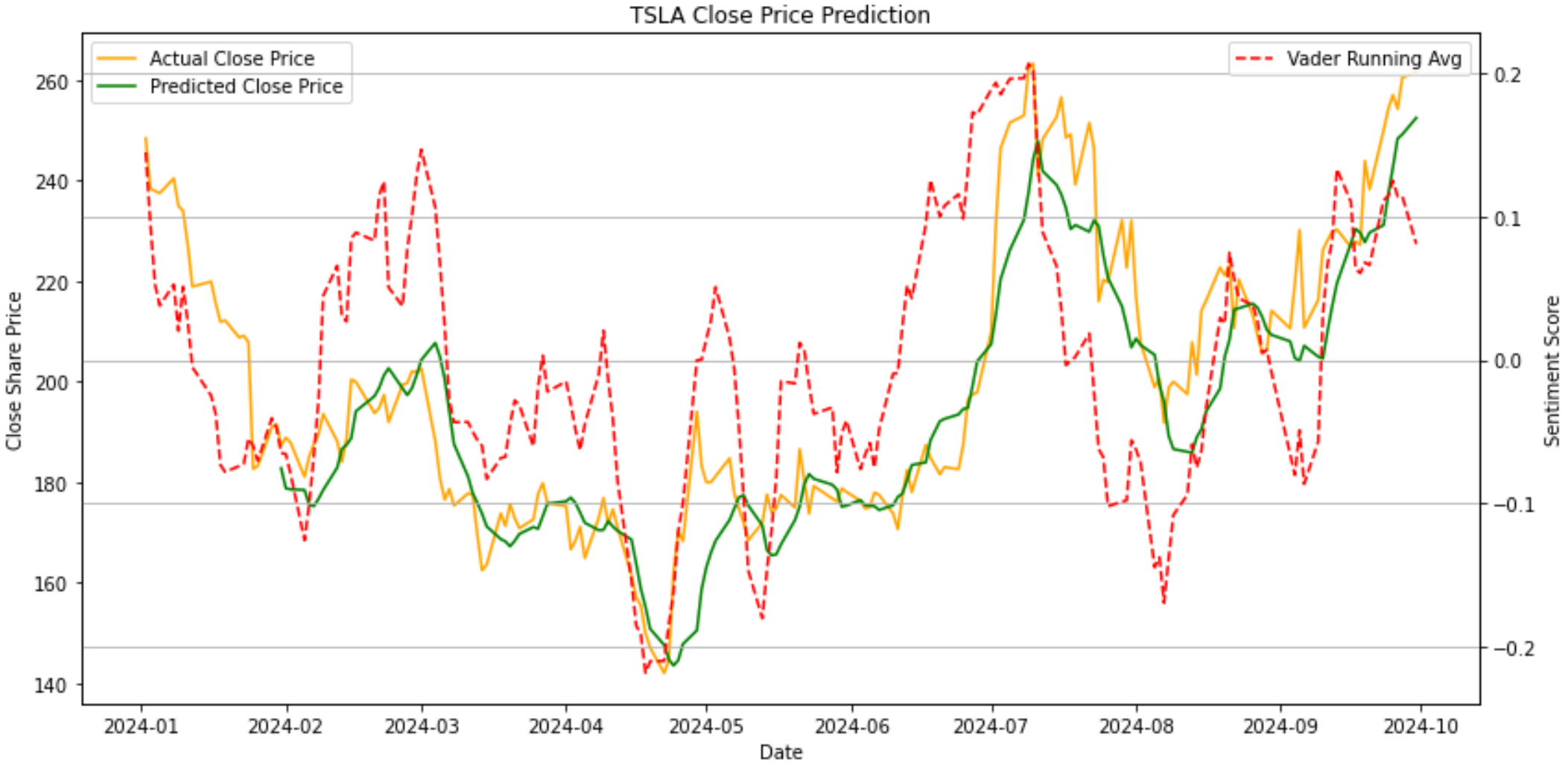
1) 5 days running average of the sentiment score
2) 5 days running average of the TSLA closing price
3) 5 days running average of TSLA daily volume
4) 5 days running average of TSLA daily volatility
5) Closing price

Model Training

- Train/test split = 80%/20%, difference to Random Forest – continous
- Sequential – layers are stacked one after the other
- Initiate a LSTM layer with 20 units (neurons) and ReLU activation.
- The model is compiled with the Adam optimizer and Mean Squared Error (MSE) as the loss function.
- # of epochs = 10 --> 10x throught the entire dataset

LONG SHORT-TERM MEMORY MODEL - RESULTS

MSE: 139 MAE: 9.02 R^2: 0.82



FROM PREDICTION TO PROFIT: TRADING SIMULATION

TRADING STRATEGY

Invested amount: 10 000 USD

Investment period: 31.01.2024 - 30.09.2024

Prediction Model: LSTM

Strategy:

Trade decision every day at market closing

If predicted price on T+1 > Close price T+0 --> buy or hold position

If predicted price on T+1 < Close price T+0 --> sell or keep cash position

Benchmark:

Close price 31.01.2024: 187.29 USD

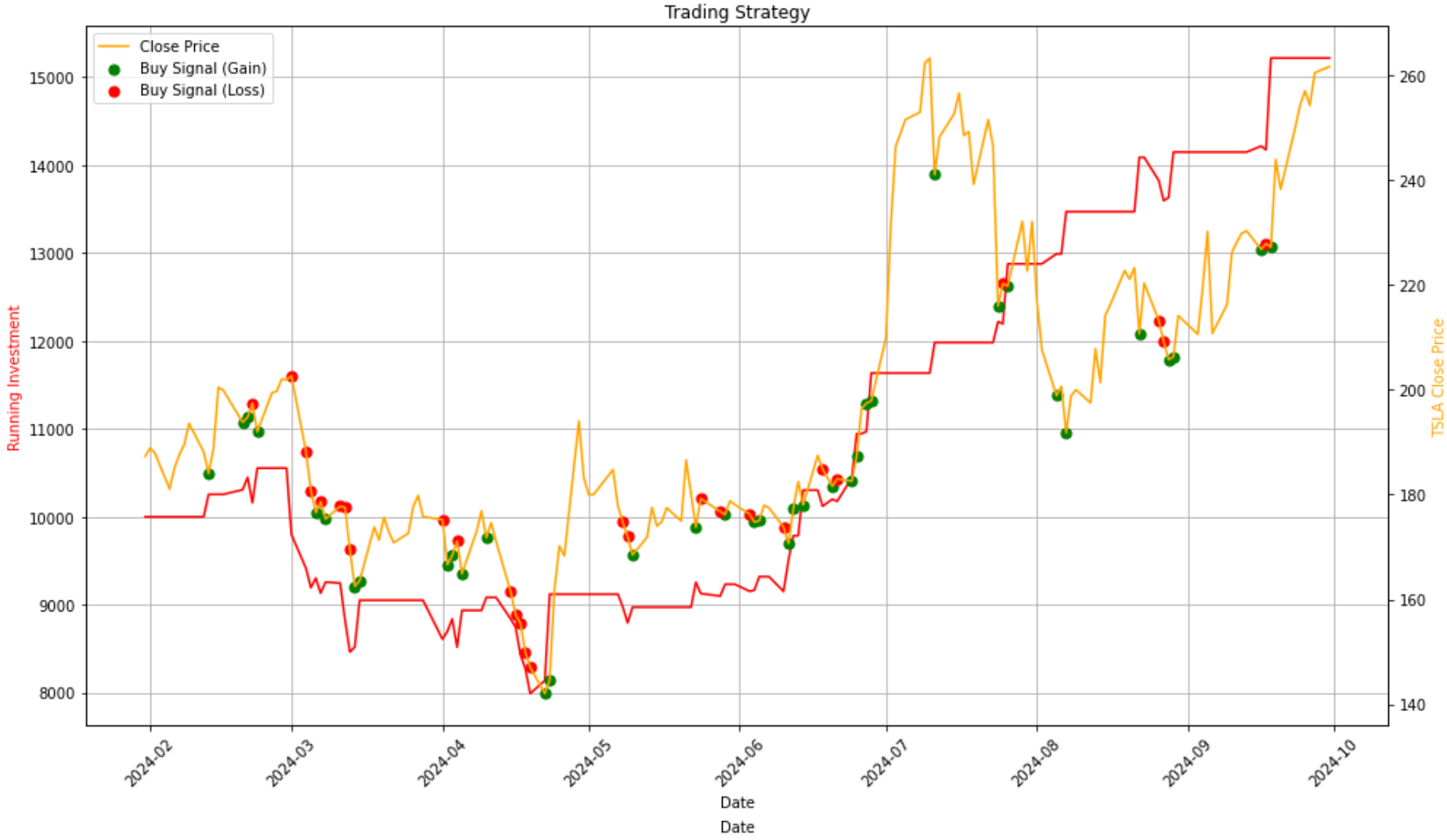
Close price 30.09.2024: 261.69 USD

Performance: +39.72%

ROI: 13 972 USD

TRADING STRATEGY - RESULTS

Trading days: **168** Days with buy signal: **64 (38%),** w/o gain **37** days and loss **27** days

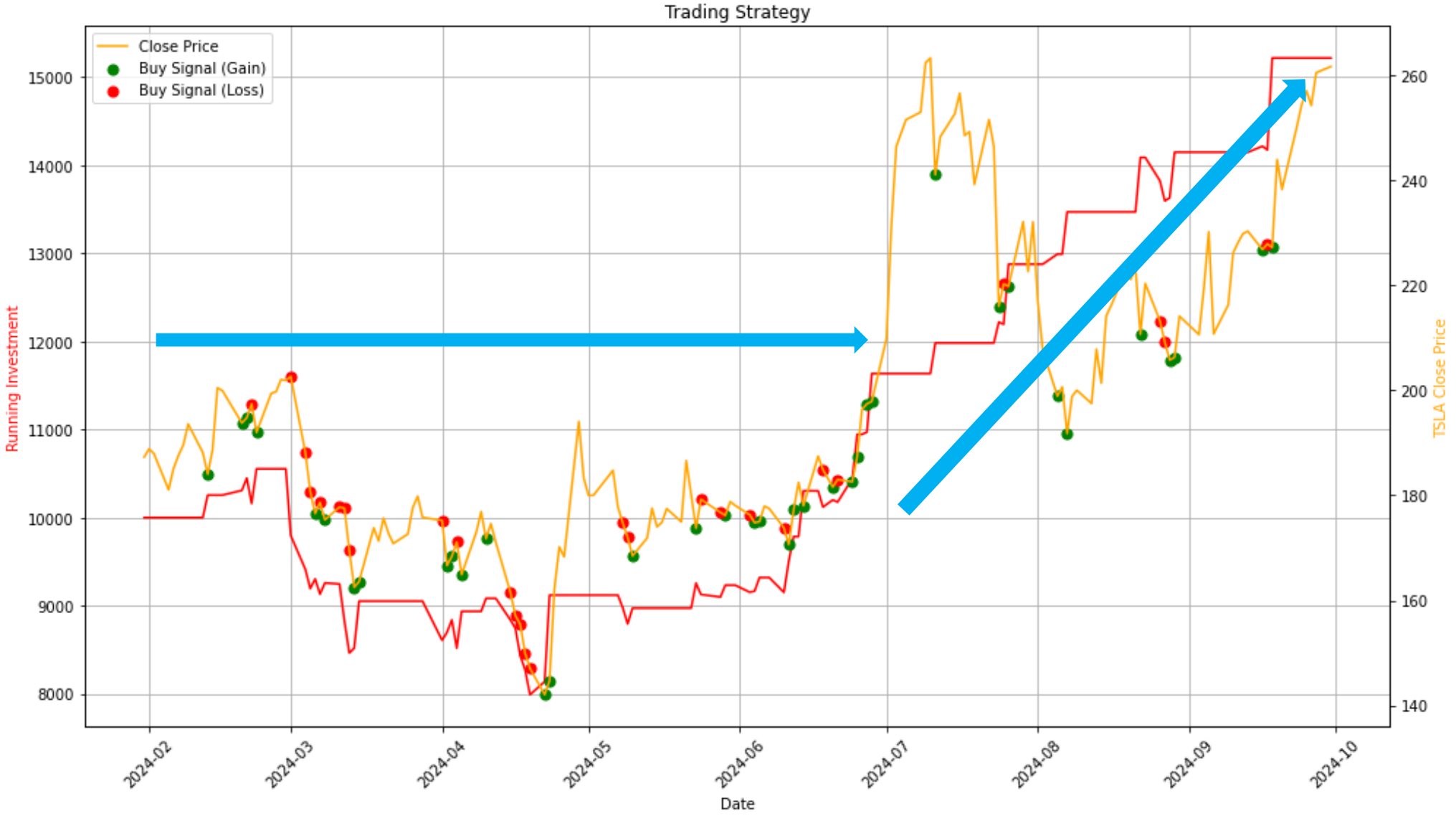


ROI: 15 215 USD

+52,2%

the strategy has exceeded the benchmark by + 1 243 USD

TRADING STRATEGY - RESULTS



REFERENCES

To see the full implementation, you can view the complete code on my GitHub:

https://github.com/lukaszmacias01/CAS_UniBern_Applied_Data_Science/tree/master/MODULE3

THANK YOU