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**Trump Tweets vs The Markets**

Final Report for CS39440 Major Project

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**Declaration of originality**

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By including my name below, I hereby agree to this dissertation being made available to other students and academic staff of the Aberystwyth Computer Science Department.

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**Acknowledgements**

I’d like to thank StackOverflow community for my Degree.

**Abstract**

“World events often have a great influence over international markets. Political uncertainty can often drive commodities up or down in value depending on where it occurs in the world. “[1]. Politicians of countries with the biggest markets have got a strong impact on the value of currencies and trading commodities. A simple message such as "With Mexico being one of the highest crime Nations in the world, we must have THE WALL. Mexico will pay for it…"[2] sent from the USA president's account can drop down Mexican Peso value. Trump’s infamous Twitter account, which is followed by almost 50 million people, can be an effective tool to influence the markets.

The goal of this project is to develop a system which considers the sentiment of tweets and can predict whether a stock index will increase or decrease depending on the current index, words, phrases and the sentiment of the tweet.

Python, Scikit-learn, and NLTK (Natural Language Toolkit) are used to process the data in this project. The web interface is created using Flask framework.

The results show that when using a Naïve Bayes classifier, the accuracy of predicting the USD Index change is 53.7%, whereas the base rate of the three-class problem (up, down, no change) is 41%.

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# 1. Background, Analysis & Process

## Background

### Machine Learning and Data Mining

Machine learning and Data Mining are becoming very quickly developing fields of computer science nowadays. The Internet is full of data that can be analysed and processed. The process of data mining is mainly focused on discovering patterns in large data sets involving methods such as machine learning and statistics. (<http://www.kdd.org/curriculum/index.html>)

“Machine Learning is the science of getting computers to learn and act like humans do, and improve their learning over time in autonomous fashion, by feeding them data and information in the form of observations and real-world interactions.” (<https://www.techemergence.com/what-is-machine-learning/>)

In other words, it is a practice of feeding data into algorithms that learn patterns from it and are able to predict the output for unseen data.

One branch of Machine Learning is Supervised learning. Starting from the labelled dataset (objects with labelled output) supervised algorithms produce a function to make predictions about the output values. The key part of supervised learning is that outputs of the training data have to be known in advance.

(http://www.expertsystem.com/machine-learning-definition/)

Instances of that data have to have it set up beforehand or be labelled manually.

### Trump Tweets

Twitter is a social networking website on which users can post short (max 140 characters length) messages called “tweets”.  As of the October 2017, Twitter had 330 million users. Among users, there can be found many celebrities and politicians, who regularly post their thoughts, news and announcements.

The USA president, Donald Trump is known for his controversial, outrageous and sometimes very hateful tweets. He posts about 10 times every day and his account is followed by over 50 million people. His account is regularly used to attack his opponents and stir up controversies.

His tweets have got a massive impact on markets and political scene. Their scope is so wide that he admitted that without Tweeter he would not be a president.

(<https://www.independent.co.uk/news/world/americas/us-politics/donald-trump-tweets-twitter-social-media-facebook-instagram-fox-business-network-would-not-be-a8013491.html>)

His simple language makes them easy to analyse. He never uses a sarcasm or exquisite words. Due to the fact that his vocabulary is fairly small, it is easy to train a machine learning classifier with it. Such a classifier learned using these tweets associated with for example market changes can be able to predict future events when fed with new data.

His tweets are also very emotional, petulant and sometimes aggressive what makes it easy to determine their sentiment by a computer. They also follow some patterns, most of his positive tweets end up with “Make America Great Again” phrase.

Analysing this data seemed to be very interesting because **BLABLABLA**

### Similar Systems

In preparation for this project, there was done some research.

<http://varianceexplained.org/r/trump-tweets/>

There was found an interesting analysis made by David Robinson (Chief Data Scientist at DataCamp), comparing Trump tweets content with the device they were sent from (part of tweets is sent from iPhone and some from Android). The results were interesting: most negative tweets attacking his rivals were sent from Android whereas iPhone was used more for benign announcements. The analysis concludes that tweets from these devices are written by different people. Almost all the tweets sent with a picture or hashtags come from iPhone and most of “emotionally charged” words were common for Android device. What we can notice from the analysis is that iPhone tweets are probably sent by people involved in planning his schedule because words like “join” or “tomorrow” come from iPhone. Fact that Android tweets are more objective may mean that these ones are sent by his public relations specialists or either by himself.

There have been many researches about predicting stock market indicators through twitter made already. One of them is :

<https://www.sciencedirect.com/science/article/pii/S1877042811023895>

Research made by XXX was based on collecting tweets about stock markets and analyse on measured hope and fear on each day. The data was used to find a correlation with markets. It was found that emotional tweets correlated to the biggest markets such as Dow Jones, NASDAQ and S&P 500.

Prior to starting with the project there was watched many tutorials on Youtube and Pluralsight. A similar project was developed by Harrison Kinsley, whose tutorials can be found on Youtube and his webpage: <https://pythonprogramming.net/tokenizing-words-sentences-nltk-tutorial/>

Tutorials show the basics of NLP (Natural Language Processing) and Twitter Sentiment Analysis. There was shown simple approach to create a live graph of tweets sentiment. The project used NLTK, TweePy and Matplotlib. Despite the fact that the project has some substantive errors, the overall approach and process are sensible.

One of the major parts of the project was phrases extraction. During the research, there were identified some modules providing this functionally. One of them was a python implementation of RAKE (Rapid Automatic Keyword Extraction) algorithm.

It was used served as an outline to write own module performing a feature extraction, what is described in more detail in the paragraph 3.2.2. Feature Extraction.

## Analysis

Most of the Twitter sentiment analysis experiments available in the Internet use ready-made analysers like the one built-in in the TextBlob. This approach is fast and easy but those classifiers are too general. It was assumed that it is better to build own classifier because peoples languages are different and one people words can have different emotions when spoken by someone else. For example, words like “Mexico” are neutral but in Trump's tweets, they usually have a negative attitude. Another example could be “Make America Great Again” which in all of the cases goes in positive tweets.

The initial idea of the program workflow looked as follows:

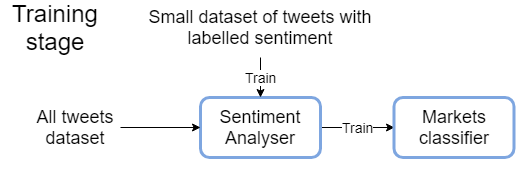


Figure ‑. Draft of a training process

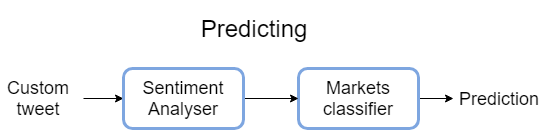


Figure ‑. Draft of a tweet predicting process

## Proposed tasks

Tasks proposed in OPS are presented as follows:

**Setting up git repository -**  create a private git repository, download libraries, start the design of the project.

**Tweets sentiment analysis** – investigating which framework or library use to do the sentiment analysis. Probably with NLTK. Setting up the framework to output correct results.

**Scrapping tweets and U.S. Dollar value and selection** – investigating how to obtain tweets from Twitter REST API. Twitter official docs provide many libraries made by people such as “python-twitter” or “tweepy”[2]. Investigate how to store scrapped tweets. Selection of tweets. An investigation how to scrap currencies values. Investigating how to store tweets and currencies data. Can be used CSV file format or simple database such as Sqlite3 so that data can be presented easily later on.

**Window size** – investigating how long should be the window size, how long do the tweets influence the market.

**Building a model that predicts USD changes depending on tweets** – Building a model that can predict if currency will drop down or go up depending on a tweet sentiment. Investigating how to do that, for example, use ANNs or Naïve Bayes. The investigation which library to use (i.e. TensorFlow) and implementation.

**Creating an API** – creating a webpage presenting graphs and charts of currency values, which tweets affect the currency changes, adding an option for a user to provide own tweet contents and presenting what effect would it have. Investigating which framework to use to create an API. To create a webpage there will be used probably Django with Bootstrap and some JavaScript library to create charts, i.e. ChartJS.

**Project Meetings and Project Diary** – The project will involve half an hour meeting every week with a supervisor on Mondays at 2 pm. A project diary will be kept to remember what was done and all the tasks will be documented.

**Tasks to do when there will be spare time:**

Adding other currencies – adding more currencies to the program such as Mexican Peso or Russian Ruble.

Adding other commodities – adding gold or fuels to the program.

Adding option to use any twitter account to build a model – adding a functionality to choose other twitter accounts than Donal Trump’s one. For example, Theresa May can have an influence on the market due to the Brexit.

## Process

Deciding about the development process was simple. It was decided to use agile methodologies that ensure high product quality, end product satisfaction and reduces the risk of failure with delivering a project.

The project has been split into sprints what allows to deliver new features quickly and frequently. We are sure that if there was too little time then we would still be able to deliver some working software. With waterfall methodology, it would be very likely that there will not be enough time to do tests because implementing all of the features took too much time.

The agile approach that fit the project specification the best is Scrum. Weekly meetings with a supervisor can be treated as client meetings during which a further direction is determined. Each week can be treated as a sprint within which there should be planned adding a new small functionality to the project. Therefore, a student can be seen as a Scrum master and development team whereas a supervisor can be treated as a product owner.

The project was split into sprints and at the end, they looked as follows:

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Tasks for each week** | **W1** | **W2** | **W3** | **W4** | **W5** | **W6** | **W7** | **W8** | **W9** | **W10** | **W11** | **W12** |
| Setting up Git, IDE, research |  |  |  |  |  |  |  |  |  |  |  |  |
| Data collection |  |  |  |  |  |  |  |  |  |  |  |  |
| Sentiment analysis |  |  |  |  |  |  |  |  |  |  |  |  |
| Phrases extraction |  |  |  |  |  |  |  |  |  |  |  |  |
| Markets model building |  |  |  |  |  |  |  |  |  |  |  |  |
| Feature selection |  |  |  |  |  |  |  |  |  |  |  |  |
| Creating a webpage |  |  |  |  |  |  |  |  |  |  |  |  |
| Adding new currencies |  |  |  |  |  |  |  |  |  |  |  |  |
| Integration tests |  |  |  |  |  |  |  |  |  |  |  |  |
| Writing a report |  |  |  |  |  |  |  |  |  |  |  |  |

After each completed sprint there was a retrospective with a supervisor where was reviewed a progress and were discussed next task for the next sprint.

Alternative for Scrum that was considered for the project was XP (Extreme Programming). XP was rejected because its aspects such as pair programming or daily stand up meetings would be rather more efficient in teamwork that in single person project. There was also no need to use any Continuous Integration tool, the tests were run manually in the meantime.

# Design

## Overall Architecture

### Programming Language

When choosing a programming language, main criteria were usability for the project, its libraries, ease of use and experience. The language should provide:

* Machine learning and natural language processing libraries
* Simple Web framework
* Ease of experimenting
* Simple tools to gather the data from web APIs
* Simple tools to do data manipulations and analysis

In this project Python was the best choice. It provides very popular and in-depth machine learning libraries (NLTK, Scikit-learn, Textblob), web frameworks (Flask, Django, Pyramid) and Interpreter which is useful to do quick, ad hoc experimenting. It also provides a Pandas library that allows forming data into DataFrames what is very handy in data analysis and provides many built-in data processing functions. This language was also used by the student during the Industrial Year. Python is also very popular and has got documentation and there are many tutorials and snippets available on the Internet. Most of the researchers and projects that were review during background research were done in Python. All of them used Pandas DataFrames, NLTK and Scikit-learn.

Other languages that were taken into account are:

* **R** - has good ML and data processing libraries. Language is used mostly for data processing and data analysis, therefore, has not got any libraries providing a way to create a web interface. Choosing this language would require to learn it from scratch.
* **Ruby** – provides a good web framework (Ruby on Rails) but does not provide any good libraries/gems to do ML. There is Weka for JRuby and there also other ways to use Java Weka library in Ruby. Was rejected due to the lack of ML tools and lack of experience in coding in this language.
* **Java** – Provides many web frameworks such as Spring, JSF or Vaadin. If the project was done in Java there could be also used Weka (Waikato Environment for Knowledge Analysis) that is a very popular software suite. Writing a code in Java would not be so quick as in Python due to the language syntax. Executing any algorithms in Java would also take more time what would slow down experimenting.

Moreover, choosing Python is a good opportunity to develop skills that are used in the industry and meet the needs of the labour market.

In the project was used the most recent Python version what is 3.6.

### Libraries

To do a language processing firstly was used Textblob library which is built on top of NLTK but unfortunately, due to the poor documentation and lack of its capabilities, there was made a decision to move into NLTK.

To build a classifier which predicts market changes there was used Scikit-learn. It has got good documentation with many examples and there are also many topics about it on sites such as StackOverflow.

Another possibility was to use Weka but it would require to use either Jython(implementation of the Python language for the Java platform[3]) or run Weka library using wrappers around JNI calls such as javabridge(a package that allows Python to interact with JVM[4]) but both ways are too complicated. Finally, Weka was used anyway to do features selection. However, it was run as a command in a separate subprocess.

The web interface of the program is very simple so I chose Flask. It is a micro web framework using Jinja2 template engine. It allows creating simple pages in the very easy way. I did not use Django as it was planned while doing OPS because it is rather better for more complex web applications. Pyramid framework is also good for creating simple web pages but is much less popular, what makes it harder to find some solutions and helpful articles on the Internet.

To present the results on there was used common technologies such as HTML, CSS, Javascript. To create neat and decent graphs it was decided to use ChartJS library. It allows creating HTML5 charts in a simple way.

To do data processing and analysing there were used Pandas and NumPy which are the most popular Python modules. They are used in similar projects and most of the machine learning online tutorials, so it was assumed that it is a good choice. Operations on Pandas DataFrames and NumPy arrays are much faster than on regular arrays and other language built-in collections.

Scikit-learn does not provide any association rules algorithms so there had to be used another library. It was decided to use Mlxtend library and its Apriori algorithm implementation.

To scrap tweets from Twitter there was used Tweepy library. It is popular, easy to use module that allows accessing Twitter API.

To write unit test there was used built-in unittest model, and for integration testing it was decided to use Behave. The most popular integration testing framework Cucumber does not support Python. Behave seemed to be the best choice. Other alternatives that were identified are Lettuce and Aloe. The first has been abandoned a long time ago and does not support Python3. The second one is a Python3 port of Lettuce but also has not been developed for 3 years (link to GitHub) and has got very short and poor documentation.

### Data storage

All the stocks historical data available on the Internet is usually in CSV (comma-separated values) format. CSV is also easy-understandable, simple and well supported by Python. Reading and writing to CSV files in Python and using Pandas is fairly simple. Therefore, it was decided to store all processed data in that format.

The data about the analysed stocks that is presented on the webpage had to be stored somewhere. It was decided to use small database than JSON or just plain text files because is simpler and quicker to implement. ORM(Object relational mapping) handles saving/reading data, verifying the format and checking if the currency is already analysed, what is more convenient.

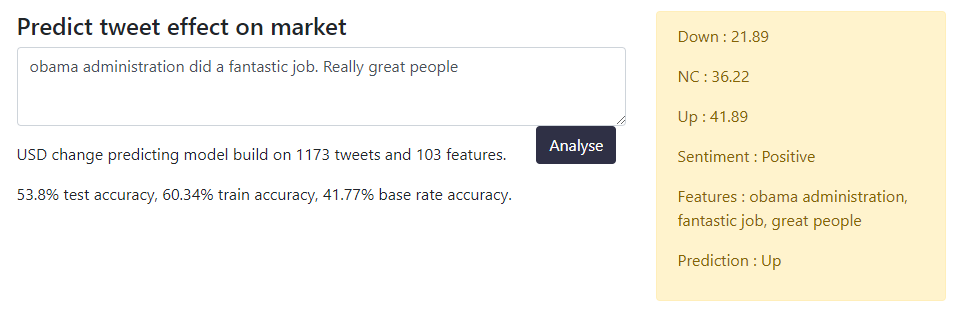
For this purpose, was used Flask-SQLAlchemy module that is a Flask extension adding support for SQLAlchemy(<http://flask-sqlalchemy.pocoo.org/2.3/>). (SQLAlchemy is a simple object-relational mapper) (wiki). The database system that has been used is SQLite3.

### Interface

The web interface created in Flask presents details about each stock on a separate subpage.



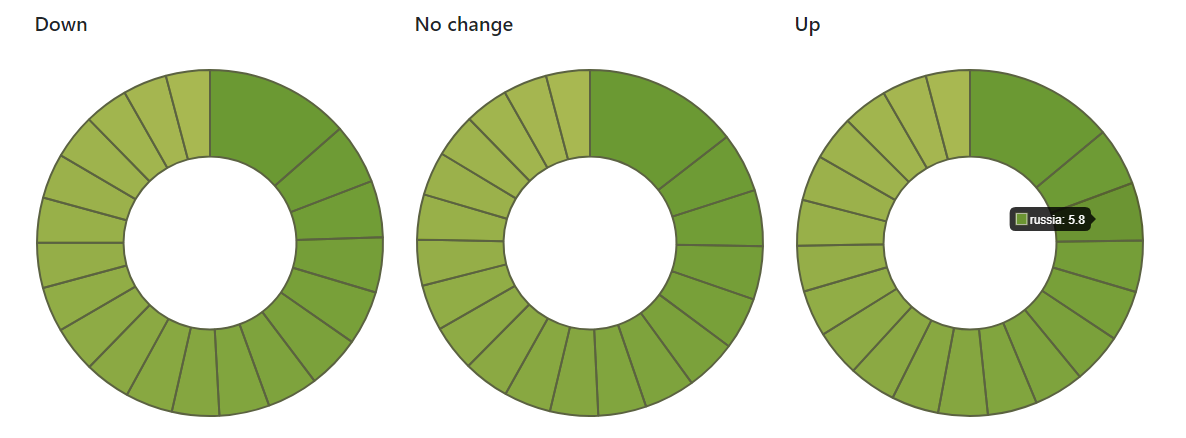
The text form on the top of the page allows the user to input a custom tweet message that will be classified. On the right, there is presented the result of a classification.



The graph presents the currency price change and when hovering over, the tooltip shows all tweets that were written on a particular day.



The doughnut charts below present 20 the most coefficient features for each class.



The table below presents association rules learned from the dataset used to build a classifier. That means that these are only rules extracted from the sifted dataset and they present only features that appear together (all frequent and infrequent words that have not been included in features vector are omitted). Each row is a set of features that occurred together at least twice and when the row is clicked there are presented rules for each particular rule consisting these words.



## Detailed Design

The project can be split into main two parts: market analysis and web interface. Therefore, it was split into three packages separating project concerns:

* Markets package
* Webpage package
* Tests package

### Markets package

All the code in “markets” package was split into modules that group together logically related code.

**Dataset** – a module with a TweetsDataSet class that wraps a Pandas DataFrame and represents a set of tweets with their features, sentiments, and market effect.

**Tweeter Scrapping** – a module used to scrap tweets from Tweeter.

**Phrases Extraction** – contains a PhrasesExtractor class which builds a vocabulary of phrases and words found in the set of texts and then extracts those features from particular tweets.

**Sentiment Analysis** – module containing a class responsible for tweets sentiment analysis. It wraps NaiveBayesClassifier from NLTK library and uses a PhrasesExtractor to extract features from tweets which are then used to train a model or predict a value of the particular tweet. All the functionality was wrapped in a class because it is more convenient to load and save the Analyser and perform any tests.

**Tweets Features Extraction** – contains all the functions used to extract features from the tweet such as sentiment and phrases/words in the tweet. To gather those information uses SentimentAnalyser and PhrasesExtractor instances.

**Feature Selection** – module containing functions responsible for selecting the most significative sets of features to obtain the best accuracy.

**Currency Analysis** – the main module that connects all the functionalities. There is a CurrencyAnalyser class that is used to analyse a CSV file of stock prices and provides results of this analysis such as association rules, model to predict markets or the most coefficient features. It holds the functionality of reading files and saving the results.

**Association** – a module holding all the code that is responsible for reading stock prices from files and merging them with tweets datasets.

**Market** **Predicting**– contains all the code that is responsible for training a classifier that predicts stock changes. Contains 3 classes: Classifier representing a classifier model (MultinomialNB by default) and wrapping all its functionality, AnalysResult that represents a result of a single tweet analysis, MarketPredictingModel that contains two Classifier objects and decides which one to use to do a prediction.

**Rules** – contains functions used to do association rules learning.

The markets module has got also a “data” and “pickled\_models” directories. “data” folder stores all data used to do analysis such as a list of stop words, scrapped tweets and CSV files generated by the application. “pickled\_models” stores saved sentiment analysis and market predicting models.

### Webpage package

Web page module has got a typical structure for Flask projects.

It is split into:

* Static folder – holding static files such as images or CSS styles
* Templates folder – holding Jinja2 templates that are filled with content by views.
* Views.py – this is where routes are defined. It defines routes for each currency and gathers data that is sent to the templates and presented.
* models.py – holds Currency model. This model stores information about currencies such as its name and accuracy of the model in the database.
* \_\_init\_\_.py – Initializes the application, sets up its configuration and database.
* Currencies.db – stores Currencies models that can be loaded when the application runs.

### Others

Apart from these 3 packages, there are few more files typical for a Flask project:

* -manage.py – a script used to init/drop the database, fill the database with some sample data and to run the webpage.
* -requirements.txt – file containing a list of packages that are used in the project and have to be installed
* -README – file explaining how to run the program

## Tools used to develop the project

IS THE FORM OK HERE?

For my Python IDE, I chose PyCharm made by JetBrains company. I used it during the Industrial Year and I really liked it. It has got all code assistance features such as syntax and error highlighting. It supports Flask projects and many file extensions such as HTML, CSS, JS, CSV which I used in a project. It also has got integrated debugger which I used a lot.

To keep track on changes and have a backup of the work I set up a GitHub repository. Backups of the work were kept on the GitHub repository and two machines the student worked on. As a Git client for the machine with Windows OS was chosen GitKraken and command line git for the machine with Linux.

Keeping the project both on the GitHub server and two machines prevents the loss of the project in the event of a problem with a git or even accidental deletion of the repository.

# Implementation

## Data gathering

### Tweets scrapping

The first step was to gather Donald Trump tweets. For this purpose, there was used TweePy library that allows fetching data from Twitter REST API. To communicate with the API, it was necessary to create a Twitter developers account and obtain a customer key and access tokens.

The first task to do with tweets was a sentiment analysis. There had to be collected small amount (about 120) of tweets manually. Writing a scrapping script was very useful at this stage because it allowed fetching particular tweets data from the API by the ID of the tweet. The data such as tweet id, creation date, and text were saved to the CSV file.

Next step was to scrap all the tweets since the begin of 2017. It is a bit before Donal Trump become a president so his tweets began to have some influence on markets. TweePy provides also a special function to get posts from users’ timeline. Unfortunately, it allows getting only 200 tweets at once so I had to do it sequentially. Twitter also allows only to scrap last 3240 of user tweets and hopefully, there was obtained 2935 tweets created between 01.2017 and 03.2018.

### Stocks data

Obtaining stocks indices data was arduous part of the project because all the web pages that archive historical stock data provide only daily-interval stock prices changes due to the amounts of this data. All the visited websites provide data with smaller intervals (such as hourly changes) for money. In consequence, all markets changes analysed in the project are daily open-close price changes.

## Sentiment Analysis and Phrases Extraction

### Data selection

To begin with a sentiment analysis there was scrapped 120 tweets manually and their sentiment was marked manually. It was decided that half of them had to be positive and half should be negative to have balanced classes – **ADD WHY?**

We also do not want the classifier to favour the class with the majority class because it may lead to misleading accuracies.

Tweets were selected regardless of the date. The most important aspect was to find ones that are clearly positive or very negative to train the model as best as possible.

Tweets were found using Google by searching phrases such as “Most positive Trump tweets”, “The worst Trump tweets”. Very useful was the website: <http://www.trumptwitterarchive.com/> where we can see the most popular keyword in his tweets and search for them.

**3.2.2 Building a model**

When the dataset was selected, the next step was to build a classifier.

To train a model tweets had to be split into folds to do a cross-validation what prevents overfitting and gives more reliable results. Due to the fact that scikit-learns Kfold functions seemed to be complicated, there was a decision to write a folding function manually. The code was splitting a corpus into K chunks with preservation of stratification (each chuck had half of the tweets positive and half negative).

Building a text classification system with Textblob is very trivial:

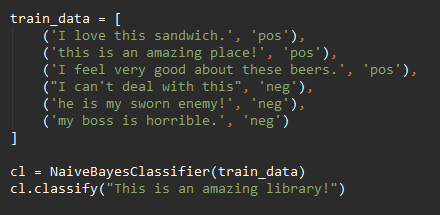


Figure ‑. Example of training a classifier with TextBlob

The Classifier object just has to be fed with the list of tuples, and each tuple has to consist of tweet text and marked sentiment.

It was decided to use a Naïve Bayes as a classifier. It is a dominant algorithm used for text classification.

WRITE HOW NB WORKS?

Its main advantage is that it treats each feature independently. Texts are full of noise and meaningless words what. It is also much faster to train that SVMs, Artificial Neural Networks or Decision Trees.

Although it is a very simple algorithm, it often performs pretty well. Text classification is not a hard problem so any linear classifier should produce decent results.

Although there were tried other classifiers because algorithms performance highly depends on the data they work with. One technique is better for a particular problem but other ones can be more suitable for different tasks.

Changing a classifier to try out another one using TextBlob/NLTK is very simple, mostly it requires to just import another class and set its parameters. Therefore, there were tried out also other alternatives but Naïve Bayes proved to be the best as expected.

To ensure that results are reliable the training process was run 40 times with 10-folds cross-validation and the result accuracy is a mean from those 40 runs. The results seemed to be surprisingly good. Naïve Bayes had 82% of test accuracy. Unfortunately, after investigating the most informative features it turned out that the most decisive features were words such as “are”, “there” or even punctuation marks such as brackets. That meant that the model was overfitted and also instead of making decisions based on words such as “good” or “bad” was using the most common words in the language. Even the sentence contained many negative words like for example: “Crooked Hillary Clinton is the worst (and biggest) loser of all time.” (twiiter/ 931877599034388480) was marked as positive because it just had words “is” and “the”.

### Features extraction

Once it had been discovered that TextBlob does not extract phrases properly and does not provide any option to change it, it was necessary to move into NLTKs’ classifier.

Next step was to write a custom feature extracting function that splits tweets into words. For this purpose were used very simple NLTKs’ functions: sent\_tokenize and word\_tokenize that split the text into sentences and then into words. Afterwards, all the extracted words had been lowercased because for example “Then” and “then” is the same word. Unfortunately, even that these functions are the part of so popular and reputable library, they had problems with splitting even simple sentences and words such as “doesn’t’ were separated into “doesn” and “’t”. Moreover, the model was still making decision basing on words such as “Did”, “of”, “And”. These senseless words are called stop words. These are words that are common in the language and do not tell anything about the meaning of the sentence.

Once it had been discovered that NLTK tokenizing functions cannot handle extracting words and phrases there were few alternatives checked out such as NLTKs ConllExtractor and FastExtractor. Most of them had problems with splitting the sentence properly. They either extract useless stop words or do not extract half of the important phrases. The only one that does it very well is a TextRazor – cloud service providing a deep learning analysis using their web API. Unfortunately, TextRazor is not free so the decision was made to write a custom phrase extractor.

After some research, there was found easy to implement an algorithm called RAKE(Rapid Automatic Keyword Extraction). There are many its implementations on the web but it was decided to write own extractor basing on the one written by XXX (LINK HERE). It was selected because of its simplicity. This implementation had to be modified because has not got enough configuration options and has too many redundant functions. Originally RAKE extracts also adjusted keywords (ones that include a stop word such as “United States of America”). This functionality was also added but was dropped later on due to the lack of these phrases in the corpus and risk of leading to unnecessary False Positives.

The algorithm basically extracts candidate phrases by splitting text by stop words. A list of stop words used in the project was downloaded from the Internet. LINK HERE

Then the candidate phrases are sifted by their length and number of occurrences. Phrases that are not accepted are split into words.

The accuracy of sentiment analyser while using a custom feature extractor increased to 84% and it is more reliable because the most informative words now are more sensible:

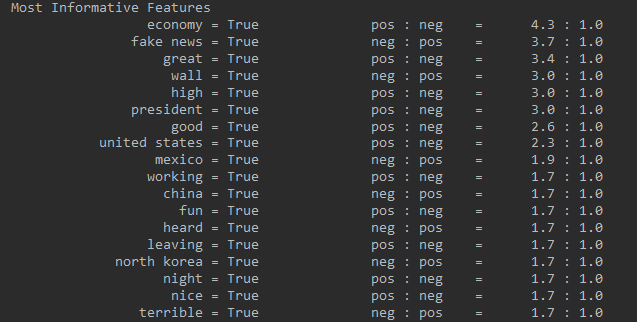


Figure ‑. Most informative features in sentiment analysis

The next step to improve the accuracy was to lemmatize words. It means that all inflected words were reduced to the root form (for example “playing, plays, played” into “play”). This time NLTKs “lemmatize\_word” function was sufficient. When subjected all the words to lemmatization, a test accuracy has increased to 86%.

The overall process of building a vocabulary looks as follows:

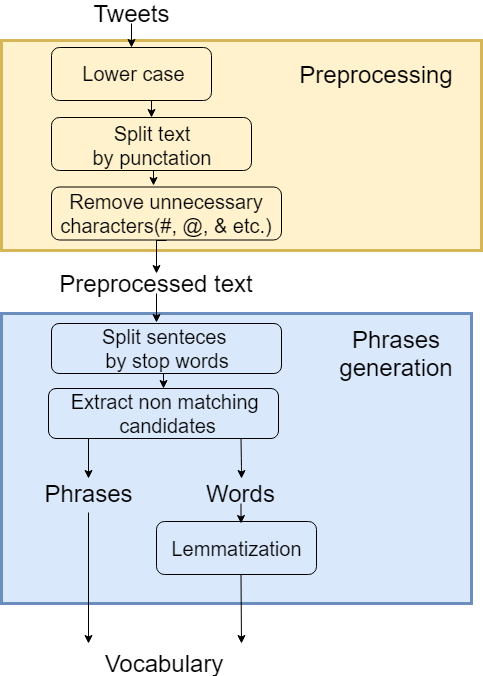


Figure ‑. Process of building phrases extractor vocabulary

All tweets are firstly pre-processed. All tweets are lowercased and split into sentences. Then from each sentence are removed useless characters such as ”@ # - “

and each of them is split by stop words:

*Very proud of my Executive Order which will allow greatly expanded access and far lower costs for HealthCare.*

Is split into:

*proud, executive order, greatly expanded access, lower costs, healthcare*

This way text is split into phrases and has got useless words removed.

Then all the phrases extracted from the corpus are counted and those that are too rare are split into words and subjected to lemmatization.

The process of training a classifier used to predict a sentiment looks as follows:

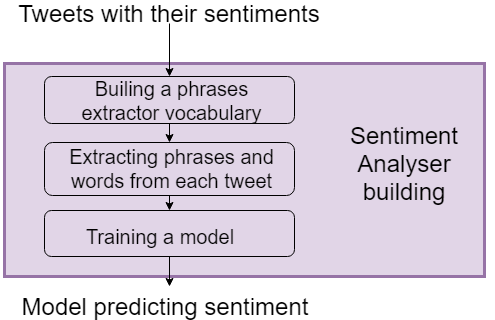


Figure ‑. Process of building a sentiment analyser

Then the process of analysing a particular tweet looks as follows:

* Pre-process tweet (lower case, split by punctuation, remove unnecessary characters)
* Find matching phrases and remove them from a tweet
* Split the rest by stop words to get rid of them
* Lemmatize words
* Mark words matching with the vocabulary
* Pass the features vector to the model to classify it

Features extraction from dataset can be run by with “markets/tweets\_features\_extraction.py” module which executes “build\_tweets\_features\_dataframe” function which reads scrapped tweets and saves the result (tweets + features) to a CSV file. All filenames are hardcoded, what would have to be changed if there was added functionality to analyse user-defined twitter users.

## Markets predicting

Once the sentiment analysis part was done, the next step was to build a market predicting model.

### Data Pre-processing

Before training a classifier, the dataset was pre-processed:

* All the tweets containing only video/image and no text were removed.
* Tweets written in languages other than English were also deleted because they would not even be taken into account due to the lack of English words and would make only noise.
* Unicode characters were removed such as ✔✅➡
* Some Unicode characters were changed into proper words or characters: &amp -> “and” because it would make phrases extraction easier. Words like “and” are stop words and are used to split the text into phrases
* There were also removed all hyperlinks

Then pre-processing involved manual removal of all the tweets that could not have any impact such as “Happy birthday”. There were also deleted all short and meaningless tweets such as “Jobs, Jobs, Jobs”.

Some of the tweets were “retweets”. It means that Trump posted someone’s tweets on his timeline. They were removed because it is not known what was the purpose of sharing those tweets. It is not known if he endorsed it, wanted to enrage his rivals or maybe shared it to show how abominably the “fake news media” lie.

Another pre-processing step was to merge all tweets that were divided into few separate ones because they were too long (Twitter allows tweets to be at most 140 characters long so when they exceed the limit they are split into few separate ones that start or end with “…”)

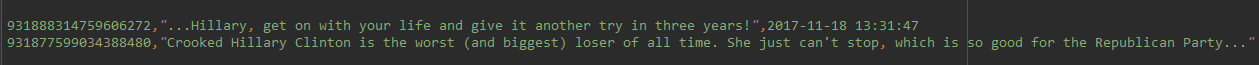


Figure ‑ Example of a tweet that exceeds 140 characters

Then the size of the dataset has decreased into 2026 tweets. All the tweets got the market change set up using stock prices that were manually collected into CSV file. It was assumed that tweets affect the market within few hours so each tweet had got assigned a percent change of the index during the day it was published. It was also decided that all the tweets that are published after 10 pm would have assigned a change value from the next day. Market changes above 0 were marked as positive and the rest as negative what resulted in a binary target classification problem.

Then for each of the tweets sentiment was predicted and features extracted.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Tweet** | **Sentiment** | **Feature 1** | **Feat 2** | **Feat 3** | **…** | **Feat n** | **Change** |
| Tweet content | Positive | 1 | 0 | 0 | … | 1 | 0.05% |
| Tweet content | Negative | 0 | 1 | 0 | … | 0 | -0.12% |

That prepared dataset could be then used to train a model.

### Building initial model

To build a model there was used a Scikit-learn MultinomialNB and LogisticRegressionCV. First one is a Naïve Bayes classifier implantation that is suitable for classifying discrete values such as “Down”, “No change”, “Up”. Logistic regression classifier used is also known as logit or MaxEnt (<http://scikit-learn.org/stable/modules/generated/sklearn.linear_model.LogisticRegressionCV.html>)

It uses a cross-validation to find the best hyperparameters to the data, what is very handy.

The data that is fed to the model has to be in proper format. Training data has to be split into a 2D array of features and their marks for each instance and a 1D array of results for each instance.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 2D array of 2 instances with 5 features:   |  |  |  |  |  | | --- | --- | --- | --- | --- | | 1 | 0 | 1 | 0 | 0 | | 0 | 0 | 0 | 1 | 0 | | 1 | 1 | 0 | 0 | 0 | | 1D array of targets for 3 instances:   |  |  |  | | --- | --- | --- | | Up | Down | Up | |

Using a DataFrame to store data was useful there because it was easy to process and format it in a such a way.

Then the model was built 30 times to take an average of results of different randomized runs. 30 runs gave the same results as 100 so there was no point to run it more times.

Each run trained a model 10 times (10-fold CV) with stratified folds.

The model was built using 2026 objects and over 6000 features and the accuracy that was obtained looks as follows:

|  |  |  |
| --- | --- | --- |
| **Classifier** | **Test accuracy** | **Train accuracy** |
| Naïve Bayes in Scikit-learn | 54.9% | 90.6% |
| Logistic in Scikit-learn | 51.6% | 100% |
| J48 in Weka | 51.2% | 81.5% |

Experiments were performed using a model written in Python and also by exporting a data to the file and using J48 in Weka.

### Removing infrequent features

Feature extractor was extracting over 6000 of features form the dataset what was a lot and the model needed a lot of time to train. The model was also trained using features that occurred only once or twice what just lead to overfitting.

A good set of features describing the data is a key factor to get successful results. Some part of the features was correlated, meaningless and noisy. Therefore, it was necessary to perform a feature selection.

Feature selection is a process of choosing only features that are the most useful or the most relevant to the problem. (<https://machinelearningmastery.com/an-introduction-to-feature-selection/>).

It removes redundant attributes what reduces the complexity of the model so it is faster to train and easier to understand (same source as above). Removing unneeded, irrelevant features also increases accuracy.

Running any feature selector on that big dataset would result in a very long time of processing so it was decided to firstly remove features that occur only a few times. After a bit of experimenting it was decided to remove features that occur less than 7 times because it decreased the number of features to more practicable size (1185). It also diminished overfitting and gave a bit better test accuracy:

|  |  |  |
| --- | --- | --- |
| **Classifier** | **Test accuracy** | **Train accuracy** |
| Naïve Bayes in Scikit-learn | 56.6% | 70.3% |
| Logistic in Scikit-learn | 52.0% | 84.0% |
| J48 in Weka | 51.8% | 76.7% |

### Feature selection

Once the number of features was dropped it was easier to try different feature selectors. The easiest way was to export the dataset to a CSV file and perform a selection in Weka. Many trials have been carried out with various selectors and finally the “Wrapper Subset Evaluator” proved to be the best. Wrapper method tries different combinations of features, evaluates them on a model and chooses the best set. The main disadvantage is that it requires a significant computation time but after all gives reasonable results.

It selected 116 features that were saved into a file. The file was read during the process of building a model. The results had improved significantly:

|  |  |  |
| --- | --- | --- |
| **Classifier** | **Test accuracy** | **Train accuracy** |
| Naïve Bayes in Scikit-learn | 67.8% | 70.0% |
| Logistic in Scikit-learn | 66.8% | 69.2% |
| J48 in Weka | 62.0% | 69.4% |

After that Weka was not used anymore to build a classifier due to the fact that uses only one thread, it is extremely slow and it is more convenient to process data and build classifier in Python at one go without saving to file and bothering with opening it in Weka.

### Target change

Since some of the tweets are completely neutral and have no influence on markets, there was add the third target: No change. Deciding which tweets did not change the market prices was quite fiddly. We do not want all tweets to be classified as positive or negative because those that are the boundary between positive and negative will spoil prediction through their vagueness.

In the USD Index dataset, there is about 3% of days that the stock did not change at all. To get three classes more balanced there had to be some threshold set up to increase a set of “No change” objects. Following feedback from the project supervisor, it was decided that the threshold should be calculated using a standard deviation. To obtain about 1/3 of the targets as a “no change” the threshold is calculated by 1/3 of the standard deviation distance from the mean:

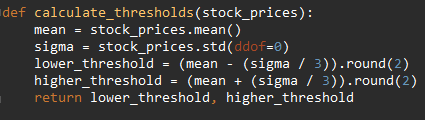


Figure ‑. A snippet of function calculating a threshold

It makes all three classes more balanced what seems to be the most reasonable solution in this case. Class distributions got almost balanced and the base rate accuracy was changed to 41%.

|  |  |  |
| --- | --- | --- |
| **Classifier** | **Test accuracy** | **Train accuracy** |
| Naïve Bayes | 52.7% | 59.7% |
| Logistic regression | 49.1% | 54.0% |

The accuracy looks very good. 52.7% compared to 41% in the 3-class problem is quite satisfying and proves that stock prices are related to Trump's tweets in some degree.

### Removing useless instances

After some investigation, it was discovered that if a lot of features is removed then there are many objects left without any feature marked. For example, if tweet “Happy Birthday” had marked “happy” and “birthday” and they were deleted then the instance got useless. Those instances have got only one feature that is a sentiment, what can just spoil training a model.

After removing tweets that do not have any feature the dataset size decreased into 1084 objects. In consequence, the model trained on that dataset gave better accuracy:

|  |  |  |
| --- | --- | --- |
| **Classifier** | **Test accuracy** | **Train accuracy** |
| Naïve Bayes | 53.6% | 60.3% |
| Logistic regression | 51.0% | 55.4% |

### Remarking features after sifting

The next step was to mark features again. Due to the fact that the feature extractor obtains features in more greedy?? Way, words are not extracted from found phrases so if “Crooked Hillary Clinton” is found then words “Crooked”, “Hillary” and “Clinton” will not be marked. This way makes phrases more favoured and increases their chances of not being filtered out during selection and also results in a bit better accuracy (marking everything that was found (In non greedy way) was dropping the accuracy for about 2%).

If some phrases are found in the text then they are removed and words that this phrase consists of are not marked as presented on the example below:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Text** | **Crooked** | **Mexico** | **Reform** | **Proud** | **Crooked Hillary Clinton** |
| Crooked Hillary Clinton is the worst loser of all time. | 0 | 0 | 0 | 0 | 1 |

After deleting “Proud” and “Crooked Hillary Clinton” it is needed to mark features again to mark words that may have been in removed phrases.

|  |  |  |  |
| --- | --- | --- | --- |
| **Text** | **Crooked** | **Mexico** | **Reform** |
| Crooked Hillary Clinton is the worst loser of all time. | 1 | 0 | 0 |

Marking features again resulted in better accuracy and 5 instances less to delete

|  |  |  |
| --- | --- | --- |
| **Classifier** | **Test accuracy** | **Train accuracy** |
| Naïve Bayes | 53.8% | 60.3% |
| Logistic regression | 52.0% | 57.4% |

The next change that was performed was making a sentiment to be a continuous value. Before the sentiment was marked as 0/1 (positive/negative). Some tweets could be more neutral and some could be evidently emotional. Therefore, the sentiment values have been changed into continuous values from 0 to 1. Although it did not change the results for Naïve Bayes at all, Logistic regression train accuracy changed only by 0.01%. This is probably due to a large number of features and the fact that Naive Bayes treats features independently so changing one feature, and moreover, in a small extent, had no influence on the result.

### Adding more stocks

The main purpose of next sprint was to implement functionality to build a model using another CSV files with stock prices. There was downloaded Euro Index that is a ratio of four major currencies (USD, British Pound, Japanese Yen and Swiss Franc) against the Euro. Due to the fact that a lot of Trump tweets were about the wall on the border with Mexico and hurting their markets with taxes (<https://www.ft.com/content/31967e6b-f227-33c4-9c8d-8952ba83b081>)

another currency that could have some effect was Peso. Unfortunately, currency indices are carried out mostly for the largest currencies and markets. In consequence, there was downloaded historical data of S&P/BMV what is a ratio of an American stock market index based on 500 the largest companies to the biggest Mexican stock exchange index.

Adding new currencies involved a lot of refactoring. All the process of building model was changed to work in one go. For each currency, the program retrieves a CSV file that has to be called “currency + \_Index.csv”, then the file is read and merged with tweets. Features are selected individually for each stock what in consequence selects most efficient features for each data. That is because targets for each stock are different so different instances (and their features) have an impact on the result. Once selected features are saved to the file in a “data” folder to be read next time while builing a new model and save time.

The most problematic was to implement feature selection to be done automatically in the program. Until that moment there were used features that had been selected in advance in Weka manually. To automate whole process features had to be selected another way. Three possible ways were identified:

-feature selection using Scikit learns selectors

-feature selection using other third-party libraries

-feature selection in Weka

The simplest way seemed to be using Scikit-learn. Despite the fact that it is the most popular framework among machine learning community, it includes only a few selectors:

* “VarianceThreshold” - removes features with low variance, what is useless because all the infrequent features are already dropped. (all that occurred less than 7 times)
* Univariate selectors such as KBest with chi2. These gave very bad results because they rank features and select K best from the top of the ranking. That approach is ineffective because features sets are chosen against their helpfulness alone, not when there are together. For example, some features can significantly improve selection when there are used together but they may be useless while being alone. In case of the ranking, they would be near to the bottom of the list and would not be selected. Besides, many of the features from the top of the ranking may be correlated (both would duplicate the information they provide so one of them would be sufficient). Moreover, correlated features make training slower and may change model outputs.

Some algorithms such as Naïve Bayes can actually benefit or loss due to the redundant features depending on their correctness. (NB treats features independently so if many correlated features are correct then they can improve the result, but on the other hand, they can spoil it when features are misinformative). That is why the best solution is to use Wrapper method for feature selector because it removes features that do not contribute directly to the performance. (<https://datascience.stackexchange.com/questions/24452/in-supervised-learning-why-is-it-bad-to-have-correlated-features>)

* Recursive feature elimination. Eliminator requires **being** given an external estimator that scores features (e.g. Naïve Bayes that assigns coefficiency to features that were used). Then they are selected by recursively considering smaller and smaller sets of features.

(<http://scikit-learn.org/stable/modules/feature_selection.html>)

After training on the whole set of features, coefficient marks are taken into account and the less important features are pruned. The process of pruning is repeated until the user-defined number of features is reached.

It was decided to try out RFECV (Recursive feature elimination with cross-validation) which tunes the number of features to prune with cross-validation. (same link here). The taken approach was to set a wide range of features number (20-300) to select by RFE and then choose the best set of features.

RFE was returning results for each number of features to prune and the results were much better than when using Weka’s wrapper.

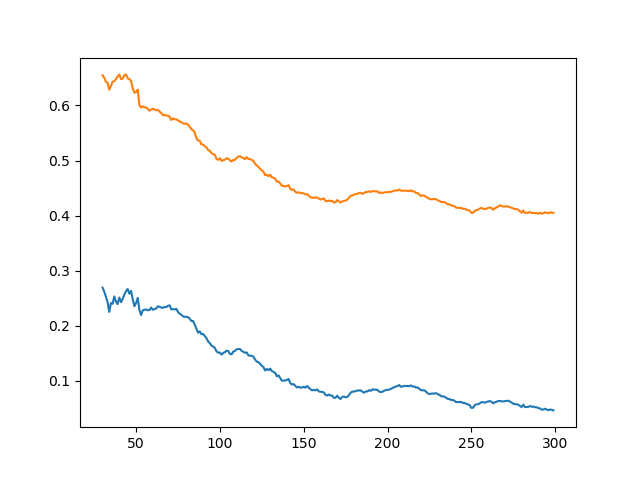


Figure ‑. The orange line is a test accuracy of the model with XXX number of features. The blue line represents a difference of test accuracy and base accuracy (changing a number of features was altering the size of the majority class).

Unfortunately, what was discovered is that selecting lower and lower number of features was simplifying the problem because tweets that did not include any of the selected features were dropped. It resulted in a smaller number of tweets that were taken into account. Therefore, this way was incorrect because a lower number of features and tweets is extremely simplifying a problem and the model would be able to predict the target only for tweets that have got any of the small set of features. The same number of features chosen by REFCV gave worse results then when chosen in Weka.

### Running Weka feature selection from Python

Due to the lack of possibilities to select features with Scikit-learn, other options have been considered. There were identified another library called Mlxtend. It provides extensions and helper modules for Python's data analysis and machine learning libraries. (https://github.com/rasbt/mlxtend)

There were tested “ExhaustiveFeatureSelector” and “SequentialFeatureSelector” from such a module but both required a lot of time to process and gave very poor results.

Thus, it was decided to use well-proven Wrapper Evaluator from Weka.

Weka is a Java library and there were two options considered to integrate it with the project. One option was to run Weka using wrappers that allow Python interact with JVM such as JavaBridge, Py4j, Jpypy.

Another way was to run Weka as a system process and parse the output. This way seemed to be the simplest and was implemented.

There was added a Weka jar file into a project directory and the package is run as system command using “subprocess” module:

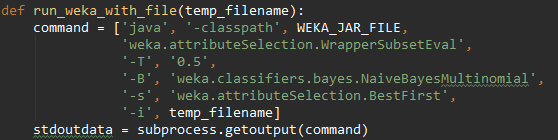


Figure ‑. A snippet of a part of a function running Weka to select features

Then the features have to be parsed from the output. Obviously, this way is not perfect because has got drawbacks such as fact that the exceptions would have to be caught and parsed in the output. It is also harder to debug and test.

The model is then build using a dataset that is sifted with selected features.

This way it was selected 103, 99, 103 features and sifted 1173, 1121, 1081 tweets for USD, EUR and MEX respectively, what seems reasonable.

Results of running the program with new currencies and feature selection done with Weka looks as follows:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Currency** | **Classifier** | **Test accuracy** | **Train accuracy** | **Baseline** |
| USD | Naïve Bayes | 53.8% | 60.3% | 41.7% |
| Logistic regression | 52.0% | 57.4% |
| EUR | Naïve Bayes | 52.6% | 58.8% | 36.0% |
| Logistic regression | 41.7% | 50.3% |
| MEX | Naïve Bayes | 51.2% | 59% | 39.7% |
| Logistic regression | 44.1% | 51.9% |

### Using two models to predict changes

At this stage when the user analysed a tweet that did not include any of the 10-ish selected features the model would predict the value based on a sentiment. Following feedback from the project supervisor, it was decided that there should be built another model on a dataset without feature selection. That model could be used when analysed tweet features do not match with ones that were selected.

The second model was trained on the dataset that has got dropped infrequent features and instances which only marked feature is sentiment. (807 features and 2022 tweets). It was decided to take the following strategy:

* if the tweet has got any feature from sifted model then use this model
* if has not got any selected features but has any of the features that is the second model built on, then use this one

if has not got any features matching to the ones that were extracted from the corpus then use both models and return average of results.

Deciding what to do in the case when the tweet does not have any features was hard. The only sensible solution was to just predict basing on sentiment. In this case, it was decided to use both modules and return the average value.

Models built on a dataset without selected features have got very poor accuracy:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Currency** | **Classifier** | **Test accuracy** | **Train accuracy** | **Baseline** |
| USD | Naïve Bayes | 38.7% | 65.3% | 36.2% |
| Logistic regression | 36.2% | 36.2% |
| EUR | Naïve Bayes | 38.0% | 66.2% | 39.3% |
| Logistic regression | 39.3% | 39.3% |
| MEX | Naïve Bayes | 39.0% | 67.4% | 36.0% |
| Logistic regression | 36.0% | 36.0% |

Naïve Bayes had slightly better accuracy than the baseline but Logistic regression predict exactly as if it was predicting randomly. Besides, NB had always got better accuracy than Logistic Regression, therefore it was chosen to be set as a default classifier.

## Rules learning

Once the model was working properly next thing that was done was association rules learning. It is a "rule-based machine learning method for discovering interesting relations between variables in large databases” (wiki).

The algorithm that has been used is Apriori. It is the most popular association rule learning algorithm and it was also available in one machine learning modules: Mlxtend.

The outcome of the learning process is a set of rules. Each rule consists of antecedents and consequents. Antecedents are words whose appearance is accompanied by consequents. Basically, rules tell us which words or phrases occur frequently together in a dataset.

For example, this rule tells us that if in any tweet in the dataset has got words “Dossier, Hillary, Trump campaign” it also has word “Clinton”:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Antecedents** | **Conse-quents** | **Antecedent support** | **Consequent support** | **Support** | **Confidence** | **LIft** |
| dossier, hillary, trump campaign | clinton | 0.00185014 | 0.03607771 | 0.00185014 | 1.0 | 27.7 |

* Support is an indication of how frequently the words set appears in the dataset.(wiki)

If there were 1080 tweets and this words set occurred twice the support is 2/1080 = 0.00185014.

* Antecedent support is an indication how frequently antecedent occurred in the dataset. (no matter what was the consequence)
* Consequent support is an indication how frequently consequent occurred in the dataset.
* Confidence tells us how often the rule has been found to be true(wiki). In example above, every time those antecedents occurred in a tweet, word “clinton” occurred as well.
* Lift is a ratio of the confidence of the rule and the support of the consequents (<https://www.ibm.com/support/knowledgecenter/en/SSEPGG_9.5.0/com.ibm.im.model.doc/c_lift_in_an_association_rule.html>)

Greater lift values indicate stronger associations what can be interpreted as an importance of a rule. (source of lift from wiki)

Rules are different for each currency because dataset used to build models are sifted differently. Rules presented on the webpage are filtered by a number of occurrences (at least twice). It was decided that there is no point to present a rule that occurred only once.

Rules presented on the webpage are grouped into words set. For example:

{daca, drug} => {military} and {drug, military} => {daca} are grouped into one set of words. Both of them have got the same confidence and support because it is common for the whole dataset. That way of presenting results is more readable. By clicking on the words set, rules containing these words are presented.



Figure ‑. Example of rules presented on the web site

### Final workflow

After all the process of analysing a currency looks as follows:

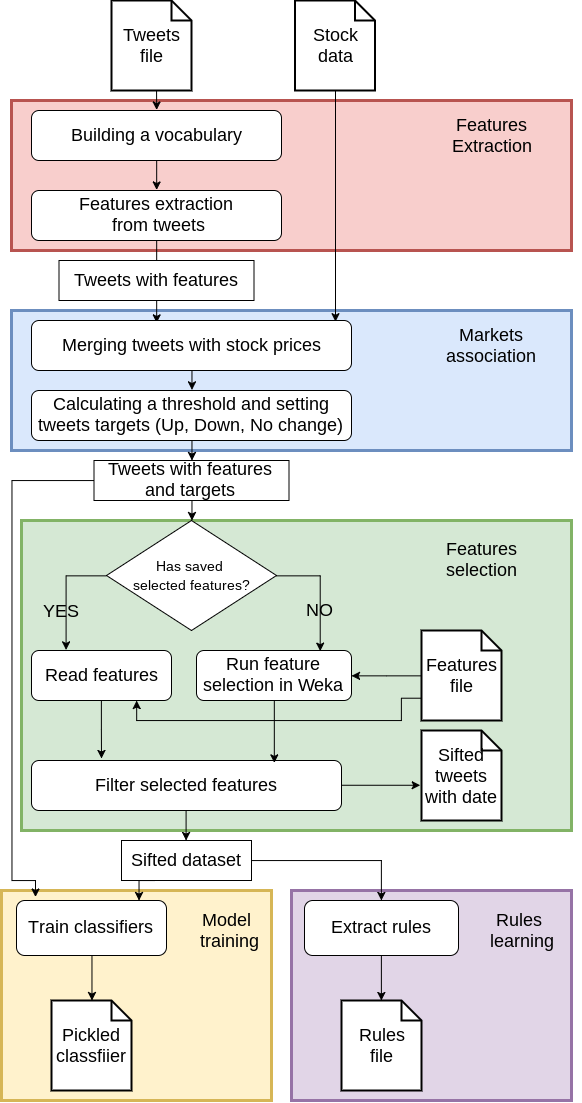


Figure ‑. The overall process of analysing association between tweets and markets

## Flask webpage

### Application initialization

Once the module analysing association between tweets and markets was done, the next step was to create a Flask web interface. The application was organized in a way typical for Flask applications.

Whole application is created in \_\_init\_\_.py file. It sets up all the configuration and creates a database object that is bind to the application.

Application is initialised from “manage.py” file. It initializes a database, and creates a CurrencyAnalyser for each hardcoded currency. It analyses the data and creates a classifier. Then the results are stored in the database and all classifiers are saved by CurrecyAnalysers implicitly. Therefore, when the application is running the data can be retrieved and presented.

When application is run, all data about analysed markets is loaded from the database and assigned to the application object. For each loaded currency there is created a CurrencyAnalyser that can be used to obtain various data about the dataset or to predict custom tweet effect.

### Views and templates

Application loads all routes from views.py file. The web interface presents all the information about the currency on one page so there is only one view specified. All currencies belong to the “/currency” path so the path for the EUR results will be “/currency/EUR”. The default path “/” was set to redirect into USD webpage.

If user wanted to access currency webpage that is not analysed there is returned 404 status code.

The data is then sent to the Jinja2 which uses it to populate templates. Templates use common technologies such as HTML, CSS and JavaScript.

Links to all the analysed stocks are added to the navbar automatically:



Figure ‑ Example of a navigation bar presenting 3 different currencies.

The webpage presents data that is fetched from the loaded CurrencyAnalyser object. In the middle of the page there is a textform that allows user to input some example tweet to classify its market influence. All the results (such as effect, sentiment, features found in the tweet, probabilities of each class) are presented on the right side of the form.

# Testing

How does this testing address the requirements and design for the project?

How comprehensive is the testing within the constraints of the project? Are you testing the normal working behavior? Are you testing the exceptional behavior, e.g. error conditions? Are you testing security issues if they are relevant to your project?

## Unit testing

Testing was carried out throughout the entire development process.

The chosen strategy was TDD (Test driven development) so while adding new functionalities, tests were written first and then was added code to fulfil their requirements and make them pass. Writing unit tests was a basic premise of the project because they prove the quality of the code and that it works at all. Having a set of tests is extremely helpful when modifying the code because we know that while adding one feature we do not break another. To write unit test there was used built-in python “unittest” module and “nose” to run them. Nose finds all the tests in the module and runs them in a more user-friendly way, errors are more readable. There were also necessary “mock” and “parametrized” modules to mock out and monkey patch some parts of the code and run parametrized tests to avoid code duplications.

There was a couple of exceptions in unit tests.

Scrapping code was not tested at all because the script was used just to download tweets and there was no point to test it. The code worked properly and tweets were scrapped as assumed. If the program was developed more, there was added a feature to choose any politicians’ tweets and scrapping was be done automatically, then tests would be obviously required.

Feature selection module has not been tested because it is mostly executing functions form other modules what would require a lot of mocking. Module functionality is tested in integration tests.

Another code that was not unit tested initially was the code that processes DataFrames. In the beginning, all the experiments were performed just in one go. The data was loaded into a DataFrame and processing was performed in a pipeline. That approach was quick for experimenting but hard to test. It would require some mocking, patching and writing many sample DataFrames, which structure also was changed many times at the begin.

When the tweets processing and classifying part of the code became more complex, the program was split into the more object-oriented way. All the DataFrame code was wrapped into a “DataSet” class encapsulating all the DataFrame operations. It made testing easier because more units were **possible** to be tested without involving DataFrames and creating whole datasets just to test one simple function.

Tests do not check too many exceptions that could occur during input files and data frames analysis. The program assumes that they are in a correct format. If the project was developed a bit more and allow users to add custom stock files then there would be much more tests to write and more corner cases to investigate?

Unit tests use parametrized module that is very popular among Python community. It allows to run tests fed with different parameters that can be used as arguments and expected results.

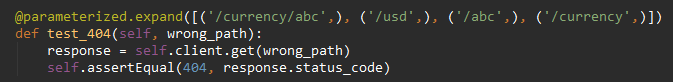


Figure ‑. Simple test using parameterized module

Unit tests cover 72% of the code. Some of the functions were not tested because they were too simple like for example saving to file or using other libraries.

SCREEN OF COVERAGE HERE

The most painful issue with unit tests was that they had been changed while implementing every new functionality. The structure of the program was changing constantly and the code was refactored what lead to the final tests looking completely different than when they written at the begin.

Most of the functionalities that are not tested separately in unit tests are tested in integration tests.

## Integration/Acceptance Testing

When it was certain that smaller bits of code work then next step was to write integration tests. This is also a very important suite of tests that prove that all the bits of code will work together and the program They test the functionality of every feature.

To write integration tests was used a Behave module. It is an equivalent of Cucumber – popular testing framework among Ruby on Rails’ community. All the features are tested by writing scenarios. All the scenarios are written in Gherkin – a simple human-readable language for automated tests.

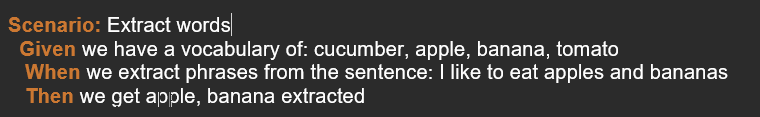


Figure ‑. Example Gherkin scenario

Those “Steps” written in simple language are converted into code through step definitions:

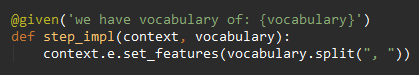


Figure ‑. Example step definition

It keeps high-level concerns separated from the code and allows non-technical people to write tests.

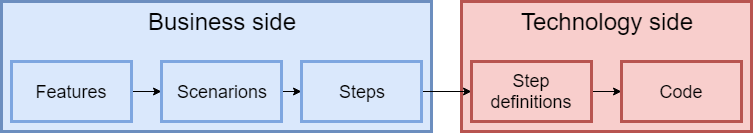


Figure ‑. Structure of creating integration tests

Functionalities that were tested are:

-Phrases extraction

-Sentiment analysis

-Stock prices prediction

Models use Scikit learn classifiers what would make testing hard and unrepeatable, therefore it was decided to mock out the models for tests. Anyway, the tests should verify the correctness of links among the bits of the project and should not tests third-party code. Mocking out with auto-speccing (mock module makes sure that the patched code has got the same interface) should be sufficient in this case.

## ****Usability testing****

Usability testing is a technique used to evaluate how easy is the interface to use. The webpage in this project is only used to present the results and only functionalities are changing currencies pages and analysing tweets what was quickly tested by the student and supervisor.

# Critical Evaluation

such questions as:

* Were the requirements correctly identified?
* Were the design decisions correct?
* Could a more suitable set of tools have been chosen?
* How well did the software meet the needs of those who were expecting to use it?
* How well were any other project aims achieved?
* If you were starting again, what would you do differently?

The aim of this project was to determine if there is any connection between Trump tweets and the markets. It was also decided to analyse the tweets dataset and find out what we can learn and what information we can gather.

The goal has been achieved, there was found a relationship between tweets and the markets. The classifier is able to predict the currency change much better than if it was doing randomly (54% accuracy to 41% base accuracy).

The most coefficient features while training the model turned out to be quite sensible:

FEATURES HERE

All of the primary tasks proposed in OPS have been accomplished. There was also time to do some additional tasks.

TODO NAPISAC O SKONCZONYCH TASKACH

Python was a great choice for this project. It had all the functionality required for the task, all the needed libraries were available, up to date and well-functioning. Programming in this language was very quick and allowed to do quick experiments.

What could be done differently/better?

* Writing data processing in the more object-oriented way instead of using DataFrames would make program simplier. I would just make a DataSet class that would have a list of tweets and each tweet would store information about its features and sentiment. I think that I would make processing a bit slower but it would help to achieve more modularity and lower cohesion. Therefore, testing would be easier.
* I think that if the code was written more modular then it would be easier to test and mocking would not be so much need in some places.

Some of the tasks that were specified as additional, to do in the spare time were not accomplished because required more work to do. The program is ready to implement an option to add custom stock prices or even select from them on the webpage to be scrapped from the internet but it would require to verify the input, check a lot of corner cases and handle all of the possible exceptions. It was decided to do not even start doing this because it would require a lot of time to do it properly.

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Graf ma bugi

Appendices

If you have taken an agile approach to developing the project, then you may be less likely to have developed a full requirements specification. Perhaps you use stories to keep track of the functionality and the ’future conversations’. It might not be relevant to include all of those in the body of your report. Instead, you might include those in an appendix.

# A. Third-Party Code and Libraries

TextBlob – a free library for processing textual data.( FROM http://textblob.readthedocs.io/en/dev/index.html) Was dropped and sci-kit learn was used in lieu

SciKit-Learn – Python machine learning library. It was used to do cross-validation and build classifiers It is free and open source. This library is released using BSD license.

Weka – is a suite of [machine learning](https://en.wikipedia.org/wiki/Machine_learning) software written in [Java](https://en.wikipedia.org/wiki/Java_(programming_language)). It is [free software](https://en.wikipedia.org/wiki/Free_software) licensed under the [GNU General Public License](https://en.wikipedia.org/wiki/GNU_General_Public_License). (<https://en.wikipedia.org/wiki/Weka_(machine_learning)>)

It was used to for experimenting with the data and to do a feature selection. It is run by the program by a subprocess XXX command. Weka Jar file is included into the project directory. Version 3.8.2 was used.

Mlxtend – The project used this library to do association rule learning with Apriori algorithm. It is released under BSD licence. Version used 0.11. (https://github.com/rasbt/mlxtend)

Pandas – library used to do data manipulation and analysis. Library is released using BSD license. Version used 0.22.0

TweePy – Python library used to access the Twitter API. It is released using MIT license. Version used 3.6.0 (<https://github.com/tweepy/tweepy/blob/master/LICENSE>)

Behave

Flask, ChartJS bootstrap

All those libraries were used without modification.

# B. Ethics Submission





# Annotated Bibliography

This final section should list all relevant resources that you have consulted in researching your project. Each reference should also include a brief annotation.

1. Neil Mac Parthaláin, “MMP: Project descriptions”, 2018 (Online) Available at: https://teaching.dcs.aber.ac.uk/mmp Accessed April 2018.

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This is of Donald Trumps’ Tweets.

3. “What is Jython?”, Jython webpage <http://www.jython.org/archive/21/docs/whatis.html> Accessed April 2018POCZ

4. <https://pypi.python.org/pypi/javabridge/1.0.17>

5. stop word list from SMART (Salton,1971). Available at ftp://ftp.cs.cornell.edu/pub/smart/english.stop

1. Sylvia Duckworth. A picture of a kitten at Hellifield Peel. <http://www.geograph.org.uk/photo/640959>, 2007. Copyright Sylvia Duckworth and licensed for reuse under a Creative Commons Attribution-Share Alike 2.0 Generic Licence. Accessed August 2011.  
     
   This is my annotation. I should add in a description here.
2. Mark Neal, Jan Feyereisl, Rosario Rascunà, and Xiaolei Wang. Don’t touch me, I’m fine: Robot autonomy using an artificial innate immune system. In *Proceedings of the 5th International Conference on Artificial Immune Systems*, pages 349–361. Springer, 2006.   
     
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3. W.H. Press et al. *Numerical recipes in C*. Cambridge University Press Cambridge, 1992.  
     
   This is my annotation. I can add in comments that are in **bold** and *italics*and then further content.
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6. Apache Software Foundation (2004) “Apache License, Version 2.0” (Online) Available at: <http://www.apache.org/licenses/LICENSE-2.0> Accessed: 14th March 2014.
7. Neil Taylor, “MMP: Final Report and Technical Work”, 2017 (Online) Available at: <http://blackboard.aber.ac.uk/> Accessed 26th April 2017.

A document that outlines information about the marking guide for the Final Report and Technical Work. This document was referred to as Structure of the Final Report before academic year 2016-2017. This is published in the Assignments folder. If you are logged in to Blackboard, you can access the folder using <http://jump.aber.ac.uk/?sxxpt>.