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| **Machine learning documentation of startup prediction system** |
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| GitHub repo: https://github.com/AhmadAmr/start-up-prediction-system |
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| Faculty of computers & information  KFS University  Predicting startup success with machine learning  **By**   * Yussef Raouf Abdelmassih * Ahmed Amr Hassan * Mohamed Gamal * Malak Ismail * Hadeer Nafea * Passant Hamdi   Advisors/Co Advisors: DR. Amr Abo Hany / ENG. Muatesm Daraz |  |  |

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Abstract

Start-ups are becoming the motor that moves our economy. Google, Apple, or more recently Airbnb and Uber are companies with tremendous impact in worldwide economy, social interactions and government. Over the past decade, both in the US and Europe, there has been an exponential growth in start-up formation. Thus, it seems a relevant challenge understanding what makes this type of high-risk ventures successful and as such, attractive to investors and entrepreneurs. Success for a start-up is defined here as the event that gives a large sum of money to the company’s founders, investors and early employees, specifically through a process of M&A (Merger and Acquisition) or an IPO (Initial Public Offering). The ability to predict success is an invaluable competitive advantage for venture capitals on the hunt for investments since first-rate targets are those who have the potential for growing rapidly soon, which ultimately, allows investors to be one step ahead of competition.

We explored the world’s largest structured database for start-ups – provided by the website CrunchBase.com, with the objective of building a predictive model, through supervised learning, to accurately classify which start-ups going to be successful and which are not. Most of the studies regarding the prediction of processes of M&A or an alternative definition of a company’s success tend to focus on traditional management metrics provided by financial reports and thus using a low number of observations compared with the present study. As technologies of information evolve it became possible to achieve highly reliable results in data analysis by manipulating it with complex machine learning algorithms or data mining techniques to define features and characterize robust models.

Further developments on previous studies such as the development of new features and a new definition for the target variable were applied. Using Random Forests on our dataset, a general model (as including all categorical features) achieved a True Positive Rate (TPR) of 96%, which is the highest recorded with this data source, and a False Positive Rate (FPR) of 9%. The author also generated models per each category of a company to provide results comparable with previous studies the values achieved ranged between 61% and 96% compared with 44% and 80%.

INDEX

Table of Contents

**1.Introduction4**

1.1Objectives 5

1.1.1 Technical objectives 5

**2.Data analysis 5**

2.1 Data Mining5

2.2 Machine learning5

**3.Methodology 6**

3.1 Data Preprocessing7

3.2 Data cleaning 7 3.2.1Data selection ……………………………………………………………………………………9 3.2.2 Data transformation …………………………………………………………………………...9

3.3 Experiment setup……………………………………………………………………………………….10 3.3.1Evaluation metrices……………………………………………………………………………10

1. **INTRODUCTION:**

**“A start-up can be defined as a human institution created to develop new products and/or services under extreme uncertainty conditions.”**

Predicting the success of a start-up is commonly defined as two-way strategy that makes a large amount of money to its founders, investors and first employees, as a company can either have an IPO (Initial Public Offering) by going to a public stock market (i.e. Facebook going public, allowing everyone to invest in the company by buying shares being sold by its insiders in the U.S stock market) or, be acquired by or merged (M&A) with another company (i.e. Microsoft acquiring LinkedIn for $26B) where those who have previously invested receive immediate cash in return for their shares. This process is often denominated as an exit strategy. This study will therefore just focusing of the percentage of which category of startup has more chance to be success than other categories in same area or country.

With a focus on how a start-up or an investor could explore all this knowledge for a better decision making in investment strategy and monetary gain, the study intends, by applying data mining and machine learning techniques, to create a predictive model that has as the dependent variable a label to classify whether a new start-up (**can be**) successful or not.

To generate the predictive model, two supervised machine learning algorithms were tested: Naïve Bayes and Random Forests. All these algorithms fit the characteristics of the dataset (265 features and more than 57805 observations),

* 1. **OBJECTIVES:**

The present work has as the main objective, the development of a predictive model to classify a start-up/company can be successful or not (binary classification).

* + 1. **Technical Objectives:**

During a first phase of Data Analysis, a full understanding of the CrunchBase database is expected, followed by the process of Data cleaning (missing values, duplicates, redundant data). Having a full database ready to be filtered it fundamental to define the scope of data to be used in the model and to be able to do an explorative analysis of key features. Transformation of data will be made by defining and creating new features which will generate the final dataset to be used in the learning task.

Followed by a second phase consisting on the Experiment Setup and its Results, where the experiment will be set up by applying different machine learning algorithms to generate the best possible model through supervised learning to try to outperform current state of art. The algorithms tested are Naïve Bayes (NB) and Random Forests (RF).

1. **Data Analysis:**

**2.1 Data Mining:**

Data Mining is a step in the KDD process that consists on applying data analysis and discovery algorithms to produce patterns (or models) over transformed data. Classification (as in the present study), regression or clustering are examples of common data analysis. The data-mining component of the KDD process often involves repeated iterative application of data-mining methods.

**2.2 Machine Learning:**

Machine learning can be divided in four different categories:

**supervised**, **unsupervised**, **semi supervised** and **reinforcement learning**. Being supervised and unsupervised learning the most widely used. **Supervised learning** algorithms make predictions based on a set of examples. A supervised learning algorithm is, having x input variables and an output variable y. The algorithm learns to map the function (y=f(x)) and can (correctly) predict/classify any new output y after getting new input data x. The possible answers from the output are known. All data is labelled, and the algorithms learn to predict the output from the input data. Supervised algorithms can be grouped into regression and classification problems: A regression function is a type of model when the output variable is a real value, i.e., 88, 130, 0%. A classification function generates models where the output is a category, i.e., “red”/ “blue” “not acquired”.

**Unsupervised** learning algorithm is when we only have input variables/features and no output (target variable). It is in the learning process that the algorithm will discover and classify possible outcomes. Here, we don’t know the possible answers. As all data is unlabeled, the algorithm should learn to create patterns from the input data. Typically, unsupervised learning can be grouped into clustering and association analysis. A clustering problem is the discovery of groups with heterogeneous characteristics between them and homogeneous characteristics between the observations of each group.

**3. METHODOLOGY :**

The methodology here applied (Figure 1– Methodology Overview) mirrors a loose interpretation of Knowledge Discovery in Databases (KDD) approach **(1) Selection** of data to be processed by defining relevant tables from the entire structured CrunchBase database; **(2) Preprocessing**, by cleaning, Selecting and Transforming data. At this stage we deal with missing values, outliers, discretization, and other common problems. An explorative analysis is made before further transformations; **(3) Experiment Setup**, where evaluation metrics are defined, and the major problems of the dataset - Imbalanced target classes and sparse data, are dealt with. these problems are only addressed at this stage. Several machine learning algorithms are chosen to test a binary classifier to classify the observations as either “successful” or “not-successful”. **(4) Experiment Results**, where we draw conclusions and interpret results.

Initial crunchbase table

Data Preprocessing

Cleaning

TPR = 98.8 %

Random forest (RF)

Experiment Result

Initial crunchbase table

All features to binary

Problem1: Sparse data

Final dataset

Problem2: Imbalanced target class

Experiment setup

Transformation

Selection

**3.1 Data Preprocessing:**

The data pre-processing consists in a 3-step process:

* **Data cleaning:** we aim to remove all redundant and irrelevant information from the database as well as duplicates, missing values and outliers. The explanation of this process is divided between specific changes in the ‘Companies’ table.
* **Data selection:** where the context of the study is defined to filter which data will be taken into the final dataset.
* **Data transformation:** consisting on the process of creating new variables.

**3.2 Data cleaning:**

|  |  |  |
| --- | --- | --- |
| **Feature** | **Description** | **Type** |

id Company id Nominal

Name company name Nominal

homepage URL company URL Nominal

permalink company link in CrunchBase Nominal

category\_list category of organization Nominal

funding\_total\_usd total fund Interval

status Operating or close Categorical

country\_code Country (i.e., USA – United States) Categorical

state\_code USA’s states (i.e., CA – California) Categorical

region Country’s region Categorical

city Country’s city Categorical

funding\_rounds Total funding rounds Ordinal

founded\_at Foundation date Date Time

first\_funding\_at Date of first fund Date Time

last\_funding\_at Date of last fund Date Time

**The first step** of pre-processing consists on treating all the irrelevant and redundant information present in tables. As a free-to-edit database with multiple purposes, the CrunchBase dataset has several columns (features) and instances (observations) whose context don’t match the objective of predicting a start-up’s success.

**From the ‘companies’ table:**

* Deleted region, city as they provide too much granularity.
* Deleted domain, homepage\_url, name as irrelevant features**.**

**General changes:**

- Only a few duplicate instances were found in the database and all were removed.

**The second step** consists on eliminating noisy or unreliable data being the two most common cases of inconsistencies, Missing Values and Outliers. A Missing value (or missing data) is a variable that has no data value stored in an observation. Missing values are a common occurrence and can have a significant effect on the conclusions that can be drawn from the data.

**From ‘companies table:**

* Deleted last\_funding\_at, first\_funding\_at, founded\_at, funding\_rounds, state\_code.

**3.2.2 Data selection:**

Before further advancements in the experiment setup of the dataset it is important to contextualize what will be the subject of study and filter data.

|  |  |  |
| --- | --- | --- |
| Feature | Description | Type |
| Categroy\_list | Company category | Nominal |
| Country\_code | Name of country | Categorical |
| Funding\_total\_usd | Amount of money | Interval |
| Status | Operating or closed | Categorical |

**3.2.3 Data transformation:**

Transforming data can be summarized as “the application of mathematical modification to the value of a variable” to extract more value than in its original state. In the present dissertation, the data transformation process achieved with two steps:

* **Changes in original data:**

Category: All companies were classified into one or more of 265 categories, it varies between “software”, “hardware”, “manufacturing”, “energy”, etc. Categories are merged into a column separated by the symbol “|”and sorted from A-Z.

to solve this, we used **one hot encoder** & **two categorial sklearn**, which give us a result all categories formed as binary data.

We now detail the process used to determine each company’s category. Originally organizations had between 1 up to 14 categories selected from a binary value list.

* **All Features to binary:**

as we see there is a must to our data set to change from actual form to binary form because this allow us to run our methods (Naïve Bayes & Random Forest).

So, with two methods in above section we transformed our **STATUS** and **COUNTRY\_CODE** to numeric data.

**3.3 Experiment Setup:**

**3.3.1 Evaluation Metrics:**

The classifier will have as its main evaluation metrics, True Positive Rate (TPR) and False Positive Rate (FPR). Not only are those standards for most binary classification tasks but they were also used in the work considered as state of art. Also, by using the same metrics we can perform a statistical comparison between the two approaches for the same problem.

**True Positive Rate (TPR = TP / (TP+FN))** or **Recall** can be defined as the percentage of all the successful companies correctly identified as successful. On the other side, **False Positive Rate (FPR = FP / (FP+TN))** can be understood as the percentage of all unsuccessful companies classified as successful. As an easy to understand metric, **TPR** clearly tells the predictive capability of the crucial aspect under study - classifying companies as successful with the features and methodology in-use.

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| Confusion matrix | 0,(predicted negative) | 1,(Predicted positive) |
| 0,(Actual negative) | True Negative (TN), company classified as not successful and it is not successful. | False Positive (FP), company classified as successful and it is not successful |
| 1,(Actual positive) | False Negative (FN), company classified as not successful and it is successful | True Positive (TP), company classified as successful and it is successful |

Precision will be shown as a support metric and can be defined as, “percentage of all successful companies correctly classified”. Although this metric is not the one used to compare results with previous studies it supports how well our instances are classified.

**Precision = (TP+TN) / (TP+FP+TN+FN)**

**TPR = 98.8%**