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BANKRUPTCY PREDICTION WITH MACHINE LEARNING MODELS

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ABSTRACT

Individuals and businesses can eliminate their debts legally by applying for bankruptcy which can impact everyone involved from the investors to individual employees. Bankruptcy is also an indicator of the health of the economy. In this research, 6819 companies' data was analyzed with 96 features for each company initially and the relationship between the features and whether the companies were bankrupt was investigated. Four machine learning algorithms were applied for the classification task: logistic regression, random forest, and XGBoost. Their performance was compared to find the best fit for the model. The accuracy of logistics regression was 0.66, of XGBoost was 0.80, and the random forest had the highest accuracy with a value of 0.93.

1. Introduction

Bankruptcy is legal, and this process makes individuals or businesses overburdened with debt remove debts and begin fresh or, in some cases, work out deals with creditors to pay debts off manageably. There are also debts that have to be written off by creditors, however, the ability to recoup the debts is given to the creditors, either.(Henricks&Strohm, 2022) This definition of bankruptcy is from Forbes. And Bankruptcy prediction, maybe some people prefer to call it corporate failure prediction or corporate bankruptcy prediction, has made an extreme important role in the field of accounting and finance. It concerns many people due to the fact that they care about whether the company is healthy, no matter what are their identities, they may be the shareholders, partners, creditors, investors, or even they can be suppliers and buyers. Every entrepreneur in the world will do everything they can to avoid bankruptcy. Even if the person is just an employee in a multinational corporation, he still invested his time and effort in the company he's employed at and would like to see the company do well. And the investors, who will suffer the greatest financial loss if the company goes bankrupt, are also expecting the company to profit. Bankruptcy also signifies the overall health of an economy which impacts everybody in the society. So the ability to predict which company is likely to get into bankruptcy is an important one to develop in the financial industry.

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And to make the prediction of a company's bankruptcy, artificial intelligence is the subject of interest. More specifically, with the help of data, machine learning models can be applied to make the prediction.

The field which aims to create artificial animals, or even artificial persons, or at least creatures made by humans similar to those artificial products, that is Artificial Intelligence, as known as AI.(SEP,2018)This is from the Stanford Encyclopedia of Philosophy. It is the machine, especially the computer algorithm, that simulates the human intelligence process. (Burns,2022)

Nowadays, people live in a world with an abundance of technology. Artificial intelligence is instilled in every aspect of our lives. It will shape our future more powerfully than any other innovation this century. AI has been developing at a great speed during the past decades, and it is still advancing now.

Over the past tens of years, a great progress of one dimension of artificial intelligence—machine learning—was made. Since then, people have been able to make predictions with the data input, and improvements have been happened to the products of tech giants, for instance, Amazon, Apple, Google and Facebook. (Agrawal&Gans&Goldfarb,2020) The Harvard Business Review introduces machine learning as above. Computer science and artificial intelligence has a branch called machine learning, the learning method of humans is simulated by computers with the use of data and algorithms to make the models more accurate gradually.(IBM, 2020) It is a field included in artificial intelligence,without explicitly being programmed, allowing computers to learn. (Brown, 2008) The machine initially inputs the labeled training data, and then the correlations and patterns of the data are analyzed through a learning algorithm, then the future states can be predicted. This process is called supervised learning, and its goal is to predict the result as accurately as possible whenever new unlabeled data is given to the machine.

Classification is one of two tasks of supervised learning which is used. The class of data points given is predicted, and the process of this prediction is called classification. Class is also known as target, label, or category. (Asiri,2018)

Machine learning is widely utilized in different businesses. For instance, business strategies and maximizing income can be represented with a complex framework called business models. And the stock prediction is also an application of machine learning models in the financial industry.

2. Data

The Taiwan Economic Journal collected the data used in the study during the years 1999 to 2009. The Taiwan Stock Exchange has business regulations, and according to that, it gives the definition of company bankruptcy.

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2.1 Data structure

There are 96 columns and 6819 rows in the dataset.

First of all, I plotted a graph to compare the difference between the number of companies that were bankrupt and those that were not, as shown in figure 1. It can be easily seen from the graph that only a small portion of the companies was bankrupt in the data.

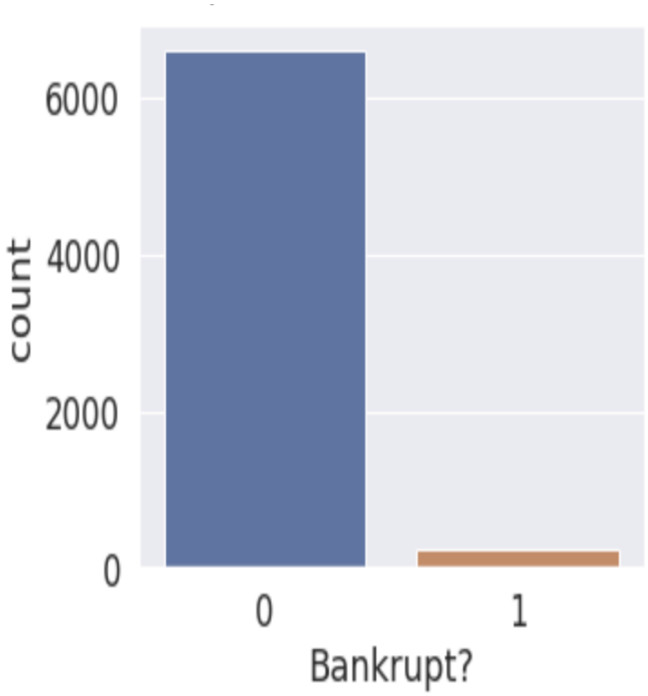

Figure 1 count plot of outcome variable "Bankruptcy?"

Figure 2 includes the histograms of each column. It shows the distribution of the data, and it was obvious that many graphs are almost straight lines among all the 96 graphs, those sharp lines had shown that the data in those columns are concentrated in a small range.

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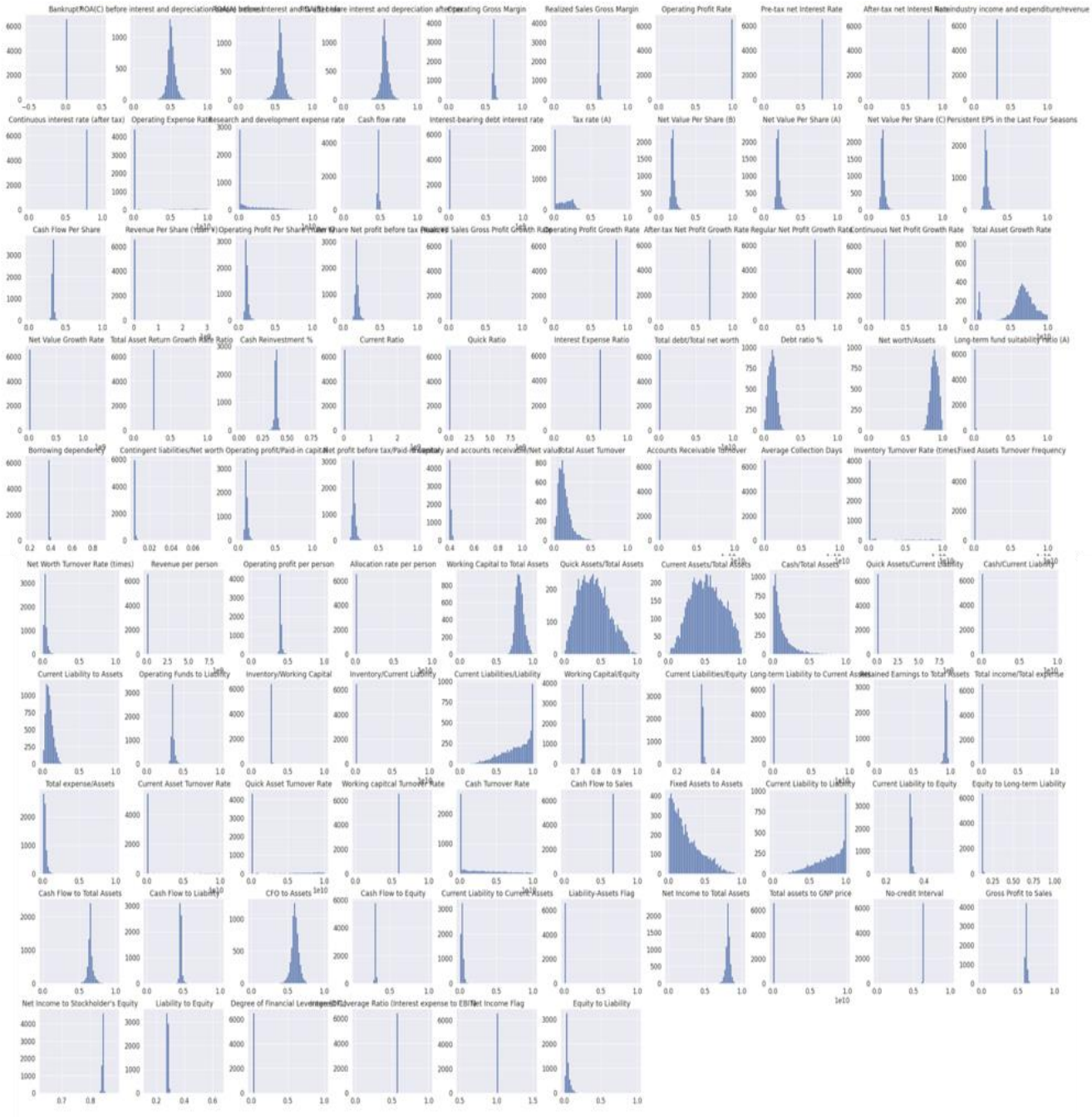

Figure 2 feature distribution plot

However, it is inefficient to study all 96 columns at once. So I started to look into the variances in these columns as the variables that are not different between companies don't contribute to bankruptcy prediction.

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Net Income Flag	0.000000
Operating Profit Growth Rate	0.000161
Operating Profit Rate	0.000170
Cash Flow to Sales	0.000193
Working capitcal Turnover Rate	0.000227
Working Capital/Equity	0.000252
Pre-tax net Interest Rate	0.000261
Continuous interest rate (after tax)	0.000263
After-tax net Interest Rate	0.000283
Net Income to Stockholder's Equity	0.000299
Interest Expense Ratio	0.000317
No-credit Interval	0.000388
After-tax Net Profit Growth Rate	0.000404
Regular Net Profit Growth Rate	0.000407
Interest Coverage Ratio (Interest expense to EBIT)	0.000546
Retained Earnings to Total Assets	0.000748
Realized Sales Gross Margin	0.000774
Operating Gross Margin	0.000776
Gross Profit to Sales	0.000776

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Inventory and accounts receivable/Net value	0.001096
Cash flow rate	0.001328
Total Asset Return Growth Rate Ratio	0.001329
Non-industry income and expenditure/revenue	0.001352
Inventory/Working Capital	0.001424
Current Liabilities/Equity	0.001656
Current Liability to Equity	0.001656
Cash Flow to Equity	0.001686
Borrowing dependency	0.001889
Continuous Net Profit Growth Rate	0.002138
Net Income to Total Assets	0.002493
Liability to Equity	0.002661
Cash Flow Per Share	0.002963
Cash Reinvestment %	0.002983
Net worth/Assets	0.003696
Cash Flow to Liability	0.004203
Working Capital to Total Assets	0.005261
Cash Flow to Total Assets	0.005315
Operating profit per person	0.006668

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CFO to Assets	0.009737
Operating Funds to Liability	0.009866
ROA(B) before interest and depreciation after tax	0.012378
ROA(A) before interest and % after tax	0.013796
ROA(C) before interest and depreciation before interest	0.014428
Persistent EPS in the Last Four Seasons	0.021129
Net profit before tax/Paid-in capital	0.028383
Equity to Long-term Liability	0.028514
Net Value Per Share (B)	0.030665
Net Value Per Share (C)	0.030827
Net Value Per Share (A)	0.030828
Per Share Net profit before tax (Yuan ¥)	0.032386
Operating profit/Paid-in capital	0.064981
Operating Profit Per Share (Yuan ¥)	0.065597
Current Liabilities/Liability	0.073632
Current Liability to Liability	0.073632
Current Assets/Total Assets	0.174381
Debt ratio %	0.226947
Quick Assets/Total Assets	0.254815

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Total Asset Growth Rate	0.276723
Realized Sales Gross Profit Growth Rate	0.290548
Current Liability to Assets	0.307569
Degree of Financial Leverage (DFL)	0.323591
Total Asset Turnover	0.510110
Total expense/Assets	0.865255
Net Worth Turnover Rate (times)	0.903108
Current Liability to Current Assets	0.958298
Equity to Liability	1.104831
Cash/Total Assets	1.258997
Cash Turnover Rate	1.412978
Tax rate (A)	1.453732
Research and development expense rate	1.774404
Inventory Turnover Rate (times)	2.283725
Quick Asset Turnover Rate	2.432547
Operating Expense Rate	2.632499
Contingent liabilities/Net worth	4.169932
Current Asset Turnover Rate	5.564607
Fixed Assets Turnover Frequency	6.033221

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Long-term fund suitability ratio (A)	10.273631
Total income/Total expense	22.504532
Bankrupt?	29.995455
Interest-bearing debt interest rate	43.327745
Inventory/Current Liability	108.763933
Long-term Liability to Current Assets	110.851196
Cash/Current Liability	188.591801
Total assets to GNP price	408.274712
Accounts Receivable Turnover	473.277969
Average Collection Days	680.550015
Allocation rate per person	684.500651
Liability-Assets Flag	851.375000
Quick Ratio	853.129754
Total debt/Total net worth	1453.890641
Revenue Per Share (Yuan ¥)	1514.333244
Quick Assets/Current Liability	2281.318433
Revenue per person	3450.486394
Net Value Growth Rate	5312.004777
Fixed Assets to Assets	6817.997213

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Current Ratio	6817.999489

The table above shows the variance of each of the column. The columns with variances less than 1 were removed from the data set, and only 24 of them were kept. The below table records the remaining columns and what they represent.

Operating Expense Rate	Operating expense/ gross operating income
Research and development expense rate	All costs of search and development + intellectual property
Interest-bearing debt interest rate	total long-term, interest-bearing debt/ equity value
Revenue Per Share (Yuan ¥)	Profit/shares of common stock
Total Asset Growth Rate	Percentage change in assets of a given period
Net Value Growth Rate	Net present value/ amount of share of all future cash flows with growth opportunities
Current Ratio	Measurement of a company's ability to make payments to short-term obligations or those due within one year
Quick Ratio	Measurement of how a company is able to eliminate or retire its current liabilities by using its quick assets or near cash immediately
Total debt/Total net worth	Debt/net worth
Accounts Receivable Turnover	Average account/net credit sales
Average Collection Days	mean of amount of days requires to take a business to do collection and conversionof its receivable accounts into cash
Inventory Turnover Rate (times)	Time between an item is bought and it is sold
Fixed Assets Turnover Frequency	Net sales/net fixed assets
Revenue per person	Total revenue/full-time labors
Allocation rate per person	Investor's cash&capital outlay/final investment
Quick Assets/Current Liability	measurement of a how a company is able to meet its obligations in a short term with most of its liquid assets
Cash/Current Liability	Comparison of the firm's most liquid assets to its short-term obligations.

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Inventory/Current Liability	a company'sfinancial obligations which lasts in a short time period less than one year or faster than a common operating cycle
Long-term Liability to Current Assets	Corporation's assets/long-term debt
Current Asset Turnover Rate	Net sales/average current assets
Quick Asset Turnover Rate	Assets can be converted to cash fast
Cash Turnover Rate	timesof cash turning over during an accounting time period
Fixed Assets to Assets	a tangible piece of property or equipment which last for a long time period that a firm has and utilizes in its operations to make profit
Total assets to GNP price	Total amount of assets

2.2 Data analysis

The spearman's correlation of each column was calculated, it is similar to the Pearson product-moment correlate which does not have a parameter. The coefficient of spearman's correlation is used in the measurement of the direction and strength between two ranked variables associated with one another. It is called "tie" that two same values appear in the data, and the average will be taken.

There are two ways to calculate the spearman's correlation, it depends on the appearance of tied data.

1. With tied data:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$$

2. Without tied data:

$$\rho = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}}$$

The heat map shows the correlation between every single column with each other. The correlation coefficients that have an absolute value bigger than or equal to 0.6 are visualized with colors on a two-dimensional map. The quick ratio has a strong positive relationship with quick assets/current liability, and there are other two columns-average collection days and accounts

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receivable turnover- with spearman's correlation of -1.0 which shows a strong negative correlation.

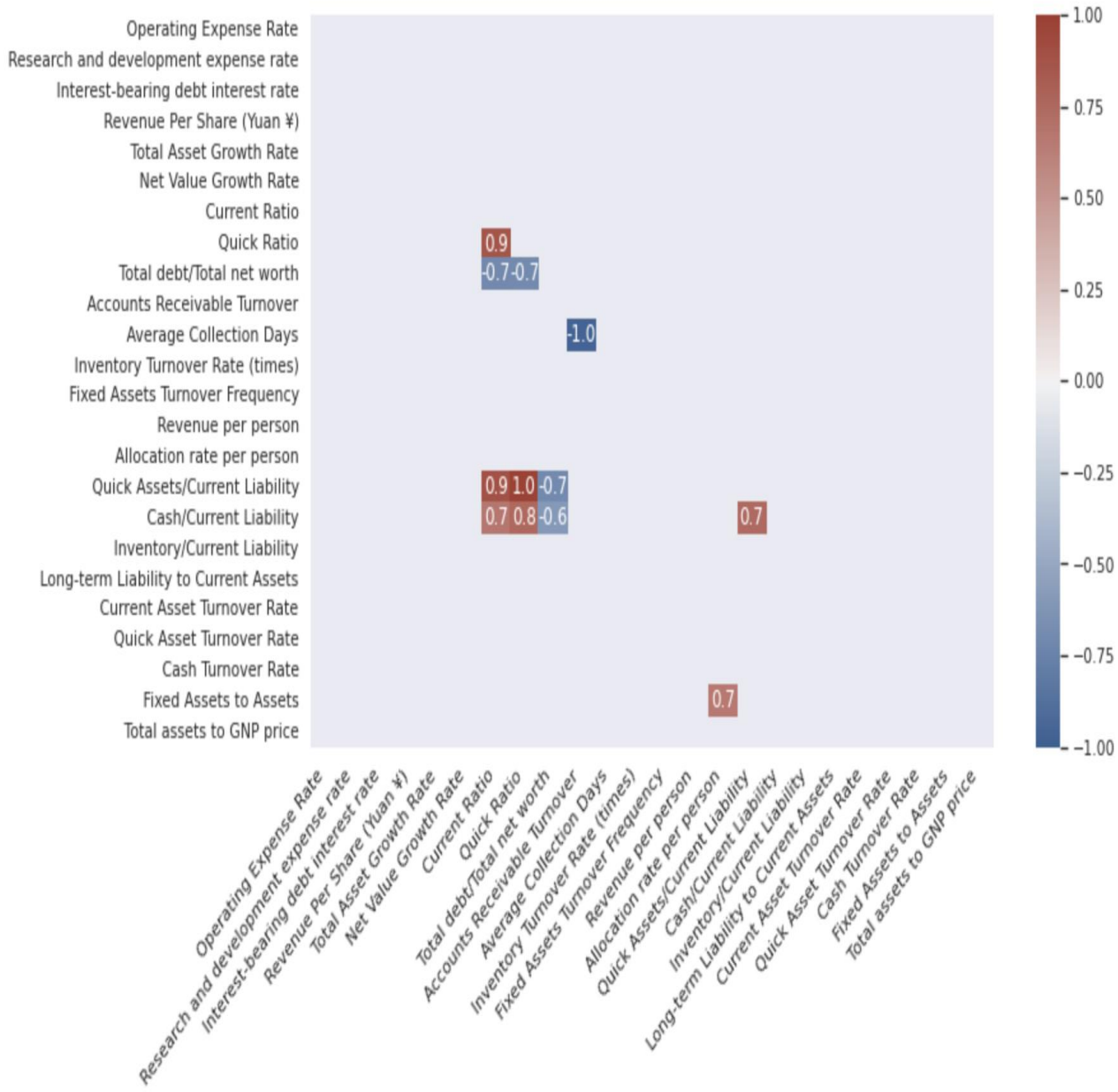

Figure 3. heat map of the correlation matrix

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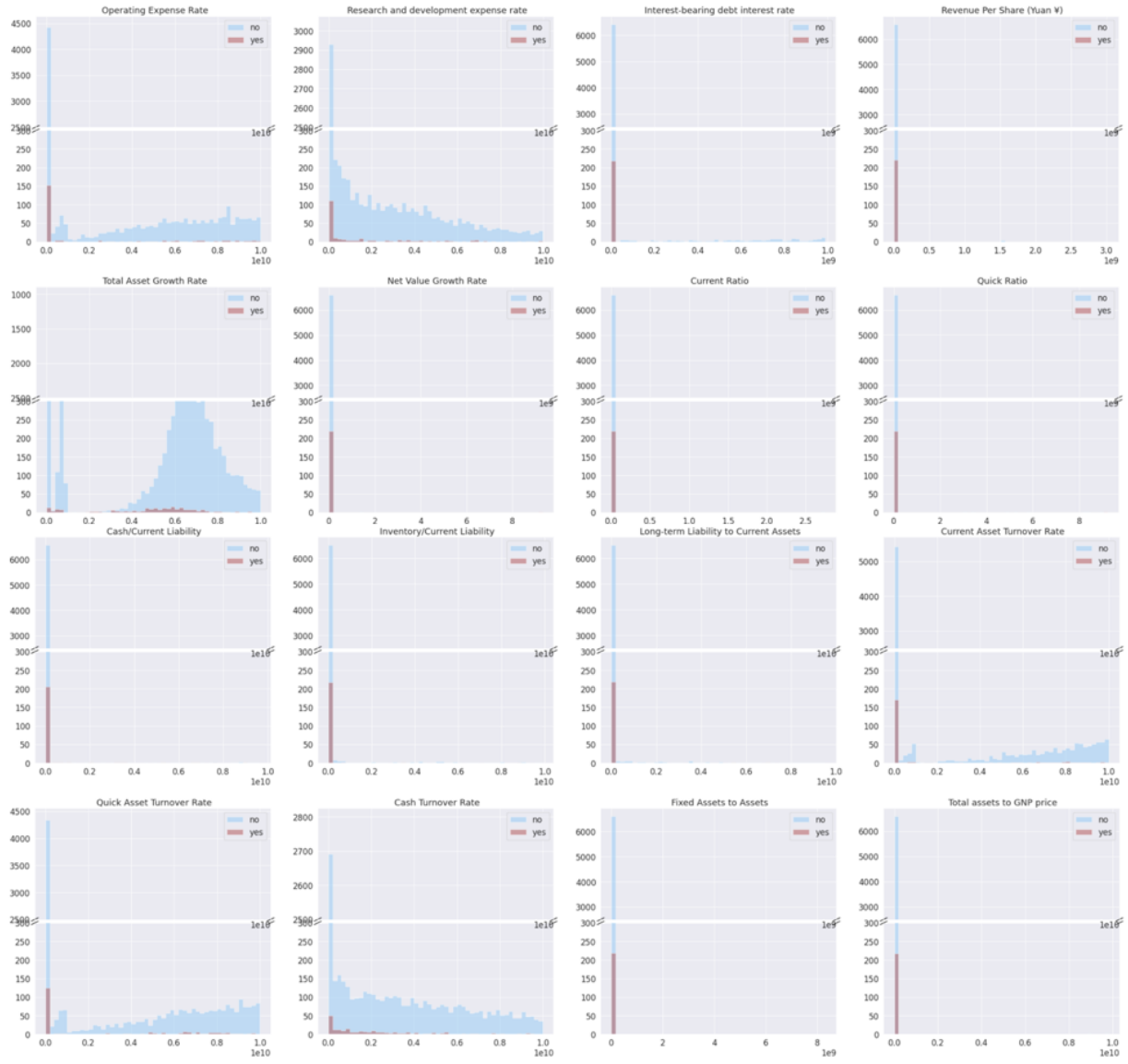

Figure 4 histogram of every column colored coded by the outcome variable

Figure 4 shows the histograms of the remaining 24 columns with discontinuous axis color-coded by the "Bankrupt?" column. It is also plotted with discontinuous axes, and the "yes" category was much more visible due to the use of a color-coded column. It is obvious that most graphs of column distribution were only a straight line, and only a few graphs have some variances on the x-axis. The representation of the blue color is the amount of companies that did not bankrupt, while the representation of the red color is the amount of companies that did bankrupt. And bars with red color are mostly concentrated around x=0.

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3. Machine learning

In total, 4 machine learning models were applied in the research. They are logistic regression, random forest, XGboost, and neural network for binary classification.

And there are two other things called precision and recall in the table of performance metrics of model evaluation. If a model can only identify positive cases, it is precision; if the model has the ability to identify all of the positive cases, it is recall.

3.1 SMOTE

SMOTE stands for Synthetic Minority Oversampling Technique, it can be used when the model is predicting imbalanced data like in this "Bankrupt?" Column. By using SMOTE algorithm, the minority category can be brought up to balance. The number of false negatives can be reduced, however, there will be more false positives.

True positives-the prediction of true is correct

False positives-the prediction of true is incorrect

True negatives-the model predicts wrong correctly

False negatives-the model predicts wrong incorrectly

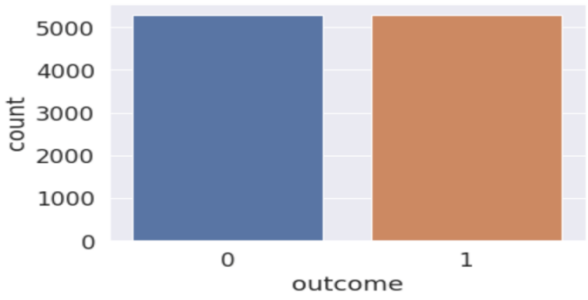

Figure 5 count plot of "Bankruptcy?" after SMOTE

3.2 Logistic Regression

When the output variable is categorical, the logistic regression can be used. It is the one which has the widest use in machine learning model for binary classification, which means the output variable only can have two values.

The precision of "0" is 0.97 while of "1" is 0.05, the weighted average is 0.94; the recall

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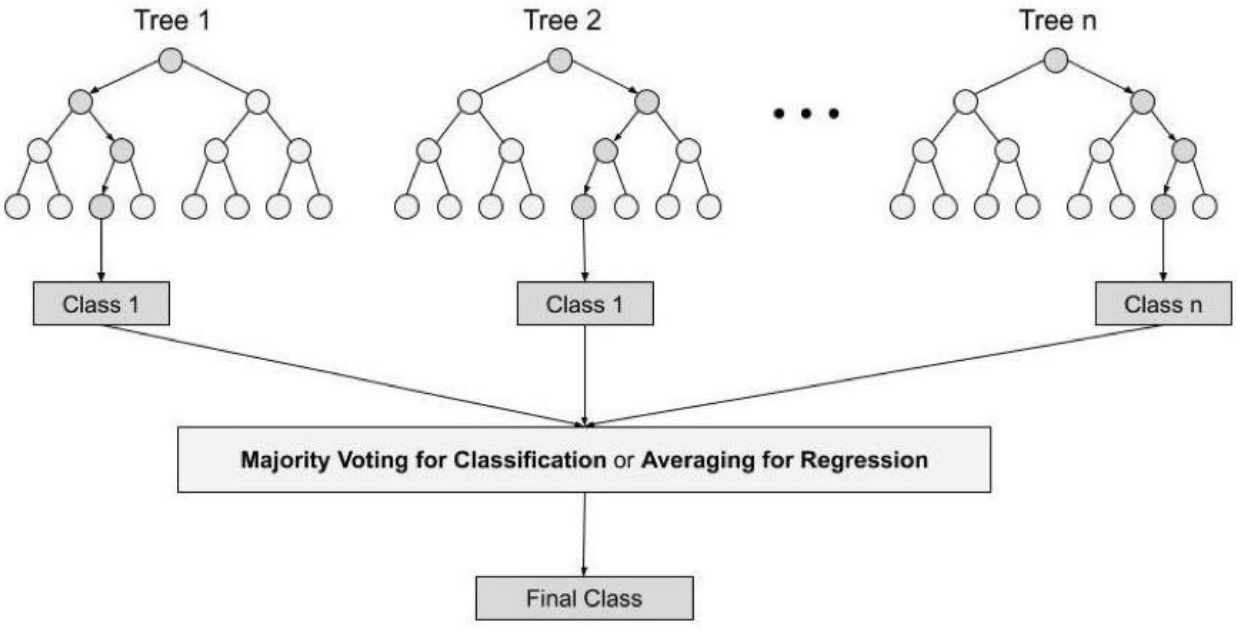
of “0” is 0.67 and of “1” is 0.46, with the weighted average of 0.66.

	precision	recall	f1-score	support
0	0.97	0.67	0.79	1318
1	0.05	0.46	0.08	46
accuracy			0.66	1364
macro avg	0.51	0.56	0.44	1364
weighted avg	0.94	0.66	0.77	1364

Figure 6 logistic regression report

3.3 Random Forest

Random forest is one of the algorithm in machine learning which is supervised, and its application appears widely in questions about regression and classification. It is able to handle data sets within continuous variables. First of all, some random records are picked; and then each of them has a constructed decision tree individually; after that, every number will output a value; at last the final output will be figure out based on averaging.



The precision of “0” is 0.97 while of “1” is 0.15, the weighted average is 0.95; the recall of “0” is 0.95 and of “1” is 0.26, with the weighted average of 0.93.

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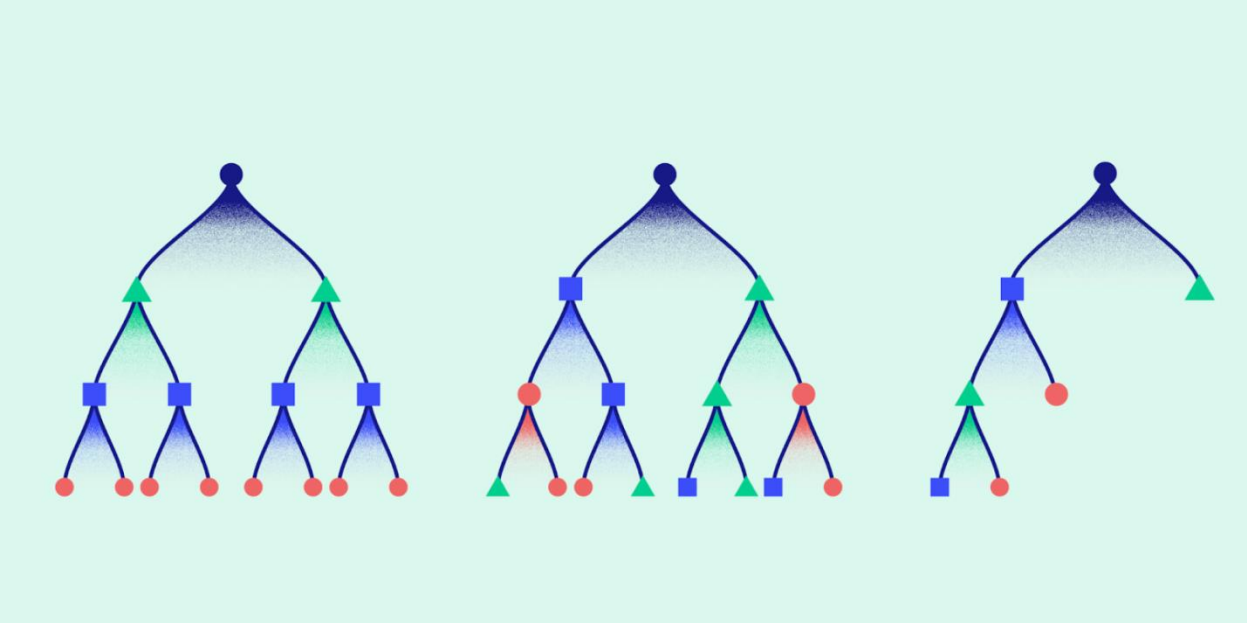
	precision	recall	f1-score	support
0	0.97	0.95	0.96	1318
1	0.15	0.26	0.19	46
accuracy			0.93	1364
macro avg	0.56	0.60	0.58	1364
weighted avg	0.95	0.93	0.93	1364

Figure 7 random forest report

3.4 XGboost

XGboost is also known as Extreme Gradient Boosting, the "gradient boosting" means a special form of boosting. It combines a few single and weak models into a strong model by altering the individual model based on the feedback from the previous model. Unlike random forest, in XGBoost, one tree is built at each time period and if the data is missing, it will be filled. During this algorithm, the samples were not modified, however, they were given various levels of importance.



The precision of class "0" is 0.99 while of "1" is 0.11, the weighted average is 0.96; the recall of "0" is 0.60 and of "1" is 0.67, with the weighted average of 0.80.

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	precision	recall	f1-score	support
0	0.99	0.80	0.88	1318
1	0.11	0.67	0.18	46
accuracy			0.80	1364
macro avg	0.55	0.74	0.53	1364
weighted avg	0.96	0.80	0.86	1364

Figure 8 XGBoost report

4. Conclusion

To eliminate debts, individuals and firms can do bankruptcy which is legal and gives creditors a chance to recoup debts. Machine learning models harness the power of data and make predictions based on available data. Three machine learning algorithms, logistic regression, random forest, and XGBoost were applied in this research to make the prediction that whether a company has its destiny of going bankrupt based on its financial features.

Among the classification reports of the machine learning models, random forest achieved the highest accuracy, for not bankruptcy, with 97% of precision and 95% of recall, however, for bankruptcy, it was only 15% of precision and 26% of recall; the accuracy is 93% in total. In contrast, the logistic regression algorithm was the least accurate model that has an accuracy of only 66% totally.

To figure out why it is much lower than the accuracies of "bankruptcy" compared to "not bankruptcy", it might have been imbalanced data. The number of companies that were not bankrupt was too big, and it is tens of times larger than the amount of not bankrupt. To solve that, the SMOTE algorithm has been used to oversample the data to reduce error at the beginning, however, it was still not adequate. As far as I am concerned, more bankruptcy data should be added to the training set.

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