Machine Learning in Finance Lab

Final Group Project (Classification)

- Saranpat Praserrtthum sp73@illinois.edu (mailto:sp73@illinois.edu)
- Hyoung Woo Hahm hwham2@illinois.edu (mailto:hwham2@illinois.edu)
- Yu-Ching Liao ycliao3@illinois.edu (mailto:ycliao3@illinois.edu)

Out[2]:

Click here to toggle on/off the raw code.

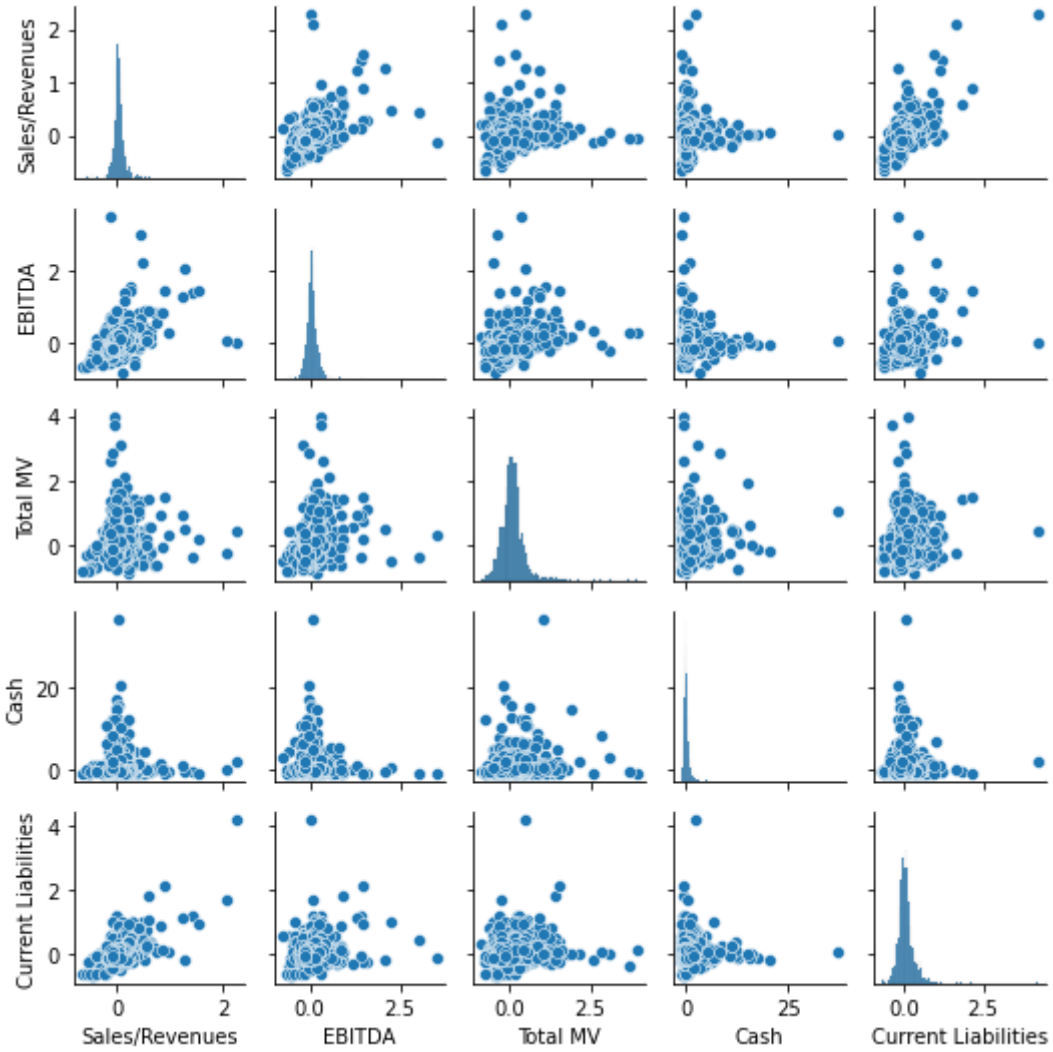
Out[2]:

	Sales/Revenues	Gross Margin	EBITDA	EBITDA Margin	Net Income Before Extras	Total Debt	Net Debt	LT Debt	
0	-0.005496	0.030763	0.018885	0.024515	0.146849	-0.029710	-0.019296	-0.042648	0
1	-0.005496	0.030763	0.088716	0.094733	0.146849	-0.029710	-0.019296	-0.042648	0
2	-0.007045	0.023159	0.088716	0.096440	0.108590	0.039410	0.034268	0.009059	0
3	-0.009396	0.028400	0.088716	0.099046	0.146137	0.030071	0.036938	-0.016964	0
4	-0.009009	0.027714	0.088716	0.098611	0.123500	0.024224	0.034445	-0.034132	0

5 rows × 28 columns

1) Introduction/Exploratory Data Analysis,

Scatter Matrix



Print the Shape Out

```
The number of Columns is 28.
The number of Rows is 1700.
```

Print the nature out

Out[5]:

	Label	Number	String	Other
0	Sales/Revenues	1700	0	0
1	Gross Margin	1700	0	0
2	EBITDA	1700	0	0
3	EBITDA Margin	1700	0	0
4	Net Income Before Extras	1700	0	0
5	Total Debt	1700	0	0
6	Net Debt	1700	0	0
7	LT Debt	1700	0	0
8	ST Debt	1700	0	0
9	Cash	1700	0	0
10	Free Cash Flow	1700	0	0
11	Total Debt/EBITDA	1700	0	0
12	Net Debt/EBITDA	1700	0	0
13	Total MV	1700	0	0
14	Total Debt/MV	1700	0	0
15	Net Debt/MV	1700	0	0
16	CFO/Debt	1700	0	0
17	CFO	1700	0	0
18	Interest Coverage	1700	0	0
19	Total Liquidity	1700	0	0
20	Current Liquidity	1700	0	0
21	Current Liabilities	1700	0	0
22	EPS Before Extras	1700	0	0
23	PE	1700	0	0
24	ROA	1700	0	0
25	ROE	1700	0	0
26	InvGrd	1700	0	0
27	Rating	0	1700	0

Summary of Statistics

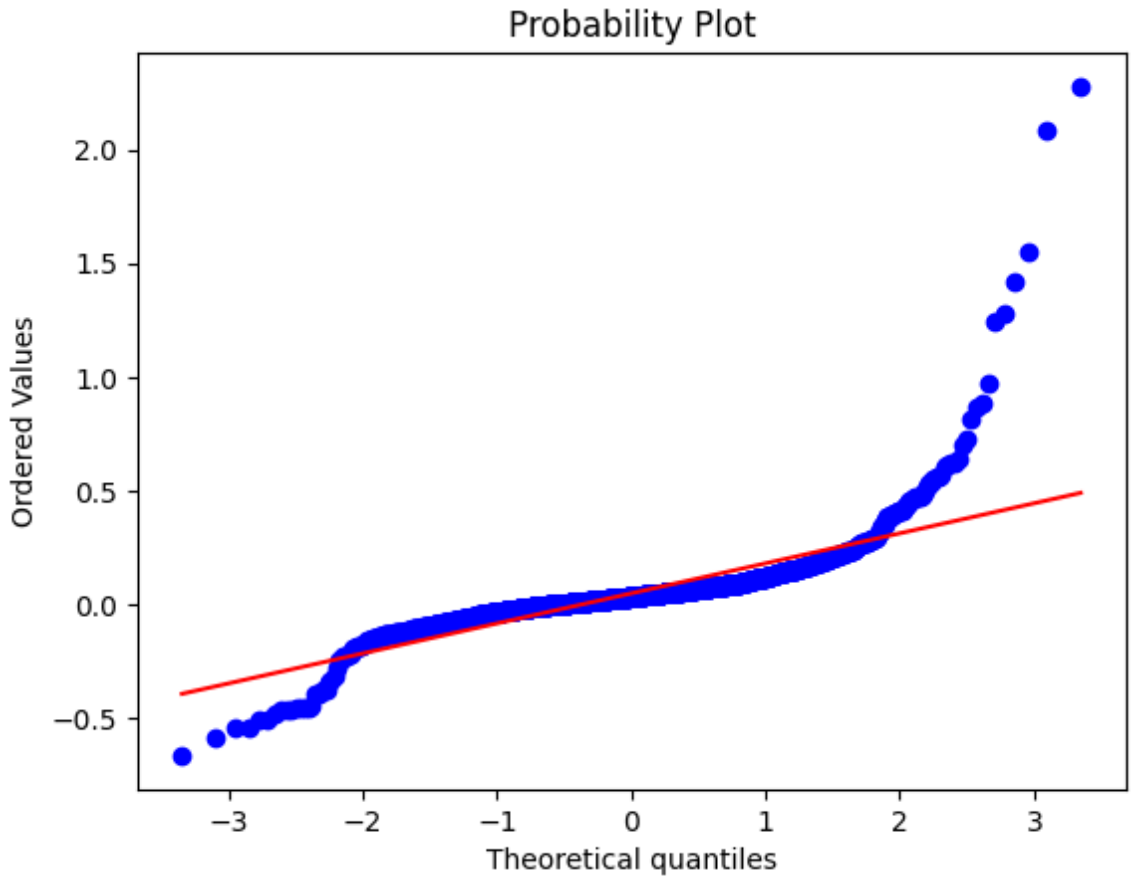
```
All the ratings
['A1' 'A2' 'A3' 'Aa2' 'Aa3' 'Aaa' 'B1' 'B2' 'B3' 'Ba1' 'Ba2' 'Ba3' 'Baa1'
 'Baa2' 'Baa3' 'Caa1']
Investment Recommended
μ = 0.05716446828049729 Var = 0.04507965336673378 σ = 0.21231969613470575

Investment Not Recommended
μ = 0.1047225816416465 Var = 0.08958951418890121 σ = 0.29931507511133015

Boundaries for 4 Equal Percentiles for Investment Recommended
 [-0.782254303, -0.0192508605, 0.044912281, 0.1074112785, 3.542424887]

Boundaries for 10 Equal Percentiles for Investment Recommended
 [-0.782254303, -0.09602339900000001, -0.03783060260000006, -0.0027125775
999999996, 0.021396558399999998, 0.044912281, 0.0693806898, 0.094985605199
99999, 0.1263567034, 0.20178858760000004, 3.542424887]

Boundaries for 4 Equal Percentiles for Investment Not Recommended
 [-0.582112521, -0.036688059, 0.065095003, 0.200948894, 2.084133001]

Boundaries for 10 Equal Percentiles for Investment Not Recommended
 [-0.582112521, -0.1707249226, -0.07302318859999998, -0.01554577360000001
6, 0.03127736020000001, 0.065095003, 0.12283974699999999, 0.175052519, 0.2
321507122, 0.3397043488, 2.084133001]

Unique Label Values
 ['Total Debt', 'Net Debt', 'Interest Coverage', 'Current Liabilities', 'S
ales/Revenues', 'PE', 'EBITDA', 'ROA', 'EBITDA Margin', 'CFO', 'Total MV',
'Total Liquidity', 'Net Debt/MV', 'Total Debt/MV', 'Total Debt/EBITDA', 'N
et Income Before Extras', 'LT Debt', 'ST Debt', 'Current Liquidity', 'RO
E', 'CFO/Debt', 'InvGrd', 'Free Cash Flow', 'Rating', 'Gross Margin', 'Cas
h', 'EPS Before Extras', 'Net Debt/EBITDA']
```

Out[6]:

Types	Total Debt	Net Debt	Interest Coverage	Current Liabilities	Sales/Revenues	PE	EBITDA	ROA	EBITDA Margin	CFO
Counts	1	1	1	1	1	1	1	1	1	1

1 rows × 28 columns

QQplot

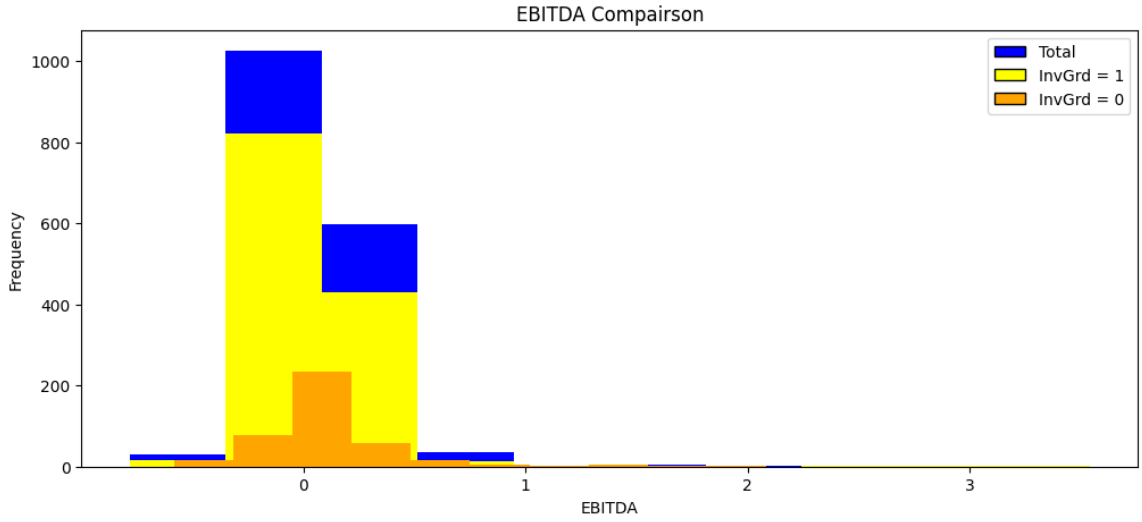


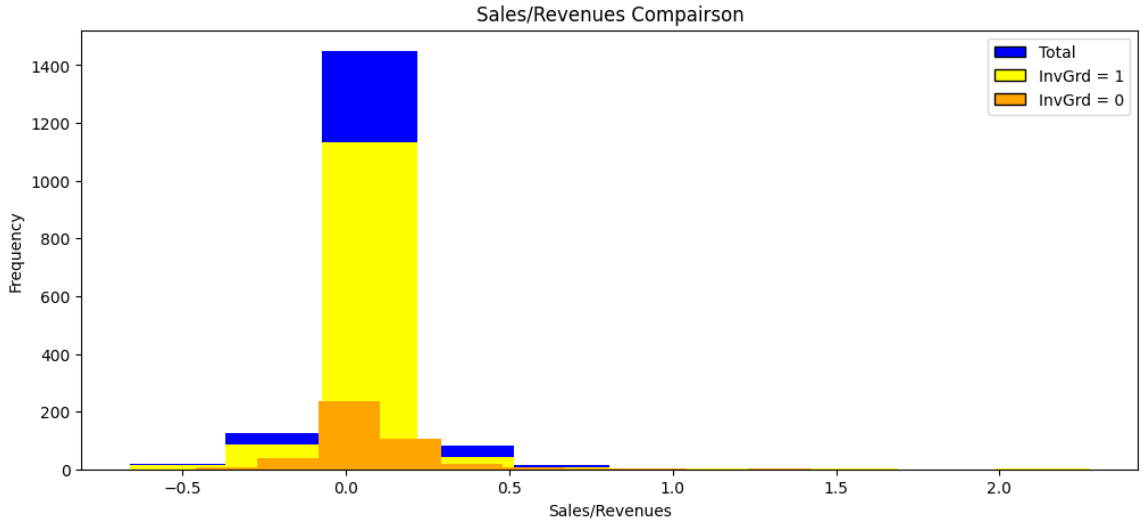

```
P-Value: 0.0
Reject H0: Client_Trade_Percentage is Normally distributed.
```

Print Summary of Data

```
       Sales/Revenues  Gross Margin       EBITDA  EBITDA Margin  \
count     1700.000000   1700.000000  1700.000000    1700.000000
mean         0.050378      0.026007     0.068718       0.021074
std          0.161910      0.273768     0.237365       0.189025
min         -0.661715     -0.794722    -0.782254      -0.805153
25%         -0.005693     -0.020028    -0.022640      -0.042771
50%          0.034000      0.003403     0.049482       0.011134
75%          0.083004      0.025595     0.124533       0.060566
max          2.277229      3.202713     3.542425       4.141182

       Net Income Before Extras   Total Debt     Net Debt      LT Debt  \
count               1700.000000  1700.000000  1700.000000  1700.000000
mean                  0.123026     0.822405    -0.419810     1.255168
std                  14.475689    13.317075    28.385702    16.224453
min                -289.000000    -0.903014  -493.305578    -0.921515
25%                  -0.158478    -0.076316    -0.120725    -0.094767
50%                   0.056627     0.005886    -0.003060    -0.002078
75%                   0.222219     0.136449     0.160251     0.174735
max                 478.280075   281.604237   865.194595   289.388178

           ST Debt         Cash  ...          CFO  Interest Coverage  \
count  1700.000000  1700.000000  ...  1700.000000        1700.000000
mean      3.142797     0.466620  ...    -0.189317           0.298785
std      51.986550     1.859494  ...     5.668669           5.265291
min      -0.997692    -0.990982  ...  -161.609425          -0.991976
25%      -0.337959    -0.195117  ...    -0.115159          -0.096996
50%       0.043092     0.075820  ...     0.046983           0.043216
75%       0.649475     0.483113  ...     0.216432           0.177340
max    2038.000000    36.980037  ...    13.005788         182.131887

       Total Liquidity  Current Liquidity  Current Liabilities  \
count      1700.000000        1700.000000          1700.000000
mean         -0.855714           0.436002             0.072802
std          22.926862           1.904282             0.266471
min        -502.000000          -0.994141            -0.684678
25%          -0.857013          -0.227327            -0.072734
50%          -0.229098           0.040446             0.041785
75%           0.512778           0.416067             0.161215
max         280.138728          34.372455             4.194381

       EPS Before Extras           PE          ROA          ROE       InvG
rd
count        1700.000000  1700.000000  1700.000000  1700.000000  1700.0000
00
mean            0.032196     0.497705     0.019394    -0.217604     0.7570
59
std             6.151994    12.102502    14.594193    15.389000     0.4289
86
min           -96.250000   -59.795133  -305.462167  -373.837267     0.0000
00
25%            -0.152894    -0.293521    -0.208483    -0.233955     1.0000
00
50%             0.066027    -0.040405    -0.009403    -0.020392     1.0000
00
75%             0.236046     0.168897     0.156136     0.201596     1.0000
00
max           187.000000   381.243282   474.847172   343.145356     1.0000
00

[8 rows x 27 columns]
```

Plot Data

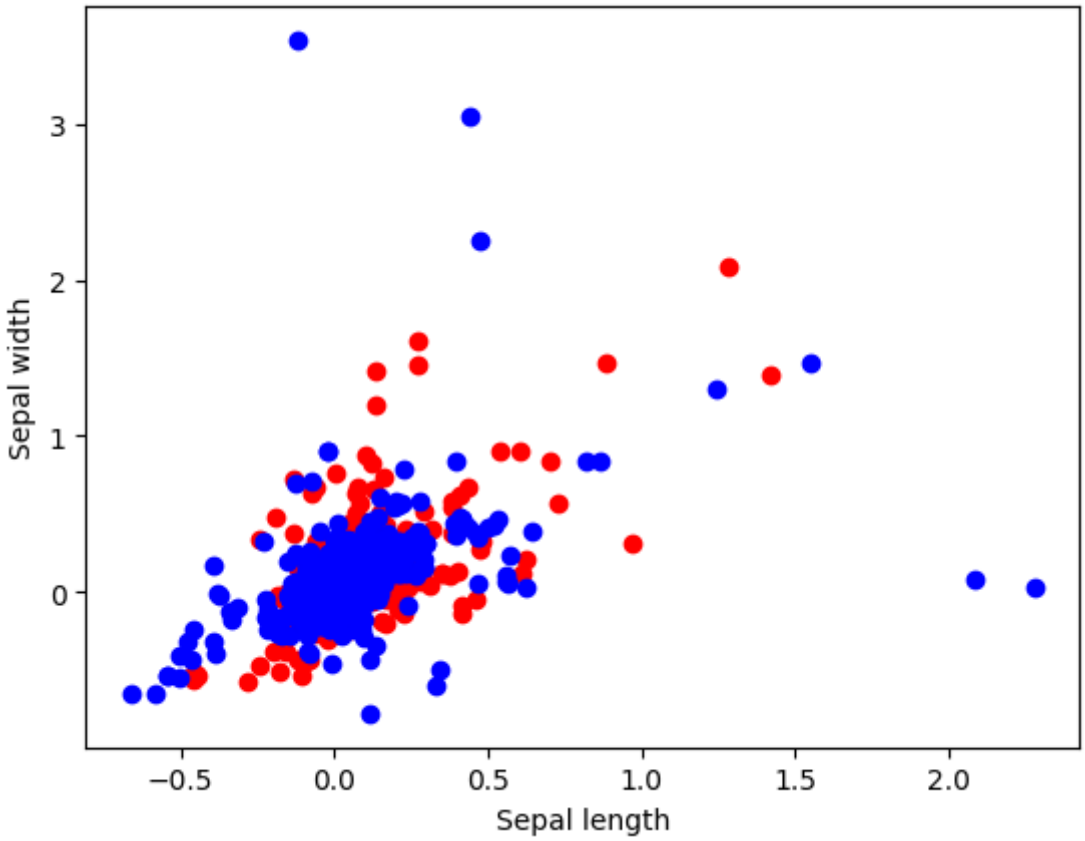




Cross Plotting Pairs of Attributes (Scatter Plot)

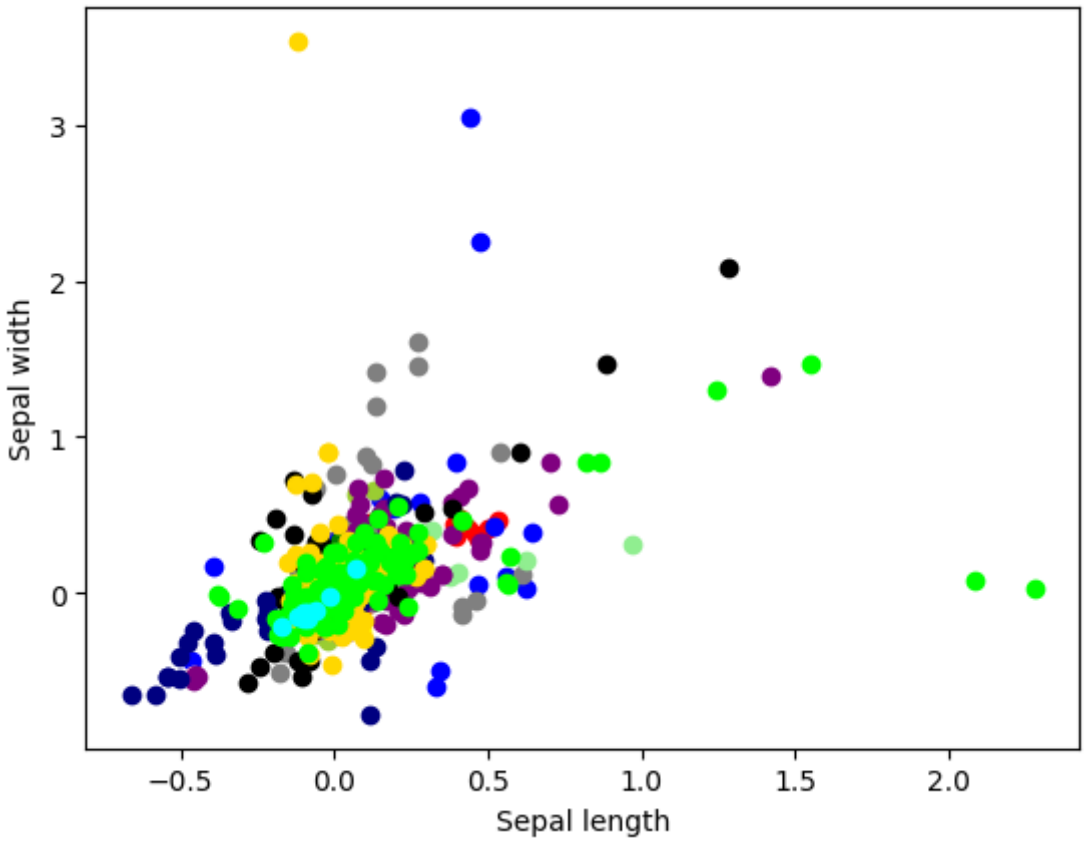
Out[11]:

```
Text(0, 0.5, 'Sepal width')
```



Out[12]:

```
Text(0, 0.5, 'Sepal width')
```



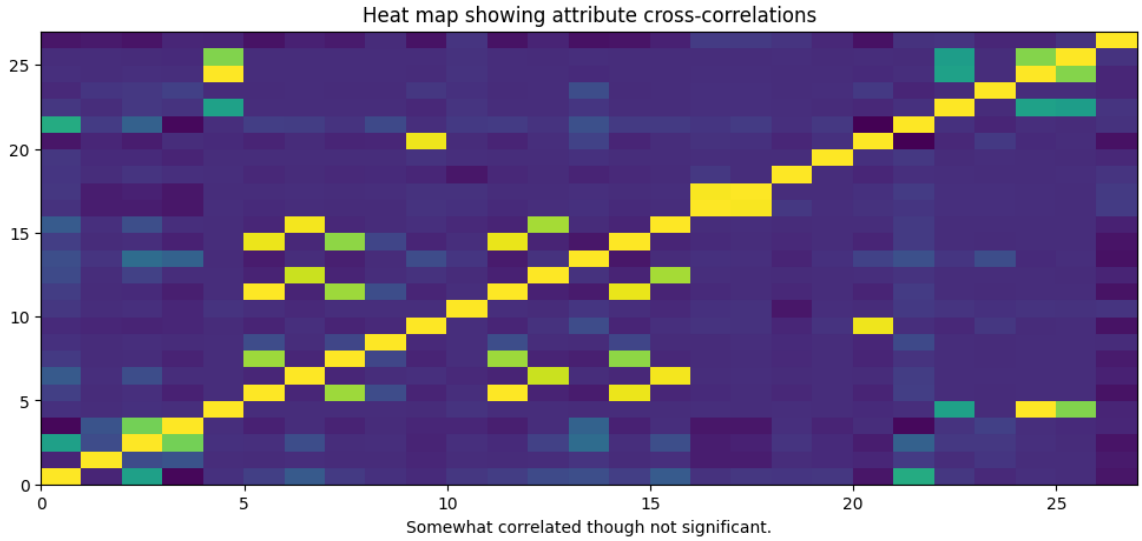
Correlation

Out[13]:

	Sales/Revenues	Gross Margin	EBITDA	EBITDA Margin	Net Income Before Extras	Total Debt	Net D
Sales/Revenues	1.000000	-0.026318	0.500178	-0.124079	0.012024	0.068938	0.1757
Gross Margin	-0.026318	1.000000	0.114092	0.147886	-0.001061	-0.002665	0.0042
EBITDA	0.500178	0.114092	1.000000	0.757142	0.012565	0.008949	0.1192
EBITDA Margin	-0.124079	0.147886	0.757142	1.000000	0.003331	-0.039804	0.0003
Net Income Before Extras	0.012024	-0.001061	0.012565	0.003331	1.000000	-0.001065	0.0008
Total Debt	0.068938	-0.002665	0.008949	-0.039804	-0.001065	1.000000	-0.0222
Net Debt	0.175741	0.004266	0.119251	0.000336	0.000867	-0.022209	1.0000
LT Debt	0.048960	-0.003149	-0.000665	-0.037009	-0.001162	0.833567	-0.0213
ST Debt	0.014987	-0.005417	0.004844	-0.006310	-0.000221	0.118240	0.0011
Cash	-0.008088	-0.024540	-0.030773	-0.023997	-0.006703	-0.030002	0.0071
Free Cash Flow	0.035716	0.001920	0.009102	-0.021301	0.023523	0.002539	-0.0132
Total Debt/EBITDA	0.056092	-0.005690	-0.009527	-0.051062	-0.001490	0.999328	-0.0314
Net Debt/EBITDA	0.110201	-0.000236	0.074284	-0.000145	0.000312	-0.035136	0.9074
Total MV	0.123111	0.024361	0.256941	0.209314	-0.005511	-0.056449	0.0001
Total Debt/MV	0.062128	-0.003954	0.002857	-0.041728	-0.001252	0.964306	-0.0192
Net Debt/MV	0.176797	0.009945	0.123084	0.004226	0.000701	-0.022305	0.9787
CFO/Debt	0.016833	-0.055521	-0.054541	-0.076554	0.002084	-0.008508	0.0015
CFO	0.034069	-0.055569	-0.041064	-0.075326	0.001832	0.000924	0.0027
Interest Coverage	0.032716	-0.002079	0.028118	0.008147	0.002233	-0.016078	-0.0035
Total Liquidity	0.035747	-0.011190	-0.008799	-0.033862	-0.001938	-0.000801	0.0004
Current Liquidity	-0.081346	-0.022793	-0.054680	-0.000036	-0.008131	-0.031600	-0.0038
Current Liabilities	0.553807	0.051386	0.207526	-0.119068	0.004226	0.062364	0.0591
EPS Before Extras	0.034722	0.000857	0.042191	0.021589	0.506547	-0.001424	0.0010
PE	-0.014842	0.029146	0.040732	0.071426	-0.003166	-0.003652	-0.0003
ROA	0.007251	-0.001583	0.007913	0.002072	0.997349	-0.001406	-0.0007
ROE	-0.000206	0.000182	-0.005701	-0.008328	0.782491	0.000301	-0.0019
InvGrd	-0.080836	-0.066103	-0.085951	-0.024112	-0.027919	-0.090372	-0.0421

27 rows × 27 columns

Correlation Visualization



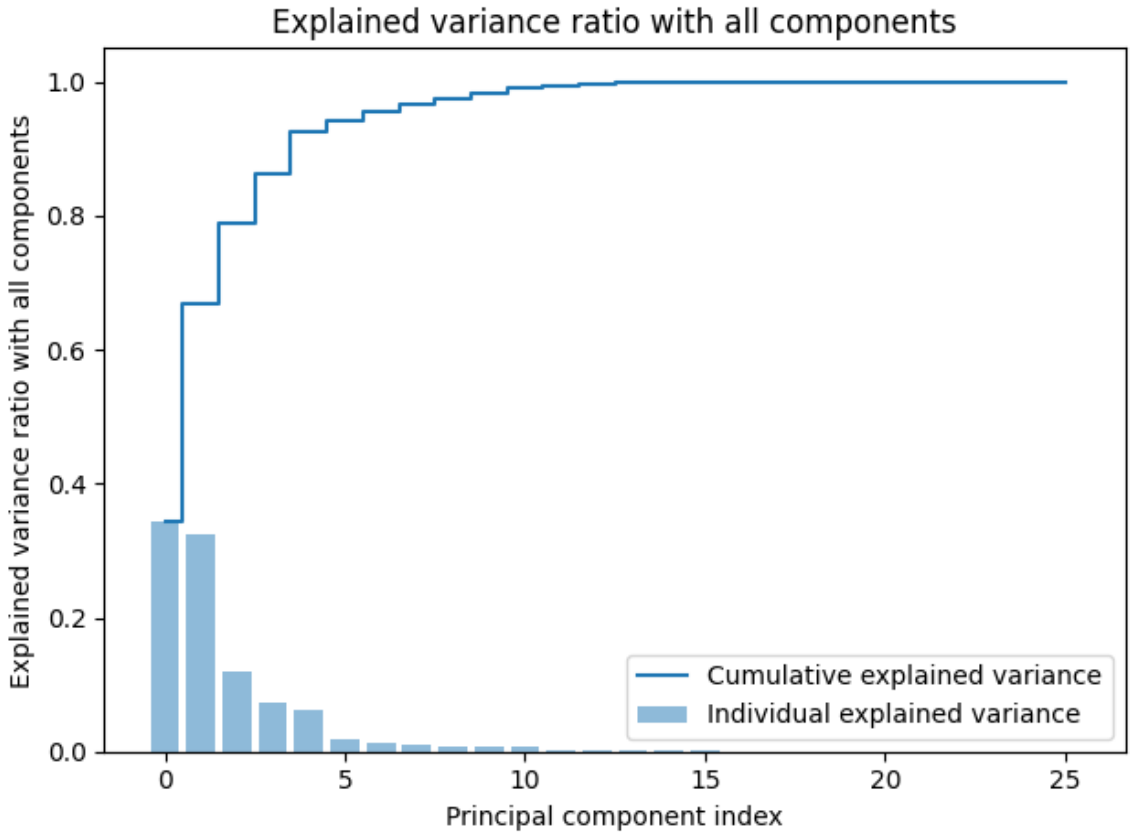
2) Preprocessing, feature extraction, feature selection

Drop Missing Value

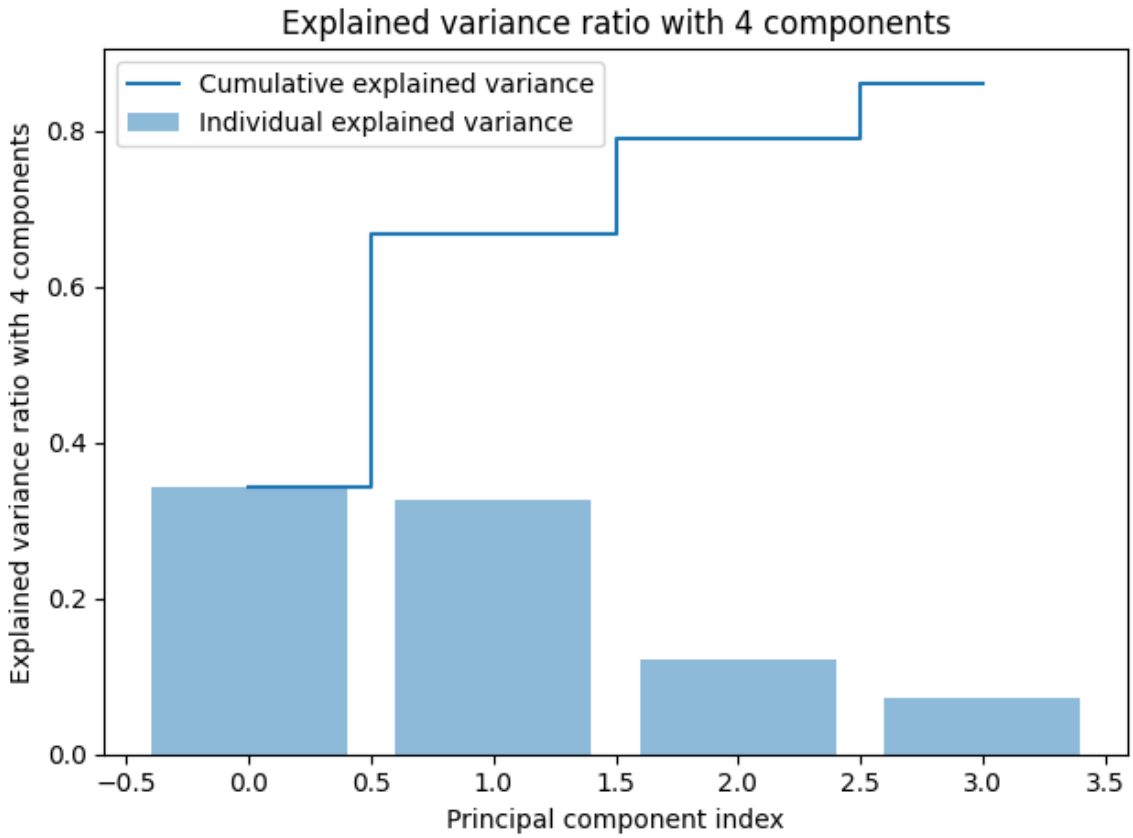
Preprocessing the Data

Variance Ratio

```
Explained Variance Ratio with all components:
 [3.43047199e-01 3.25324928e-01 1.20717674e-01 7.24409782e-02
 6.28795206e-02 1.75279579e-02 1.34937683e-02 9.49562533e-03
 8.50716279e-03 8.32593599e-03 7.69529261e-03 3.29035410e-03
 3.20490490e-03 1.70619518e-03 1.34038953e-03 8.30711631e-04
 6.59285613e-05 3.64523500e-05 2.28387916e-05 1.42339841e-05
 1.20727109e-05 8.64794299e-06 5.25124749e-06 3.85369188e-06
 1.97773212e-06 1.44521331e-07]

Culmulative Variance Ratio with all components:
 [0.3430472  0.66837213 0.7890898  0.86153078 0.9244103  0.94193826
 0.95543203 0.96492765 0.97343481 0.98176075 0.98945604 0.9927464
 0.9959513  0.9976575  0.99899789 0.9998286  0.99989453 0.99993098
 0.99995382 0.99996805 0.99998012 0.99998877 0.99999402 0.99999788
 0.99999986 1.        ]
```



```
Explained Variance Ratio with 4 components:
 [0.3430472  0.32532493 0.12071767 0.07244098]

Culmulative Variance Ratio with 4 components:
 [0.3430472  0.66837213 0.7890898  0.86153078]
```



3 + 4) Model fitting and evaluation + Hyperparameter tuning

Model: Binary Classification (Investment grade)

Model : SVM + Gridsearch (Hyperparameter tuning) w PCA

```
SVC best parameter : {'C': 0.1, 'kernel': 'linear'}
SVC best estimator : SVC(C=0.1, kernel='linear')
SVC best score:  0.7594117647058823
```

Model : Decision Tree + Gridsearch (Hyperparameter tuning) w PCA

```
DT best parameter : {'max_depth': 4, 'min_samples_leaf': 1, 'min_samples_s
plit': 2}
DT best estimator : DecisionTreeClassifier(max_depth=4)
DT best score:  0.7476470588235294
```

Model: Multiclass Classification (Moody)

One rest model

Model : Logistic Regresssion on Scaled data + One rest w/ PCA

```
Multi-Class LR best parameter : {'C': 0.1, 'penalty': 'l2'}
Multi-Class LR best estimator : LogisticRegression(C=0.1, multi_class='ov
r')
Multi-Class LR best score:  0.16882352941176473
```

Model : Decision Tree + OneRest w PCA

```
Multi-Class DT best parameter : {'estimator__max_depth': 10, 'estimator__m
in_samples_leaf': 3, 'estimator__min_samples_split': 2}
Multi-Class DT best estimator : OneVsRestClassifier(estimator=DecisionTree
Classifier(max_depth=10,
                                                    min_samples_leaf=3))
Multi-Class DT best score:  0.18294117647058825
```

Model : SVC + One v One w/ PCA

```
Multi-Class SVC best parameter : {'estimator__C': 0.1, 'estimator__gamma':
1, 'estimator__kernel': 'rbf'}
Multi-Class SVC best estimator : OneVsOneClassifier(estimator=SVC(C=0.1, g
amma=1))
Multi-Class SVC best score:  0.20294117647058824
```

5) Ensembling

Model: Binary Classification (Investment grade)

Model : Random Forest + Gridsearch (Hyperparameter tuning) w/ PCA

```
RF best parameter : {'max_depth': 10, 'min_samples_leaf': 1, 'min_samples_
split': 5, 'n_estimators': 100}
RF best estimator : RandomForestClassifier(max_depth=10, min_samples_split
=5, random_state=1)
RF best score:  0.741764705882353
```

Model : Random Forest + Gridsearch (Hyperparameter tuning) w PCA

```
RF + PCA best parameter : {'max_depth': 5, 'min_samples_leaf': 1, 'min_sam
ples_split': 5, 'n_estimators': 50}
RF + PCA best estimator : RandomForestClassifier(max_depth=5, min_samples_
split=5, n_estimators=50,
                       random_state=1)
RF + PCA best score:  0.7452941176470589
```

Model: Multiclass Classification (Moody)

Model : Random Forest + One Rest w/ PCA

```
Multi-Class RF best parameter : {'estimator__max_depth': 5, 'estimator__n_
estimators': 100}
Multi-Class RF best estimator : OneVsRestClassifier(estimator=RandomForest
Classifier(max_depth=5,
                                                    random_state=1))
Multi-Class RF best score:  0.20941176470588233
```

Model : Random Forest + One Rest w PCA

```
Multi-Class RF + PCA best parameter : {'estimator__max_depth': 2, 'estimat
or__n_estimators': 50}
Multi-Class RF + PCA best estimator : OneVsRestClassifier(estimator=Random
ForestClassifier(max_depth=2,
                                                    n_estimators=50,
                                                    random_state=1))
Multi-Class RF + PCA best score:  0.18176470588235294
```

6) Conclusions

Binary Classification

When it comes to binary classification, the Support Vector Machine (SVM) method has shown to be highly effective, achieving an accuracy rate of 76% using 5-fold cross-validation. Remarkably, this even outperformed ensemble models such as Random Forest. The second-best model was the decision tree. Based on these results, we can conclude that non-ensemble models are advantageous in binary classification might cause by low risk of overfitting.

Multi-Class Classification

For multi-class classification, I opted to use the One v One + SVM model due to its faster computation time compared to the One v Rest method. However, the Random Forest + One v Rest model outperformed it by 21% in terms of accuracy. In this scenario, an ensemble model proved to be the superior choice.

7) Appendix

Like to github:
https://github.com/Saranpatp/IE517_F2023_HW/blob/main/IE517MLF_Group_project/Classification.ipynb
(https://github.com/Saranpatp/IE517_F2023_HW/blob/main/IE517MLF_Group_project/Classification.ipynb)