Sonar Rock or Mine Prediction

Sadia Boksh

30/01/2021

Introduction

In this project we will use Sonar data from mlbench package. This is the data set used by Gorman and Sejnowski in their study of the classification of sonar signals using a neural network. Using this data set, we will train some machine learning models to classify sonar signals those bounced off a metal cylinder and those bounced off a roughly cylindrical rock. We will perform the model fitting on scaled raw data as well as PCA transformed data. We will choose the best performing model by analyzing their accuracy.

Data Analysis

Sonar data set is a data frame of 208 rows and 60 feature variables and a response variable.Approximately 47% of the sample are Rocks and 53% are Mines. This data set does not have any missing values.

```
head(Sonar)
```

```
##       V1     V2     V3     V4     V5     V6     V7     V8     V9    V10    V11
## 1 0.0200 0.0371 0.0428 0.0207 0.0954 0.0986 0.1539 0.1601 0.3109 0.2111 0.1609
## 2 0.0453 0.0523 0.0843 0.0689 0.1183 0.2583 0.2156 0.3481 0.3337 0.2872 0.4918
## 3 0.0262 0.0582 0.1099 0.1083 0.0974 0.2280 0.2431 0.3771 0.5598 0.6194 0.6333
## 4 0.0100 0.0171 0.0623 0.0205 0.0205 0.0368 0.1098 0.1276 0.0598 0.1264 0.0881
## 5 0.0762 0.0666 0.0481 0.0394 0.0590 0.0649 0.1209 0.2467 0.3564 0.4459 0.4152
## 6 0.0286 0.0453 0.0277 0.0174 0.0384 0.0990 0.1201 0.1833 0.2105 0.3039 0.2988
##      V12    V13    V14    V15    V16    V17    V18    V19    V20    V21    V22
## 1 0.1582 0.2238 0.0645 0.0660 0.2273 0.3100 0.2999 0.5078 0.4797 0.5783 0.5071
## 2 0.6552 0.6919 0.7797 0.7464 0.9444 1.0000 0.8874 0.8024 0.7818 0.5212 0.4052
## 3 0.7060 0.5544 0.5320 0.6479 0.6931 0.6759 0.7551 0.8929 0.8619 0.7974 0.6737
## 4 0.1992 0.0184 0.2261 0.1729 0.2131 0.0693 0.2281 0.4060 0.3973 0.2741 0.3690
## 5 0.3952 0.4256 0.4135 0.4528 0.5326 0.7306 0.6193 0.2032 0.4636 0.4148 0.4292
## 6 0.4250 0.6343 0.8198 1.0000 0.9988 0.9508 0.9025 0.7234 0.5122 0.2074 0.3985
##      V23    V24    V25    V26    V27    V28    V29    V30    V31    V32    V33
## 1 0.4328 0.5550 0.6711 0.6415 0.7104 0.8080 0.6791 0.3857 0.1307 0.2604 0.5121
## 2 0.3957 0.3914 0.3250 0.3200 0.3271 0.2767 0.4423 0.2028 0.3788 0.2947 0.1984
## 3 0.4293 0.3648 0.5331 0.2413 0.5070 0.8533 0.6036 0.8514 0.8512 0.5045 0.1862
## 4 0.5556 0.4846 0.3140 0.5334 0.5256 0.2520 0.2090 0.3559 0.6260 0.7340 0.6120
## 5 0.5730 0.5399 0.3161 0.2285 0.6995 1.0000 0.7262 0.4724 0.5103 0.5459 0.2881
## 6 0.5890 0.2872 0.2043 0.5782 0.5389 0.3750 0.3411 0.5067 0.5580 0.4778 0.3299
##      V34    V35    V36    V37    V38    V39    V40    V41    V42    V43    V44
## 1 0.7547 0.8537 0.8507 0.6692 0.6097 0.4943 0.2744 0.0510 0.2834 0.2825 0.4256
## 2 0.2341 0.1306 0.4182 0.3835 0.1057 0.1840 0.1970 0.1674 0.0583 0.1401 0.1628
```

```
## 3 0.2709 0.4232 0.3043 0.6116 0.6756 0.5375 0.4719 0.4647 0.2587 0.2129 0.2222
## 4 0.3497 0.3953 0.3012 0.5408 0.8814 0.9857 0.9167 0.6121 0.5006 0.3210 0.3202
## 5 0.0981 0.1951 0.4181 0.4604 0.3217 0.2828 0.2430 0.1979 0.2444 0.1847 0.0841
## 6 0.2198 0.1407 0.2856 0.3807 0.4158 0.4054 0.3296 0.2707 0.2650 0.0723 0.1238
##      V45    V46    V47    V48    V49    V50    V51    V52    V53    V54    V55
## 1 0.2641 0.1386 0.1051 0.1343 0.0383 0.0324 0.0232 0.0027 0.0065 0.0159 0.0072
## 2 0.0621 0.0203 0.0530 0.0742 0.0409 0.0061 0.0125 0.0084 0.0089 0.0048 0.0094
## 3 0.2111 0.0176 0.1348 0.0744 0.0130 0.0106 0.0033 0.0232 0.0166 0.0095 0.0180
## 4 0.4295 0.3654 0.2655 0.1576 0.0681 0.0294 0.0241 0.0121 0.0036 0.0150 0.0085
## 5 0.0692 0.0528 0.0357 0.0085 0.0230 0.0046 0.0156 0.0031 0.0054 0.0105 0.0110
## 6 0.1192 0.1089 0.0623 0.0494 0.0264 0.0081 0.0104 0.0045 0.0014 0.0038 0.0013
##      V56    V57    V58    V59    V60 Class
## 1 0.0167 0.0180 0.0084 0.0090 0.0032     R
## 2 0.0191 0.0140 0.0049 0.0052 0.0044     R
## 3 0.0244 0.0316 0.0164 0.0095 0.0078     R
## 4 0.0073 0.0050 0.0044 0.0040 0.0117     R
## 5 0.0015 0.0072 0.0048 0.0107 0.0094     R
## 6 0.0089 0.0057 0.0027 0.0051 0.0062     R
```

Plots and Principal Component Analysis

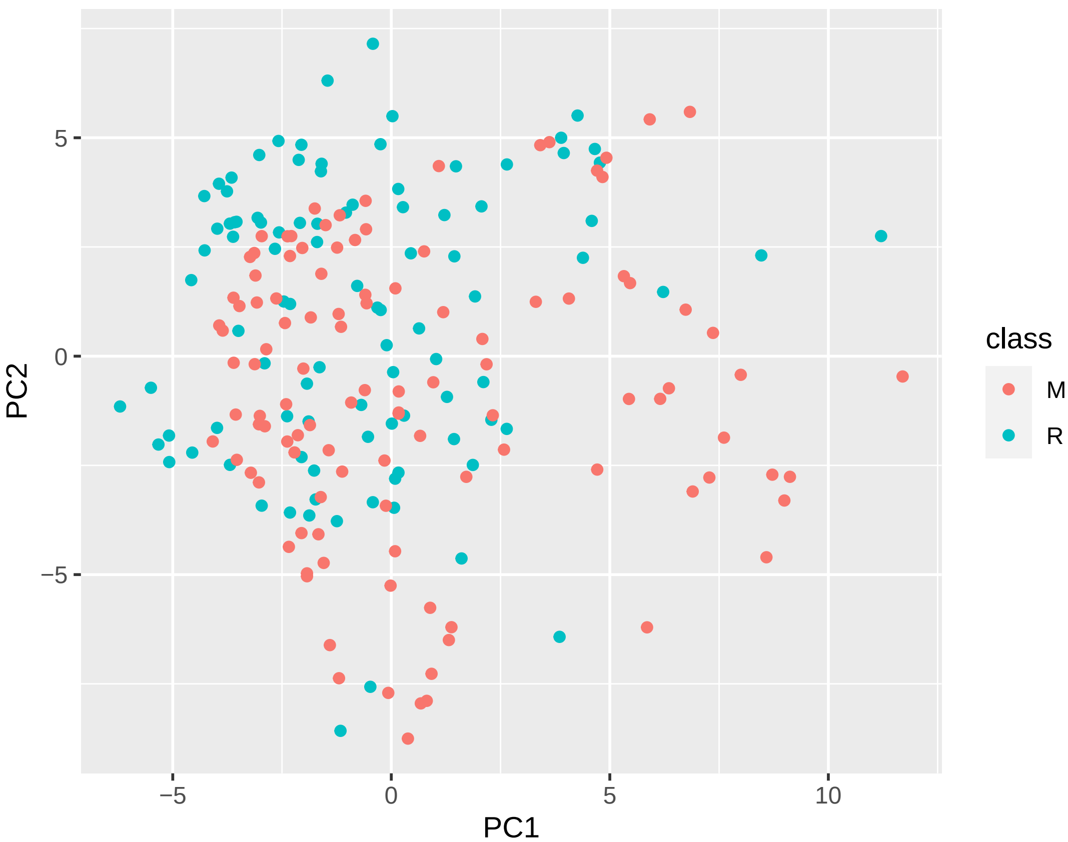
As there are 60 predictors in this data set, principal component analysis seems appropriate for this data set.

In order to do principal component analysis, first we need to scale the matrix. After Scaling, the column mean for the first column is: 1.025822e-17 and standard deviation: 1.

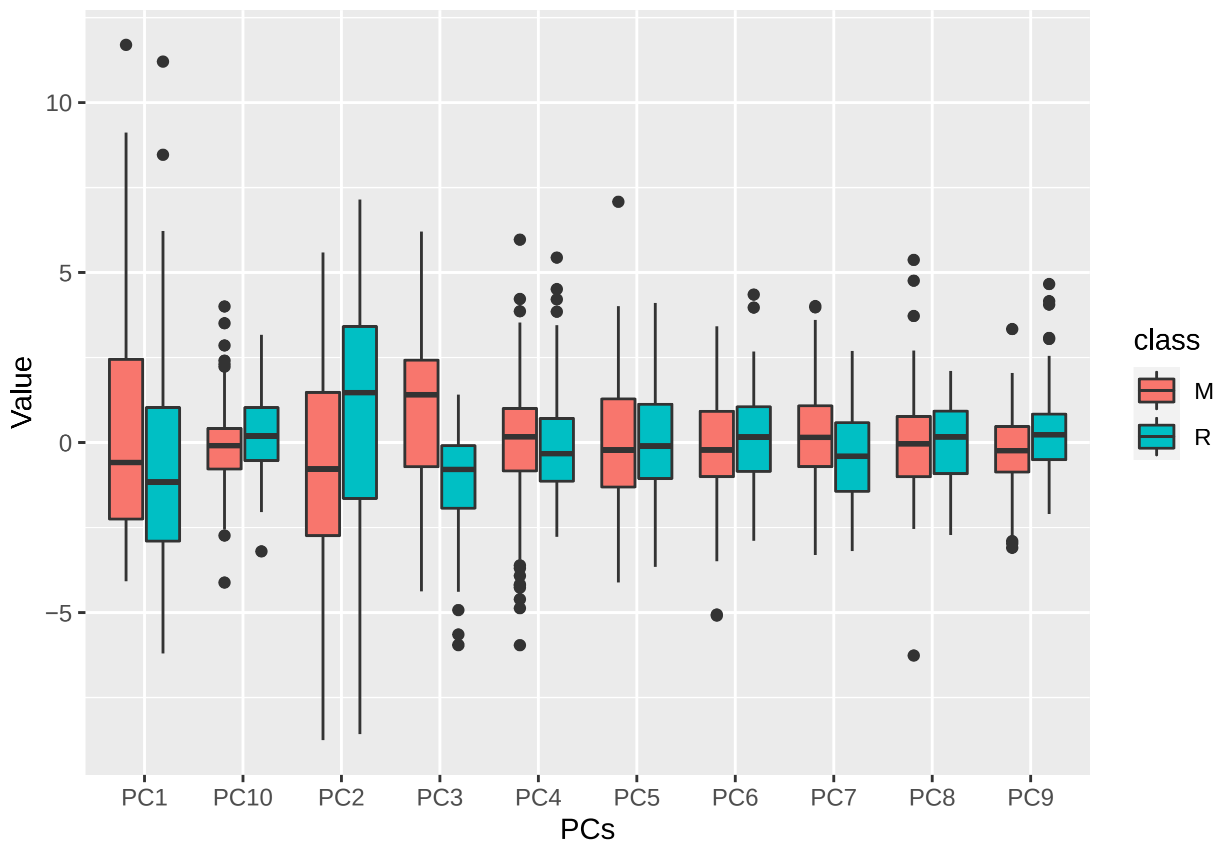
Then we perform the principal component analysis on the scaled matrix. In order to explain 95% of variance we need 30 PCs.

```
##                             PC1      PC2      PC3      PC4      PC5      PC6
## Standard deviation     3.493985 3.367244 2.264949 1.845945 1.733277 1.561729
## Proportion of Variance 0.203470 0.188970 0.085500 0.056790 0.050070 0.040650
## Cumulative Proportion  0.203470 0.392440 0.477940 0.534730 0.584800 0.625450
##                             PC7      PC8      PC9     PC10     PC11     PC12
## Standard deviation     1.402639 1.351991 1.240797 1.222563 1.115871 1.068267
## Proportion of Variance 0.032790 0.030460 0.025660 0.024910 0.020750 0.019020
## Cumulative Proportion  0.658240 0.688700 0.714360 0.739280 0.760030 0.779050
##                           PC13     PC14      PC15      PC16     PC17      PC18
## Standard deviation     1.02381 0.960776 0.9255691 0.9036455 0.860677 0.8373695
## Proportion of Variance 0.01747 0.015380 0.0142800 0.0136100 0.012350 0.0116900
## Cumulative Proportion  0.79652 0.811900 0.8261800 0.8397900 0.852140 0.8638200
##                             PC19     PC20      PC21      PC22      PC23
## Standard deviation     0.7864253 0.766421 0.7526271 0.7297509 0.7098764
## Proportion of Variance 0.0103100 0.009790 0.0094400 0.0088800 0.0084000
## Cumulative Proportion  0.8741300 0.883920 0.8933600 0.9022400 0.9106400
##                             PC24      PC25      PC26      PC27      PC28
## Standard deviation     0.6800756 0.6581472 0.6463919 0.6076369 0.5647656
## Proportion of Variance 0.0077100 0.0072200 0.0069600 0.0061500 0.0053200
## Cumulative Proportion  0.9183400 0.9255600 0.9325300 0.9386800 0.9440000
##                             PC29      PC30
## Standard deviation     0.5610961 0.5451957
## Proportion of Variance 0.0052500 0.0049500
## Cumulative Proportion  0.9492400 0.9542000
```

Below are the plots for first 2 PCs to see how they explain the variance. Although there is not much variability explained but we can somewhat say Mines have higher PC1 value and Rocks have higher PC2 values.



Also plot for first 10 PCs:



In the lot above,PCs are overlapping, but we can say PC1 ad PC2 explains most of the variability.

Modelling on scaled dataset

Now We will fit logistic, LDA, KNN and Random forest models to the scaled dataset. First we will split the scaled dataset to 80% train set and 20% test set.

For KNN, we are using tuning parameter k from 3 to 21. The best accuracy is achieved at k = 3.

```
##   k
## 1 3
```

For random forest,the best accuracy is achieved at mtry = 3 and most important variable is V12.

```
##   mtry
## 1    3
```

```
## rf variable importance
##
##   only 20 most important variables shown (out of 60)
##
##     Importance
## V12     100.00
## V11      90.72
## V9       74.97
## V10      68.84
```

```
## V37       66.43
## V36       64.45
## V49       63.10
## V48       61.86
## V45       61.26
## V28       57.73
## V27       51.71
## V23       49.80
## V43       49.51
## V52       49.50
## V16       49.47
## V46       45.99
## V20       44.67
## V47       43.60
## V21       43.48
## V33       42.82
```

We also combined all above models prediction to create an ensemble.

Modelling on PCA transformed Data

Here we performed the same analysis above but on PCA transformed data to see if we get better accuracy for this dataset. We will take the first 30 PCs (explain 95% variability).

Results

Now we can compare the results of different models and their accuracy.

Model Result (Raw data)

Below is the accuracy table when models fitted on non PCA'ed data:

```
##                glm       lda       knn        rf     ensem
## Accuracy 0.7674419 0.7906977 0.9069767 0.8139535 0.8372093
```

Model Result (PCA tranformed data)

Below is the accuracy table when models fitted on PCA transformed data:

```
##            glm_pca   lda_pca   knn_pca    rf_pca
## Accuracy 0.6976744 0.6511628 0.8372093 0.7209302
```

It looks like on pca transformed data the models don't fit well. This is expected as the first PC did not explain much of the variability. KNN has the highest accuracy in both analysis, so it is the preferred model for this data set.

Conclusion

In summary, this analysis shows it is possible to classify the sonar signals those bounce off a metal cylinder and those bounce off a roughly cylindrical rock. KNN is the highest performing model with accuracy around 90%. Future work can be done to improve the accuracy above 90%.