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Predicictive Modeling Project Report

Letter Image Recognition

Goal of this project is to compare different classifier systems to learn to correctly guess the letter categories associated with feature of 16 integer attributes extracted from scan images of the letters.

Data set information :

Data Set Characteristics:	Multivariate	**Number of Instances:**	20000	**Area:**	Computer
Attribute Characteristics:	Integer	**Number of Attributes:**	16	**Date Donated**	1991-01-01
Associated Tasks:	Classification	**Missing Values?**	No	**Number of Web Hits:**	112212

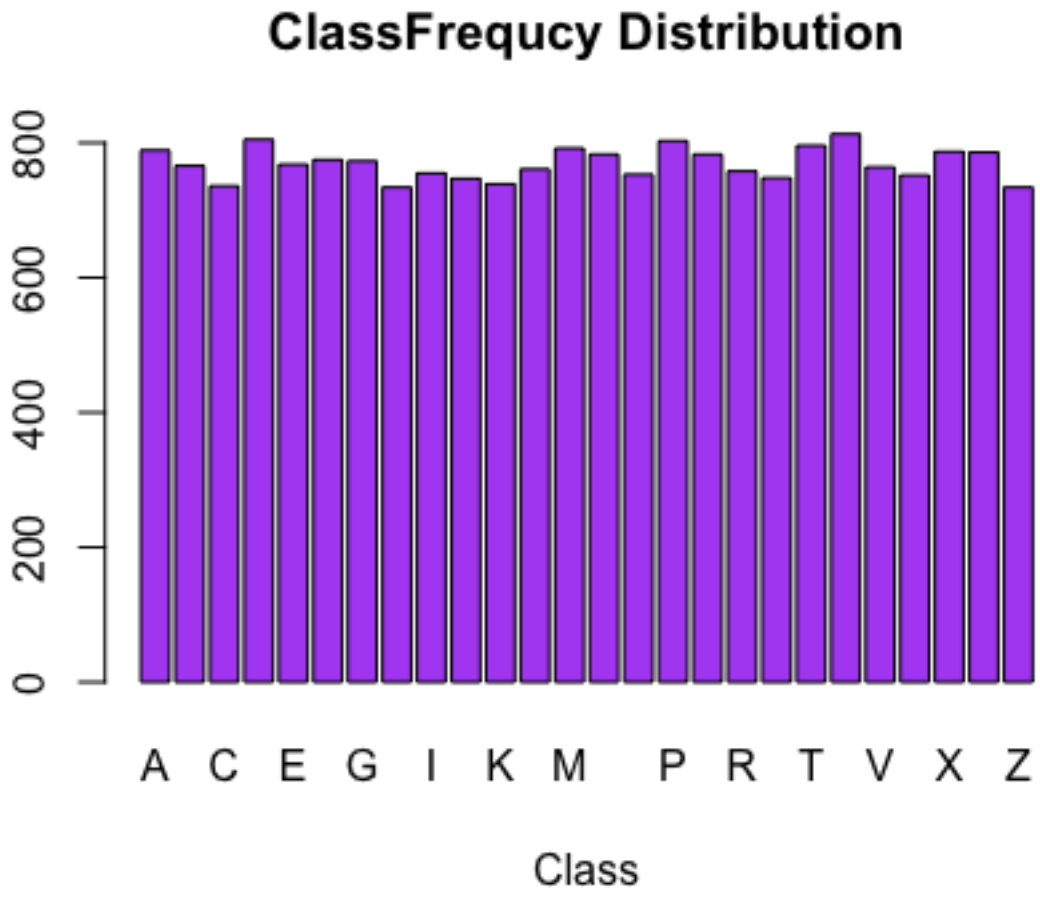
The objective is to identify each of a large number of black-and-white rectangular pixel displays as one of the 26 capital letters in the English alphabet.

Attribute Information:

1. lettr capital letter (26 values from A to Z)
2. x-box horizontal position of box (integer)
3. y-box vertical position of box (integer)
4. width width of box (integer)
5. high height of box (integer)
6. onpix total # on pixels (integer)
7. x-bar mean x of on pixels in box (integer)
8. y-bar mean y of on pixels in box (integer)
9. x2bar mean x variance (integer)
10. y2bar mean y variance (integer)
11. xybar mean x y correlation (integer)

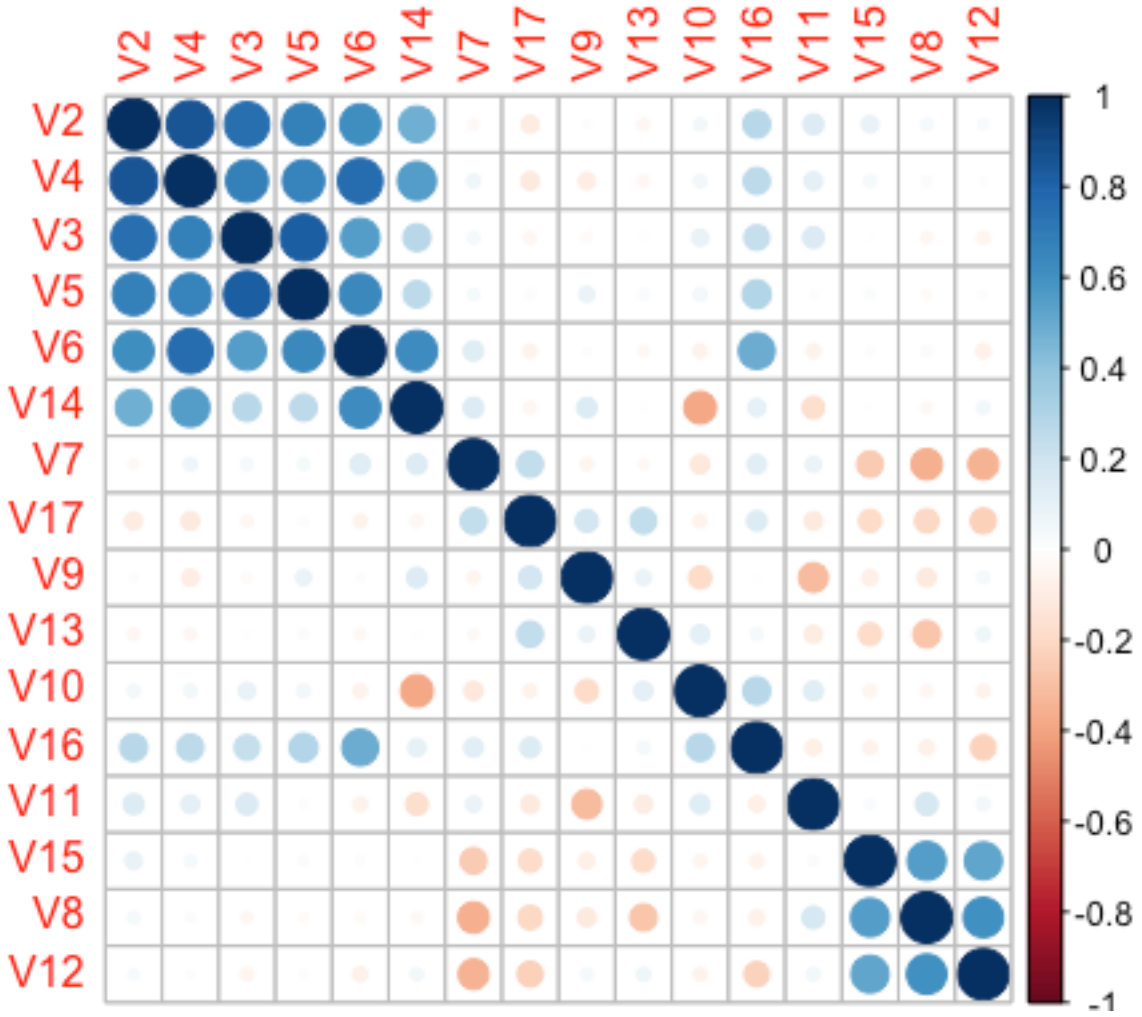
12.	x2ybr	mean of x * x * y	(integer)
13.	xy2br	mean of x * y * y	(integer)
14.	x-ege	mean edge count left to right	(integer)
15.	xegvy	correlation of x-ege with y	(integer)
16.	y-ege	mean edge count bottom to top	(integer)
17.	yegvx	correlation of y-ege with x	(integer)

After loading the data, class distributions were observed to see any class imbalances. As the figure below shows class frequency distribution is uniform.



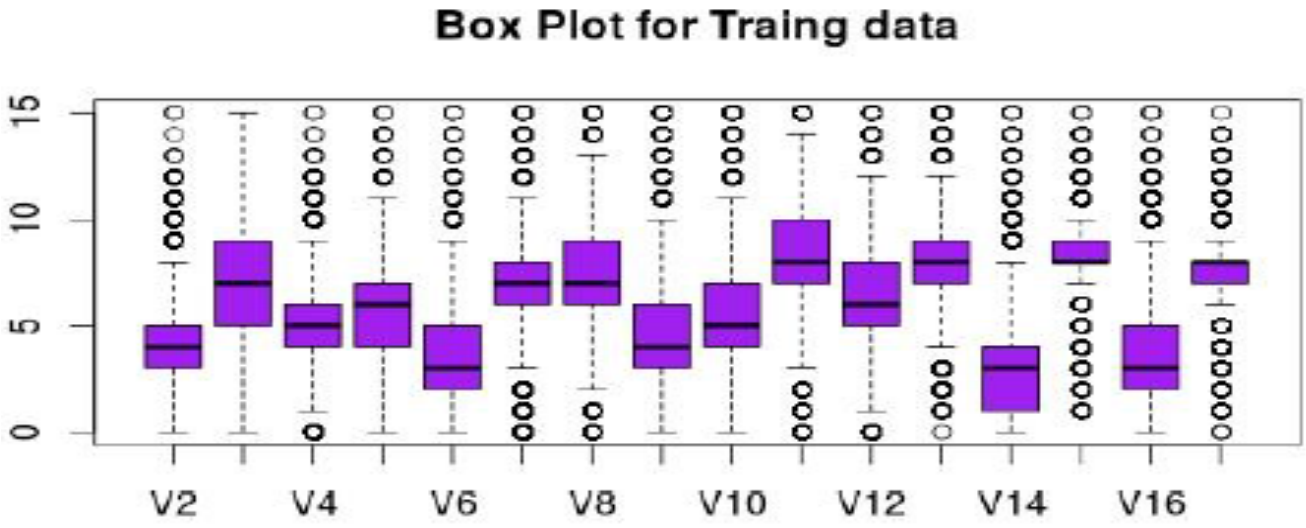
Preprocessing the data set:

Correlations between predictors were visualized to find out if there are correlations greater than 0.75. As the figure below shows there are some predicators, which are correlated. These high correlated predictors were removed using the caret packages, findCorrelation() function.



After removing the high correlated predictors, box plots were used to find out skewness in predictor variables.

The figure below shows boxplots for all the predictors and none of them show too high or low skewness. So transformations of data weren't necessary.



Data set was split to 75% training and 25% testing using random sampling.

Linear Models

1. Linear Discriminant Analysis

```
  15000 samples
     13 predictor
     26 classes: 'A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'J', 'K', 'L', 'M', 'N', 'O
', 'P', 'Q', 'R', 'S', 'T', 'U', 'V', 'W', 'X', 'Y', 'Z'

  Pre-processing: centered, scaled
  Resampling: Bootstrapped (25 reps)

  Summary of sample sizes: 15000, 15000, 15000, 15000, 15000, 15000, ...

  Resampling results across tuning parameters:

    dimen  Accuracy   Kappa      Accuracy SD  Kappa SD
     1     0.1685297  0.1355126  0.008434755  0.008705092
     2     0.3497718  0.3236751  0.006712291  0.006945867
     3     0.4289124  0.4060080  0.015855319  0.016455423
     4     0.5390830  0.5205938  0.007712305  0.008013558
     5     0.5833730  0.5666671  0.006934202  0.007205122
     6     0.6151006  0.5996624  0.008165075  0.008487258
     7     0.6250795  0.6100264  0.009064244  0.009421349
     8     0.6726983  0.6595546  0.006922812  0.007192980
     9     0.6816396  0.6688550  0.006811382  0.007074126
    10     0.6904524  0.6780292  0.006649750  0.006907253
    11     0.6867831  0.6742183  0.007103359  0.007377300
    12     0.6925854  0.6802618  0.007167037  0.007444857
    13     0.6915845  0.6792207  0.006972897  0.007243935

  Kappa was used to select the optimal model using  the largest value.
  The final value used for the model was dimen = 12.
```

```
Confusion Matrix and Statistics

  Overall Statistics

                Accuracy : 0.6882


                   Kappa : 0.6757
```

2. Partial Least Squares

```
  15000 samples
     13 predictor
     26 classes: 'A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'J', 'K', 'L', 'M', 'N', 'O
', 'P', 'Q', 'R', 'S', 'T', 'U', 'V', 'W', 'X', 'Y', 'Z'

  Pre-processing: centered, scaled
  Resampling: Bootstrapped (25 reps)

  Summary of sample sizes: 15000, 15000, 15000, 15000, 15000, 15000, ...

  Resampling results across tuning parameters:

    ncomp  Accuracy    Kappa      Accuracy SD  Kappa SD
    1      0.07420849  0.0372415  0.003271222  0.002700414
    2      0.17892449  0.1469015  0.010474731  0.010607809

  Kappa was used to select the optimal model using  the largest value.
  The final value used for the model was ncomp = 2.


  Overall Statistics

                 Accuracy : 0.1908


                    Kappa : 0.1571
```

3. Penalized Models

```
glmnet



15000 samples

   13 predictor

   26 classes: 'A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'J', 'K', 'L', 'M', 'N', 'O',
'P', 'Q', 'R', 'S', 'T', 'U', 'V', 'W', 'X', 'Y', 'Z'



Pre-processing: centered, scaled
Resampling: Bootstrapped (25 reps)

Summary of sample sizes: 15000, 15000, 15000, 15000, 15000, 15000, ...



Resampling results across tuning parameters:
```

alpha	lambda	Accuracy	Kappa	Accuracy SD	Kappa SD
0.0	0.1000000	0.5768891	0.5600010	0.01298131	0.01342248
0.0	0.1111111	0.5682126	0.5509860	0.01323037	0.01367192
0.0	0.1222222	0.5601518	0.5426123	0.01334577	0.01378078
0.0	0.1333333	0.5533433	0.5355393	0.01346102	0.01389497
0.0	0.1444444	0.5470622	0.5290141	0.01383478	0.01427529
0.0	0.1555556	0.5410713	0.5227907	0.01451011	0.01496821
0.0	0.1666667	0.5353392	0.5168374	0.01481343	0.01527790
0.0	0.1777778	0.5304621	0.5117712	0.01490745	0.01537096
0.0	0.1888889	0.5251520	0.5062547	0.01485169	0.01530962
0.0	0.2000000	0.5203919	0.5013103	0.01492080	0.01537833
0.1	0.1000000	0.5014833	0.4816663	0.01289188	0.01327896
0.1	0.1111111	0.4852512	0.4648082	0.01358775	0.01398503
0.1	0.1222222	0.4703423	0.4493276	0.01356431	0.01394621
0.1	0.1333333	0.4548711	0.4332666	0.01519515	0.01561544
0.1	0.1444444	0.4402404	0.4180760	0.01596798	0.01640747
0.1	0.1555556	0.4254912	0.4027650	0.01725252	0.01773493
0.1	0.1666667	0.4094354	0.3860944	0.01900821	0.01954999
0.1	0.1777778	0.3940862	0.3701506	0.01849510	0.01903835
0.1	0.1888889	0.3794613	0.3549606	0.02072140	0.02135320
0.1	0.2000000	0.3638619	0.3387574	0.02230321	0.02300903

Accuracy was used to select the optimal model using the largest value.
The final values used for the model were alpha = 0 and lambda = 0.1.

Overall Statistics

```
               Accuracy : 0.5808
                 95% CI : (0.567, 0.5945)
    No Information Rate : 0.0456
    P-Value [Acc > NIR] : < 2.2e-16

                  Kappa : 0.5639
```

```
 Mcnemar's Test P-Value : NA
```

4. Nearest Shrunken Centroids

```
15000 samples
   13 predictor
   26 classes: 'A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'J', 'K', 'L', 'M', 'N', 'O',
'P', 'Q', 'R', 'S', 'T', 'U', 'V', 'W', 'X', 'Y', 'Z'

Pre-processing: centered, scaled
Resampling: Bootstrapped (25 reps)

Summary of sample sizes: 15000, 15000, 15000, 15000, 15000, 15000, ...

Resampling results across tuning parameters:
```

threshold	Accuracy	Kappa	Accuracy SD	Kappa SD
0	0.6080019	0.5923025	0.006248540	0.006473857
1	0.6036960	0.5878307	0.006435820	0.006662524
2	0.5948069	0.5785900	0.007077063	0.007325056
3	0.5842482	0.5676138	0.008558737	0.008860115
4	0.5717130	0.5545881	0.010274424	0.010647078
5	0.5579820	0.5403286	0.011095785	0.011497738
6	0.5403542	0.5220250	0.012315319	0.012748859
7	0.5183379	0.4991683	0.012693090	0.013130464
8	0.4929050	0.4727736	0.011473305	0.011865651
9	0.4612455	0.4399211	0.013049754	0.013482382
10	0.4308509	0.4083684	0.014772277	0.015266688
11	0.4022141	0.3786233	0.014943307	0.015434551
12	0.3711531	0.3463274	0.015064321	0.015529815
13	0.3455720	0.3197119	0.014186495	0.014597165
14	0.3228725	0.2960926	0.014237422	0.014671842
15	0.3043471	0.2767924	0.011561100	0.011919913
16	0.2915882	0.2634689	0.013995954	0.014411181

```
  17         0.2846178  0.2561714  0.017144759  0.017666049

Kappa was used to select the optimal model using  the largest value.

The final value used for the model was threshold = 0.

Overall Statistics


               Accuracy : 0.614

                  Kappa : 0.5985
```

Non - Linear models

1. K- Nearest Neighbour

```
15000 samples

   13 predictor

   26 classes: 'A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'J', 'K', 'L', 'M', 'N', '
O', 'P', 'Q', 'R', 'S', 'T', 'U', 'V', 'W', 'X', 'Y', 'Z'


Pre-processing: centered, scaled

Resampling: Bootstrapped (25 reps)


Summary of sample sizes: 15000, 15000, 15000, 15000, 15000, 15000, ...


Resampling results across tuning parameters:


  k   Accuracy   Kappa      Accuracy SD  Kappa SD
   3  0.9188318  0.9155698  0.003479140  0.003618114
   5  0.9170265  0.9136917  0.003572591  0.003715878
   7  0.9163788  0.9130183  0.003412833  0.003549829
   9  0.9150894  0.9116772  0.003584294  0.003727636
  11  0.9134054  0.9099255  0.003621076  0.003766167


Kappa was used to select the optimal model using  the largest value.

The final value used for the model was k = 3.
```

```
Overall Statistics for Testing set:


                Accuracy : 0.9544
                   Kappa : 0.9526
```

Improved KNN. For the problem of nearest neighbor classification, a simpler approach called "leave-out-one" cross-validation can be used, and this is provided by the knn.cv function. Using this technique, the observation itself is ignored when looking for its neighbors.

2. K- Neareset Neighbout with CV

```
myknn<-knn.cv(x, y, k = 3, l = 0, prob = FALSE, use.all = TRUE)
confusionMatrix(myknn, y)
```

```
  Overall Statistics for testing set.

                Accuracy : 0.9614
                   Kappa : 0.9599
```

3. SVM

```
Support Vector Machines with Radial Basis Function Kernel

  15000 samples
     13 predictor
     26 classes: 'A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'J', 'K', 'L', 'M', 'N', 'O
', 'P', 'Q', 'R', 'S', 'T', 'U', 'V', 'W', 'X', 'Y', 'Z'

  Pre-processing: centered, scaled
  Resampling: Bootstrapped (25 reps)

  Summary of sample sizes: 15000, 15000, 15000, 15000, 15000, 15000, ...

  Resampling results across tuning parameters:

    C     Accuracy   Kappa      Accuracy SD  Kappa SD
    0.25  0.8116716  0.8041039  0.005517341  0.005736462
    0.50  0.8429431  0.8366312  0.004796872  0.004988122
    1.00  0.8686856  0.8634081  0.004181792  0.004350780
```

```
    2.00  0.8903813  0.8859756  0.003851433  0.004006828
    4.00  0.9079643  0.9042654  0.003491611  0.003631531

    8.00  0.9224697  0.9193564  0.002909209  0.003025576

    16.00  0.9336818  0.9310184  0.002754771  0.002865363

   32.00  0.8263113  0.8359756  0.002861032  0.00425156



   Tuning parameter 'sigma' was held constant at a value of 0.0223395
Kappa was used to select the optimal model using  the largest value.
The final values used for the model were sigma = 0.0223395 and C = 16.


  Overall Statistics

                 Accuracy : 0.9392
                    Kappa : 0.9368
```

4. Neural Network

```
  15000 samples
     13 predictor
     26 classes: 'A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'J', 'K', 'L', 'M', 'N', 'O
', 'P', 'Q', 'R', 'S', 'T', 'U', 'V', 'W', 'X', 'Y', 'Z'

  Pre-processing: centered, scaled
  Resampling: Bootstrapped (25 reps)

  Summary of sample sizes: 15000, 15000, 15000, 15000, 15000, 15000, ...


Resampling results across tuning parameters:

    size  decay  Accuracy   Kappa       Accuracy SD  Kappa SD
     1    0.0    0.1721552  0.13925465  0.012104369  0.012588550
     1    0.1    0.1645228  0.13141653  0.008313172  0.008761456
     1    1.0    0.1366458  0.10276125  0.006194946  0.006369236
     1    2.0    0.1243592  0.09018002  0.008899931  0.008694901
     2    0.0    0.3392758  0.31291087  0.039539183  0.041060387
     2    0.1    0.3389576  0.31261560  0.011208979  0.011558657
     2    1.0    0.2963639  0.26850521  0.011969575  0.012334720
     2    2.0    0.2724686  0.24372387  0.014093756  0.014460833
     3    0.0    0.5012276  0.48124893  0.022398048  0.023284106
     3    0.1    0.4965047  0.47636823  0.008824991  0.009161699
     3    1.0    0.4581531  0.43656710  0.008548176  0.008836588
     3    2.0    0.4261495  0.40337037  0.011090971  0.011372202
```

```
Kappa was used to select the optimal model using  the largest value.
  The final values used for the model were size = 3 and decay = 0.


  Overall Statistics for Testing set

                 Accuracy : 0.4882
                    Kappa : 0.4675
```

Base on Testing data metrics(Kappa and Accuracy) KNN with CV is chosen to do the predicti ve model based on the below table.

Model(blue=linear, red=Non linear)	Kappa	Accuracy
LDA	0.68	0.67
PLSDA	0.15	0.19
Penalize Models	0.5962	0.5808
Nearest Shrunken Centroids	0.5921	0.6193
KNN	0.9529	0.9544
KNN-CV	**0.9599**	**0.9614**
SVM	0.9392	0.9396
NeuralNet	0.4882	0.4246