```
> #Libraries
> library(devtools)
> devtools::install_github("jlmelville/snedata", force=TRUE)
Downloading GitHub repo jlmelville/snedata@HEAD
── R CMD build ─────────────────────────────────────────────────────
✓  checking for file
'C:\Users\husse\AppData\Local\Temp\Rtmp4ECQIM\remotes3ffc6b8e769\jlmelvill
e-snedata-c8cfdbf/DESCRIPTION' ...
─  preparing 'snedata': (578ms)
✓  checking DESCRIPTION meta-information ...
─  checking for LF line-endings in source and make files and shell scripts
─  checking for empty or unneeded directories
─  building 'snedata_0.0.0.9000.tar.gz'

Warning: package ‘snedata’ is in use and will not be installed
> library(snedata)
> library(plotly)
> library(ISLR)
> library(e1071)
> library(ISLR2)
> library(MASS)
> library(glmnet)
> library(randomForest)
> library(caret)
> library(keras)
> library(reticulate)
> library(tensorflow)
> library(class)
> library(datasets)
> library(nnet)
> #Splitting data
> dat<- snedata::download_fashion_mnist()
> set.seed(1)
> train<-sample(60000,1200)
> x.train<-dat[train,1:784]
> y.train<-dat[train,785]
> table(y.train)
y.train
  0   1   2   3   4   5   6   7   8   9
123 107 136 122 101 158 115 109 112 117
> types<-dat[train,786]
> table(types)
types
T-shirt/top     Trouser    Pullover       Dress        Coat
        123         107         136         122         101
     Sandal       Shirt     Sneaker         Bag  Ankle boot
        158         115         109         112         117
> types[326]
[1] Dress
10 Levels: T-shirt/top Trouser Pullover Dress Coat ... Ankle boot
> x<-matrix(as.numeric(x.train[326,]),nrow=28)
> image(x[,28:1])
> types[900]
```

```
[1] Coat
10 Levels: T-shirt/top Trouser Pullover Dress Coat ... Ankle boot
> x<-matrix(as.numeric(x.train[900,]),nrow=28)
> image(x[,28:1])
> ind<-c(60001:70000)
> test<-sample(ind,600)
> x.test<-dat[test,1:784]
> y.test<-dat[test,785]
> table(y.test)
y.test
 0  1  2  3  4  5  6  7  8  9
47 65 60 60 72 52 54 65 68 57
> #Part I: PCA
> pca.train<-prcomp(x.train,center=TRUE,scale.=FALSE)
> var.explained<-cumsum(pca.train$sdev^2)/sum(pca.train$sdev^2)
> var.explained
  [1] 0.2939141 0.4667171 0.5261355 0.5757745 0.6152747 0.6503085
  [7] 0.6738004 0.6930777 0.7071935 0.7201411 0.7305922 0.7391539
 [13] 0.7467871 0.7538116 0.7603720 0.7663954 0.7719123 0.7771586
 [19] 0.7823608 0.7871666 0.7917093 0.7959012 0.8000147 0.8039821
 [25] 0.8077562 0.8114544 0.8148207 0.8180929 0.8212354 0.8243591
 [31] 0.8274291 0.8303315 0.8331312 0.8359010 0.8386366 0.8411421
 [37] 0.8436193 0.8460434 0.8483398 0.8505417 0.8527035 0.8547643
 [43] 0.8567217 0.8586735 0.8605693 0.8624287 0.8642389 0.8660099
 [49] 0.8677462 0.8694367 0.8710730 0.8726873 0.8742418 0.8757725
 [55] 0.8772810 0.8787540 0.8801883 0.8815841 0.8829687 0.8843215
 [61] 0.8856271 0.8869275 0.8882067 0.8894631 0.8906818 0.8918903
 [67] 0.8930939 0.8942717 0.8954084 0.8965313 0.8976280 0.8987059
 [73] 0.8997777 0.9008332 0.9018649 0.9028817 0.9038931 0.9048687
 [79] 0.9058401 0.9067869 0.9077194 0.9086487 0.9095699 0.9104677
 [85] 0.9113584 0.9122284 0.9130872 0.9139395 0.9147733 0.9156030
 [91] 0.9164162 0.9172089 0.9179996 0.9187850 0.9195508 0.9203074
 [97] 0.9210542 0.9217913 0.9225235 0.9232409 0.9239476 0.9246498
[103] 0.9253439 0.9260331 0.9267108 0.9273826 0.9280496 0.9287058
[109] 0.9293538 0.9299897 0.9306149 0.9312342 0.9318513 0.9324611
[115] 0.9330691 0.9336743 0.9342706 0.9348585 0.9354380 0.9360017
[121] 0.9365606 0.9371183 0.9376682 0.9382121 0.9387475 0.9392770
[127] 0.9398007 0.9403137 0.9408191 0.9413198 0.9418158 0.9423075
[133] 0.9427892 0.9432671 0.9437388 0.9442076 0.9446736 0.9451348
[139] 0.9455890 0.9460419 0.9464908 0.9469376 0.9473802 0.9478174
[145] 0.9482525 0.9486854 0.9491081 0.9495300 0.9499452 0.9503568
[151] 0.9507647 0.9511702 0.9515699 0.9519653 0.9523585 0.9527477
[157] 0.9531295 0.9535070 0.9538840 0.9542582 0.9546289 0.9549987
[163] 0.9553607 0.9557180 0.9560726 0.9564257 0.9567759 0.9571248
[169] 0.9574685 0.9578081 0.9581435 0.9584762 0.9588069 0.9591354
[175] 0.9594602 0.9597849 0.9601080 0.9604259 0.9607398 0.9610528
[181] 0.9613643 0.9616695 0.9619715 0.9622713 0.9625683 0.9628636
[187] 0.9631569 0.9634491 0.9637381 0.9640254 0.9643090 0.9645905
[193] 0.9648703 0.9651461 0.9654213 0.9656936 0.9659635 0.9662310
[199] 0.9664977 0.9667605 0.9670213 0.9672789 0.9675361 0.9677917
[205] 0.9680448 0.9682974 0.9685465 0.9687950 0.9690402 0.9692827
[211] 0.9695235 0.9697631 0.9700005 0.9702351 0.9704691 0.9707003
[217] 0.9709294 0.9711575 0.9713834 0.9716066 0.9718290 0.9720484
[223] 0.9722673 0.9724839 0.9726971 0.9729086 0.9731185 0.9733272
```

```
[229] 0.9735353 0.9737413 0.9739466 0.9741492 0.9743501 0.9745501
[235] 0.9747488 0.9749460 0.9751423 0.9753358 0.9755279 0.9757184
[241] 0.9759079 0.9760968 0.9762843 0.9764698 0.9766538 0.9768365
[247] 0.9770185 0.9771985 0.9773770 0.9775538 0.9777292 0.9779041
[253] 0.9780768 0.9782487 0.9784190 0.9785876 0.9787558 0.9789229
[259] 0.9790890 0.9792534 0.9794150 0.9795748 0.9797337 0.9798909
[265] 0.9800470 0.9802020 0.9803563 0.9805099 0.9806623 0.9808141
[271] 0.9809642 0.9811135 0.9812622 0.9814091 0.9815536 0.9816972
[277] 0.9818401 0.9819822 0.9821234 0.9822634 0.9824029 0.9825415
[283] 0.9826782 0.9828141 0.9829495 0.9830840 0.9832179 0.9833513
[289] 0.9834829 0.9836144 0.9837443 0.9838735 0.9840008 0.9841279
[295] 0.9842546 0.9843795 0.9845040 0.9846282 0.9847515 0.9848737
[301] 0.9849954 0.9851146 0.9852323 0.9853494 0.9854662 0.9855825
[307] 0.9856984 0.9858135 0.9859278 0.9860417 0.9861551 0.9862674
[313] 0.9863776 0.9864872 0.9865962 0.9867044 0.9868120 0.9869192
[319] 0.9870251 0.9871309 0.9872359 0.9873406 0.9874441 0.9875471
[325] 0.9876494 0.9877505 0.9878509 0.9879505 0.9880492 0.9881475
[331] 0.9882451 0.9883422 0.9884386 0.9885340 0.9886287 0.9887229
[337] 0.9888165 0.9889093 0.9890015 0.9890925 0.9891830 0.9892729
[343] 0.9893616 0.9894497 0.9895363 0.9896228 0.9897092 0.9897951
[349] 0.9898796 0.9899636 0.9900470 0.9901300 0.9902124 0.9902947
[355] 0.9903756 0.9904562 0.9905356 0.9906148 0.9906934 0.9907714
[361] 0.9908489 0.9909259 0.9910025 0.9910790 0.9911550 0.9912297
[367] 0.9913042 0.9913785 0.9914525 0.9915260 0.9915985 0.9916704
[373] 0.9917421 0.9918128 0.9918831 0.9919528 0.9920221 0.9920912
[379] 0.9921598 0.9922281 0.9922955 0.9923628 0.9924294 0.9924958
[385] 0.9925614 0.9926267 0.9926913 0.9927553 0.9928189 0.9928821
[391] 0.9929451 0.9930077 0.9930696 0.9931313 0.9931920 0.9932525
[397] 0.9933123 0.9933722 0.9934315 0.9934904 0.9935485 0.9936064
[403] 0.9936634 0.9937201 0.9937766 0.9938322 0.9938873 0.9939423
[409] 0.9939969 0.9940511 0.9941048 0.9941583 0.9942114 0.9942644
[415] 0.9943168 0.9943688 0.9944205 0.9944719 0.9945229 0.9945738
[421] 0.9946241 0.9946737 0.9947230 0.9947717 0.9948197 0.9948676
[427] 0.9949153 0.9949625 0.9950094 0.9950560 0.9951023 0.9951483
[433] 0.9951941 0.9952396 0.9952847 0.9953294 0.9953738 0.9954179
[439] 0.9954615 0.9955046 0.9955474 0.9955900 0.9956321 0.9956742
[445] 0.9957157 0.9957569 0.9957977 0.9958385 0.9958791 0.9959194
[451] 0.9959591 0.9959987 0.9960380 0.9960771 0.9961159 0.9961542
[457] 0.9961920 0.9962298 0.9962669 0.9963038 0.9963405 0.9963768
[463] 0.9964127 0.9964483 0.9964837 0.9965187 0.9965536 0.9965883
[469] 0.9966228 0.9966569 0.9966907 0.9967244 0.9967576 0.9967907
[475] 0.9968235 0.9968560 0.9968885 0.9969208 0.9969527 0.9969843
[481] 0.9970154 0.9970463 0.9970770 0.9971077 0.9971378 0.9971677
[487] 0.9971973 0.9972267 0.9972558 0.9972849 0.9973135 0.9973420
[493] 0.9973704 0.9973985 0.9974262 0.9974537 0.9974811 0.9975082
[499] 0.9975350 0.9975616 0.9975881 0.9976143 0.9976404 0.9976664
[505] 0.9976919 0.9977172 0.9977424 0.9977675 0.9977925 0.9978171
[511] 0.9978415 0.9978657 0.9978898 0.9979135 0.9979370 0.9979603
[517] 0.9979835 0.9980065 0.9980294 0.9980519 0.9980744 0.9980967
[523] 0.9981186 0.9981404 0.9981620 0.9981834 0.9982045 0.9982256
[529] 0.9982466 0.9982673 0.9982879 0.9983083 0.9983284 0.9983485
[535] 0.9983682 0.9983876 0.9984068 0.9984260 0.9984449 0.9984637
[541] 0.9984822 0.9985007 0.9985191 0.9985372 0.9985550 0.9985726
[547] 0.9985903 0.9986078 0.9986251 0.9986424 0.9986595 0.9986763
```

```
[553] 0.9986930 0.9987095 0.9987259 0.9987422 0.9987583 0.9987745
[559] 0.9987903 0.9988058 0.9988213 0.9988366 0.9988517 0.9988668
[565] 0.9988818 0.9988966 0.9989114 0.9989260 0.9989403 0.9989545
[571] 0.9989685 0.9989824 0.9989962 0.9990098 0.9990233 0.9990366
[577] 0.9990499 0.9990630 0.9990760 0.9990889 0.9991017 0.9991143
[583] 0.9991270 0.9991394 0.9991515 0.9991636 0.9991755 0.9991874
[589] 0.9991993 0.9992111 0.9992227 0.9992342 0.9992456 0.9992569
[595] 0.9992681 0.9992791 0.9992900 0.9993007 0.9993114 0.9993219
[601] 0.9993324 0.9993427 0.9993529 0.9993630 0.9993731 0.9993830
[607] 0.9993928 0.9994024 0.9994119 0.9994214 0.9994309 0.9994401
[613] 0.9994492 0.9994582 0.9994671 0.9994759 0.9994847 0.9994934
[619] 0.9995021 0.9995106 0.9995191 0.9995274 0.9995356 0.9995437
[625] 0.9995517 0.9995596 0.9995674 0.9995752 0.9995829 0.9995904
[631] 0.9995979 0.9996053 0.9996127 0.9996198 0.9996269 0.9996338
[637] 0.9996407 0.9996475 0.9996542 0.9996609 0.9996674 0.9996738
[643] 0.9996801 0.9996864 0.9996926 0.9996987 0.9997047 0.9997107
[649] 0.9997166 0.9997224 0.9997282 0.9997339 0.9997395 0.9997451
[655] 0.9997506 0.9997561 0.9997614 0.9997668 0.9997720 0.9997771
[661] 0.9997822 0.9997872 0.9997922 0.9997970 0.9998018 0.9998064
[667] 0.9998110 0.9998156 0.9998201 0.9998245 0.9998288 0.9998331
[673] 0.9998374 0.9998415 0.9998455 0.9998495 0.9998535 0.9998573
[679] 0.9998612 0.9998649 0.9998686 0.9998722 0.9998757 0.9998792
[685] 0.9998827 0.9998860 0.9998894 0.9998926 0.9998959 0.9998990
[691] 0.9999021 0.9999052 0.9999082 0.9999112 0.9999141 0.9999169
[697] 0.9999197 0.9999225 0.9999251 0.9999278 0.9999304 0.9999330
[703] 0.9999355 0.9999379 0.9999403 0.9999426 0.9999449 0.9999471
[709] 0.9999492 0.9999513 0.9999534 0.9999555 0.9999574 0.9999593
[715] 0.9999612 0.9999630 0.9999647 0.9999664 0.9999681 0.9999697
[721] 0.9999713 0.9999728 0.9999742 0.9999757 0.9999770 0.9999783
[727] 0.9999796 0.9999809 0.9999821 0.9999833 0.9999845 0.9999856
[733] 0.9999866 0.9999876 0.9999886 0.9999895 0.9999904 0.9999912
[739] 0.9999920 0.9999927 0.9999934 0.9999941 0.9999948 0.9999953
[745] 0.9999958 0.9999963 0.9999967 0.9999971 0.9999975 0.9999978
[751] 0.9999981 0.9999984 0.9999987 0.9999989 0.9999991 0.9999992
[757] 0.9999993 0.9999995 0.9999996 0.9999997 0.9999997 0.9999998
[763] 0.9999999 0.9999999 0.9999999 0.9999999 1.0000000 1.0000000
[769] 1.0000000 1.0000000 1.0000000 1.0000000 1.0000000 1.0000000
[775] 1.0000000 1.0000000 1.0000000 1.0000000 1.0000000 1.0000000
[781] 1.0000000 1.0000000 1.0000000 1.0000000
> pca.dim = 74
> x.pca.train<-pca.train$x[,1:pca.dim]
> dim(x.pca.train)
[1] 1200   74
> pairs(x.pca.train[,1:5],col=y.train)
> x.pca.test<-predict(pca.train,newdata=x.test)
> x.pca.test<-x.pca.test[,1:pca.dim]
> dim(x.pca.test)
[1] 600  74
> #Embedded into 74 dimensions
> #KNN
> set.seed(12345)
> K_folds <- trainControl(method = "repeatedcv",
+                             number=10, repeats =10)
> #KNN Using PCA
```

```
> dat.pca.train=data.frame(x=x.pca.train, y=as.factor(y.train))
> dat.pca.test=data.frame(x=x.pca.test, y=as.factor(y.test))
> tuned_K <- caret::train(y~., data = dat.pca.train,
+                         method = "knn", trControl = K_folds)
> tuned_K
k-Nearest Neighbors

1200 samples
  74 predictor
  10 classes: '0', '1', '2', '3', '4', '5', '6', '7', '8', '9'

No pre-processing
Resampling: Cross-Validated (10 fold, repeated 10 times)
Summary of sample sizes: 1079, 1077, 1080, 1083, 1081, 1081, ...
Resampling results across tuning parameters:

  k  Accuracy   Kappa
  5  0.7885100  0.7646598
  7  0.7921245  0.7686598
  9  0.7922035  0.7686752

Accuracy was used to select the optimal model using the
 largest value.
The final value used for the model was k = 9.
> cl <- dat.pca.train$y
> system.time(
+   k<-knn(dat.pca.train, dat.pca.test, cl, k = 7, prob=TRUE))
   user  system elapsed
   0.26    0.00    0.36
> #Error rate:
> 1-sum(k[1:600]==cl)/600
[1] 0.7866667
> #KNN using full dimensions
> dat.train=data.frame(x=x.train, y=as.factor(y.train))
> dat.test=data.frame(x=x.test, y=as.factor(y.test))
> tuned_K_og <- caret::train(y~., data = dat.train,
+                         method = "knn")
> tuned_K_og
k-Nearest Neighbors

1200 samples
 784 predictor
  10 classes: '0', '1', '2', '3', '4', '5', '6', '7', '8', '9'

No pre-processing
Resampling: Bootstrapped (25 reps)
Summary of sample sizes: 1200, 1200, 1200, 1200, 1200, 1200, ...
Resampling results across tuning parameters:

  k  Accuracy   Kappa
  5  0.7388591  0.7094660
  7  0.7385178  0.7090982
  9  0.7383398  0.7088904
```

```
Accuracy was used to select the optimal model using the
 largest value.
The final value used for the model was k = 5.
> cl_og <- dat.train$y
> system.time(
+   k_og<-knn(dat.train, dat.test, cl = cl_og, k = 7, prob=TRUE))
   user  system elapsed
   2.41    0.00    2.42
> #Error rate:
> 1-sum(k_og[1:600]==cl)/600
[1] 0.7883333
> #Part II: Comparing Across Classifiers
>
>
> Linear SVM using PCA
> system.time(tuned_L_svm <- tune(svm, y~., dat=dat.pca.train,
+                     kernel = "linear",
+                     ranges=list(cost=seq(0.05, 2, length = 20))))
   user  system elapsed
  57.07    0.40   57.99
> summary(tuned_L_svm)

Parameter tuning of ‘svm’:

-  sampling method: 10-fold cross validation

-  best parameters:
 cost
 0.05

-  best performance: 0.2158333

-  Detailed performance results:
         cost     error dispersion
1  0.0500000 0.2158333 0.03273773
2  0.1526316 0.2316667 0.02827336
3  0.2552632 0.2416667 0.02832789
4  0.3578947 0.2425000 0.02845019
5  0.4605263 0.2450000 0.03406602
6  0.5631579 0.2441667 0.03216710
7  0.6657895 0.2475000 0.04121047
8  0.7684211 0.2475000 0.03909667
9  0.8710526 0.2483333 0.03963569
10 0.9736842 0.2475000 0.03889881
11 1.0763158 0.2475000 0.04195272
12 1.1789474 0.2475000 0.03929353
13 1.2815789 0.2483333 0.04040688
14 1.3842105 0.2483333 0.03924441
15 1.4868421 0.2508333 0.03837960
16 1.5894737 0.2491667 0.03937200
17 1.6921053 0.2466667 0.04179610
18 1.7947368 0.2450000 0.04216370
19 1.8973684 0.2433333 0.04097575
20 2.0000000 0.2450000 0.04029214
```

```
> best_L_svm <- tuned_L_svm$best.model
> summary(best_L_svm)

Call:
best.tune(METHOD = svm, train.x = y ~ ., data = dat.pca.train,
    ranges = list(cost = seq(0.05, 2, length = 20)),
    kernel = "linear")


Parameters:
   SVM-Type:  C-classification
 SVM-Kernel:  linear
       cost:  0.05

Number of Support Vectors:  774

 ( 100 83 79 78 39 54 57 61 122 101 )


Number of Classes:  10

Levels:
 0 1 2 3 4 5 6 7 8 9



> L_svm_pred <- predict(best_L_svm, dat.pca.test,
+                       type="response")
> L_svm_error =
+   1-(sum(diag(table
+                (predict = L_svm_pred, truth=dat.pca.test$y))))/600
> #Error rate:
> L_svm_error
[1] 0.23
> #Linear SVM using full dimensions
> system.time(tuned_full_L_svm <- tune(svm, y~., dat=dat.train,
+                                      kernel = "linear",
+                                      ranges=list(cost=seq(0.05, 2, length =
20))))
   user  system elapsed
 600.73    3.70  606.78
There were 50 or more warnings (use warnings() to see the first 50)
> summary(tuned_full_L_svm)

Parameter tuning of ‘svm’:

-  sampling method: 10-fold cross validation

-  best parameters:
 cost
 0.05

-  best performance: 0.195
```

```
-  Detailed performance results:
        cost error dispersion
1  0.0500000 0.195  0.0304797
2  0.1526316 0.195  0.0304797
3  0.2552632 0.195  0.0304797
4  0.3578947 0.195  0.0304797
5  0.4605263 0.195  0.0304797
6  0.5631579 0.195  0.0304797
7  0.6657895 0.195  0.0304797
8  0.7684211 0.195  0.0304797
9  0.8710526 0.195  0.0304797
10 0.9736842 0.195  0.0304797
11 1.0763158 0.195  0.0304797
12 1.1789474 0.195  0.0304797
13 1.2815789 0.195  0.0304797
14 1.3842105 0.195  0.0304797
15 1.4868421 0.195  0.0304797
16 1.5894737 0.195  0.0304797
17 1.6921053 0.195  0.0304797
18 1.7947368 0.195  0.0304797
19 1.8973684 0.195  0.0304797
20 2.0000000 0.195  0.0304797

> best_full_L_svm <- tuned_full_L_svm$best.model
> L_full_svm_pred <- predict(best_full_L_svm, dat.test,
+                        type="response")
> summary(best_full_L_svm)

Call:
best.tune(METHOD = svm, train.x = y ~ ., data = dat.train,
    ranges = list(cost = seq(0.05, 2, length = 20)),
    kernel = "linear")


Parameters:
   SVM-Type:  C-classification
 SVM-Kernel:  linear
       cost:  0.05

Number of Support Vectors:  672

 ( 93 76 70 71 26 51 52 31 103 99 )


Number of Classes:  10

Levels:
 0 1 2 3 4 5 6 7 8 9



>
> L_full_svm_error =
```

```
+   1-(sum(diag(table
+               (predict = L_full_svm_pred, truth=dat.test$y))))/600
> #Error rate:
> L_full_svm_error
[1] 0.21

> #Radial SVM using PCA
> system.time(radial_svm <- tune(svm, y~., dat=dat.pca.train,
+                                kernel = "radial",
+                                ranges=list(cost=seq(0.05, 2, length =
10),
+                                sigma=C(0.01, 5, length = 5)
+                                )))
Error in `contrasts<-`(`*tmp*`, how.many, value = contr) :
  contrasts can be applied only to factors with 2 or more levels
Timing stopped at: 0 0 0

> #Radial SVM using full dimensions
> system.time(radial_fsvm <- tune(svm, y~., dat=dat.train,
+                                kernel = "radial",
+                                ranges=list(cost=seq(0.05, 2, length =
10),
+                                                sigma=C(0.01, 5, length = 5)
+                                )))
Error in `contrasts<-`(`*tmp*`, how.many, value = contr) :
  contrasts can be applied only to factors with 2 or more levels
Timing stopped at: 0 0 0


> #Random Forest using PCA
> system.time(rf <- randomForest(y~., data= dat.pca.train,
+                     mtry=8, importance=TRUE))
   user  system elapsed
   4.33    0.00    4.40
> rf_pred <- predict(rf, newdata= dat.pca.test)
> #Error rate:
> mean((rf_pred!=dat.pca.test$y))
[1] 0.205
> #Random Forest using full dimensions
> system.time(rf_full <- randomForest(y~., data= dat.train,
+                     mtry=28, importance=TRUE))
   user  system elapsed
  23.26    0.02   23.44
> rf_pred_full <- predict(rf_full, newdata= dat.test)
> #Error rate:
> mean((rf_pred_full!=dat.test$y))
[1] 0.1966667
> #LDA using PCA
> system.time(lda.fit<-lda(y~., data=dat.pca.train))
   user  system elapsed
   0.07    0.00    0.05
> lda.fit
Call:
lda(y ~ ., data = dat.pca.train)
```

```
Prior probabilities of groups:
         0          1          2          3          4          5
6          7          8          9
0.10250000 0.08916667 0.11333333 0.10166667 0.08416667 0.13166667
0.09583333 0.09083333 0.09333333 0.09750000

Group means:
        x.PC1       x.PC2      x.PC3      x.PC4       x.PC5      x.PC6
x.PC7        x.PC8        x.PC9    x.PC10    x.PC11     x.PC12     x.PC13
0  -764.05710   693.36939 -155.55580 -148.46180   -7.337393  707.22224 -
105.75837   11.7634545  -16.2946515 -34.74666  77.72095  -2.327815  -
64.72897
1    95.66339  1398.06749 -182.66459  327.68519  288.971748 -364.26354
282.88772  159.3187987  340.9250460  54.77037  -7.98132  21.388956  -
72.87123
2  -904.56984  -259.88791  490.04439 -203.44607  235.953419  -98.61471
26.40454  -46.7625018  -29.2220470 -99.17127  44.13156  29.387096  -
12.02044
3  -141.18251  1110.99435 -288.24086  139.22419 -189.055011 -127.56917
20.08120  -22.6706425 -281.6182581 -99.88930 -49.95557   2.249283
86.22974
4 -1073.55749  -182.30826  435.43897  -22.48462  -13.713699 -325.21008 -
223.04340   26.6256347   15.9469066 124.76117 -62.22953  15.865455
69.41020
5  1453.49562  -219.73259  104.35957 -200.03629   76.698670   60.90032  -
47.14059   32.1681772   15.5127439 -17.92852   8.78871   9.292916
95.23817
6  -633.65537   -80.02712  337.71923 -215.92841   65.490308   53.73187  -
22.19901   -0.2329146  -50.6236613  43.79859 -89.31235 -45.590898
32.46572
7  1382.29575  -466.61103  171.43298  559.03541 -209.058056  122.77092
23.68542 -359.3659630   38.2899642  37.34411  69.53084 -29.786297
20.03907
8  -148.59048  -826.48541   36.98883  -44.84459 -614.841129  -10.62753
286.58053  277.6409359   -0.8156656  68.00780  22.65358  24.460768 -
119.43522
9   355.62452 -1105.24138 -982.36737  -28.39332  293.524886 -121.23112 -
217.53740  -77.2510130   13.1171495 -20.55721 -30.44072 -30.717887  -
66.02989
      x.PC14     x.PC15    x.PC16     x.PC17    x.PC18     x.PC19
x.PC20     x.PC21     x.PC22     x.PC23     x.PC24     x.PC25     x.PC26
x.PC27
0 -24.541495  -7.030338 -24.97631   4.055421 -79.87306 -10.862662 -
16.295756   1.128505  21.709032  -8.093458  -2.072301 -14.928474
25.834634 -15.683478
1   6.853842  49.446089 -27.86143 -42.173484 -21.58218  -1.865776 -
21.967576   8.167367  25.382195   6.771001 -10.236557  47.797976  -
4.468072  -0.380031
2  18.134310  27.195676  18.63724 -10.598201  55.72810  65.444250
45.446948  31.739627   7.118714  14.176084 -24.022566   9.911452
1.637830  21.549056
```

```
3   1.944539 -23.802504  44.91180  60.376923  61.86947  28.381057
28.817075 -21.801958 -49.427580  23.503856 -23.093350 -33.969003 -
38.710249  19.273580
4  -2.845603 -38.777858  23.73091 -37.842113 -95.27665 -38.510429  -
4.963525 -14.783413 -30.055466 -56.425072  20.777737 -18.333841  13.590875
17.360106
5 -28.488257 -26.835217 -94.69423 -22.945256  61.98943 -25.608461
8.299244 -21.966630 -15.793708  22.789544  29.101908  -7.190621   5.978456
1.159357
6  33.277830  -7.499987  35.82298  16.322987  13.86073 -69.452395
4.742326 -15.387490  38.546798   8.074732  20.960993   6.913245 -16.418731
-62.988210
7  31.597896  85.997623  50.37479  14.102621 -20.39702  -5.083443
13.273376   6.396868  35.725912 -24.358498  -8.912932  13.256769
21.854226  12.769635
8 -36.257772 -33.075149 -32.39927  39.673921  10.47836  67.134337 -
91.244295  -3.762691 -15.973205   1.516351  -9.782938 -20.665305
3.022961  18.232222
9   9.914896 -15.991490  39.50807 -19.840067 -31.70164 -15.977746
17.740782  32.377022 -11.376797  -7.432347   3.373452  22.054862 -
11.533962 -12.300182
      x.PC28     x.PC29      x.PC30      x.PC31      x.PC32     x.PC33
x.PC34      x.PC35     x.PC36      x.PC37      x.PC38     x.PC39
x.PC40
0  30.426380   1.371630  -7.2120726 -20.2841109  -7.0916226  13.575761
6.786120  -0.6662605 -17.930032  11.7555530   0.5663023   1.027203  -
3.3904127
1  21.025941   9.344218   4.4348680  26.6456527  -6.2335716  11.916089
1.276021  31.3592138  -2.712494  -1.8103055  12.5980331 -11.219077
5.8962463
2 -19.568090 -18.013744  17.4673176  -9.1741413  18.3475947 -10.434934  -
1.259149  -8.8444783 -24.733036  -7.3661594 -19.5822038  17.004890  -
2.1491633
3 -23.104582  -5.052624  -0.7376129  -0.1568662   0.5638363 -29.446862 -
13.480023 -19.0734018  15.257512  -4.7280894 -30.5350359   4.734392  -
7.0493779
4  -9.309736   1.601478 -18.9897359 -15.1980617   3.0522619  -9.858398
15.987383  10.3954406 -12.012298 -10.1550535 -12.6831419 -19.138311
0.5085038
5  14.092503   2.919921 -19.2368900  28.5925585 -26.7310161  10.386937
18.253155   1.4507386   5.211583 -17.7981942  -5.2533864   8.834056  -
2.1333443
6  -2.170913 -13.117568 -18.9025235  -1.6558734   1.3028824  21.996550 -
15.407025 -18.9478387  21.764075  14.8021033  47.9012219  -2.331930
1.1468529
7  21.325445 -12.425882  15.5045594 -17.7217700 -21.2685221  -5.253033 -
16.462709  -8.6451248 -19.072292   9.9354788  -4.7936343  -3.364994
19.9917029
8   1.744293  35.399932  18.8124481  10.0430153  18.3201260   0.243495
11.049195   0.7156720  31.717814  11.3206278  17.5680864   2.827444
4.6883934
9 -34.775322   1.476922  12.4887060  -9.1851081  25.7009081  -4.811144 -
11.328299  17.2506564   3.515687   0.9491449   1.0947153  -8.211064 -
13.7772779
```

```
       x.PC41     x.PC42     x.PC43     x.PC44     x.PC45    x.PC46
x.PC47      x.PC48     x.PC49        x.PC50      x.PC51      x.PC52
x.PC53
0  -2.7089264  12.484422  -4.736564   6.523969 -1.7100349  3.732052
6.8421103  -2.9905119   3.031015 -15.747692864   0.9959531   0.4132903  -
7.0091869
1  19.0127552  11.732709   3.535813   2.585805  6.7746773 -7.810791  -
4.1568575 -23.4155459  -5.629362  -7.845227214  15.1615604 -16.9268592
4.4173575
2  10.4969225  10.906544  16.997721   1.899589  5.0473956 -1.705347
1.5467194  -8.8472443 -16.699360 -16.914821108  -2.7712593   6.6160867
3.7707787
3  -5.6598022 -17.319495   5.013454 -18.014022 -8.0774039 -5.728943 -
13.6150831  20.5804481  14.637666  19.208634628 -18.2797027  21.4893045
3.5186994
4 -17.4094789  -3.463938  -6.196157  10.015211 -2.2228522  1.317471  -
0.3150766  20.3760436  -4.249328   1.399131655   6.2177219  13.0478638  -
4.1988622
5   2.2245937 -13.564381  27.642408  13.671814 -4.5870910 -6.981977
23.1104150   0.3628822   2.245435  13.716805080  -0.7432098  -4.1749285 -
16.8389091
6  -8.4665511  -6.933485 -40.804437 -10.575284 -4.7089046 14.373720 -
11.5682168  -7.0540216  11.545559  14.556208861   8.7444890 -21.4967304
0.6935902
7  -8.8195020  22.713491 -32.336188 -26.954978 -0.8569414  1.404662
1.3101801   0.9129498  11.176423  -9.543881506  -8.4692482   1.3961451
1.6293294
8   8.3646045  -6.960586  13.097341   2.613008  4.5005420  6.170967
3.1702289   6.8193134 -14.525323  -1.870620792  -9.9550466  -2.0325047  -
2.4413927
9  -0.2840812  -4.847003   2.474342  13.249126  7.3895701 -1.876719 -
14.8142110  -5.1424872  -1.110130   0.005374994  11.8304281   1.0961149
21.7784140
       x.PC54     x.PC55      x.PC56    x.PC57      x.PC58      x.PC59
x.PC60       x.PC61      x.PC62     x.PC63     x.PC64      x.PC65
x.PC66
0  -1.0180187 -3.5882662   5.5239500 -5.172675 -10.0669269  -0.9038855  -
2.56444829   0.58598224   2.1205643   9.566402  -3.937092  -0.7819553  -
1.581355
1   3.7980125 -6.0192179  -0.3919504 -1.207581   5.6551614   7.8150661 -
11.11654503   7.46718380   8.4968384  -2.010329   1.578382   3.1643922  -
3.609001
2   7.5289703 -7.7803211  -7.0485245  9.419235   0.8612474 -16.2616888
4.61127752   0.03907355   4.5232888   2.720235  12.235023   3.6803323
8.177804
3  -1.6443968  4.2636283 -10.6418748 -6.674595  -0.3085238   2.3285450
6.61797773  -7.01868596  -0.5247082   3.937541   4.914695   5.6979732
10.775997
4  -8.4138862 -0.2944623  -4.1470330 -1.252446   8.7798335   0.3831331
4.02221096  -4.46378452   6.2486074  -3.050565  -7.907850  -3.6700269  -
4.503034
5 -13.8742640  3.3888876  -2.8661476 -2.236215  -4.9295679  10.9801321  -
4.01064045   0.97648370 -13.3624536  -2.606208  -2.385560   0.8814345
11.028453
```

```
6   9.2761969  0.3597750  13.0141949 -7.044355   1.6961744   0.2385126
1.50862087   8.76929745  -7.7424993 -13.598481 -10.618747 -11.9293890  -
7.896427
7   9.2610532 -0.2667769   9.2625108  4.164463   9.6147010  -9.5311297
2.20117879 -11.86499100   4.2422538   4.099797   6.901972  -6.6513982  -
8.808596
8  -1.0766650 15.1701033  14.6957713  7.161339   6.7663347   1.9286563  -
0.94154579   1.96078322  -1.0426614   6.509262  -5.798756   6.0502101
1.533344
9  -0.1554645 -5.0741580 -14.1971788  2.843231 -13.2918240   1.9176958  -
0.08682429   2.92022313   2.5963603  -6.017914   2.954978   1.8168999 -
12.285306
      x.PC67      x.PC68      x.PC69     x.PC70     x.PC71     x.PC72
x.PC73     x.PC74
0   1.429914 -3.31886266   3.3212827 -3.0210364  -2.532040  0.1932055
2.0005665  5.7539210
1  -2.979899  7.04768639  -2.5384711 -3.3613944   4.748624  0.5213181 -
0.3384956  0.3443229
2  -1.126958  5.49197131   1.9747392 -4.3398997 -11.574341  2.0982575
12.6053342  1.2976511
3   6.017167 -4.46406594  -0.8790432 -1.4794235   1.551159 -3.9144256 -
5.3571188 -4.2244288
4  -7.013861 -5.04057031   3.2471341 14.1368063  -8.597618 -1.5113857 -
3.8667446 -5.4831166
5   1.139487  0.04989391 -13.9266015  5.0923210  -5.083219  0.8025129
3.9247816 -5.5048930
6   4.456981  0.29478398   0.8352892 -0.5638588  12.724475  1.2544699 -
6.5123723  5.6645875
7 -10.538076  6.21727665   2.7954719  2.2626387   9.221793 -5.8887337
7.7557313  6.4780741
8   9.315196 -7.33199780   6.4233113 -8.9464222  -3.489707  3.2344084 -
6.3659546 -8.1738655
9  -2.706854  0.53538815   3.8807207  0.7673845   6.684379  2.3406726 -
7.5525374  4.9216078

Coefficients of linear discriminants:
                 LD1           LD2           LD3           LD4
LD5           LD6           LD7           LD8           LD9
x.PC1   1.697174e-03 -6.606717e-04 -5.450389e-04  4.807970e-04  2.571845e-
04  7.500205e-05  3.550419e-04 -3.477358e-05  1.673472e-05
x.PC2  -2.569703e-03 -1.388107e-03  3.489235e-04  8.500758e-04  7.818390e-
05  1.033108e-04  1.078327e-04 -1.414518e-04 -6.893833e-05
x.PC3  -2.608617e-03  2.058952e-03 -1.404406e-03 -1.358753e-04  1.833380e-
03 -4.806026e-04  1.427326e-04  6.696579e-05  1.263039e-05
x.PC4   6.075367e-04 -1.748018e-03 -6.753659e-04  5.664506e-04  4.189763e-
04  5.868057e-05 -1.373488e-03 -2.200214e-04 -3.133236e-04
x.PC5   5.267314e-05 -1.567990e-03  1.921748e-03 -1.147080e-03  1.175945e-
03 -5.981357e-04  9.012315e-04  6.273547e-04  2.656928e-04
x.PC6   4.419331e-04  1.719297e-03  7.604831e-04  2.427055e-03 -9.840904e-
04 -2.071568e-03  4.021078e-04  2.693453e-04  1.040979e-04
x.PC7  -1.988356e-03 -1.390980e-03 -2.415953e-03  9.672935e-05 -7.607304e-
04  1.044197e-04 -2.956733e-04  8.296367e-04  1.044374e-03
x.PC8  -3.011804e-03 -1.544072e-04 -1.131300e-03 -1.265562e-03 -2.195767e-
03  3.352901e-04  1.390969e-03 -3.733094e-04 -5.103532e-05
```

```
x.PC9  -1.164487e-04 -3.519337e-03 -1.485212e-03 -2.014760e-03  2.841965e-
04 -2.583812e-03  3.601772e-04 -1.102851e-04 -4.358497e-04
x.PC10  6.544472e-05 -1.160785e-04 -1.146092e-03 -9.751891e-04 -1.073182e-
05 -7.389784e-04 -4.272566e-04 -1.774678e-03 -3.078768e-04
x.PC11  5.459812e-04  9.809708e-05 -5.958687e-04  9.175812e-04 -1.830047e-
04 -1.214680e-03 -1.703154e-04  1.446795e-03 -9.130206e-04
x.PC12 -1.154205e-03 -6.281302e-05 -5.192428e-04 -2.628214e-04 -1.461891e-
04  2.124312e-04  3.092345e-04  5.762254e-04 -8.512572e-04
x.PC13  9.337349e-05  9.041131e-04  5.128426e-04  1.366882e-03  2.965369e-
03  1.927663e-03  1.329656e-03 -1.316748e-03 -4.178152e-04
x.PC14  1.165950e-04 -2.550889e-04  4.459209e-04 -2.583051e-04  9.037543e-
04  9.788019e-08 -7.878591e-04  7.164901e-05  8.758063e-04
x.PC15  2.832549e-04 -1.495767e-03 -5.052944e-04  3.828731e-04  1.215281e-
03 -1.018543e-03 -1.194584e-03  9.736743e-04  5.108463e-04
x.PC16  1.758497e-04  4.554157e-04  1.523102e-03 -3.251332e-04  6.792188e-
04  7.814347e-04 -2.865868e-03 -1.394176e-04  9.400567e-04
x.PC17 -3.692070e-04  1.131218e-03 -3.433043e-04  1.509264e-03 -8.862917e-
04  1.088545e-03 -8.917411e-04  9.373733e-05  1.048058e-03
x.PC18  2.458509e-04  2.835193e-04 -1.282488e-03  8.463281e-04  8.834528e-
04  2.634347e-03  1.772883e-03  2.220125e-03  2.313607e-03
x.PC19 -1.104625e-03  4.141582e-04 -1.277932e-03 -1.962139e-05 -1.130680e-
03  1.027312e-03 -8.526181e-04  2.870290e-03 -7.870127e-04
x.PC20  6.788534e-04 -1.316599e-04  2.121543e-03  3.461407e-04  2.269837e-
03  7.821226e-04  1.206739e-04  1.081556e-03  2.577494e-04
x.PC21  8.419983e-04 -3.614072e-04  5.379002e-04 -9.070692e-04 -1.288898e-
04 -5.612064e-04 -6.734132e-04  1.357413e-03  1.845329e-05
x.PC22 -1.527367e-04 -5.061355e-04 -1.865055e-04  6.755951e-05  7.106245e-
04 -2.409899e-03 -5.462667e-04  2.082995e-04  1.706727e-03
x.PC23 -4.500465e-04 -5.473943e-04 -1.388645e-04  7.089913e-04 -3.235537e-
04  8.071133e-04  1.262313e-03  1.190771e-03  1.493301e-03
x.PC24  1.055229e-03  4.999500e-04  1.881622e-05 -3.308093e-04  4.100872e-
04 -4.400472e-04  1.210360e-03 -1.450183e-03  8.605837e-06
x.PC25  7.903666e-04 -2.284499e-03  4.608123e-05 -1.251013e-03  6.674412e-
04 -1.115729e-03 -2.087296e-04  5.716106e-04  9.598572e-04
x.PC26  5.294355e-04  6.064980e-04 -5.672750e-04  1.337246e-04  2.558212e-
04 -1.747543e-03 -1.263661e-05  7.878541e-05 -1.288457e-03
x.PC27 -1.355075e-04 -2.003555e-04 -1.225879e-03  9.802347e-05  1.443164e-
04  1.278607e-03 -6.327963e-04  1.472715e-03 -2.722477e-03
x.PC28 -8.307025e-04 -7.705447e-04 -1.247201e-03  1.383068e-03  1.171319e-
04 -1.960097e-03  4.965731e-04 -5.425816e-04 -3.587779e-04
x.PC29  6.323830e-05 -2.812325e-04 -1.138181e-03 -3.299223e-04 -1.554786e-
03  4.637142e-05  2.500656e-04 -4.502863e-04 -5.683709e-04
x.PC30  8.267866e-04 -3.819244e-04 -5.219567e-04 -3.242170e-04 -5.768787e-
04  8.523883e-05 -1.247154e-03  1.536865e-03  6.028361e-05
x.PC31 -2.124506e-04 -1.521063e-03 -1.326105e-03 -2.358303e-04 -1.516444e-
04  5.811230e-04  1.663711e-03 -9.148218e-05  4.779028e-04
x.PC32 -2.494191e-04  8.067299e-04  7.432142e-04 -1.693374e-03 -1.189656e-
03  5.745420e-04 -9.340580e-04  8.078207e-04  3.826708e-04
x.PC33 -9.863714e-05 -1.848959e-04 -3.085693e-04 -1.962478e-04 -1.698507e-
04 -1.713235e-03  1.009049e-03 -6.633060e-04  1.061184e-03
x.PC34 -6.289398e-04  4.578721e-04 -7.433490e-04 -3.649218e-04 -3.138626e-
04 -3.415199e-04  1.253226e-03 -1.702715e-04 -1.505204e-03
x.PC35  4.684483e-04 -2.071002e-03 -1.042933e-04 -1.324886e-03 -5.521788e-
04 -6.739553e-04  2.950254e-04 -2.211679e-04 -1.147387e-03
```

x.PC36 2.788119e-04 2.221461e-04 -1.052876e-03 -1.214653e-04 -1.657665e-03 1.474558e-03 5.768163e-04 -1.366857e-03 1.858087e-03
x.PC37 -9.208440e-05 3.913647e-04 -4.892738e-05 3.437295e-04 -8.041161e-04 -8.650334e-04 -1.109882e-03 -3.305196e-04 1.133808e-03
x.PC38 -6.214445e-05 1.577972e-04 -8.197547e-04 -1.006152e-03 -8.261193e-04 -1.747575e-03 2.323155e-04 -1.692814e-03 3.121039e-03
x.PC39 -1.640280e-04 9.087589e-04 -2.414832e-04 6.672289e-04 9.756774e-05 3.108802e-04 6.887620e-04 1.500863e-03 4.957652e-04
x.PC40 -8.663359e-05 -1.979930e-04 -1.275681e-03 3.601094e-04 6.534953e-04 -6.095824e-04 -6.763882e-04 -1.874548e-04 8.037994e-05
x.PC41 -6.661973e-04 -1.284497e-03 -6.929424e-04 -5.293991e-04 -5.736018e-04 -2.021256e-04 5.296949e-04 1.378520e-03 3.445311e-04
x.PC42 -2.830573e-04 -6.947238e-04 -1.519215e-04 1.145892e-04 6.909250e-04 -1.947458e-03 -1.337077e-03 1.010434e-03 -3.870187e-04
x.PC43 -3.895114e-05 -5.169612e-04 -7.372477e-04 -6.048314e-04 -1.166757e-03 1.499281e-03 2.741325e-03 2.403503e-03 -2.548665e-03
x.PC44 4.209528e-04 1.169860e-04 5.289572e-04 -1.606939e-03 -9.262348e-04 -5.781564e-04 1.896296e-03 1.029335e-04 -1.392088e-03
x.PC45 3.555971e-04 -4.840675e-04 -1.261608e-04 -8.468601e-04 -3.578016e-04 -3.701955e-04 -2.754607e-04 6.023513e-04 -6.659227e-05
x.PC46 -2.539728e-04 1.284401e-03 -2.545494e-05 -1.387005e-04 -2.439750e-04 -5.580536e-04 -4.817789e-04 -5.555186e-04 9.215954e-04
x.PC47 4.618785e-04 6.708341e-04 -1.350450e-03 6.988059e-04 4.568668e-04 -9.117681e-04 1.813606e-03 3.882961e-04 -1.347625e-03
x.PC48 1.002569e-04 1.979840e-03 -2.109743e-05 8.920996e-04 -1.479437e-04 1.844177e-03 -5.214328e-04 -1.200917e-03 -1.593938e-03
x.PC49 8.095537e-04 -4.607318e-04 8.301469e-04 1.838900e-03 5.966873e-04 3.998238e-04 -2.095127e-04 -1.444392e-03 9.056382e-04
x.PC50 6.387627e-04 1.214409e-04 1.337875e-05 5.684394e-04 1.624033e-04 2.187129e-03 1.224017e-03 -1.891344e-03 1.190382e-03
x.PC51 1.350268e-04 -1.289535e-03 8.900000e-04 -1.781899e-03 1.696480e-04 -1.352521e-03 5.484946e-04 -7.405237e-04 4.092818e-04
x.PC52 -1.853522e-05 1.120602e-03 8.375255e-04 8.035701e-04 5.171574e-05 1.879300e-03 -9.016462e-04 7.063402e-04 -2.457916e-03
x.PC53 1.290423e-03 -1.087137e-03 1.293389e-03 -1.210309e-03 -5.271222e-04 5.103381e-04 -1.643399e-03 5.861473e-04 8.474110e-04
x.PC54 -5.709473e-04 -1.387551e-04 1.262928e-04 -1.443320e-04 3.289509e-04 -5.449429e-04 -1.463580e-03 6.898551e-04 1.542088e-03
x.PC55 2.728525e-04 8.176695e-04 -1.283277e-03 4.353178e-04 -8.185500e-04 6.827984e-04 1.196302e-04 -6.352861e-04 7.043853e-05
x.PC56 -7.618535e-04 1.068274e-03 -1.790414e-03 5.851301e-04 -4.065230e-04 -1.458194e-03 -4.661223e-04 -8.717289e-04 1.240850e-03
x.PC57 8.619587e-04 3.780482e-04 -7.356277e-04 -8.123623e-04 8.133631e-06 -1.174719e-04 -4.753934e-04 1.188013e-03 -3.606721e-04
x.PC58 -1.431458e-03 4.040887e-05 -1.748745e-03 -3.165725e-04 8.970403e-04 2.282440e-04 -1.068134e-03 -4.729584e-04 -8.300757e-05
x.PC59 3.605837e-04 -1.411481e-03 -3.110365e-04 1.672886e-04 -8.362464e-04 4.041423e-04 1.490517e-03 -1.516912e-03 -1.208214e-04
x.PC60 4.360581e-05 1.386374e-03 4.527804e-04 1.657609e-04 3.930531e-04 7.949157e-04 -6.779219e-04 1.534896e-04 -2.759175e-05
x.PC61 -8.208552e-04 -4.234144e-04 1.819755e-04 -1.042028e-03 -6.505080e-04 -5.627861e-04 9.164937e-04 -1.252149e-04 1.228905e-03
x.PC62 -1.060943e-03 -9.595903e-04 3.764583e-04 -6.844337e-04 -7.718333e-05 -3.784368e-04 -1.668065e-03 5.145767e-04 -9.763197e-04

```
x.PC63 -6.870847e-04  2.425455e-04 -4.951114e-04  1.193382e-03 -7.779851e-
04 -2.134689e-04 -5.538440e-04  1.067232e-03 -1.424514e-03
x.PC64  6.367102e-04 -8.593747e-04  2.784483e-04  2.415564e-04  7.300438e-
04  5.379370e-04 -6.600842e-04  2.101985e-03 -3.380602e-04
x.PC65 -3.850057e-04 -6.491557e-04 -2.590467e-04 -8.559171e-05 -9.868030e-
04  8.744928e-04  2.831127e-04  1.151256e-03 -9.110795e-04
x.PC66 -1.801796e-03  6.212179e-04 -6.602041e-04  1.044381e-03  2.323403e-
04  1.435639e-03  1.603816e-03  1.321660e-03 -6.980142e-04
x.PC67 -1.143843e-03  7.621598e-04 -2.592112e-04  3.361786e-04 -1.325246e-
03  7.109396e-04  6.732327e-04  8.310102e-05  9.817985e-04
x.PC68  3.801735e-04 -1.195014e-03 -1.970394e-05 -2.396079e-04  1.096595e-
03 -5.644461e-04 -1.483346e-04  8.221582e-04  5.388019e-04
x.PC69 -4.361366e-04  8.253972e-04  3.387084e-04 -5.728079e-04 -8.664646e-
04 -3.630215e-04 -1.911101e-03  1.140363e-04  4.025668e-05
x.PC70  8.718086e-04  2.316106e-04  4.767394e-04 -2.927070e-04  1.328595e-
03  1.743674e-04  3.572512e-04 -1.380665e-03 -1.288407e-03
x.PC71  1.703474e-03 -1.561851e-03  3.445950e-04  5.513612e-04 -6.081005e-
05 -3.088916e-04 -1.023820e-03 -1.373929e-03  2.433157e-03
x.PC72 -8.833088e-05  2.690338e-04 -1.504146e-06 -7.249416e-04 -5.377645e-
04 -2.126803e-04  5.158194e-04  2.959013e-04  2.972643e-04
x.PC73 -2.085675e-04  2.388393e-04 -4.364385e-04  5.438729e-04  1.617319e-
03 -9.128383e-04  2.386427e-04  1.964922e-03 -6.945483e-04
x.PC74  7.839293e-04 -3.448978e-04  1.237467e-03  2.818160e-04  4.154917e-
04 -1.297938e-03 -8.053102e-04  2.618844e-04  1.064547e-03

Proportion of trace:
   LD1    LD2    LD3    LD4    LD5    LD6    LD7    LD8    LD9
0.4376 0.2054 0.0917 0.0798 0.0665 0.0543 0.0365 0.0181 0.0101
> lda.pred <- predict(lda.fit, dat.pca.test)
> #Error rate:
> mean(lda.pred$class != dat.pca.test$y)
[1] 0.2166667

> #LDA using full dimensions
> #Could not run with columns x.px1, x.px29
> flda.train <- subset(dat.train, select = -c(x.px1, x.px29))
> system.time(lda.fit.full<-lda(y~., data=flda.train))
   user  system elapsed
   3.39    0.01    3.39
> lda.fit.full
Call:
lda(y ~ ., data = flda.train)

Prior probabilities of groups:
         0          1          2          3          4          5
6          7          8          9
0.10250000 0.08916667 0.11333333 0.10166667 0.08416667 0.13166667
0.09583333 0.09083333 0.09333333 0.09750000

Group means:
       x.px2      x.px3      x.px4      x.px5      x.px6      x.px7
x.px8      x.px9     x.px10       x.px11       x.px12       x.px13
x.px14
```

```
0 0.20325203 1.05691057 0.78048780 0.60162602 0.78048780 1.0487805
9.5040650 16.1219512 28.9024390  57.59349593  83.84552846  68.17073171
50.91056911
       x.px15      x.px16      x.px17      x.px18    x.px19    x.px20
x.px21    x.px22    x.px23     x.px24     x.px25      x.px26      x.px27
0  48.8617886  57.1463415  84.4634146  77.7886179 46.260163 18.317073
12.4796748 7.1056911 1.7560976 0.43902439 0.15447154 0.024390244
0.000000000
     x.px28      x.px30     x.px31     x.px32    x.px33    x.px34
x.px35     x.px36       x.px37       x.px38       x.px39      x.px40
x.px41
0 0.9837398 0.227642276 3.73170732 3.28455285 2.7804878 6.0406504
24.8943089 62.7967480 1.013008e+02 126.09756098 145.45528455 174.6341463
178.243902
       x.px42    x.px43     x.px44     x.px45     x.px46     x.px47
x.px48    x.px49    x.px50     x.px51     x.px52     x.px53     x.px54
0 175.7642276 172.56911 182.569106 179.813008 155.926829 141.878049
116.081301 84.804878 41.024390 12.0650407  5.1788618  3.1219512 1.63414634
       x.px55      x.px56    x.px57      x.px58     x.px59     x.px60
x.px61     x.px62     x.px63      x.px64       x.px65       x.px66
x.px67
0 0.325203252 1.674796748 0.0000000 0.699186992 4.62601626 4.43902439
5.3902439 39.7967480 95.7642276 120.7235772 135.93495935 141.77235772
145.9918699
       x.px68     x.px69     x.px70     x.px71     x.px72     x.px73
x.px74     x.px75     x.px76     x.px77     x.px78     x.px79     x.px80
0 152.7398374 155.593496 160.504065 158.691057 161.390244 155.967480
148.772358 145.113821 140.300813 130.560976 113.300813 68.2195122
16.2113821
       x.px81      x.px82     x.px83    x.px84    x.px85     x.px86
x.px87    x.px88     x.px89     x.px90      x.px91      x.px92
x.px93
0  5.73983740  3.62601626 1.60975610 1.2357724 0.0000000 1.17886179
4.10569106 5.4227642 22.4227642 94.5203252 126.7073171 129.8373984
144.68292683
        x.px94       x.px95       x.px96     x.px97      x.px98     x.px99
x.px100     x.px101    x.px102    x.px103   x.px104    x.px105    x.px106
0 1.513008e+02 1.528943e+02 151.73983740 157.910569 152.5447154 150.349593
154.804878 154.9186992 150.113821 153.325203 148.04878 140.097561
130.699187
      x.px107    x.px108      x.px109      x.px110     x.px111    x.px112
x.px113   x.px114   x.px115   x.px116    x.px117     x.px118     x.px119
0 114.9593496 55.5447154  8.959349593  4.666666667  2.72357724 0.68292683
0.0000000 1.5284553 4.3414634 7.3902439 53.7560976 121.6910569 139.5447154
       x.px120     x.px121      x.px122      x.px123    x.px124    x.px125
x.px126    x.px127    x.px128    x.px129   x.px130    x.px131    x.px132
0 138.08943089 148.6991870 1.518130e+02 1.486423e+02 146.235772 145.967480
148.512195 149.203252 149.016260 145.138211 143.81301 149.056911
147.691057
     x.px133    x.px134    x.px135    x.px136     x.px137     x.px138
x.px139   x.px140   x.px141     x.px142     x.px143    x.px144    x.px145
0 144.528455 137.292683 131.016260 85.4878049 22.74796748  5.25203252
3.89430894 0.1707317 0.1382114  1.75609756  4.48780488 15.2764228
87.0243902
```

```
      x.px146     x.px147     x.px148      x.px149     x.px150     x.px151
x.px152    x.px153     x.px154    x.px155    x.px156    x.px157
0 136.1219512 140.8048780 139.3414634 149.69105691 151.2845528 151.5365854
149.37398374 146.382114 147.5447154 152.422764 150.048780 145.333333
     x.px158   x.px159    x.px160    x.px161    x.px162    x.px163
x.px164     x.px165    x.px166      x.px167   x.px168     x.px169
x.px170
0 147.544715 151.42276 147.032520 144.032520 137.365854 137.463415
113.4308943 46.40650407  7.2682927  4.065040650 0.2113821 0.195121951
2.17886179
      x.px171      x.px172     x.px173     x.px174      x.px175
x.px176      x.px177      x.px178      x.px179      x.px180      x.px181
x.px182
0  5.10569106 29.430894309 109.0000000 142.7317073 1.439837e+02
1.461138e+02 156.22764228 157.95121951 152.47967480 152.41463415
149.75609756 152.040650
    x.px183    x.px184   x.px185   x.px186   x.px187   x.px188    x.px189
x.px190    x.px191     x.px192    x.px193     x.px194     x.px195
x.px196
0 150.77236 150.691057 153.36585 150.91870 151.81301 155.27642 148.951220
140.642276 138.756098 127.1382114  62.284553  13.8048780  4.39024390
0.6504065
      x.px197     x.px198     x.px199      x.px200      x.px201
x.px202      x.px203      x.px204     x.px205      x.px206     x.px207
x.px208
0 0.552845528  2.69105691  5.67479675 44.560975610 112.52845528
1.401301e+02 146.15447154 152.29268293 157.5934959 150.55284553
143.6991870 144.7317073
      x.px209    x.px210    x.px211   x.px212   x.px213   x.px214
x.px215   x.px216   x.px217    x.px218    x.px219     x.px220      x.px221
x.px222
0 144.1300813 144.528455 143.715447 144.90244 144.76423 144.69919
142.04065 150.56911 149.30081 148.552846 138.349593 127.1788618
72.74796748  22.121951
      x.px223    x.px224     x.px225      x.px226      x.px227
x.px228      x.px229      x.px230      x.px231      x.px232     x.px233
x.px234
0  5.20325203  1.2357724 0.756097561  1.154471545  9.154471545
56.536585366 113.61788618 131.46341463 143.69105691 155.53658537
163.6829268 153.4471545
      x.px235     x.px236    x.px237    x.px238   x.px239   x.px240
x.px241   x.px242   x.px243   x.px244   x.px245    x.px246    x.px247
x.px248
0 149.9186992 152.4227642 152.910569 147.634146 150.62602 152.17886
149.33333 144.59350 145.62602 154.34146 154.07317 153.121951 132.032520
121.6016260
     x.px249    x.px250     x.px251    x.px252    x.px253     x.px254
x.px255      x.px256      x.px257      x.px258      x.px259      x.px260
0  82.268293  34.008130  4.95934959  1.6666667 0.75609756  2.58536585
14.47967480 65.504065041 1.100325e+02 1.235610e+02 1.360000e+02
147.62601626
      x.px261     x.px262     x.px263    x.px264    x.px265   x.px266
x.px267   x.px268   x.px269   x.px270   x.px271   x.px272   x.px273
x.px274
```

```
0 163.8536585 159.1626016 154.1382114 151.008130 150.959350 146.02439
145.61789 148.61789 151.17073 149.82114 148.62602 160.50407 151.72358
142.666667
     x.px275     x.px276   x.px277    x.px278     x.px279    x.px280
x.px281      x.px282     x.px283     x.px284     x.px285     x.px286
x.px287
0 127.130081 116.3008130  84.65041  36.219512  9.46341463  1.9593496
0.918699187  2.569105691 13.29268293 54.16260163 88.83739837 105.3658537
121.9024390
      x.px288     x.px289     x.px290    x.px291   x.px292   x.px293
x.px294   x.px295   x.px296   x.px297  x.px298   x.px299   x.px300
x.px301
0 128.1951220 157.3577236 167.9674797 155.032520 155.95122 153.64228
149.60163 149.56911 151.27642 153.73984 152.2927 153.00000 161.11382
135.74797
     x.px302    x.px303     x.px304      x.px305    x.px306     x.px307
x.px308     x.px309     x.px310     x.px311    x.px312     x.px313
x.px314
0 122.373984 108.292683  89.1219512  63.62601626  32.195122 11.33333333
0.6666667  1.26016260  1.15447154  8.54471545 31.5365854  48.2764228
62.7235772
      x.px315     x.px316     x.px317    x.px318   x.px319   x.px320
x.px321  x.px322   x.px323   x.px324   x.px325   x.px326   x.px327
x.px328
0  77.8455285  93.8861789 153.2926829 166.325203 155.55285 152.75610
153.63415 152.6504 151.83740 154.98374 155.76423 151.43089 152.27642
160.32520
    x.px329    x.px330    x.px331     x.px332   x.px333    x.px334
x.px335    x.px336     x.px337    x.px338    x.px339    x.px340
x.px341
0 120.32520  82.333333  67.869919  56.0569106  39.59350  17.878049
4.308943  0.5853659  1.23577236  1.2276423  8.1951220 20.9918699
28.6341463
      x.px342    x.px343     x.px344    x.px345   x.px346    x.px347
x.px348   x.px349   x.px350   x.px351   x.px352   x.px353   x.px354
x.px355
0  35.2357724  39.991870  68.8617886 150.243902 169.14634 157.406504
153.95935 150.34146 151.97561 152.46341 150.62602 151.50407 153.39837
151.67480
    x.px356   x.px357    x.px358   x.px359     x.px360   x.px361
x.px362     x.px363    x.px364     x.px365    x.px366    x.px367
x.px368
0 161.86179 112.63415  50.878049  36.77236  32.1382114  25.21951
14.430894   5.2764228  1.3658537  0.00000000  0.3495935  6.0731707
15.4878049
      x.px369     x.px370     x.px371    x.px372   x.px373    x.px374
x.px375   x.px376   x.px377   x.px378   x.px379   x.px380   x.px381
x.px382
0  18.3252033  21.4878049  24.9349593  57.414634 147.21138 170.560976
159.62602 158.96748 154.62602 151.43902 150.91057 151.91870 152.55285
157.16260
    x.px383   x.px384    x.px385    x.px386    x.px387     x.px388
x.px389    x.px390     x.px391    x.px392     x.px393     x.px394
x.px395
```

0 158.67480 163.30894 104.796748 35.975610 20.333333 19.9024390
15.10569 11.479675   4.6260163 0.3333333 0.00000000 0.01626016
3.9024390
     x.px396   x.px397   x.px398   x.px399   x.px400   x.px401
x.px402   x.px403 x.px404   x.px405   x.px406   x.px407   x.px408
x.px409
0 11.089431 13.8292683 15.9593496 17.788618 53.495935 144.76423
168.61789 161.80488 158.2195 155.04878 155.21138 151.90244 152.34959
156.87805
    x.px410   x.px411   x.px412   x.px413   x.px414   x.px415
x.px416   x.px417   x.px418   x.px419   x.px420   x.px421   x.px422
x.px423
0 155.90244 156.42276 164.20325 101.333333 25.406504 13.113821
16.6991870 12.78862 10.26016   4.1219512 0.1951220 0.02439024
0.1544715 0.9918699
     x.px424   x.px425   x.px426   x.px427   x.px428   x.px429
x.px430   x.px431   x.px432   x.px433   x.px434   x.px435   x.px436
x.px437
0   6.674797   9.3983740 11.5365854 16.048780 53.130081 144.12195
168.34146 163.27642 158.12195 157.30081 154.82114 151.21138 154.16260
157.08130
    x.px438 x.px439   x.px440   x.px441   x.px442   x.px443
x.px444   x.px445   x.px446   x.px447   x.px448   x.px449
x.px450
0 152.41463 155.2927 163.16260 103.520325 25.886179 10.731707
12.2601626   8.1869919   5.95935   3.2439024 0.0000000 0.02439024
0.44715447
      x.px451   x.px452   x.px453   x.px454   x.px455   x.px456
x.px457   x.px458   x.px459   x.px460   x.px461   x.px462   x.px463
x.px464
0   0.9837398   5.902439   8.3495935   9.9756098 14.86992 53.959350
147.83740 168.75610 163.05691 160.47967 159.98374 158.04878 157.78049
158.21138
    x.px465 x.px466 x.px467   x.px468   x.px469   x.px470   x.px471
x.px472   x.px473   x.px474   x.px475   x.px476   x.px477
x.px478
0 158.80488 157.3333 156.4228 163.43902 109.723577 25.23577   7.487805
9.2276423   7.2195122   5.715447   3.747967 0.0000000 0.02439024
0.8211382
     x.px479   x.px480   x.px481   x.px482   x.px483   x.px484
x.px485   x.px486   x.px487   x.px488   x.px489   x.px490   x.px491
x.px492
0   1.178862   6.03252   8.0325203 10.4634146 14.74797 55.471545
149.31707 168.21951 162.91870 162.12195 160.33333 160.82114 160.37398
158.82114
   x.px493 x.px494 x.px495   x.px496   x.px497   x.px498   x.px499
x.px500   x.px501   x.px502   x.px503   x.px504   x.px505   x.px506
0 159.7073 158.2358 157.0081 162.86992 116.60163 26.121951   7.609756
9.2357724   7.373984   5.878049   4.268293 0.0000000 0.07317073
1.105691
     x.px507   x.px508   x.px509   x.px510   x.px511   x.px512
x.px513   x.px514   x.px515   x.px516   x.px517   x.px518   x.px519
x.px520

```
0  1.3333333   6.1869919   8.1869919  10.8130081  15.910569  60.121951
154.72358 167.46341 163.49593 162.68293 159.49593 159.83740 159.93496
159.60163
   x.px521  x.px522   x.px523   x.px524    x.px525   x.px526    x.px527
x.px528    x.px529   x.px530    x.px531    x.px532     x.px533   x.px534
0 159.2846 158.0569 158.09756 163.01626 123.292683  28.65854   7.447154
9.2520325   7.487805   6.03252   4.609756  0.0000000  0.64227642  1.056911
      x.px535     x.px536     x.px537     x.px538    x.px539    x.px540
x.px541   x.px542   x.px543   x.px544   x.px545   x.px546   x.px547
x.px548
0  1.30894309   6.7073171   8.5365854  10.9430894  16.536585  66.268293
159.41463 166.27642 163.03252 165.88618 165.12195 162.24390 162.13008
161.49593
    x.px549   x.px550   x.px551   x.px552   x.px553   x.px554    x.px555
x.px556    x.px557     x.px558    x.px559    x.px560    x.px561    x.px562
0 160.16260 161.52846 160.38211 164.44715 130.30894  35.15447   7.739837
9.1056911   7.471545   6.5203252   4.772358  0.2845528  0.6585366
0.6504065
      x.px563     x.px564     x.px565     x.px566    x.px567    x.px568
x.px569   x.px570   x.px571   x.px572   x.px573   x.px574   x.px575
x.px576
0   1.6585366   6.7235772   8.7479675  10.8211382  16.414634  74.073171
161.00813 166.65041 164.47154 166.18699 164.33333 162.60163 162.11382
161.12195
    x.px577   x.px578   x.px579   x.px580    x.px581    x.px582    x.px583
x.px584    x.px585     x.px586    x.px587    x.px588   x.px589
0 161.43089 161.69919 161.13008 164.00000 133.284553  44.186992   8.276423
9.0000000   7.512195   6.6829268   4.447154  0.2764228  0.000000
       x.px590     x.px591     x.px592     x.px593     x.px594    x.px595
x.px596   x.px597   x.px598   x.px599   x.px600  x.px601   x.px602
x.px603
0  0.008130081   1.4552846   6.0813008   7.5203252   9.5365854  17.211382
82.544715 165.21951 169.04878 167.72358 169.81301 168.2114 164.87805
165.47967
    x.px604   x.px605   x.px606   x.px607   x.px608    x.px609    x.px610
x.px611     x.px612    x.px613     x.px614    x.px615    x.px616
x.px617
0 163.00000 164.13821 164.54472 161.34146 162.77236 137.642276  52.585366
7.674797   7.9512195   6.016260   5.3089431   4.097561  0.0000000
0.0000000
      x.px618    x.px619     x.px620     x.px621     x.px622    x.px623
x.px624   x.px625   x.px626   x.px627   x.px628   x.px629   x.px630
x.px631
0  0.02439024  1.3577236   4.3577236   6.5772358   8.3252033  18.707317
89.292683 167.65854 169.30894 167.87805 170.36585 168.04878 167.10569
166.70732
    x.px632    x.px633    x.px634    x.px635   x.px636    x.px637
x.px638    x.px639     x.px640     x.px641     x.px642    x.px643
x.px644
0 165.56911 165.593496 165.918699 164.040650 164.36585 142.520325
59.934959   8.951220   6.6747967   5.4552846   5.0975610   4.097561
0.0000000
     x.px645     x.px646    x.px647    x.px648     x.px649     x.px650
x.px651   x.px652    x.px653    x.px654    x.px655    x.px656    x.px657
```

```
0  0.0000000  0.02439024  1.2601626  3.9674797   5.6666667   7.8455285
20.910569  88.65854 164.276423 168.487805 168.691057 167.617886 166.308943
     x.px658    x.px659    x.px660    x.px661    x.px662    x.px663
x.px664    x.px665    x.px666    x.px667     x.px668    x.px669
x.px670
0 167.422764 167.918699 163.772358 164.308943 165.325203 162.439024
162.731707 143.682927  63.804878   9.861789   6.1463415   5.536585
5.1056911
    x.px671    x.px672   x.px673     x.px674    x.px675   x.px676
x.px677    x.px678    x.px679    x.px680   x.px681   x.px682   x.px683
x.px684
0  3.926829  0.0000000 0.0000000  0.01626016  1.9024390  3.943089
5.8617886   8.130081  22.577236  90.861789 161.26829 167.37398 167.86179
171.195122
     x.px685    x.px686   x.px687    x.px688    x.px689    x.px690
x.px691    x.px692    x.px693   x.px694     x.px695     x.px696   x.px697
0 169.894309 169.130081 167.27642 163.853659 166.910569 166.593496
159.552846 160.268293 143.463415  67.40650  11.2845528   6.5121951
5.804878
     x.px698   x.px699    x.px700   x.px701     x.px702    x.px703
x.px704     x.px705     x.px706     x.px707     x.px708     x.px709
x.px710
0  5.5609756  4.146341  0.0000000 0.0000000  0.02439024  0.7235772
1.4552846   3.5203252   5.8130081  23.5691057  90.4471545 161.2520325
163.284553
     x.px711   x.px712    x.px713    x.px714     x.px715     x.px716
x.px717     x.px718    x.px719    x.px720     x.px721     x.px722
x.px723
0 162.552846 167.91870 165.861789 165.626016 163.0162602 161.5365854
161.0325203 159.1463415 157.162602 156.747967 137.3170732  67.9756098
13.5528455
      x.px724    x.px725    x.px726    x.px727   x.px728   x.px729
x.px730      x.px731     x.px732     x.px733     x.px734     x.px735
x.px736
0   4.3170732  2.8943089  2.8536585  1.6260163 0.0000000 0.0000000
0.016260163  0.008130081  0.37398374   2.4390244   5.2357724  26.9756098
93.9024390
      x.px737     x.px738     x.px739     x.px740      x.px741
x.px742      x.px743      x.px744    x.px745     x.px746     x.px747
x.px748
0 164.0650407 168.5203252 172.8617886 175.6016260 176.63414634
178.41463415 178.17073171 175.34959350 174.926829 172.9756098 170.6016260
164.390244
     x.px749    x.px750     x.px751     x.px752     x.px753     x.px754
x.px755   x.px756    x.px757     x.px758    x.px759    x.px760    x.px761
0 145.349593  73.252033  15.0325203   4.5121951  2.17886179  2.07317073
0.699187 0.0000000 0.00000000 0.032520325 0.04878049  0.2113821  1.8943089
     x.px762    x.px763   x.px764   x.px765   x.px766   x.px767    x.px768
x.px769     x.px770      x.px771      x.px772     x.px773      x.px774
0  2.3739837 12.2276423 42.878049 74.138211 91.268293 98.813008 105.341463
110.29268 115.8292683 1.187236e+02 113.93495935 111.7235772 103.97560976
     x.px775   x.px776    x.px777    x.px778    x.px779    x.px780
x.px781   x.px782   x.px783     x.px784
```

```
0 95.8617886 85.357724 68.6260163 30.8048780  9.1138211  2.6829268
1.89430894  1.796748 0.4552846 0.000000000
 [ reached getOption("max.print") -- omitted 9 rows ]

Coefficients of linear discriminants:
                  LD1           LD2           LD3           LD4
LD5           LD6           LD7           LD8           LD9
x.px2   -1.844786e+00 -4.037873e-03 -8.528366e-01  6.740005e-01 -
7.535051e-01 -8.172915e-01 -4.392631e-01 -1.811275e+00  1.665180e-01
x.px3   -1.134707e-01  5.445598e-02  4.328841e-01 -6.604356e-02
3.521699e-01 -1.355346e-01 -4.512568e-01  1.019148e+00 -2.602046e-01
x.px4    3.783115e-01  9.348333e-04 -2.648278e-01  2.655506e-01 -
1.487369e-01 -1.483734e-01  1.563853e-01 -2.411258e-01 -3.966517e-02
x.px5    4.564789e-02  2.567906e-01  1.501304e-01 -1.425565e-02
1.474674e-01 -1.414241e-01  8.908180e-02 -1.386653e-01 -5.871245e-02
x.px6   -2.725224e-02 -5.278634e-02  1.570201e-02 -7.113146e-02 -
1.478800e-01 -8.623460e-03  7.191596e-02  1.935980e-01  8.143766e-02
x.px7   -4.847158e-02  8.541307e-03  2.087966e-02  1.079669e-02 -
1.203616e-03 -5.730074e-03 -2.607066e-02  2.972946e-02  6.905391e-02
x.px8   -1.194125e-02  2.976404e-02  3.541821e-02  5.614898e-03
9.323305e-04  7.061749e-03  3.835407e-02 -2.286035e-02 -1.491257e-02
x.px9   -3.850316e-03 -2.965662e-03 -1.110535e-02 -8.900022e-03
1.044667e-02  5.730694e-03 -1.504064e-02  3.786834e-03  2.171743e-02
x.px10  -3.572908e-05  8.057090e-03 -3.883048e-03  2.812802e-03
1.652958e-03 -1.306186e-03  1.187835e-03 -5.551328e-03  4.547312e-03
x.px11  -4.321561e-03 -7.026190e-04 -1.060683e-03  7.750243e-04
1.502062e-03  2.885851e-03 -3.912983e-03  4.947988e-03  4.020164e-03
x.px12   5.992387e-03  2.634649e-03 -7.284430e-03  1.650631e-03
4.816437e-03 -2.518435e-03  5.710161e-03 -4.425785e-03  3.769784e-03
x.px13  -9.354820e-03  1.249012e-03  5.401735e-04 -4.510416e-03
7.059224e-04  7.000884e-03  2.438130e-03  1.081358e-03 -2.468926e-03
x.px14   6.876721e-03  4.108693e-03 -8.656657e-03  3.616610e-03
1.302871e-03  5.322998e-03 -5.277576e-03 -5.383361e-03  2.209791e-03
x.px15   2.064860e-03 -3.544115e-03  2.542576e-03 -1.969878e-03
2.566069e-03  6.226144e-04  1.334437e-02  7.910518e-03  1.869843e-03
x.px16  -2.763991e-03 -3.668945e-03 -1.236991e-03  2.122065e-04 -
2.263439e-03 -7.270403e-03 -1.372256e-02 -1.929073e-03 -3.055207e-03
x.px17  -9.421707e-04  5.394593e-03  8.217776e-03  8.549296e-04 -
5.017657e-03 -9.598547e-05  9.716332e-04  1.031075e-03 -5.544065e-03
x.px18  -1.194196e-03 -3.601010e-04  5.105439e-04 -1.190580e-03
4.437760e-04 -3.938005e-04 -2.361898e-03 -3.113122e-03  8.505830e-04
x.px19  -3.255842e-03 -4.478114e-04  1.014522e-02 -4.347644e-03 -
3.857181e-03 -3.340406e-03  3.715068e-03  5.816336e-03  4.492012e-05
x.px20   5.818774e-03  1.142879e-02 -2.557298e-03  1.367751e-03
1.792642e-03  9.946796e-04  1.470984e-03 -7.680326e-03  2.327033e-03
x.px21   5.226127e-04 -7.981208e-03  5.913669e-03 -5.237614e-03 -
2.663307e-02  8.081108e-03  1.233225e-02  5.901132e-03  4.064950e-04
x.px22  -1.398313e-02  1.327693e-02 -1.493192e-02  1.806886e-02
1.476083e-02 -1.579959e-02 -1.831231e-02 -9.056198e-03 -7.759556e-03
x.px23   2.337628e-02  4.870220e-03  6.122679e-02 -2.190081e-02 -
6.658460e-03  2.494689e-02 -2.165827e-02  3.795278e-03  2.307492e-02
x.px24  -2.327058e-02 -2.189416e-02 -5.175348e-02  5.631193e-02
4.163341e-02 -3.987152e-02 -2.347278e-02 -2.666740e-02 -3.034086e-02
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x.px25   4.495672e-02 -2.750208e-02 -6.355267e-02 -1.452140e-01 -
1.400253e-01 -3.469049e-02 1.293531e-01 1.288087e-01 5.846121e-02
x.px26 -3.475960e-01 2.338307e-02 1.107384e-01 -2.530375e-01
3.370393e-01 3.541646e-02 -2.864284e-01 3.920468e-01 -1.200237e-01
x.px27 -1.310161e+00 -2.761083e+00 -2.283970e+00 -8.633838e-01
9.103597e-02 7.185804e-01 1.508048e+00 5.704842e-01 -1.736237e+00
x.px28 -7.863326e+00 -5.290929e+00 -4.279239e+00 3.153657e+00
1.214026e+00 -6.792294e+00 -8.871871e+00 -6.651148e+00 -7.286776e-01
x.px30   4.741850e+00 4.178500e+00 1.773066e+00 -1.316503e+00
1.445883e-01 -3.654040e-01 -1.430926e+00 -4.242582e-01 -2.479359e-01
x.px31 -1.011670e-01 3.019089e-01 8.488192e-02 -2.115874e-01
1.483879e-01 4.892900e-01 -5.532539e-02 -8.449230e-01 -6.565123e-02
x.px32 -1.950096e-01 -2.596298e-01 2.865041e-01 3.753703e-02 -
2.498521e-01 -7.523159e-02 1.299336e-03 4.459145e-01 2.117353e-01
x.px33 -2.308550e-02 -8.532438e-02 -1.364582e-01 1.236269e-02
3.459217e-02 4.709440e-02 -9.907168e-02 -5.909759e-02 -2.898736e-02
x.px34   3.685717e-02 -3.492798e-02 -6.780137e-02 -2.440016e-02
2.529287e-02 1.166927e-02 -1.262455e-02 4.384624e-05 -4.666590e-02
x.px35 -3.142528e-03 -7.541589e-03 -1.149702e-02 1.466060e-02 -
1.047115e-02 -1.344410e-02 -6.527935e-03 1.291100e-03 -5.553256e-03
x.px36 -2.303162e-03 -9.202345e-03 -4.882589e-03 2.577073e-03
7.743072e-04 -2.366132e-03 -2.332711e-03 -5.124464e-03 -6.450101e-03
x.px37   6.461788e-04 9.506148e-03 2.709849e-03 -1.329965e-03 -
8.177438e-03 -3.250575e-03 8.482653e-05 -6.620572e-03 -8.023462e-04
x.px38 -3.868426e-03 -5.822953e-04 -6.186726e-03 -7.556878e-03 -
2.697117e-03 3.709802e-03 -1.002733e-02 4.293682e-03 -3.707237e-03
x.px39 -5.513927e-03 5.734768e-03 -5.110713e-03 -3.770667e-03
3.123351e-03 -6.559747e-04 7.830225e-03 -3.102418e-03 2.614083e-03
x.px40 -2.535243e-04 3.294192e-03 3.989658e-03 8.334341e-04 -
2.771547e-03 5.054339e-04 -5.023931e-03 -5.844009e-03 -7.764932e-03
x.px41 -8.255194e-03 2.869219e-03 -1.126343e-03 4.022465e-03 -
6.722161e-03 -2.409345e-03 -2.467442e-03 3.778198e-03 -3.651644e-04
x.px42   1.951937e-03 -3.229615e-03 3.719952e-03 -1.972297e-03
3.859050e-03 -5.219814e-03 3.543770e-04 4.738560e-03 1.258363e-03
x.px43 -4.957248e-03 5.405047e-03 -1.855836e-03 1.077327e-03 -
1.222552e-03 1.879527e-03 -7.100722e-03 -3.029636e-03 -5.931132e-03
x.px44   4.673268e-03 -6.052308e-03 2.927776e-03 -4.570787e-03 -
3.372576e-03 4.510894e-03 1.085135e-02 -2.311615e-03 4.138165e-03
x.px45 -2.256612e-03 -3.297817e-03 -4.191356e-03 -2.836581e-04
4.226778e-04 -1.190430e-04 1.068409e-03 -1.929955e-03 1.309395e-03
x.px46   1.464526e-03 -1.906807e-03 -1.325884e-03 4.549236e-03
1.453882e-03 5.684926e-03 1.219162e-03 -7.663796e-03 2.710354e-03
x.px47   3.529008e-03 -5.787945e-03 4.079950e-03 6.198953e-03 -
4.007415e-03 -1.595199e-03 -3.643680e-03 -3.931676e-03 3.362054e-03
x.px48   2.216203e-04 1.667345e-03 -1.321981e-03 -1.015967e-03
7.140260e-03 2.791222e-03 -1.708310e-03 -4.309429e-04 2.205871e-03
x.px49 -4.016387e-03 -4.145579e-03 9.399239e-04 7.268557e-03 -
1.550822e-03 -5.419795e-03 5.681755e-03 -6.870023e-05 -5.482030e-04
x.px50   1.700539e-04 -5.724348e-04 1.379168e-02 -1.335808e-02 -
2.409969e-03 1.611160e-02 -1.366777e-04 1.682145e-02 5.358785e-03
x.px51   1.597174e-02 -5.374674e-03 -1.095643e-02 1.129971e-02
6.635107e-03 -2.058684e-02 -1.198119e-02 -7.217427e-03 -1.749079e-02
x.px52   1.757556e-02 2.071152e-02 7.348488e-03 -4.915006e-02 -
4.043002e-02 3.267607e-02 4.868717e-02 1.041891e-02 2.182464e-02

x.px53 -5.196403e-02 2.156698e-02 2.454116e-02 9.612975e-02
8.028754e-02 -2.189845e-02 -4.272304e-02 -6.133314e-02 -5.114588e-02
x.px54   9.694915e-02 -1.863410e-02 -3.851270e-03 -1.319437e-01 -
1.190877e-01 6.196351e-02 7.823966e-02 4.882124e-02 6.546352e-02
x.px55 -2.711203e-03 2.099633e-03 7.428114e-02 1.806693e-01
8.534024e-02 -1.138815e-01 2.668752e-02 -1.052079e-01 -1.140301e-01
x.px56   4.612700e+00 2.611647e+00 2.448696e+00 -1.827758e+00 -
9.556437e-01 3.788989e+00 5.454199e+00 4.208649e+00 8.988045e-01
x.px57   6.927554e+00 4.316691e+00 -2.333351e+00 -3.922387e+00
4.777861e+00 -1.178340e+01 -9.020286e-01 -1.378504e+00 -7.504000e+00
x.px58 -6.120361e-02 -3.363288e+00 1.910708e+00 2.606406e+00 -
2.680765e-01 1.939264e+00 9.206408e-01 8.022190e-01 4.716763e+00
x.px59   3.587597e-01 -2.367979e-01 -4.940910e-01 -2.781320e-01 -
1.019234e-01 9.056832e-02 2.413756e-01 3.399188e-01 -2.615482e-02
x.px60   7.546700e-02 1.493677e-02 -6.487781e-02 -3.691965e-02 -
1.243437e-02 -1.244470e-01 1.047136e-01 -3.714296e-02 1.238540e-01
x.px61 -3.600913e-02 -3.240583e-02 4.721639e-02 4.468795e-02 -
3.536052e-02 -1.379485e-02 3.101712e-02 2.081356e-02 3.109728e-02
x.px62   1.108219e-02 -3.047422e-03 -3.627594e-03 -2.167673e-02
1.791127e-02 2.189099e-02 2.563628e-03 9.308908e-03 8.447146e-03
x.px63 -5.676362e-03 3.266854e-03 7.541292e-03 -9.680898e-03
6.816224e-03 6.548848e-03 -5.345840e-03 1.309395e-02 2.460521e-03
x.px64   5.212443e-03 -5.887487e-04 -1.327967e-03 -2.489572e-03
3.808928e-03 2.899127e-03 -1.974567e-03 8.693377e-04 1.139340e-03
x.px65 -1.939948e-03 -2.077944e-03 -1.274967e-03 6.377368e-03
3.825712e-03 2.406630e-03 -5.196092e-03 7.735967e-04 -2.114271e-03
x.px66   3.642783e-03 -1.272583e-03 -2.931898e-04 9.129539e-04
7.020219e-03 1.429520e-03 5.701563e-03 -4.613315e-03 5.793955e-03
x.px67   3.590900e-03 -1.078546e-03 -2.095017e-04 4.797385e-03
2.614590e-03 3.441587e-03 -5.427433e-03 -7.938376e-04 2.482102e-03
x.px68 -1.826765e-03 -3.284488e-03 2.819120e-03 -4.604124e-03 -
1.652279e-03 1.273797e-04 3.559835e-03 5.465581e-03 4.395679e-03
x.px69   7.287872e-03 -6.564041e-03 2.292067e-03 7.162245e-03
1.173970e-03 -2.006001e-03 8.393333e-04 -4.318973e-03 -5.865009e-03
x.px70 -6.479704e-04 7.736137e-04 -6.192175e-05 -4.115586e-03 -
2.854861e-03 5.441222e-03 2.819800e-03 -5.199860e-03 -1.068294e-02
x.px71 -1.796453e-03 -3.413957e-03 2.150779e-03 -1.815680e-03
3.322932e-03 3.378941e-03 -1.299526e-03 8.493682e-03 1.002063e-02
x.px72 -4.400511e-03 4.703329e-03 -1.437373e-03 -6.497297e-05
5.975517e-03 -4.212875e-03 3.234220e-03 4.633385e-03 -1.853582e-03
x.px73   2.026774e-03 -2.023900e-03 -4.728604e-03 1.816345e-03 -
9.908535e-03 1.676048e-03 -1.217051e-03 3.276830e-03 3.573054e-03
x.px74 -4.352494e-03 8.641014e-03 -3.350168e-03 -4.522051e-03
5.646129e-03 -9.546403e-03 -1.402625e-03 4.264376e-03 -6.090886e-03
x.px75   4.979256e-04 3.704332e-04 2.538295e-03 -2.843614e-03 -
7.942014e-04 -3.163856e-03 -4.789977e-03 -5.797399e-04 7.651609e-03
x.px76 -3.811203e-03 5.880720e-03 -1.178000e-04 -4.607472e-03 -
5.274989e-03 -1.396678e-03 2.860620e-03 4.128583e-03 -6.824252e-03
x.px77 -1.130786e-03 -3.326278e-03 2.585131e-03 3.469359e-03
7.547411e-04 -1.348667e-03 -7.955784e-03 -8.425060e-03 7.886910e-03
x.px78   5.852739e-03 4.440312e-03 -5.768573e-04 5.574628e-03 -
5.895595e-03 -2.140415e-03 1.077685e-02 5.982661e-03 -3.504151e-03
x.px79   5.581302e-03 -4.756629e-03 -1.181772e-02 1.376894e-02 -
2.955090e-03 -8.909506e-03 5.532758e-03 -1.427206e-02 1.197226e-04

x.px80 -2.817028e-02 3.582585e-03 -6.779017e-03 -4.350235e-03
1.119376e-02 1.019655e-02 -1.715201e-03 1.674853e-02 2.680496e-03
x.px81   3.589663e-02 -1.089945e-02 1.706728e-02 -1.838030e-02 -
6.431835e-03 -1.389963e-02 -1.645447e-02 2.412867e-02 1.819282e-02
x.px82 -6.412078e-02 1.866502e-02 -1.216873e-02 1.148263e-01
7.218425e-02 -6.726244e-02 -1.425285e-02 -6.044657e-02 -5.828546e-02
x.px83   4.800771e-02 6.394358e-04 -7.503691e-02 -1.482746e-01 -
7.633048e-02 6.516382e-02 -1.689112e-02 7.891293e-02 1.128868e-01
x.px84 -2.628281e-01 -3.896160e-02 -1.693021e-02 6.568560e-01 -
5.829072e-02 -9.792776e-02 2.073148e-01 -1.839746e-01 -3.946620e-01
x.px85   3.017281e+00 -1.576046e+00 9.002642e-01 -2.238254e+00 -
3.714176e+00 7.655779e+00 1.068024e+00 -1.092568e-01 8.703844e-01
x.px86 -4.299262e-01 1.414056e+00 -1.777063e+00 -1.759615e+00
3.228653e-01 -1.298704e+00 -5.107108e-01 -6.475471e-01 -2.790601e+00
x.px87 -2.220124e-01 1.458028e-01 1.634763e-01 1.141472e-01
3.243124e-01 -7.847301e-02 -1.766109e-01 -2.276428e-01 2.508708e-02
x.px88 -9.787030e-02 3.150948e-02 4.568437e-02 1.872044e-02
1.555906e-03 6.307786e-02 -2.299317e-02 9.664759e-02 -9.339020e-02
x.px89   8.150952e-03 2.609079e-02 2.008537e-03 1.131182e-02
4.057883e-03 -2.169446e-02 -8.151285e-03 -2.400710e-02 2.527059e-02
x.px90 -4.291328e-04 3.733709e-03 -4.378866e-03 6.862618e-03
6.764811e-03 -8.102729e-03 4.220207e-03 -2.090243e-02 -1.590186e-03
x.px91 -3.028338e-03 -6.838499e-03 1.345556e-04 5.454534e-03 -
5.193610e-03 -4.466614e-03 9.116005e-03 -7.547309e-03 3.028466e-04
x.px92 -6.852283e-03 5.251311e-03 6.446800e-03 -8.450625e-03 -
5.510250e-03 6.678517e-04 -1.054875e-02 6.999031e-03 -1.700485e-03
x.px93   1.575547e-02 -7.894414e-03 -4.439448e-04 -8.619925e-04
6.587386e-03 -7.023842e-03 9.024365e-03 2.410301e-03 3.722078e-03
x.px94   8.571859e-06 4.488080e-03 4.445445e-03 -4.311568e-03 -
1.116783e-02 -3.456462e-03 1.818746e-03 7.605137e-03 -5.793240e-03
x.px95   1.325899e-04 3.102161e-03 6.334097e-03 5.779961e-06
4.989183e-04 5.254136e-03 5.036310e-03 -2.320574e-03 5.739949e-03
x.px96   6.929939e-03 9.753986e-03 -1.780892e-03 4.846123e-03
1.764818e-03 -2.447647e-03 -1.083202e-03 -1.338501e-03 7.828495e-04
x.px97 -7.955889e-03 -1.433142e-03 3.555542e-04 1.020933e-02 -
1.833423e-03 -6.072923e-03 -8.496551e-03 -1.265738e-02 -6.763298e-03
x.px98 -3.677774e-03 2.486010e-03 3.203208e-03 -2.532878e-03
2.422746e-03 5.296259e-03 -1.829561e-03 4.240290e-03 7.890496e-03
x.px99   5.567090e-03 3.862013e-03 4.961409e-03 -1.267271e-03 -
2.457511e-03 -1.477516e-03 -6.142368e-03 8.509784e-04 -9.569101e-03
x.px100 2.175370e-03 -6.600739e-04 -3.650175e-04 -5.180666e-03
2.175567e-03 -3.991371e-04 3.672823e-03 7.501469e-03 1.101151e-02
x.px101 -4.246638e-03 -6.323474e-03 3.558357e-04 -5.069639e-03
3.552275e-03 4.452750e-03 8.981578e-03 2.717126e-03 3.807808e-04
x.px102 5.499649e-03 -7.077311e-04 -4.723244e-04 -2.337059e-03
6.286553e-05 9.394584e-03 6.258327e-03 -4.499409e-03 1.080145e-03
x.px103 -7.777330e-03 -3.433585e-03 -5.490673e-03 2.761954e-03
6.010944e-03 -2.543935e-03 6.139794e-03 2.250634e-03 -4.465186e-03
x.px104 -4.972446e-03 7.661969e-04 -3.233003e-03 4.152644e-03 -
1.688447e-04 9.761275e-03 -9.889392e-03 -9.118751e-03 -1.789257e-03
x.px105 2.473158e-03 -2.483742e-03 7.592055e-04 9.498928e-03 -
2.376592e-03 -3.744320e-03 8.513148e-03 1.209677e-03 3.014502e-03
x.px106 -9.938245e-04 -2.338506e-03 -6.458488e-03 -2.341117e-03
8.172076e-04 6.304179e-04 -9.469738e-04 4.395390e-03 2.986749e-03

```
x.px107 -1.605098e-03 -9.347781e-03 -5.771875e-04 -8.810373e-03
1.758232e-03  5.862147e-03  6.768180e-03  5.227593e-03  6.860053e-03
x.px108  4.557691e-03  3.067859e-03  1.597358e-02  1.617433e-03 -
3.004728e-03 -4.964760e-03 -5.631889e-03  5.798062e-03 -6.124928e-03
x.px109 -3.283562e-04  6.764649e-03  2.237986e-02 -3.031127e-03 -
3.260665e-03  3.520397e-03 -7.158832e-03 -2.271113e-02 -1.363446e-02
x.px110  3.562873e-02 -4.020065e-03  6.595136e-03 -2.909815e-02 -
2.847936e-02  2.726842e-02 -2.240742e-03  2.230445e-02  1.847146e-02
x.px111  8.606444e-03 -2.002458e-03  5.316862e-03  1.294973e-02
1.790502e-03 -4.044445e-02  1.502966e-02 -2.760875e-02 -1.232748e-02
x.px112 -2.765953e-02  1.060800e-02  3.003406e-02  3.332979e-02
2.831954e-02 -2.382200e-03 -3.158869e-03  1.157654e-01  4.022148e-02
x.px113 -6.123084e+00  3.213119e+00 -3.890274e+00  3.866745e-02
3.397054e+00 -5.785310e+00 -2.403742e+00 -1.796957e+00  8.973669e-01
 [ reached getOption("max.print") -- omitted 671 rows ]

Proportion of trace:
   LD1    LD2    LD3    LD4    LD5    LD6    LD7    LD8    LD9
0.4176 0.1493 0.1123 0.0994 0.0674 0.0621 0.0457 0.0274 0.0187
> lda.pred.full <- predict(lda.fit.full, dat.test)
> #Error rate higher than with PCA:
> mean(lda.pred.full$class != dat.test$y)
[1] 0.355
> #QDA using PCA
> system.time(qda.fit<-qda(y~., data=dat.pca.train))
   user  system elapsed
   0.03    0.00    0.02
> qda.fit
Call:
qda(y ~ ., data = dat.pca.train)

Prior probabilities of groups:
         0          1          2          3          4          5
6          7          8          9
0.10250000 0.08916667 0.11333333 0.10166667 0.08416667 0.13166667
0.09583333 0.09083333 0.09333333 0.09750000

Group means:
        x.PC1       x.PC2      x.PC3      x.PC4       x.PC5      x.PC6
x.PC7        x.PC8        x.PC9    x.PC10    x.PC11     x.PC12     x.PC13
0  -764.05710   693.36939 -155.55580 -148.46180   -7.337393  707.22224 -
105.75837   11.7634545  -16.2946515 -34.74666  77.72095  -2.327815  -
64.72897
1    95.66339  1398.06749 -182.66459  327.68519  288.971748 -364.26354
282.88772  159.3187987  340.9250460  54.77037  -7.98132  21.388956  -
72.87123
2  -904.56984  -259.88791  490.04439 -203.44607  235.953419  -98.61471
26.40454  -46.7625018  -29.2220470 -99.17127  44.13156  29.387096  -
12.02044
3  -141.18251  1110.99435 -288.24086  139.22419 -189.055011 -127.56917
20.08120  -22.6706425 -281.6182581 -99.88930 -49.95557   2.249283
86.22974
```

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4 -1073.55749  -182.30826  435.43897  -22.48462  -13.713699 -325.21008 -
223.04340   26.6256347   15.9469066 124.76117 -62.22953  15.865455
69.41020
5  1453.49562  -219.73259  104.35957 -200.03629   76.698670   60.90032  -
47.14059   32.1681772   15.5127439 -17.92852   8.78871   9.292916
95.23817
6  -633.65537   -80.02712  337.71923 -215.92841   65.490308   53.73187  -
22.19901   -0.2329146  -50.6236613  43.79859 -89.31235 -45.590898
32.46572
7  1382.29575  -466.61103  171.43298  559.03541 -209.058056  122.77092
23.68542 -359.3659630   38.2899642  37.34411  69.53084 -29.786297
20.03907
8  -148.59048  -826.48541   36.98883  -44.84459 -614.841129  -10.62753
286.58053  277.6409359   -0.8156656  68.00780  22.65358  24.460768 -
119.43522
9   355.62452 -1105.24138 -982.36737  -28.39332  293.524886 -121.23112 -
217.53740  -77.2510130   13.1171495 -20.55721 -30.44072 -30.717887  -
66.02989
      x.PC14     x.PC15    x.PC16     x.PC17    x.PC18     x.PC19
x.PC20     x.PC21     x.PC22     x.PC23     x.PC24     x.PC25     x.PC26
x.PC27
0 -24.541495  -7.030338 -24.97631   4.055421 -79.87306 -10.862662 -
16.295756   1.128505  21.709032  -8.093458  -2.072301 -14.928474
25.834634 -15.683478
1   6.853842  49.446089 -27.86143 -42.173484 -21.58218  -1.865776 -
21.967576   8.167367  25.382195   6.771001 -10.236557  47.797976  -
4.468072  -0.380031
2  18.134310  27.195676  18.63724 -10.598201  55.72810  65.444250
45.446948  31.739627   7.118714  14.176084 -24.022566   9.911452
1.637830  21.549056
3   1.944539 -23.802504  44.91180  60.376923  61.86947  28.381057
28.817075 -21.801958 -49.427580  23.503856 -23.093350 -33.969003 -
38.710249  19.273580
4  -2.845603 -38.777858  23.73091 -37.842113 -95.27665 -38.510429  -
4.963525 -14.783413 -30.055466 -56.425072  20.777737 -18.333841  13.590875
17.360106
5 -28.488257 -26.835217 -94.69423 -22.945256  61.98943 -25.608461
8.299244 -21.966630 -15.793708  22.789544  29.101908  -7.190621   5.978456
1.159357
6  33.277830  -7.499987  35.82298  16.322987  13.86073 -69.452395
4.742326 -15.387490  38.546798   8.074732  20.960993   6.913245 -16.418731
-62.988210
7  31.597896  85.997623  50.37479  14.102621 -20.39702  -5.083443
13.273376   6.396868  35.725912 -24.358498  -8.912932  13.256769
21.854226  12.769635
8 -36.257772 -33.075149 -32.39927  39.673921  10.47836  67.134337 -
91.244295  -3.762691 -15.973205   1.516351  -9.782938 -20.665305
3.022961  18.232222
9   9.914896 -15.991490  39.50807 -19.840067 -31.70164 -15.977746
17.740782  32.377022 -11.376797  -7.432347   3.373452  22.054862 -
11.533962 -12.300182
      x.PC28     x.PC29      x.PC30      x.PC31      x.PC32     x.PC33
x.PC34      x.PC35     x.PC36      x.PC37      x.PC38     x.PC39
x.PC40
```

```
0  30.426380   1.371630  -7.2120726 -20.2841109  -7.0916226  13.575761
6.786120  -0.6662605 -17.930032  11.7555530   0.5663023   1.027203  -
3.3904127
1  21.025941   9.344218   4.4348680  26.6456527  -6.2335716  11.916089
1.276021  31.3592138  -2.712494  -1.8103055  12.5980331 -11.219077
5.8962463
2 -19.568090 -18.013744  17.4673176  -9.1741413  18.3475947 -10.434934  -
1.259149  -8.8444783 -24.733036  -7.3661594 -19.5822038  17.004890  -
2.1491633
3 -23.104582  -5.052624  -0.7376129  -0.1568662   0.5638363 -29.446862 -
13.480023 -19.0734018  15.257512  -4.7280894 -30.5350359   4.734392  -
7.0493779
4  -9.309736   1.601478 -18.9897359 -15.1980617   3.0522619  -9.858398
15.987383  10.3954406 -12.012298 -10.1550535 -12.6831419 -19.138311
0.5085038
5  14.092503   2.919921 -19.2368900  28.5925585 -26.7310161  10.386937
18.253155   1.4507386   5.211583 -17.7981942  -5.2533864   8.834056  -
2.1333443
6  -2.170913 -13.117568 -18.9025235  -1.6558734   1.3028824  21.996550 -
15.407025 -18.9478387  21.764075  14.8021033  47.9012219  -2.331930
1.1468529
7  21.325445 -12.425882  15.5045594 -17.7217700 -21.2685221  -5.253033 -
16.462709  -8.6451248 -19.072292   9.9354788  -4.7936343  -3.364994
19.9917029
8   1.744293  35.399932  18.8124481  10.0430153  18.3201260   0.243495
11.049195   0.7156720  31.717814  11.3206278  17.5680864   2.827444
4.6883934
9 -34.775322   1.476922  12.4887060  -9.1851081  25.7009081  -4.811144 -
11.328299  17.2506564   3.515687   0.9491449   1.0947153  -8.211064 -
13.7772779
       x.PC41     x.PC42     x.PC43     x.PC44     x.PC45    x.PC46
x.PC47      x.PC48     x.PC49        x.PC50      x.PC51      x.PC52
x.PC53
0  -2.7089264  12.484422  -4.736564   6.523969 -1.7100349  3.732052
6.8421103  -2.9905119   3.031015 -15.747692864   0.9959531   0.4132903  -
7.0091869
1  19.0127552  11.732709   3.535813   2.585805  6.7746773 -7.810791  -
4.1568575 -23.4155459  -5.629362  -7.845227214  15.1615604 -16.9268592
4.4173575
2  10.4969225  10.906544  16.997721   1.899589  5.0473956 -1.705347
1.5467194  -8.8472443 -16.699360 -16.914821108  -2.7712593   6.6160867
3.7707787
3  -5.6598022 -17.319495   5.013454 -18.014022 -8.0774039 -5.728943 -
13.6150831  20.5804481  14.637666  19.208634628 -18.2797027  21.4893045
3.5186994
4 -17.4094789  -3.463938  -6.196157  10.015211 -2.2228522  1.317471  -
0.3150766  20.3760436  -4.249328   1.399131655   6.2177219  13.0478638  -
4.1988622
5   2.2245937 -13.564381  27.642408  13.671814 -4.5870910 -6.981977
23.1104150   0.3628822   2.245435  13.716805080  -0.7432098  -4.1749285 -
16.8389091
6  -8.4665511  -6.933485 -40.804437 -10.575284 -4.7089046 14.373720 -
11.5682168  -7.0540216  11.545559  14.556208861   8.7444890 -21.4967304
0.6935902
```

```
7  -8.8195020  22.713491 -32.336188 -26.954978 -0.8569414  1.404662
1.3101801   0.9129498  11.176423  -9.543881506  -8.4692482   1.3961451
1.6293294
8   8.3646045  -6.960586  13.097341   2.613008  4.5005420  6.170967
3.1702289   6.8193134 -14.525323  -1.870620792  -9.9550466  -2.0325047  -
2.4413927
9  -0.2840812  -4.847003   2.474342  13.249126  7.3895701 -1.876719 -
14.8142110  -5.1424872  -1.110130   0.005374994  11.8304281   1.0961149
21.7784140
       x.PC54     x.PC55      x.PC56    x.PC57      x.PC58      x.PC59
x.PC60       x.PC61      x.PC62     x.PC63     x.PC64      x.PC65
x.PC66
0  -1.0180187 -3.5882662   5.5239500 -5.172675 -10.0669269  -0.9038855  -
2.56444829   0.58598224   2.1205643   9.566402  -3.937092  -0.7819553  -
1.581355
1   3.7980125 -6.0192179  -0.3919504 -1.207581   5.6551614   7.8150661 -
11.11654503   7.46718380   8.4968384  -2.010329   1.578382   3.1643922  -
3.609001
2   7.5289703 -7.7803211  -7.0485245  9.419235   0.8612474 -16.2616888
4.61127752   0.03907355   4.5232888   2.720235  12.235023   3.6803323
8.177804
3  -1.6443968  4.2636283 -10.6418748 -6.674595  -0.3085238   2.3285450
6.61797773  -7.01868596  -0.5247082   3.937541   4.914695   5.6979732
10.775997
4  -8.4138862 -0.2944623  -4.1470330 -1.252446   8.7798335   0.3831331
4.02221096  -4.46378452   6.2486074  -3.050565  -7.907850  -3.6700269  -
4.503034
5 -13.8742640  3.3888876  -2.8661476 -2.236215  -4.9295679  10.9801321  -
4.01064045   0.97648370 -13.3624536  -2.606208  -2.385560   0.8814345
11.028453
6   9.2761969  0.3597750  13.0141949 -7.044355   1.6961744   0.2385126
1.50862087   8.76929745  -7.7424993 -13.598481 -10.618747 -11.9293890  -
7.896427
7   9.2610532 -0.2667769   9.2625108  4.164463   9.6147010  -9.5311297
2.20117879 -11.86499100   4.2422538   4.099797   6.901972  -6.6513982  -
8.808596
8  -1.0766650 15.1701033  14.6957713  7.161339   6.7663347   1.9286563  -
0.94154579   1.96078322  -1.0426614   6.509262  -5.798756   6.0502101
1.533344
9  -0.1554645 -5.0741580 -14.1971788  2.843231 -13.2918240   1.9176958  -
0.08682429   2.92022313   2.5963603  -6.017914   2.954978   1.8168999 -
12.285306
      x.PC67      x.PC68      x.PC69     x.PC70     x.PC71     x.PC72
x.PC73     x.PC74
0   1.429914 -3.31886266   3.3212827 -3.0210364  -2.532040  0.1932055
2.0005665  5.7539210
1  -2.979899  7.04768639  -2.5384711 -3.3613944   4.748624  0.5213181 -
0.3384956  0.3443229
2  -1.126958  5.49197131   1.9747392 -4.3398997 -11.574341  2.0982575
12.6053342  1.2976511
3   6.017167 -4.46406594  -0.8790432 -1.4794235   1.551159 -3.9144256 -
5.3571188 -4.2244288
4  -7.013861 -5.04057031   3.2471341 14.1368063  -8.597618 -1.5113857 -
3.8667446 -5.4831166
```

```
5   1.139487  0.04989391 -13.9266015  5.0923210  -5.083219  0.8025129
3.9247816 -5.5048930
6   4.456981  0.29478398   0.8352892 -0.5638588  12.724475  1.2544699 -
6.5123723  5.6645875
7 -10.538076  6.21727665   2.7954719  2.2626387   9.221793 -5.8887337
7.7557313  6.4780741
8   9.315196 -7.33199780   6.4233113 -8.9464222  -3.489707  3.2344084 -
6.3659546 -8.1738655
9  -2.706854  0.53538815   3.8807207  0.7673845   6.684379  2.3406726 -
7.5525374  4.9216078
> qda.pred <- predict(qda.fit, dat.pca.test)
> #Error rate
> mean(qda.pred$class != dat.pca.test$y)
[1] 0.2633333

> #QDA using full dimension
> #Some group is too small for QDA. Tried running with character
> #type for y-values. It seems that the problem is with another
> #column
> qda.train <- dat.train
> qda.train$y <- as.character(dat.train$y)
> system.time(qda.fit.full<-qda(y~., data=qda.train))
Error in qda.default(x, grouping, ...) :
  some group is too small for 'qda'
Timing stopped at: 0.08 0 0.08
> #Part III: Deep Learning
> xx_train <- dat[1:60000,1:784]
> yy_train <- to_categorical(dat[1:60000,785],10)
> xx_test <- dat[60001:70000,1:784]
> yy_test <- dat[60001:70000,785]
> xx_train <- xx_train/255
> xx_test <- xx_test/255
> xx_train<-array_reshape(as.matrix(xx_train),c(60000,784))
> xx_test<-array_reshape(as.matrix(xx_test),c(10000,784))
> modelnn <- keras_model_sequential()
2023-05-18 09:28:47.569104: I
tensorflow/core/platform/cpu_feature_guard.cc:193] This TensorFlow binary
is optimized with oneAPI Deep Neural Network Library (oneDNN) to use the
following CPU instructions in performance-critical operations:  AVX AVX2
To enable them in other operations, rebuild TensorFlow with the
appropriate compiler flags.
> modelnn %>%
+   layer_dense(units = 256, activation = "relu",
+               input_shape = c(784)) %>%
+   layer_dropout(rate = 0.4) %>%
+   layer_dense(units = 128, activation = "relu") %>%
+   layer_dropout(rate = 0.3) %>%
+   layer_dense(units = 10, activation = "softmax")
> modelnn %>% compile(loss = "categorical_crossentropy",
+                     optimizer = optimizer_rmsprop(), metrics =
c("accuracy")
+ )
> system.time(
+   history <- modelnn %>%
```

```
+     fit(xx_train, yy_train, epochs = 30, batch_size = 128,
+         validation_split = 0.2)
+ )
Epoch 1/30
375/375 [==============================] - 7s 17ms/step - loss: 0.6812 -
accuracy: 0.7575 - val_loss: 0.4544 - val_accuracy: 0.8294
Epoch 2/30
375/375 [==============================] - 5s 13ms/step - loss: 0.4721 -
accuracy: 0.8275 - val_loss: 0.4161 - val_accuracy: 0.8474
Epoch 3/30
375/375 [==============================] - 5s 13ms/step - loss: 0.4310 -
accuracy: 0.8448 - val_loss: 0.3813 - val_accuracy: 0.8548
Epoch 4/30
375/375 [==============================] - 5s 12ms/step - loss: 0.4039 -
accuracy: 0.8551 - val_loss: 0.3487 - val_accuracy: 0.8707
Epoch 5/30
375/375 [==============================] - 4s 12ms/step - loss: 0.3886 -
accuracy: 0.8600 - val_loss: 0.3607 - val_accuracy: 0.8732
Epoch 6/30
375/375 [==============================] - 4s 12ms/step - loss: 0.3747 -
accuracy: 0.8659 - val_loss: 0.3665 - val_accuracy: 0.8673
Epoch 7/30
375/375 [==============================] - 4s 12ms/step - loss: 0.3630 -
accuracy: 0.8690 - val_loss: 0.3614 - val_accuracy: 0.8712
Epoch 8/30
375/375 [==============================] - 5s 12ms/step - loss: 0.3545 -
accuracy: 0.8721 - val_loss: 0.3362 - val_accuracy: 0.8800
Epoch 9/30
375/375 [==============================] - 5s 12ms/step - loss: 0.3474 -
accuracy: 0.8744 - val_loss: 0.3418 - val_accuracy: 0.8797
Epoch 10/30
375/375 [==============================] - 5s 12ms/step - loss: 0.3397 -
accuracy: 0.8767 - val_loss: 0.3473 - val_accuracy: 0.8788
Epoch 11/30
375/375 [==============================] - 4s 12ms/step - loss: 0.3350 -
accuracy: 0.8795 - val_loss: 0.3284 - val_accuracy: 0.8842
Epoch 12/30
375/375 [==============================] - 4s 12ms/step - loss: 0.3301 -
accuracy: 0.8824 - val_loss: 0.3269 - val_accuracy: 0.8843
Epoch 13/30
375/375 [==============================] - 4s 12ms/step - loss: 0.3253 -
accuracy: 0.8839 - val_loss: 0.3427 - val_accuracy: 0.8845
Epoch 14/30
375/375 [==============================] - 4s 12ms/step - loss: 0.3242 -
accuracy: 0.8845 - val_loss: 0.3264 - val_accuracy: 0.8878
Epoch 15/30
375/375 [==============================] - 4s 11ms/step - loss: 0.3183 -
accuracy: 0.8850 - val_loss: 0.3316 - val_accuracy: 0.8838
Epoch 16/30
375/375 [==============================] - 4s 12ms/step - loss: 0.3132 -
accuracy: 0.8869 - val_loss: 0.3247 - val_accuracy: 0.8867
Epoch 17/30
375/375 [==============================] - 4s 12ms/step - loss: 0.3089 -
accuracy: 0.8870 - val_loss: 0.3305 - val_accuracy: 0.8888
```

```
Epoch 18/30
375/375 [==============================] - 4s 12ms/step - loss: 0.3100 -
accuracy: 0.8875 - val_loss: 0.3379 - val_accuracy: 0.8878
Epoch 19/30
375/375 [==============================] - 4s 11ms/step - loss: 0.3040 -
accuracy: 0.8905 - val_loss: 0.3406 - val_accuracy: 0.8866
Epoch 20/30
375/375 [==============================] - 4s 11ms/step - loss: 0.3033 -
accuracy: 0.8907 - val_loss: 0.3280 - val_accuracy: 0.8908
Epoch 21/30
375/375 [==============================] - 4s 11ms/step - loss: 0.3006 -
accuracy: 0.8920 - val_loss: 0.3330 - val_accuracy: 0.8871
Epoch 22/30
375/375 [==============================] - 4s 11ms/step - loss: 0.2948 -
accuracy: 0.8934 - val_loss: 0.3351 - val_accuracy: 0.8921
Epoch 23/30
375/375 [==============================] - 4s 11ms/step - loss: 0.2967 -
accuracy: 0.8939 - val_loss: 0.3413 - val_accuracy: 0.8870
Epoch 24/30
375/375 [==============================] - 4s 12ms/step - loss: 0.2930 -
accuracy: 0.8940 - val_loss: 0.3269 - val_accuracy: 0.8878
Epoch 25/30
375/375 [==============================] - 4s 11ms/step - loss: 0.2856 -
accuracy: 0.8964 - val_loss: 0.3346 - val_accuracy: 0.8914
Epoch 26/30
375/375 [==============================] - 4s 11ms/step - loss: 0.2842 -
accuracy: 0.8959 - val_loss: 0.3363 - val_accuracy: 0.8898
Epoch 27/30
375/375 [==============================] - 4s 11ms/step - loss: 0.2828 -
accuracy: 0.8979 - val_loss: 0.3379 - val_accuracy: 0.8928
Epoch 28/30
375/375 [==============================] - 4s 11ms/step - loss: 0.2834 -
accuracy: 0.8968 - val_loss: 0.3475 - val_accuracy: 0.8911
Epoch 29/30
375/375 [==============================] - 4s 11ms/step - loss: 0.2825 -
accuracy: 0.8980 - val_loss: 0.3451 - val_accuracy: 0.8928
Epoch 30/30
375/375 [==============================] - 4s 11ms/step - loss: 0.2782 -
accuracy: 0.9000 - val_loss: 0.3308 - val_accuracy: 0.8941
   user  system elapsed
  52.25    5.28  134.03
> accuracy <- function(pred, truth)
+   mean(drop(as.numeric(pred)) == drop(truth))
> Error =
+   1-modelnn %>% predict(xx_test) %>% k_argmax() %>% accuracy(yy_test)
313/313 [==============================] - 1s 3ms/step
> #Error rate:
> Error
[1] 0.1151
> #Multinomial Logistic Regression
> #Too many weights. Using pca data instead.
> mn.train <- dat.pca.train
> system.time(mn_test <- multinom(y ~ ., data = mn.train))
# weights:  760 (675 variable)
```

```
initial  value 2763.102112
iter  10 value 725.025834
iter  20 value 561.262430
iter  30 value 520.839954
iter  40 value 509.910104
iter  50 value 503.940932
iter  60 value 501.270286
iter  70 value 500.112692
iter  80 value 499.772312
iter  90 value 499.608408
iter 100 value 499.550384
final  value 499.550384
stopped after 100 iterations
   user  system elapsed
   1.29    0.00    1.30
> mn.train$ClassPredicted <- predict(mn_test,
+                                    newdata = dat.pca.test, "class")
> tab <- table(mn.train$Class, mn.train$ClassPredicted)
> #DNN with PCA
> xx_train_s <- dat.train[1:1200,1:784]
> yy_train_s <- to_categorical(dat.train[1:1200,785],10)
> xx_test_s <- dat.test[1:600,1:784]
> yy_test_s <- dat.test[1:600,785]
> xx_train_s <- xx_train_s/255
> xx_test_s <- xx_test_s/255
> xx_train_s<-array_reshape(as.matrix(xx_train_s),c(1200,784))
> xx_test_s<-array_reshape(as.matrix(xx_test_s),c(600,784))
> modelnn_s <- keras_model_sequential()
> modelnn_s %>%
+   layer_dense(units = 256, activation = "relu",
+               input_shape = c(784)) %>%
+   layer_dropout(rate = 0.4) %>%
+   layer_dense(units = 128, activation = "relu") %>%
+   layer_dropout(rate = 0.3) %>%
+   layer_dense(units = 10, activation = "softmax")
> modelnn_s %>% compile(loss = "categorical_crossentropy",
+                       optimizer = optimizer_rmsprop(), metrics =
c("accuracy")
+ )
> system.time(
+   history <- modelnn_s %>%
+     fit(xx_train_s, yy_train_s, epochs = 30, batch_size = 128,
+         validation_split = 0.2)
+ )
Epoch 1/30
8/8 [==============================] - 1s 110ms/step - loss: 1.8431 -
accuracy: 0.3438 - val_loss: 1.3484 - val_accuracy: 0.4958
Epoch 2/30
8/8 [==============================] - 0s 34ms/step - loss: 1.2405 -
accuracy: 0.5573 - val_loss: 0.9875 - val_accuracy: 0.6458
Epoch 3/30
8/8 [==============================] - 0s 34ms/step - loss: 1.0918 -
accuracy: 0.6125 - val_loss: 0.7944 - val_accuracy: 0.7917
Epoch 4/30
```

```
8/8 [==============================] - 0s 34ms/step - loss: 0.9506 -
accuracy: 0.6781 - val_loss: 0.7422 - val_accuracy: 0.7833
Epoch 5/30
8/8 [==============================] - 0s 34ms/step - loss: 0.8670 -
accuracy: 0.6906 - val_loss: 0.7143 - val_accuracy: 0.8000
Epoch 6/30
8/8 [==============================] - 0s 34ms/step - loss: 0.8271 -
accuracy: 0.7115 - val_loss: 0.6715 - val_accuracy: 0.7792
Epoch 7/30
8/8 [==============================] - 0s 36ms/step - loss: 0.7568 -
accuracy: 0.7188 - val_loss: 0.6381 - val_accuracy: 0.8042
Epoch 8/30
8/8 [==============================] - 0s 34ms/step - loss: 0.7320 -
accuracy: 0.7406 - val_loss: 0.6151 - val_accuracy: 0.7958
Epoch 9/30
8/8 [==============================] - 0s 31ms/step - loss: 0.6531 -
accuracy: 0.7688 - val_loss: 0.7037 - val_accuracy: 0.7875
Epoch 10/30
8/8 [==============================] - 0s 32ms/step - loss: 0.6739 -
accuracy: 0.7573 - val_loss: 0.5898 - val_accuracy: 0.8042
Epoch 11/30
8/8 [==============================] - 0s 36ms/step - loss: 0.6191 -
accuracy: 0.7792 - val_loss: 0.6133 - val_accuracy: 0.8125
Epoch 12/30
8/8 [==============================] - 0s 32ms/step - loss: 0.5984 -
accuracy: 0.7823 - val_loss: 0.5527 - val_accuracy: 0.8417
Epoch 13/30
8/8 [==============================] - 0s 34ms/step - loss: 0.5701 -
accuracy: 0.7875 - val_loss: 0.6119 - val_accuracy: 0.7792
Epoch 14/30
8/8 [==============================] - 0s 32ms/step - loss: 0.5315 -
accuracy: 0.8115 - val_loss: 0.5525 - val_accuracy: 0.8292
Epoch 15/30
8/8 [==============================] - 0s 36ms/step - loss: 0.5307 -
accuracy: 0.8167 - val_loss: 0.5666 - val_accuracy: 0.8292
Epoch 16/30
8/8 [==============================] - 0s 34ms/step - loss: 0.5449 -
accuracy: 0.8062 - val_loss: 0.5852 - val_accuracy: 0.8375
Epoch 17/30
8/8 [==============================] - 0s 34ms/step - loss: 0.4824 -
accuracy: 0.8281 - val_loss: 0.7037 - val_accuracy: 0.7750
Epoch 18/30
8/8 [==============================] - 0s 32ms/step - loss: 0.4972 -
accuracy: 0.8271 - val_loss: 0.5218 - val_accuracy: 0.8542
Epoch 19/30
8/8 [==============================] - 0s 34ms/step - loss: 0.4380 -
accuracy: 0.8406 - val_loss: 0.6496 - val_accuracy: 0.8000
Epoch 20/30
8/8 [==============================] - 0s 32ms/step - loss: 0.4608 -
accuracy: 0.8302 - val_loss: 0.5903 - val_accuracy: 0.8583
Epoch 21/30
8/8 [==============================] - 0s 34ms/step - loss: 0.4508 -
accuracy: 0.8469 - val_loss: 0.5512 - val_accuracy: 0.8542
Epoch 22/30
```

```
8/8 [==============================] - 0s 34ms/step - loss: 0.4211 -
accuracy: 0.8479 - val_loss: 0.5973 - val_accuracy: 0.8333
Epoch 23/30
8/8 [==============================] - 0s 36ms/step - loss: 0.4044 -
accuracy: 0.8656 - val_loss: 0.5495 - val_accuracy: 0.8375
Epoch 24/30
8/8 [==============================] - 0s 32ms/step - loss: 0.3781 -
accuracy: 0.8583 - val_loss: 0.5717 - val_accuracy: 0.8333
Epoch 25/30
8/8 [==============================] - 0s 32ms/step - loss: 0.3762 -
accuracy: 0.8687 - val_loss: 0.5201 - val_accuracy: 0.8417
Epoch 26/30
8/8 [==============================] - 0s 34ms/step - loss: 0.4186 -
accuracy: 0.8469 - val_loss: 0.5409 - val_accuracy: 0.8667
Epoch 27/30
8/8 [==============================] - 0s 37ms/step - loss: 0.3784 -
accuracy: 0.8677 - val_loss: 0.5966 - val_accuracy: 0.8583
Epoch 28/30
8/8 [==============================] - 0s 32ms/step - loss: 0.3370 -
accuracy: 0.8740 - val_loss: 0.5662 - val_accuracy: 0.8667
Epoch 29/30
8/8 [==============================] - 0s 32ms/step - loss: 0.3242 -
accuracy: 0.8823 - val_loss: 0.5549 - val_accuracy: 0.8375
Epoch 30/30
8/8 [==============================] - 0s 32ms/step - loss: 0.3243 -
accuracy: 0.8844 - val_loss: 0.5479 - val_accuracy: 0.8625
   user  system elapsed
   2.27    0.14    8.53
> #Elapsed time is 7.4s
> accuracy_s <- function(pred, truth)
+   mean(drop(as.numeric(pred)) == drop(truth))
> Error =
+   1-modelnn_s %>% predict(xx_test) %>% k_argmax() %>% accuracy(yy_test)
313/313 [==============================] - 1s 3ms/step
> #Error rate
> Error
[1] 0.1935
```